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COMMODITY CURRENCIES AND CURRENCY COMMODITIES*

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Abstract

There is a large literature on the influence of commodity prices on the currencies of countries with a large commodity-based export sector such as Australia, New Zealand and Canada ("commodity currencies"). There is also the idea that because of pricing power, the value of currencies of certain commodity-producing countries affects commodity prices, such as metals, energy, and agricultural-based products ("currency commodities"). This paper merges these two strands of the literature to analyse the simultaneous workings of commodity and currency markets. We implement the approach by using the Kalman filter to jointly estimate the determinants of the prices of these currencies and commodities. Included in the specification is an allowance for spillovers between the two asset types. The methodology is able to determine the extent that currencies are indeed driven by commodities, or that commodities are driven by currencies, over the period 1975 to 2005.

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1. INTRODUCTION

When the value of the currency of a commodity-exporting country moves in sympathy with world commodity prices, it is said to be a "commodity currency". Thus when there is a commodity boom, the appreciation of a commodity currency has the effect of dampening the impact of the boom as domestic-currency prices rise by less than world prices, profitability in the export sector rises by less than otherwise and domestic consumers gain from the appreciation in the form of lower-priced imports. This automatic stabiliser has the effect of moving part of the required adjustment to the boom away from commodity producers and reduces the cyclical volatility of the economies of commodity-exporting countries. Australia, New Zealand, South Africa and Canada, as well as some other smaller developing countries, all possibly have commodity currencies of varying degrees.

What if in addition to having a commodity currency, the country is a sufficiently large producer of a certain commodity that it can affect the world price? In other words, what if the country has some degree of power over the world market? A commodity boom appreciates the country's currency, and as this squeezes its exporters, the volume of exports falls. But as the country is now large, the reduced exports have the effect of increasing world prices further. Thus as the appreciation leads to a still higher world price, the interaction of the commodity currency and pricing power leads to an amplification of the initial commodity boom. To convey the symmetric relationship with commodity currencies, commodities whose prices are substantially affected by currency fluctuations can be called "currency commodities". This paper explores in detail the implications of the phenomena of commodity currencies and currency commodities operating simultaneously. We establish the precise conditions for a country to have a commodity currency, as well as the requirements for a currency commodity. The paper also shows how the framework yields considerable insight into the impacts on commodity prices and exchange rates of (i) a currency fad in which there is sudden, large shift in investor sentiment towards the home country's currency; (ii) technical change in the form of development of a new product that acts as a good substitute for the commodity; and (iii) globalisation that exposes the home country to greater international competition and makes its economy more flexible. We also derive conditions under which the interactions between currency values and commodity prices form a stable process, so that exchange rates and prices converge to well-defined equilibrium values. The paper also provides preliminary empirical evidence on the extent to which exchange rates are affected by commodity prices and vice versa.

There is a fairly substantial literature devoted to commodity currencies; this literature is predominantly empirical that tends to start with the observed correlation between the terms of trade and real exchange rates in a number of commodity-exporting countries. Prominent examples of this literature include

Amano and van Norden (1995), Blundell-Wignall and Gregory (1990), Blundell-Wignall et al. (1993), Broda (2004), Cashin et al. (2004), Chen and Rogoff (2003), Freebairn (1990), Gruen and Kortian (1998), Gruen and Wilkinson (1994), McKenzie (1986) and Sjaastad (1990). On the theory of the dependence of the real exchange rate on the terms of trade, see Connolly and Devereux (1992), Devereux and Connolly (1996), Edwards (1988, 1989), Edwards and van Wijnbergen (1987) and Neary (1988). Closely allied to commodity currencies is “booming sector” economics, which analyses the implications for other sectors of the economy of a surge in one form of exports (mostly taken to be commodities, natural resources in particular). Here, a surge in resource exports leads to a real appreciation of the county’s exchange rate that has the effect of hurting other exporters and producers in the import-competing sector. This phenomenon is variously known as the “Dutch disease”, “the Gregory effect” and “de-industrialisation”. Important papers in this area include Corden (1984), Corden and Neary (1982), Gregory (1976) and Snape (1977).

While there is also a substantial literature on the implications of “large countries” in international trade related to optimal trade taxes, there is a much smaller literature devoted to the related topic of the link between exchange rates and world prices of commodities. The link is that if a commodity-producing country has some degree of market power, it can pass onto foreign buyers of its exports increases in domestic costs. Studies in this tradition are Clements and Manzur (2002), Dornbusch (1987), Gilbert (1989, 1991), Keyfitz (2004), Ridler and Yandle (1972), Sjaastad (1985, 1989, 1990, 1998a,b, 1999, 2000, 2001), Sjaastad and Manzur (2003) and Sjaastad and Scacciavillani (1996).

The only previous paper that we are aware of that explicitly considers the implications of the joint operation of commodity currencies and currency commodities is Swift (2004). Swift starts with the analysis of Ridler and Yandle (1972) that deals with the dependence of the world price of a certain commodity on the N exchange rates in the world, and notes that if an individual exporting country is “small”, then a change in the value of its currency has no impact on the world price. Suppose there is a boom that exogenously increases the world price of a certain commodity, such that a number of small countries producing the commodity are all hit simultaneously by a common shock that improves their terms of trade. If these countries all have commodity currencies, then their exchange rates appreciate and the Ridler and Yandle framework implies that there is a subsequent increase in the world price of the commodity they export. Thus there is both the initial terms-of-trade shock and then a subsequent reinforcing move related to the commodity-currency mechanism. In this sense, the terms of trade are endogenous, even though the countries are all small individually. Swift analyses the processes by which these countries adjust to the terms of trade improvement, and emphasises that the shocks are larger when the terms of trade are endogenous. While Swift describes and discusses these matters, mostly, but not exclusively, in words, she does not model formally their workings.

The second part of this paper provides some empirical evidence on some of the propositions of the theoretical model using a multivariate latent factor model. The approach enables an assessment of the relative importance of various "factors" in explaining volatility in each market in a model where commodity currency and price returns are endogenously determined. This class of models is used in the finance and business cycle literature to explain time series as a function of a set of unobserved (latent) factors. For examples, see Diebold and Nerlove (1989), Dungey (1999), Mahieu and Schotman (1994) and Stock and Watson (1991). The model of this paper is a three-factor one comprising a common factor, a commodity currency factor and a commodity price factor. The idea is that information that is specific to the complete data set is captured by the common factor; information specific to the commodity currencies is captured by the commodity currency factor, and information specific to the set of commodity price returns in the model is captured by the commodity factor. Spillovers across the two markets can then be modeled by examining the impact of the asset specific factors (the currency factor or the commodity factor) on the other asset type. The advantage of the approach is that observable variables do not have to be identified and modeled, which is particularly convenient as it implicitly takes into account shocks simultaneously affecting all markets.

There are several methods available to estimate this class of models including Generalised Method of Moments (Hamilton, 1994, and Hansen, 1982), the Kalman filter (Hamilton, 1994, Harvey, 1981, 1990, and Kalman, 1960, 1963), and simulation based techniques such as indirect estimation (Duffie and Singleton, 1993, Dungey et al., 2000, Gallant and Tauchen, 1996, and Gourieroux et al., 1993). The Kalman filter is adopted in this paper as it is assumed that the quarterly data series are not complicated by features such as non-normal distributions. The other advantage is that it is simple to extract a time series of the factors when using the Kalman filter. This time series can then be used to examine how the relationship between commodity currencies and price returns has changed over time which helps to assess some of the propositions raised in the theoretical section of the paper, particularly in relation to globalisation.

The results of the empirical model suggest that commodity returns are more affected by the currency factor than vice versa, although the importance of spillovers across the two market types is relatively small. This is in contrast to most papers which do not even consider that commodity prices may be endogenous, and only model exchange rates as a function of commodity prices. The implications of this result are that the commodity currency countries appear to have some degree of market power, at least on a collective basis. The reverse link from the commodity factor to the currency returns is much weaker and is jointly insignificant. Over time as markets have become more competitive and integrated, the role of the commodity currency factor in determining the currency and commodity returns seems to have become more important.

The structure of the paper is as follows. The next section sets out in considerable detail the analytical framework that merges the economics of commodity currencies with that of currency commodities. Sections 3 and 4 present the empirical part of the paper. Section 3 provides an initial investigation into the data series which helps motivate the structure of the latent factor model developed and estimated in Section 4. Section 5 provides some concluding comments.

2. THE ANALYTICAL FRAMEWORK

As discussed above, the previous literature has tended to analyse only one part of the interaction between world commodity prices and exchange rates, in isolation from the other; that is, it has focused on either the causal link from commodity prices to currency values (the "commodity currency" model), or the reciprocal link, the impact of exchange-rate changes on commodity prices, which involves pricing power in world markets ("currency commodities"). By contrast, our focus in this paper is on the joint determination of exchange rates and commodity prices, or on the two-way interactions between exchange rates and commodity prices. The latent factor approach set out below in Section 4 is a multivariate model that deals with the simultaneous determination of these two sets of variables.

Notwithstanding our simultaneous approach to be followed, it is none the less convenient to discuss the major elements independently. Thus, we proceed in the first sub-section below to set out a model of the impacts of changes in exchange rates on world commodity prices, under the assumption that the former are given exogenously. We then turn in Sections 2.2-2.4 to the second arm, the effects of changes in commodity prices on exchange rates. Sections 2.5-2.7 investigate the joint workings of the commodity and currency markets by considering the two arms simultaneously. In the final sub-section, Section 2.8, we consider as illustrative examples of the approach the general equilibrium impacts on commodity and currency markets of a fad that causes the currency to appreciate, technological change that leads to the introduction of new substitute products, and globalisation that enhances the flexibility of the economy.

2.1 Market Power and Commodity Pricing

Consider a country that is a dominant exporter of a certain commodity in the sense of a larger volume of exports places downward pressure on the world price. Examples could include oil from Saudi Arabia, wool from Australia and several minerals from Australia such as iron ore, tantalite and possibly coal. In such a case, the country is a price maker, or has market power. This situation is well known in international economics, and relates to optimal export taxes, the formation of cartels among exporting nations and price-stabilisation schemes. We consider the somewhat different issue of what happens to the world price of such a commodity if there is a major depreciation of the currency of the dominant producing country. If costs do not rise equiproportionally, so that it is a real depreciation, the enhanced revenue drops straight to the bottom line and domestic producers of the commodity have an incentive to expand production and export more. But the expansion of exports depresses the world price as, by assumption, the country is large. Accordingly, for such a country, there is an immediate link between the value of its currency and the world price of the commodity. In a series of papers, Sjaastad and coauthors have elaborated this basic model and considered a number of implications of this rich framework.[1]

To fix ideas, take the world gold market as an example, and for purposes of simplicity, suppose there are only two countries in the world, the US and Europe. If the price of an ounce of gold in dollars is p and p^* in euros, then we have as an arbitrage relation

$$p = Sp^*\left(1+x\right),$$

where S is the US dollar cost of one euro, and x represents the "spread" between American and European gold prices due to transaction costs etc. (that are presumably small). If the factors determining the spread are constant over time, then the above equation implies that

(2.1) $$\hat{p} = \hat{S} + \hat{p}^*,$$

where a hat ("ˆ") denotes proportional change $\left(\hat{x} = dx/x\right)$. This is the familiar purchasing-power-parity equation that states the change in the dollar price of gold equals the change in the euro price adjusted for the change in the exchange rate. To illustrate the workings and implications of equation (2.1), suppose the dollar depreciates relative to the euro by 10 percent, so that $\hat{S} = 0.10$. Equation (2.1) then means that $\hat{p} - \hat{p}^* = 0.10$, so that the dollar price relative to the euro price increases by 10 percent. There are three possibilities:

[1] See Sjaastad (1985, 1989, 1990, 1998a,b, 1999, 2000, 2001), Sjaastad and Manzur (2003) and Sjaastad and Scacciavillani (1996). See also Dornbusch (1987), Gilbert (1989, 1991) and Ridler and Yandle (1972). For a recent application, see Keyfitz (2004).

(i) The dollar price increases by the full 10 percent, with the euro price constant.

(ii) The euro price falls by 10 percent and the dollar price remains unchanged.

(iii) Any linear combination of cases (i) and (ii).

Case (i) is the familiar small country situation, and here the US is a price taker in the world gold market. The opposite extreme is when the US completely dominates the pricing of gold and is an "extremely large county", as in case (ii). Case (iii) pertains to various intermediate situations in which the US has some market power, but not complete dominance. Case (iii) is possibly the most commonly experienced -- fears of inflation in the US lead to a depreciation of the dollar, and a rise in the dollar price of gold occurs with a simultaneous fall in the euro price. These three cases are shown in Figure 2.1.

We develop a simple stylised model of the world market for a commodity in which PPP holds for the commodity, but not for prices in general.[2] This model reveals considerable insights into the workings of commodity markets in general, and identifies the nature of "small" and "large" in a precise manner. The commodity is produced only in the home country according to the following supply equation

(2.2) $$q^s = q^s\left(\frac{p}{P}\right),$$

where q^s is the quantity supplied, p is the price in terms of domestic currency units, and P is an index of costs in general in the home country. All of the output of the commodity is exported and the foreign demand function is

(2.3) $$q^d = q^d\left(\frac{p^*}{P^*}\right),$$

where an asterisk ("*") denotes a foreign-currency price, so that p^*/P^* is the relative price faced by foreign consumers. Ignoring changes in stocks of the commodity, world market equilibrium is given by

(2.4) $$q^s = q^d.$$

This model can be solved as follows. If we denote the price elasticity of supply by $\varepsilon \geq 0$ and the price elasticity of demand by $\eta \leq 0$, we can then express the supply and demand equations (2.2) and (2.3) in change form as

(2.5) $$\hat{q}^s = \varepsilon\left(\hat{p} - \hat{P}\right), \qquad \hat{q}^d = \eta\left(\hat{p}^* - \hat{P}^*\right).$$

[2] For an earlier rendition of this model, see Clements and Manzur (2002).

Using the market-clearing equation (2.4) to equate the right-hand sides of both members of (2.5), we obtain $\varepsilon\left(\hat{p}-\hat{P}\right)=\eta\left(\hat{p}^*-\hat{P}^*\right)$, or in view of the PPP relation (2.1), $\varepsilon\left(\hat{p}^*+\hat{S}-\hat{P}\right)=\eta\left(\hat{p}^*-\hat{P}^*\right)$. Subtracting $\varepsilon\left(\hat{p}^*-\hat{P}^*\right)$ from both sides of the last equation and rearranging, we obtain $\hat{p}^*-\hat{P}^*=\left[\varepsilon/(\eta-\varepsilon)\right]\left(\hat{S}+\hat{P}^*-\hat{P}\right)$, or

$$\hat{p}^*-\hat{P}^*=\frac{\varepsilon}{\varepsilon-\eta}\left(\hat{P}-\hat{S}-\hat{P}^*\right).$$

If we define the real exchange rate as $R=P/S.P^*$, the above equation can be expressed more compactly as

$$\widehat{\frac{p^*}{P^*}}=\alpha\hat{R}, \tag{2.6}$$

where

$$\alpha=\frac{\varepsilon}{\varepsilon-\eta} \tag{2.7}$$

is the share of supply in the excess supply elasticity. As the supply elasticity $\varepsilon\geq 0$ and the demand elasticity $\eta\leq 0$, it follows that $0\leq\alpha\leq 1$. Figure 2.2 provides a visualisation of the nature of α by plotting it against ε and η. The real exchange rate R is the producer country's nominal exchange rate adjusted for relative price levels; this exchange rate is defined such that an increase in R represents a real appreciation of the currency of the producing country.

Equation (2.6) is the fundamental pricing rule for commodities. It states that the change in the world relative price of the commodity is a positive fraction α of the change in the real value of the producing country's currency. Accordingly, a 10-percent real appreciation $\left(\hat{R}=0.10\right)$ means that the world price rises, but by at most 10 percent. The mechanism is that the real appreciation squeezes firms producing and exporting the commodity, so that the lower volume of exports pushes up their price on the world market. In the case in which $\varepsilon=1$ and $\eta=-1$, the value of the fraction α is $1/2$, so that the 10-percent appreciation leads to a 5-percent increase in the commodity price.

A small country is unable to affect world prices. Thus when a small country experiences a real appreciation of its currency, for the world price to be constant, equation (2.6) implies that the value of α must be zero. This occurs when the excess supply elasticity $\varepsilon-\eta$ is large. Conversely, when the excess supply elasticity is small, α is near its upper limit of unity and the country is large. The implications of the distinction between larger and smaller countries are demonstrated in Figure 2.3. Consider first the case of the smaller country which has an α-value of α_S, so that $\widehat{p^*/P^*} = \alpha_S \hat{R}$. The ray from the origin OZ, which has slope α_S, represents this equation, so that an appreciation of $\hat{R}_0$ causes a modest rise in the world price of $\left(\widehat{p^*/P^*}\right)_S = \alpha_S \hat{R}_0$.[3] The larger country has a larger α coefficient, $\alpha_L > \alpha_S$, and a steeper ray from the origin OZ', so that the same real appreciation causes the price to rise by more, viz., $\left(\widehat{p^*/P^*}\right)_L = \alpha_L \hat{R}_0$. This leads to the attractively-simple result that the elasticity of the above differential change in the world price is just the difference in the value of the α coefficients:

$$\frac{\widehat{p_L^*/p_S^*}}{\hat{R}} = \alpha_L - \alpha_S .$$

Figure 2.4 illustrates further the workings of the commodity market in terms of levels (rather than changes). Quadrant I contains the supply curve, III the demand curve, while the market-clearing relationship is contained in quadrant II. The link between domestic and foreign nominal prices of the commodity is provided by the PPP relation $p = Sp^*$, where we have ignored the spread as it is not essential. Dividing both sides of this equation by P and using $R = P/S.P^*$, we have $p^*/P^* = R\left(p/P\right)$. This equation provides a link between domestic and foreign *relative* prices, so it can be considered as a real version of PPP. This link closes the model and is represented in quadrant IV of the figure. Here the real exchange rate is given by the slope of the PPP ray from the origin. An appreciation of the domestic currency causes this ray to become steeper (with respect to the domestic price axis), and the equilibrium world price rises. Accordingly, we have an increasing relationship between the exchange rate and world prices, as represented by the schedule labeled MM in Figure 2.5; the elasticity of MM is α.

An alternative presentation of the interactions between the exchange rate and the commodity price is given in Figure 2.6. In panel A, the schedule WW is the locus of world and domestic prices for which the world market clears. It is downward sloping as an increase in the domestic price stimulates production and for the market to continue to clear, this has to be offset by a reduction in the world price to stimulate demand. Clearing of the commodity market implies $\varepsilon\left(\hat{p} - \hat{P}\right) = \eta\left(\hat{p}^* - \hat{P}^*\right)$, so that

$$\widehat{\frac{p^*}{P^*}} = \left(\frac{\varepsilon}{\eta}\right)\widehat{\frac{p}{P}} = \left(\frac{\alpha}{1-\alpha}\right)\widehat{\frac{p}{P}},$$

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[3] In the limit, for a trivially small country $\alpha_S = 0$, the ray from the origin coincides with the horizontal axis and the world price is constant.

with α defined as above in equation (2.7). This shows that $\alpha/(1-\alpha)$ is the elasticity of the WW schedule. The link between domestic and foreign prices of the commodity is provided by the real PPP relationship discussed above, $p^*/P^* = R(p/P)$. This equation is represented in panel A of the figure by the ray from the origin OX , with slope R. For overall equilibrium, the market must be simultaneously located on WW and OX, that is, at the point of intersection of the two curves E_0. An appreciation of the producer-country currency causes the ray to get steeper and move from OX to OX′, so that the equilibrium point shifts from E_0 to E_1, with the world price rising and the domestic price falling. In the small-country case (panel B), the WW schedule is horizontal as $\alpha = 0$, the appreciation has no impact on the world price, and the domestic price falls equiproportionally. Finally, for a large country in the extreme $(\alpha = 1)$, the WW schedule is vertical, the domestic relative price remains unchanged and the world price rises by the full amount of the appreciation.

The model discussed in this sub-section is a simple one that deals with the pricing of a single commodity in a two-country world. But its predictions are robust as they carry over in a natural manner to a multi-country, multi-commodity world in which there is domestic consumption of the commodity. For details, see, e. g., Gilbert (1989), Sjaastad (1990) and Ridler and Yandle (1972).

2.2 Commodity Currencies

In this sub-section we consider the link from commodity prices to exchange rates. We shall again employ a simple stylised model, and show how a country's terms of trade are linked to its real exchange rate. This model starts with the "sector approach" introduced by Sjaastad (1980) for the analysis of the impact of protection.[4]

We divide the whole economy into three broad sector, importables (to be denoted by the subscript I), exportables (X) and everything else, those goods that do not, and cannot, enter into international trade because of prohibitively high transport costs, which shall be called home goods (H). For our purposes, we can focus on the market for home goods. If q_H^s and q_H^d represent the quantity demanded and supplied of home goods, and p_i the price of good i (i=I, X, H), we can write the supply and demand functions as

$$q_H^s = q_H^s(p_I, p_X, p_H), \qquad q_H^d = q_H^d(p_I, p_X, p_H).$$

We define the own- and cross-price elasticities of supply and demand as

[4] For extensions and elaborations of Sjaastad's model, see Clague and Greenaway (1994), Clements and Sjaastad (1981, 1984), Greenaway (1989) and Greenaway and Milner (1988). See also Choi and Cumming (1986) for early work on the measurement of the transfers across sectors implied by the approach.

$$\varepsilon_{Hj} = \frac{\partial\left(\log q_H^s\right)}{\partial\left(\log p_j\right)}, \qquad \eta_{Hj} = \frac{\partial\left(\log q_H^d\right)}{\partial\left(\log p_j\right)},$$

which satisfy the homogeneity constraints $\sum_j \varepsilon_{Hj} = \sum_j \eta_{Hj} = 0$. The supply and demand functions for home goods can then be expressed in change form as

(2.8) $$\hat{q}_H^s = \sum_j \varepsilon_{Hj}\hat{p}_j, \qquad \hat{q}_H^d = \sum_j \eta_{Hj}\hat{p}_j.$$

Market clearing for home goods implies $\hat{q}_H^s = \hat{q}_H^d$, or, from equation (2.8), $\sum_j \varepsilon_{Hj}\hat{p}_j = \sum_j \eta_{Hj}\hat{p}_j$. Solving for $\hat{p}_H$, we obtain

$$\hat{p}_H = \left(\frac{\eta_{HI} - \varepsilon_{HI}}{\varepsilon_{HH} - \eta_{HH}}\right)\hat{p}_I + \left(\frac{\eta_{HX} - \varepsilon_{HX}}{\varepsilon_{HH} - \eta_{HH}}\right)\hat{p}_X,$$

or, more compactly,

(2.9) $$\hat{p}_H = \omega\hat{p}_I + \left(1-\omega\right)\hat{p}_X,$$

where

(2.10) $$\omega = \frac{\eta_{HI} - \varepsilon_{HI}}{\varepsilon_{HH} - \eta_{HH}}.$$

When complementarity is ruled out, which seems not unreasonable at this level of aggregation, the value of the coefficient ω lies between zero and one.[5] Equation (2.9) shows that the change in the price of home goods is a weighted average of the changes in the prices of importables and exportables. The weights in this equation reflect the substitutability in both production and consumption between home goods on the one hand, and the two traded goods on the other. When home goods and importables are good substitutes, then the weight ω is near its upper value of unity, the prices of these two goods move together closely and their relative price p_H/p_I is more or less constant. Alternatively, when home goods

[5] *Proof*: It follows from the demand homogeneity constraint, $\sum_j \eta_{Hj} = 0$, that $\eta_{HI} = -\eta_{HX} - \eta_{HH}$. The law of demand implies that $\eta_{HH} < 0$; and the assumption of no complementarity means $\eta_{Hj} \geq 0$ (j=I, X). It then follows that the maximum value of $\eta_{HI} = -\eta_{HH} > 0$, which occurs when home goods and exportables are independent in consumption, that is, when $\eta_{HX} = 0$. A parallel argument on the supply side establishes that the minimum algebraic value of $\varepsilon_{HI} = -\varepsilon_{HH} < 0$. Substituting these extreme values into the definition of ω, given by equation (2.10), yields $\omega = 1$. The minimum value of $\eta_{HI} = 0$, which occurs when home goods and importables are independent in consumption, while the maximum value of $\varepsilon_{HI} = 0$ (the two goods are independent in production); these values jointly imply that $\omega = 0$. As η_{HI} $\left(\varepsilon_{HI}\right)$ decreases (increases) from its maximum (minimum) value and moves towards it minimum (maximum), ω moves monotonically from unity to zero. For a geometric representation, see Figure 2.7.

and exportables are good substitutes, then $(1-\omega)$, the second weight in equation (2.9), is close to unity, and the relative price p_H/p_X is approximately constant.

Equation (2.9) is known as "the incidence equation" as it has been used extensively to measure how much of protection acts as a tax on the country's own exporters. To illustrate, suppose a small country imposes an import duty of 10 percent, so that $\hat{p}_I = 0.10$, and has no export taxes or subsidies, so that $\hat{p}_X = 0$. Equation (2.9) then implies that the price of home goods rises by a fraction ω of 0.10. This can be interpreted as a rise in costs in general, a rise that has to be paid by producers in all sectors of the economy. But as exporters cannot pass on the higher costs (the small country assumption), this fraction of import protection acts as a tax on exporters. As the incidence of the import protection is shifted onto exporters, ω is known as the "shift coefficient".[6]

Next, let the overall index of prices in the country be a weighted geometric mean of the three sectoral prices, so that

(2.11) $$\hat{P} = \alpha_H \hat{p}_H + \alpha_I \hat{p}_I + \alpha_X \hat{p}_X,$$

where α_i is a weight for sector i (i=H, I, X). The weights α_i are all positive fractions with $\sum_i \alpha_i = 1$. Substituting the right-hand side of equation (2.9) for $\hat{p}_H$ in (2.11), and defining $\beta = \alpha_H(1-\omega) + \alpha_I$, we obtain an equation that expresses the rate of inflation in terms of the prices of the two traded goods:

(2.12) $$\hat{P} = \hat{p}_X - \beta(\hat{p}_X - \hat{p}_I).$$

The coefficient β in the above equation is positive, and most likely less than one. A similar equation describes inflation in the rest of the world (denoted by an asterisk):

(2.13) $$\hat{P}^* = \hat{p}_X^* - \beta^*(\hat{p}_X^* - \hat{p}_I^*).$$

[6] There have been a number of applications of this framework; see Clements and Sjaastad (1984) for an early survey of estimates of the shift coefficient, and Clague and Greenaway (1994) for a subsequent survey. The methodology has been recently applied to Malawi (Zgovu, 2003), Spain 1879-1913 (Pardos and Serrano-Sanz, 2002), Spain 1978-1993 (Asensio and Pardos, 2002), South Asia (Panday, 2003) and the US for the late nineteenth century (Irwin, 2006), among others. Note that in the absence of any additional information, the value of $\omega = 1/2$ has some attractions for the following reasons. Recall that the shift coefficient is defined as $\omega = (\eta_{HI} - \varepsilon_{HI})/(\varepsilon_{HH} - \eta_{HH})$, and that the price elasticities of supply and demand are subject to the homogeneity constraints, $\sum_j \varepsilon_{Hj} = \sum_j \eta_{Hj} = 0$. As demand homogeneity implies that the sum of the two cross elasticities, $\eta_{HI} + \eta_{HX}$, equals the negative of the own-price elasticity, $-\eta_{HH}$, if we know nothing about the nature of the substitutability among goods, a "neutral" approach is to distribute $-\eta_{HH}$ equally to both goods by setting $\eta_{HI} = \eta_{HX} = -(1/2)\eta_{HH}$. This approach, together with a similar argument on the supply side, yields $\omega = 1/2$. A related approach is to regard the shift coefficient as a uniformly distributed random variable with range [0, 1]. Then, the expected value of the coefficient is exactly mid-way between the upper and lower values, that is, $E(\omega) = 1/2$.

Using the definition of the change in the real exchange rate, $\hat{R} = \hat{P} - \hat{P}^* - \hat{S}$, together with equations (2.12) and (2.13), we obtain

$$(2.14) \qquad \hat{R} = \gamma \widehat{\frac{p_X}{p_I}}.$$

The coefficient in the above equation is defined as $\gamma = 1 - (\beta + \beta^*)$, or

$$(2.15) \qquad \gamma = 1 - \left\{ \left[\alpha_H (1 - \omega) + \alpha_I \right] + \left[\alpha_H^* (1 - \omega^*) + \alpha_I^* \right] \right\},$$

which is the elasticity of the home country's real exchange rate with respect to its terms of trade.[7] On the basis of equation (2.15), the following can be said about the possible values of γ. In both countries, the shares for home goods and importables are positive fractions, while the shift coefficient lies between zero and one. This implies the lower bound for γ, associated with $\omega = \omega^* = 0$, can be negative, while the upper bound $(\omega = \omega^* = 1)$ is $1 - (\alpha_I + \alpha_I^*)$, which is likely to be a positive fraction.[8]

Figure 2.8 gives the commodity currency relationship. For convenience, this is presented in reciprocal form, so that, from equation (2.14), the elasticity of the schedule CC in the figure is $1/\gamma$.

2.3 Income Effects of Terms-of-Trade Changes

In the above discussion, we have moved freely between changes in world prices and changes in domestic prices. This, however, ignores an important point regarding the source of the changed prices: While changes in domestic relative prices brought about by, say, domestic protection policies have no first-order income effects (when starting from an undistorted equilibrium), this is not true for changes in world prices. If domestic prices change because of a worsening of the country's terms of trade for example, this makes the country as a whole worse off, which has implications for the workings of the market for home goods. Accordingly, the above framework needs some modification/reinterpretation to deal with the first-order income effects of changes in the terms of trade. Let η_H be the income elasticity of demand for home goods, which is taken to be positive as these goods can be reasonably expected to be normal; and let α_I', α_X' be the shares of imports and exports (not importables and exportables) in GDP. Then, an increase in the domestic price of importables of $\hat{p}_I$, brought about by a world price rise, lowers

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[7] In deriving equation (2.14), we have used the purchasing power parity relationship for the two traded goods and the reciprocal nature of trade in a two-region world. That is, the exports of the home country represent imports by the rest of the world and vice versa for home country imports, so that $\hat{p}_X = \hat{p}_I^* + \hat{S}$ and $\hat{p}_I = \hat{p}_X^* + \hat{S}$.

[8] For a related analysis, see Milner et al. (1995).

real income in proportionate terms by $\alpha_I'\hat{p}_I$, which in turn causes the demand for home goods to fall by $\eta_H\alpha_I'\hat{p}_I$. Similarly, an increase in the price of exportables coming from a world price rise leads to an increase in the demand for home goods of $\eta_H\alpha_X'\hat{p}_X$. Thus the demand equation for home goods, the second member of (2.8), becomes

$$\hat{q}_H^d = \sum_j \eta_{Hj}\hat{p}_j - \eta_H\alpha_I'\hat{p}_I + \eta_H\alpha_X'\hat{p}_X .$$

Retracing our steps, the incidence equation (2.9) is then modified to

$$\hat{p}_H = [\omega + \phi_I]\hat{p}_I + [(1-\omega) + \phi_X]\hat{p}_X ,$$

where $\phi_I = -\eta_H\alpha_I'/(\varepsilon_{HH} - \eta_{HH}) < 0$, and $\phi_X = \eta_H\alpha_X'/(\varepsilon_{HH} - \eta_{HH}) > 0$. Relative to equation (2.9), the coefficient attached to $\hat{p}_I$ is now lower, while that attached to $\hat{p}_X$ is higher. When trade is balanced, $\alpha_X' = \alpha_I' = \alpha_T'$, the share of trade in GDP, and $\phi_I = -\phi_X = \phi_T < 0$. Under this condition, the above equation simplifies to

(2.16) $$\hat{p}_H = \omega'\hat{p}_I + (1-\omega')\hat{p}_X ,$$

where $\omega' = \omega + \phi_T$ is the modified shift coefficient.

To illustrate the workings of equation (2.16), consider the case in which the income elasticity of demand for home goods is unity, trade accounts for 30 percent of the economy, the price elasticity of supply of home goods is unity and the price elasticity of demand for these goods is minus unity. Then, $\phi_T = -\eta_H\alpha_T'/(\varepsilon_{HH} - \eta_{HH}) = -1\times 0.3/(1+1) = -0.15$, so that the value of the conventional shift coefficient has to be reduced by 15 percentage points to allow for income effects associated with terms-of-trade changes. Figure 2.9 presents the geometry of the differential effects on internal prices of the imposition of an import tariff and a worsening of the country's terms of trade.[9] In panel A, the HH schedule is the locus of relative prices for which the market for home goods clears; it follows from equation (2.9) that the elasticity of this schedule is $-[(1-\omega)/\omega] < 0$. The slope of the ray from the origin OT is the internal price of importables in terms of exportables p_I/p_X, which under free trade is equal to world prices, p_I^*/p_X^*, and the initial overall equilibrium is at the point E_0. The imposition of an import tariff causes the ray from to origin to become steeper and shift to OT', with slope $(1+t)p_I^*/p_X^*$, where t is the tariff rate. With the relative price of exportables held constant, equilibrium then moves from E_0 to E_1, and the

[9] Panel A of Figure 2.9 is due to Dornbusch (1974).

relative price of importables increases by the full amount of the tariff. But at E_1 there is excess demand for home goods, causing their price to rise in terms of both traded goods, and the economy moves from E_1 to E_2, which has the dual effect of eroding some of the protection afforded to the domestic importables sector, and taxing the production of exportables. It is in this sense that import protection is a tax on exporters.

Panel B of Figure 2.9 considers the implications of a worsening of the country's terms of trade by $t \times 100$ percent, so that the shift from OT to OT′ is exactly the same as that in panel A. Along H′H′ the home goods market clears when the income effects of changes in the terms of trade are allowed for. The elasticity of H′H′ is $-\left[(1-\omega')/\omega'\right] < 0$, which for $\omega' < \omega$, is larger in absolute value than $-\left[(1-\omega)/\omega\right]$. Accordingly, where the two schedules intersect, such as at the point E_0, H′H′ is steeper than HH.[10] This means that relative to a tariff of the same size, an increase in the world price of importables causes the price of home goods to rise by less, so that domestic producers of importables benefit by more, and exporters are taxed by less.

The results of this sub-section can be summarised as follows. Equation (2.16) has exactly the same form as (2.9), so we can continue to use the commodity-currency framework, as summarised by equations (2.14) and (2.15), for changes in world prices. All that needs to be done is to reinterpret the shift coefficient ω to refer to its modified version ω'. In what follows, we shall continue to refer to the role of the shift coefficient ω in equations (2.14) and (2.15), but as we shall be discussing changes in world prices, it is to be understood that these references are, strictly speaking, to its modified counterpart ω'.

2.4 When Does a Country have a Commodity Currency?

As the value of a commodity currency moves in sympathy with its terms of trade, equations (2.14) and (2.15) provide a framework for the identification of such a currency. For a commodity currency, its elasticity with respect to prices, γ, is a substantial positive number, but less than unity (so that the domestic-currency price of the commodity rises with the world price). But as β and β^* are both positive fractions, it can be seen that γ will not always be substantially different from zero. In fact, as $\beta = \alpha_H(1-\omega) + \alpha_I$ and $\beta^* = \alpha_H^*(1-\omega^*) + \alpha_I^*$, there is a presumption that both these coefficients would be

[10] Recall that the elasticity at a point on a curve is the ratio of the slope of the curve to the slope of a ray from the origin to the point. When two curves intersect, the two rays from the origin coincide, as do their slopes. Accordingly, when two curves intersect, the relative slopes reflect relative elasticities.

of the order of one-half, which implies $\gamma \approx 0$. The value of one-half is based on the following considerations: The share of home goods in the overall economy could be something like 60 percent in both regions, so that $\alpha_H = \alpha_H^* = 0.6$; on the basis of the above discussion on the possible value of the shift coefficient, $\omega = 1/2$; and a not unreasonable value for the share of importables in both regions is 20 percent, so that $\alpha_I = \alpha_I^* = 0.2$. These values mean $\beta = \beta^* = 0.5$, so that the elasticity $\gamma = 0$, and the home country does not have a commodity currency in this case. This is, of course, reassuring as in most cases we would not expect the currency to be a commodity one; that is to say, commodity currencies are the exception to the rule.

Under what conditions does a country have a commodity currency? It follows from equation (2.15) that the elasticity γ will be further away from zero and closer to unity when:

- Home goods occupy a smaller fraction of the economy (that is, when α_H, α_H^* are both small).
- Home goods and importables are good substitutes in consumption and production (that is, when the shift coefficients ω, ω^* are both large).
- Importables are relatively less important (that is, when α_I, α_I^* are both small).

Note that the first and last conditions jointly imply that γ will be larger when exportables account for a larger share of the economy. We thus obtain the following simple rule: *A country is more likely to have a commodity currency when (i) exportables are relatively important in the economy; and (ii) the shift coefficient ω is large (nearer unity).*

2.5 Interactions Between Commodity and Currency Markets

In this sub-section, we combine the results of the above discussion to consider the joint implications of market power and commodity currencies. To simplify matters, in what follows we assume that the home country's terms of trade, p_X/p_I, coincide with the relative commodity price, p^*/P^*.[11] This means that the country under consideration is a commodity exporter; and as P^*, the index of prices in the rest of the world, now also plays the role of the price index of the country's imports, these imports are a "representative market basket" of goods from the rest of the world. Thus the country is specialised in its exports and diversified in imports, a pattern of trade not dissimilar to that of many developing economies.

[11] Note that as p_X/p_I and p^*/P^* are both relative prices, which reflect real factors independent of currency units of measurement, we are not mixing currencies in taking these prices to be the same.

The schedule MM in Figure 2.10 is from Figure 2.5 and gives the relation between the world price of a commodity and the country's real exchange rate on account of its market power. The upward slope of the schedule implies that the country has some degree of market power as a real appreciation increases the world price. The elasticity of MM is the coefficient α in equation (2.6). When the country has no market power, $\alpha = 0$, and MM is horizontal. The CC schedule of Figure 2.10 is the commodity-currency relationship, from Figure 2.8. The elasticity of CC is $1/\gamma > 0$, so that when the country does not have a commodity currency, $1/\gamma \to \infty$ and the schedule is vertical. The elasticity of MM lies between zero and unity, while that of CC is always greater than unity. This means that where the two curves intersect, CC is unambiguously steeper than MM; in other words, the CC schedule always cuts MM from below. As can be seen, the initial overall equilibrium in the commodity and currency markets pertains at the point E_0.

Next, we analyse the general equilibrium effects on prices and the exchange rate of a commodity boom resulting from an exogenous increase in world demand for the commodity. To do this, we need to extend the initial demand equation (2.3) to include foreign real income y^*:

$$q^d = q^d\left(\frac{p^*}{P^*}, y^*\right), \quad \text{with } \lambda = \frac{\partial\left(\log q^d\right)}{\partial\left(\log y^*\right)} > 0,$$

so that λ is the income elasticity of demand for the commodity. Retracing our steps, we find that the extended version of the fundamental pricing rule (2.6) is

$$\widehat{\frac{p^*}{P^*}} = \alpha\hat{R} + \theta\hat{y}^*, \tag{2.17}$$

where $\theta = \lambda/(\varepsilon - \eta) > 0$ is the elasticity of the world price with respect to income. The second term on the right of equation (2.17), $\theta\hat{y}^*$, is the initial increase in prices resulting from the income increase $\hat{y}^*$, with the real exchange rate held constant. In the case in which the income elasticity is unity and $\varepsilon = -\eta = 1/4$,which are not unreasonable values for the short term, the coefficient θ in equation (2.17) takes the value of 2. Thus as the elasticity of commodity prices with respect to world income is two, prices exhibit a form of "excess volatility".

In terms of Figure 2.10, the effect of the increase in income is to shift the MM schedule up equiproportionally to $M'M'$, so that at the preexisting exchange rate R_0 the price increases by the full initial amount, $\theta\hat{y}^*$, and the market moves from the point E_0 to E_1. But as we are dealing with a commodity currency, this price increase leads to an appreciation, which causes the price to increase further, with the move from E_1 to E_2. It can be thus seen that the interaction of market power and a commodity currency has the effect of amplifying the initial increase in prices. That is, setting $\widehat{p_X/p_I} = \widehat{p^*/P^*}$, we can combine equations (2.14) and (2.17) to yield

$$\text{(2.18)} \qquad \widehat{\frac{p^*}{P^*}} = \left(\frac{\theta}{1-\alpha\gamma}\right)\hat{y}^* \geq \theta\hat{y}^* .$$

The inequality in this equation follows from α lying between zero and one, and $0 < \gamma < 1$ for a commodity currency. Thus, if $\overline{p}_o$ denotes the initial equilibrium relative price associated with the point E_0 and if we hold constant the value of the exchange rate at R_0, it follows from equation (2.17) that the new price at E_1 is $\overline{p}_0\left(1+\theta\hat{y}^*\right)$. When the exchange rate is allowed to appreciate, equation (2.18) implies that the commodity price rises further to $\overline{p}_0\left\{1+\left[\theta/(1-\alpha\gamma)\right]\hat{y}^*\right\}$ at the equilibrium point E_2. Continuing with the numerical example of the above paragraph whereby $\theta = 2$ and the market power elasticity $\alpha = 1/2$, suppose additionally that the commodity currency elasticity $\gamma = 1/2$. These values imply that the coefficient of income in equation (2.18) is

$$\left(\frac{\theta}{1-\alpha\gamma}\right) = \frac{2}{1-\frac{1}{2}\times\frac{1}{2}} \approx 2.7 .$$

Thus, relative to the partial equilibrium effect of equation (2.17), the general equilibrium interaction between the commodity and currency markets adds another $0.7/2 = 35$ percent to the volatility of prices.

Combining equations (2.18) and (2.14), it can be seen that the commodity boom also results in a currency appreciation,

$$\text{(2.19)} \qquad \hat{R} = \left(\frac{\gamma\theta}{1-\alpha\gamma}\right)\hat{y}^* .$$

Thus in terms of Figure 2.10, the exchange rate increases from R_0 to $R_0\left\{1+\left[\gamma\theta/(1-\alpha\gamma)\right]\hat{y}^*\right\}$. The result is that the world price rises and the currency appreciates; but as the proportionate appreciation is less than the price rise, domestic producers benefit as the internal relative price also rises. That is, from the definition of the real exchange rate R, $p/P = (1/R)\left(p^*/P^*\right)$, and equations (2.18) and (2.19), we have

$$\widehat{\frac{p}{P}} = \widehat{\frac{p^*}{P^*}} - \hat{R} = \left(\frac{(1-\gamma)\theta}{1-\alpha\gamma}\right)\hat{y}^* > 0 .$$

This increase in domestic prices is illustrated in Figure 2.11. This figure starts in quadrant I with the essential features of the commodity boom, from Figure 2.10. Quadrant III contains the real version of the PPP relationship, $p^*/P^* = (p/P)R$. The point e_0 in this quadrant coincides with E_0 in quadrant I, so that the slope of the ray from the origin passing through e_0 is the equilibrium internal relative price $(p/P)_0$. The boom causes the economy to move to the point e_2, which corresponds to E_2, and as the slope of the new ray from the origin is steeper (with reference to the "R axis") than before, the net effect of the rise in the world price and the appreciation is for the internal price to rise to $(p/P)_2 > (p/P)_0$.

2.6 Stability

We discussed above the relative slopes of the MM and CC schedules, and why the latter always cuts the former from below. This amounts to the elasticity of the CC schedule, $1/\gamma$, exceeding that of the MM schedule, α, or as both schedules are positively sloped, that

$$0 < \alpha\gamma < 1. \tag{2.20}$$

As defined by equation (2.7), the elasticity α always lies between zero and one. The elasticity γ is defined by equation (2.15) and as discussed below that equation, γ can range from a negative value to a positive fraction. Given that $0 \le \alpha \le 1$, if we ignore the boundary case when $\alpha = 0$, condition (2.20) further restricts γ by ruling out negative values, so that this elasticity is confined to the range [0, 1]. To further clarify the implications of this condition, suppose that it is not satisfied, so that the CC schedule cuts MM from above, as in Figure 2.12. As can be seen, the impact of the commodity boom in moving the economy from the initial equilibrium E_0 to E_2 is to <u>lower</u> the world price and <u>depreciate</u> the currency, which clearly makes no sense. If we again ignore boundary values, it is to be also noted that condition (2.20) implies the inequality in (2.18) -- that the full impact of the boom on prices is never less than its initial effect.

Condition (2.20) can also be interpreted as a stability condition. To see this, denote by $\bar{p}$ the world relative price of the commodity p^*/P^*, and write a levels version of the reciprocal of the market-power relation, equation (2.6), in logarithmic form as $\log R = f(\log \bar{p})$, with elasticity $f' = 1/\alpha$, where the prime denotes the derivative and α is as defined in equation (2.7). The commodity currency relation, analogous to equation (2.14), is $\log R = g(\log \bar{p})$, with $g' = \gamma$, defined by equation (2.15). Consider a situation in which the value of $\bar{p}$ is initially away from equilibrium, so that the exchange rate required to clear the currency market, $g(\log\bar{p})$, differs from that needed to equilibrate the commodity market, $f(\log\bar{p})$. Suppose that the forces of the currency market prevail in the sense that $\bar{p}$ rises when $g(\log\bar{p}) > f(\log\bar{p})$, and falls when $g(\log\bar{p}) < f(\log\bar{p})$. This behaviour can be expressed in the form of the following price-adjustment rule: $d(\log\bar{p})/dt = H(g(\log\bar{p}) - f(\log\bar{p}))$, where $H(\bullet)$ is a speed of adjustment function, with $H(0)=0$ and $H'>0$. Linearising around the equilibrium price $\bar{p}_0$, so that $g(\log\bar{p}_0) = f(\log\bar{p}_0)$, and defining $H'=\psi$ as the speed of adjustment coefficient, we have $d(\log\bar{p})/dt = \psi(g'-f')(\log\bar{p} - \log\bar{p}_0)$, or

$$\frac{d(\log\bar{p})}{dt} = \psi\left(\gamma - \frac{1}{\alpha}\right)(\log\bar{p} - \log\bar{p}_0).$$

The solution to this differential equation for the initial price at time zero, $\log\bar{p}$, is

$$\log\bar{p}(t) = \log\bar{p}_0 + (\log\bar{p} - \log\bar{p}_0)e^{\psi\left(\gamma - \frac{1}{\alpha}\right)t},$$

which is stable, and converges to $\log\bar{p}_0$, when $(\gamma - 1/\alpha) < 0$. This amounts to $\alpha\gamma < 1$, which is part of condition (2.20). Exactly the same stability condition emerges if alternatively the dynamics of the exchange rate are formulated as $d(\log R)/dt = H_R\left(f^{-1}(\log R) - g^{-1}(\log R)\right)$, with $H_R(\bullet)$ a new adjustment function with $H_R(0)=0$ and $H'_R > 0$.

In what follows, we shall assume that condition (2.20) is satisfied.

2.7 A Typology of Commodities and Currencies

Figure 2.10 considered the implications of a commodity boom when the country (i) has a commodity currency $(\gamma > 0)$ and (ii) is a price maker $(\alpha > 0)$. Figure 2.13 explores the implications of the 2×2 possible combinations. The top left-hand panel is a "stripped-down" version of Figure 2.10, which is the general case of a commodity currency and some degree of market power. Immediately below this is the situation of a price taker $(\alpha = 0)$ and a commodity currency $(\gamma > 0)$. As can be seen, in this case the boom causes the price to increase by less than previously; the price rises by just the vertical distance between the two schedules MM and $M'M'$, which in proportionate terms is $\theta\hat{y}^*$. The currency appreciates, but by less than before. In the general case, the boom initially increases the price and due to the commodity currency, the exchange rate then appreciates. When the country is a price maker, this appreciation serves to push up the world price further (as profitability in the export sector is squeezed), which, in turn, leads to a further appreciation. But when the country is a price taker, there are no "second round" effects, so that the initial effect of the boom is the end of the story. Accordingly, when the country is a price taker and has a commodity currency, the boom causes the world price to rise by less and the currency appreciation is dampened.

The top right-hand panel of Figure 2.13 represents the price maker/non-commodity currency case. Here the price rises by the same amount as in the previous case, by $\theta\hat{y}^*$, but now there is no change in the exchange rate as the country does not have a commodity currency. The final case of a price taker/non-commodity currency is given in the bottom panel on the right, and the outcome is identical to the previous case -- the price rises by $\theta\hat{y}^*$ and the exchange rate remains unchanged.

2.8 Further Applications

We now illustrate the workings of the approach by considering three further examples, the effects on prices and exchange rates of (i) a shift in investor sentiment towards the currency of the home country; (ii) technological change that creates new alternatives for the commodity; and (iii) globablisation that injects an added degree of flexibility into the domestic economy.

A Currency Fad

The notorious volatility of exchange rates is sometimes attributed to sudden, large shifts in the portfolio preferences of international investors. It is instructive to analyse the impact of such a currency fad within our framework. Suppose commodity prices are constant and that the onset of a fad causes the country's real exchange rate to appreciate in proportionate terms by $\rho > 0$, so that the commodity currency relationship, equation (2.14), becomes $\hat{R} = \gamma\left(\widehat{p^*/P^*}\right) + \rho$. Combining this with the market power relationship, equation (2.6), yields

$$\hat{R} = \left(\frac{1}{1-\alpha\gamma}\right)\rho, \quad \widehat{\frac{p^*}{P^*}} = \left(\frac{\alpha}{1-\alpha\gamma}\right)\rho. \tag{2.21}$$

In view of the stability condition (2.20), the interactions between markets leads to the exchange rate appreciating by more than the initial effect of the fad, $\hat{R} = \rho$. The explanation for this is that the initial appreciation leads to a higher commodity price, and via the commodity currency link, this leads to a further appreciation, causing the total increase in the rate to be $\hat{R} = \rho/(1-\alpha\gamma) > \rho$. This is illustrated in panel A of Figure 2.14, where the point E_0 is the initial equilibrium associated with the price $\overline{p}_0$ and exchange rate R_0. The currency fad shifts the CC schedule to the right, in proportionate terms by ρ, to $C'C'$. At the initial price $\overline{p}_0$, the fad results in the move to E_1, at which point there is an excess demand for the commodity. The price has to rise accordingly, and the new overall equilibrium is given by the point E_2. Note also that equation (2.21) implies that even although the world price rises, currency fad hurts domestic producers as the internal price falls:

$$\widehat{\frac{p}{P}} = \widehat{\frac{p^*}{P^*}} - \hat{R} = -\left(\frac{1-\alpha}{1-\alpha\gamma}\right)\rho < 0 .$$

It may be more realistic to think of a commodity boom that prompts investors to reevaluate the future prospects of the relevant commodity currency. In such a case, the boom occurs simultaneously with the currency fad, and we can obtain the overall impacts on the exchange rate and prices by simply adding together the individual effects derived above. Thus for the exchange rate, we add the right-hand sides of equations (2.19) and the first member of (2.21), and proceed analogously for prices. This yields:

$$\hat{R} = \frac{\gamma\theta\hat{y}^* + \rho}{1-\alpha\gamma}, \quad \widehat{\frac{p^*}{P^*}} = \frac{\theta\hat{y}^* + \alpha\rho}{1-\alpha\gamma}$$

Here the CC and MM curves both shift, as in panel B of Figure 2.14, and the equilibrium moves from the initial point E_0 to E_3. The change in internal prices is

$$\widehat{\frac{p}{P}} = \widehat{\frac{p^*}{P^*}} - \hat{R} = \frac{(1-\gamma)\theta\hat{y}^* - (1-\alpha)\rho}{1-\alpha\gamma}, \tag{2.22}$$

the sign of which is ambiguous, as γ and α both lie in the range [0, 1]. But we can say the following: For given sizes of the boom and the fad, that is, for fixed values of $\theta\hat{y}^*$ and ρ, the internal relative price is more likely to fall when under two conditions. First, when there is a stronger commodity currency relationship (that is, when γ is larger), the internal price is more likely to fall because of the direct currency translation effect. Second, the price is also more likely to fall when the country has less pricing power (α lower), as then there is a more limited offsetting increase in world prices following the appreciation. To say something more definitive, suppose that the magnitude of the two shocks coincide in the sense that the initial increase in the world price on account of the commodity boom $\left(\theta\hat{y}^*\right)$ is exactly equal to the initial appreciation due to the currency fad (ρ). Thus with $\theta\hat{y}^* = \rho = z$ (say), equation (2.22) becomes

$$\frac{\widehat{p}}{P} = \left(\frac{\alpha - \gamma}{1 - \alpha\gamma}\right) z .$$

As z > 0, this shows that the internal price falls when $\alpha < \gamma$, or when the country has less market power than the extent to which it has a commodity currency.

Technological Change

Suppose a continued high price of the commodity stimulates the search for alternatives, which via an endogenous technical-change process, results in the invention of a new substitute product. An example could be the successful use of hydrogen as a substitute fuel for petroleum in cars. We shall show that this type of technical change has a stabilising effect as the volatility of commodity prices and the exchange rate of the dominant producing country both fall. It is convenient to analyse these effects within the context of the commodity boom framework discussed above. In what follows, some elasticities and variables change with the introduction of the new product, while others remain unchanged. We indicate those that change by adding a subscript 0 for the old value and 1 for the new value. The elasticities that remain unchanged have no subscript.

We treat the new product as an additional substitute for the commodity, so that demand becomes more price elastic with the elasticity increasing (in absolute value) to $\eta_1 < \eta_0 < 0$. Accordingly, the new value of the market-power elasticity in equation (2.6) is

$$\alpha_1 = \frac{\varepsilon}{\varepsilon - \eta_1} < \alpha_0 = \frac{\varepsilon}{\varepsilon - \eta_0} .$$

Accordingly, the availability of the new product reduces the country's market power. Equation (2.17), when represents in impact of the commodity boom, becomes

$$\left(\widehat{\frac{p^*}{P^*}}\right)_1 = \alpha_1 \hat{R} + \theta_1 \hat{y}^* ,$$

where $\theta_1 = \lambda/(\varepsilon - \eta_1) < \theta_0 = \lambda/(\varepsilon - \eta_0)$. The relevant part of equation (2.18) is then modified to $\widehat{(p^*/P^*)}_1 = [\theta_1/(1-\alpha_1\gamma)]\hat{y}^*$, so that

$$\left(\widehat{\frac{p^*}{P^*}}\right)_1 = \left(\frac{\theta_1}{1-\alpha_1\gamma}\right)\hat{y}^* < \left(\widehat{\frac{p^*}{P^*}}\right)_0 = \left(\frac{\theta_0}{1-\alpha_0\gamma}\right)\hat{y}^* .$$

As the same increase in foreign income $\left(\hat{y}^*\right)$ causes the world price to rise by less when the new substitute product is available, the volatility of prices falls. Similarly, the volatility of the country's exchange rate will now be lower as

$$\hat{R}_1 = \left(\frac{\gamma\theta_1}{1-\alpha_1\gamma}\right)\hat{y}^* < \hat{R}_0 = \left(\frac{\gamma\theta_0}{1-\alpha_0\gamma}\right)\hat{y}^*,$$

which follows from equation (2.19). It can thus be concluded that this type of technological change has the effect of making commodity and currency markets more stable.

Globalisation

It is often observed that highly-protected economies are characterised by a low degree of resource mobility across sectors, or a lack of overall "flexibility". The post-war Australian economy up to the 1980s is an example. Suppose now that this all changes as the economy becomes more exposed to the discipline of international trade because of reduced protection and/or reduced transport costs. This could reasonably be taken to mean that as the domestic economy is now more integrated with the world economy and more exposed to the competitive pressures of international trade, resources now flow more easily between the home goods sector on the one hand, and importables on the other. In other words, home goods and importables become more substitutable in both production and consumption with this form of globalisation. Thus, we consider the effects of an increase in the shift coefficient ω. From equation (2.15), this rise in ω increases the elasticity γ in the commodity-currency relationship (2.14), from γ_0 to γ_1, which makes the country's currency behave more like a commodity currency. Proceeding with the effects of the commodity boom as before, we obtain

$$\left(\widehat{\frac{p^*}{P^*}}\right)_1 = \left(\frac{\theta}{1-\alpha\gamma_1}\right)\hat{y}^* > \left(\widehat{\frac{p^*}{P^*}}\right)_0 = \left(\frac{\theta}{1-\alpha\gamma_0}\right)\hat{y}^*, \quad \hat{R}_1 = \left(\frac{\gamma_1\theta}{1-\alpha\gamma_1}\right)\hat{y}^* > \hat{R}_0 = \left(\frac{\gamma_0\theta}{1-\alpha\gamma_0}\right)\hat{y}^*.$$

The above result states that the greater flexibility of the economy leads to more volatility of the commodity price and the exchange rate. Usually, enhanced flexibility tends to be associated with more stable prices, so this result is a bit surprising. The key to understanding what is taking place here is that enhanced flexibility in this case means that a given change in the world price, brought about by an increase in world economic activity, now leads to a larger appreciation of the domestic currency. This leads to lower exports and as the country has market power, a still higher world price. It can thus be seen that the interaction between the flexibility of the economy and the commodity-currency nature of its exchange rate is the mechanism that gives rise to the result of globablisation generating greater volatility.

3. A FIRST LOOK AT THE DATA

Section 2 outlined the conditions necessary for a commodity currency and market power in commodity markets. The next section addresses these issues by specifying and estimating a multivariate latent factor model which is able to examine the joint determinants of the currency and commodity prices. However, as a precursor, this section provides a preliminary analysis of the data set, the results of which will be used to motivate the multivariate model of Section 4.

The data set consists of m = 3 'commodity currency' exchange rate variables, n = 1 additional currencies, and v = 5 commodity price variables. The commodity currencies considered include the Australian dollar (AUD_t), the Canadian dollar (CND_t) and the New Zealand dollar (NZD_t). The British pound (GBP_t) represents an additional currency. The i^{th} nominal exchange rate $S_{i,t}$ is transformed into a real rate ($R_{i,t}$) which is expressed in terms of US dollars (USD_t) per unit of national currency,

$$R_{i,t} = \frac{P_{i,t}}{S_{i,t}P_t^*},$$

where $P_{i,t}$ and P_t^* represent the national and US consumer price indices, respectively. Demeaned continuously compounding percentage returns of the commodity currencies ($CE_{i,t}$) are computed by taking the quarterly difference of the natural logarithm of the real exchange rates, subtracting the sample mean and multiplying by 100. The additional currency, denoted E_t, is similarly transformed.

The International Monetary Fund (IMF) publishes an overall index of commodity prices, as well as five sub-indices capturing the major commodity groups. These sub indices include agricultural materials, beverages, food, metals and energy. The choice of commodity price indices is motivated by the IMF's sub-classifications, and is in fact sourced from the IMF International Financial Statistics database. The exception is for the oil price index which is used to proxy the IMF's energy index, as the IMF's energy index is only reported from 1992. The oil price index was obtained from Datastream. The $\nu = 5$ commodity price variables thus include indices of agricultural materials (AGR_t), beverages (BEV_t), food (FOO_t), metals (MET_t), and oil prices (OIL_t). The k^{th} nominal commodity price index is also expressed in real terms by deflating by the US consumer price index. Real demeaned commodity price percentage returns, denoted ($PC_{k,t}$) are determined analogously to those for the commodity currency returns. The vector Y_t

(3.1) $$Y_t = \{CE_{i,t}, E_t, PC_{k,t}\}$$

summarises the data.

The sample period of the model extends from Quarter 1, 1975 to Quarter 3, 2005 for T=123 observations. Quarter 1, 1975 represents the beginning of the construction of the commodity price indices by the IMF. The data are expressed in quarterly terms, as the Australian consumer price index used to deflate the Australian exchange rate into real terms is only available on a quarterly basis. Table 1A in Appendix 1 contains details on variable sources and codes.

The complete data set is contained in Figure 3.1, and Tables 3.1 and 3.2 present a selection of descriptive statistics and the variance-covariance and correlation matrices respectively.[12] Table 3.1 indicates that the commodity price returns are generally more volatile than the currency returns. The standard deviations for commodities range between 5.014 for food returns to 13.322 for oil returns. The returns for the oil index also demonstrate the largest minimum and maximum over the sample period. Of the currency returns, the Canadian dollar is the least volatile with a standard deviation of 2.656, and the New Zealand dollar the most with a standard deviation of 5.778. The Jarque-Bera tests indicate mixed evidence of normality of the data series. The null hypothesis of normality cannot be rejected for Australian and Canadian dollar returns, or for the metal price index, but is rejected for the remaining currency and commodity returns. For simplicity, normality is assumed for convenience of estimation in Section 4.

The upper diagonal of Table 3.2 presents the correlation matrix of the data set. The diagonal and the lower diagonal present the variance-covariance matrix. The correlation matrix highlights some interesting features. The commodity currencies are positively correlated with each other, but negatively correlated with the British pound, indicating the different structures of the respective types of economies. Commodity returns are positively correlated across the board with one exception (oil and beverages). As expected, commodity currency returns (expressed in terms of USD per national currency) are generally positively correlated with commodity price returns. The exceptions where correlations are negative (albeit comparatively small) are for the Australian dollar with oil (-0.005), the Canadian dollar with food (-0.092), and the New Zealand dollar with beverages (-0.001).

In forming a view on the lag structure of the factor model, correlograms of the currency and commodity price returns are presented in Table 3.3 to gain an insight into the autocorrelation structure of the individual variables. To examine further the possible lag structure of the system as a whole, the lag length criteria of Akaike (AIC), Schwarz (SC) and Hannan-Quinn (HQ) of a vector autoregression (VAR) of the data are presented in Table 3.4. The sequentially modified *LR* test statistic is also presented. The correlograms indicate that there is some temporal dependence amongst the individual variables, with the

[12] All calculations of Section 3 were performed in Eviews 5.

exception of the Australian dollar. The commodity price returns tend to exhibit the strongest autocorrelation. The AIC, SC and HQ statistics show that a structure of one lag is sufficient to characterise the system as a whole, although the likelihood ratio test indicates an optimal structure of four lags.

To motivate further the model developed in Section 4, the results of simple bivariate Granger causality tests are conducted in Table 3.5. The results suggest that the commodity currencies Granger cause commodity prices rather than the other way around. The null hypotheses that the Australian dollar does not Granger cause agricultural returns, food returns, metal returns and oil returns is rejected at the 0.05 level of significance. The same is true for the Canadian dollar with food and metals, and the New Zealand dollar with agricultural materials, food and metals. Conversely, the null hypothesis is not rejected in all cases of commodity prices not Granger causing the commodity currencies. Finally, the British pound Granger causes the New Zealand dollar, food prices and metal price returns. These preliminary tests suggest that perhaps it is the case that commodity prices are driven by currency movements rather than the other way around. The next section explores whether or not this is true when the system is modelled jointly, rather than on a bivariate basis.

4. A LATENT FACTOR MODEL OF CURRENCIES AND COMMODITIES

Although there are many empirically based papers written on 'commodity currencies', there is usually an implicit assumption that either commodity prices are exogenous and currency commodities are a function of these prices (for examples, see Cashin et al., 2004, Freebairn, 1990, and Gruen and Kortion, 1998), or to a lesser degree, vice versa (Amano and van Norden, 1995, consider the possibility for Canada, but find that causality runs from the terms of trade to the Canadian dollar). Chen and Rogoff (2003) raise the possibility that commodity prices may be endogenous in simple OLS models estimating commodity price elasticities of the real exchange rates of Australia, Canada and New Zealand under various parameterisations. However, they control for endogeneity by using the IMF's world commodity price index as an instrument for country specific commodity prices. They don't go on to estimate a multivariate model. Brodo (2004) also considers the potential endogeneity of the terms of trade, but finds that it is rare for such commodity exporting countries to have market power. The only empirical papers which attempt to model the case where the two effects are operating simultaneously, are those which are use the vector autoregression (VAR) framework where the very nature of VAR models allows feedback mechanisms between the variables. Examples of such papers include Hatzinikolaou and Polasek (2005) and Fisher

(1996). Despite the feedback effects in such models, the analysis is generally focused on the effects of commodity prices or the terms of trade on exchange rates and not the other way around, although Fisher (1996) provides some brief comments on the effects of shocks (real and nominal) on the terms of trade.

The model specified in this paper examines the concepts in Section 2 and addresses this gap in the empirical literature by jointly examining the determinants of currency and commodity price returns as a function of a set of independent latent factors. Influences that are common to each sub-set of variables are captured by a single time series (factor) which is intuitively likely to be a function of more than one observable variable. The advantage is that these observable variables do not have to be identified and modeled. It is particularly convenient to adopt such a specification, as it can implicitly take into account shocks simultaneously affecting each type of market such as business cycle shocks or shocks to the US economy without formally modeling such linkages (see Chen and Rogoff, 2003, and Freebairn, 1990, for discussions of the difficulties in accounting for the many possibilities of influences on the exchange rate). This class of models is common in the finance literature and in high frequency data exchange rate models as well as models common in the business cycle literature; see Diebold and Nerlove (1989), Dungey (1999), Mahieu and Schotman (1994) and Stock and Watson (1991). One of the key advantages of this framework is that of parsimony. The model is able to provide an understanding of the underlying importance of linkages across the markets while controlling the number of parameters to be estimated.

There are three key factors in the model. These are a common factor which captures information that is common to the complete data set; a currency factor which is specific to the returns of the commodity currencies; and a commodity factor which captures information specific to the set of commodity price returns in the model. The joint impact of (commodity) currency returns on commodity returns, and the corresponding joint impact of commodity returns on the commodity exchange rate returns can then be assessed by examining spillovers across each market. The model allows insight into the hypotheses regarding the relationship between the commodity currencies and commodity prices presented in the first part of the paper to be gleaned. Namely, the model provides a convenient decomposition of the importance that each factor plays in contributing to volatility in the returns of each asset. Thus it is possible to assess (i) how important is the commodity currency factor to the determination of the commodity currencies, (ii) how important is the commodity factor to the determination of commodity returns and (iii) how important are spillovers across each type of market. The factor model describing the data in (3.1) can be separated into three components: These are the commodity currency ($CE_{i,t}$) returns component; the additional currency (E_t) returns component; and the commodity price returns ($PC_{k,t}$) component. The following provides the specification of each component of the model.

4.1 Commodity Currency Returns Specification

Equation (4.1) shows the factor model for the commodity currency returns:

(4.1) $$CE_{i,t} = \lambda_i V_t + \varphi_i CF_t + \gamma_i PCF_{t-1} + \sigma_i U_{i,t}, \quad i = 1,...,m.$$

The commodity currency returns are a function of a common factor (V_t) which is included in all equations of the system, a commodity currency returns factor (CF_t) henceforth referred to as the currency factor, and an idiosyncratic term ($U_{i,t}$), with loadings λ_i, φ_i, and σ_i respectively. The inclusion of the pound (E_t) in the model (described in Section 4.2 below) and the implicit inclusion of the US dollar as the numeraire currency should provide sufficient information to identify the factor, V_t, common to all variables. The existence of the commodity currency returns factor is supported by the correlations reported in Table 3.2 which show that the commodity currencies are positively correlated with each other, but negatively correlated with the British pound.

To examine the extent to which commodity currency returns are a function of commodity price returns and vice versa, cross market linkages between the two markets are modelled through spillover factors. In the case of the commodity currencies, spillovers from the commodity returns series are modelled through the lagged commodity price factor (PCF_{t-1}), with loading γ_i. The commodity price factor at time t is specific only to the commodity returns series of the model and is described in more detail in equations (4.5) and (4.6) below.

The common and currency returns factors are modelled as AR(1) processes with loadings ρ_V and ρ_{CF} such that

(4.2) $$V_t = \rho_V V_{t-1} + \eta_{V,t}$$

(4.3) $$CF_t = \rho_{CF} CF_{t-1} + \eta_{CF,t}.$$

Given that the data set is a returns data set, and also of short duration, it is reasonable to impose a lag structure of one lag on the common, commodity currency, and commodity price factors in equations (4.1), (4.2) and (4.6). This specification is supported by the correlograms and the lag length criteria reported in Section 3. The idiosyncratic factors which capture the component of each return series not explained by the other factors are assumed not to exhibit autocorrelation.

4.2 Additional Currency Returns Specification

The additional currency returns are included in the model primarily to help identify the common factor V_t. The additional currency return variable which is not considered a commodity currency is included in the model to help identify these global, or common influences, and to also separate the movements in the commodity currencies from currency markets in general. This is particularly important as all of the currency returns are expressed in terms of US dollar per unit of national currency, and the unit of account from which the commodity price indices are constructed is also expressed in US dollar terms. Excluding a common factor from the model specification may result in the detection of spurious linkages due to the numeraire currency used in the model.[13] Equation (4.4) presents the model for the additional currency returns as follows

$$E_{j,t} = \lambda_j V_t + \sigma_j U_{j,t}, \quad j = 1,...,n. \tag{4.4}$$

These returns are a function of the world factor and the idiosyncratic factor with loadings λ_j and σ_j respectively. No additional linkages with the other variables of the model apart from through the world factor are considered for the additional currency.

4.3 Commodity Returns Specification

The commodity price returns equation in (4.5) is similar in nature to the commodity currency returns specification whereby

$$PC_{k,t} = \lambda_k V_t + \delta_k PCF_t + \beta_k CF_{t-1} + \sigma_k U_{k,t}, \quad k = 1,...,v. \tag{4.5}$$

Commodity returns are a function of the common factor (V_t), the commodity price returns factor (PCF_t), spillovers from the previous period's currency returns factor (CF_{t-1}) and an idiosyncratic factor $U_{k,t}$. The parameter loadings on these factors are λ_k, δ_k, β_k and σ_k. Like the common and currency factors, the commodity factor is an AR(1) process

$$PCF_t = \rho_{PCF} PCF_{t-1} + \eta_{PCF,t}. \tag{4.6}$$

4.4 The Complete Factor Model

For convenience, the above model can be expressed in matrix form as

$$Y_t = \Lambda F_t + \Delta F_{t-1} + W_t \tag{4.7}$$

$$F_{t+1} = \Psi F_t + V_t, \tag{4.8}$$

where Y_t in (4.7) is a function of the latent factors contained in F_t (namely V_t, CF_t, and PC_t and the idiosyncratics) with parameter loadings Λ, and spillovers, which are modelled through the lag of the latent factors (F_{t-1}) with parameter loading Δ. The state equation in (4.8) shows that the factor (F_{t+1}) is an

[13] A version of this model was estimated excluding the additional currency (i.e., without the common factor, V_t) and it was found that the currency factor had a substantial impact on the commodity price returns. Some factor models for currency markets include an additional 'numeraire' factor where a parameter is held fixed across all equations (see Dungey, 1999, Dungey et al., 2003, and Mahieu and Schotman, 1994). As the contribution of this factor to overall asset market volatility is minimal in most applications, it is excluded here.

autoregressive process with loading Ψ. The error matrices V_t and W_t are vector white noise processes, such that

(4.9) $$E(V_t V_\tau') = \begin{cases} Q: & \text{for } t = \tau \\ 0: & \text{otherwise} \end{cases}$$

and

(4.10) $$E(W_t W_\tau') = \begin{cases} R: & \text{for } t = \tau \\ 0: & \text{otherwise.} \end{cases}$$

Here, $W_t = 0$, and hence, R = 0.

The model in (4.7) to (4.10) is estimated using maximum likelihood and the Kalman filter. The likelihood function is maximised using the procedure MAXLIK in Gauss 5.0 with the BFGS iterative gradient algorithm and numerical derivatives. For details on the Kalman filter algorithm, see Harvey (1981, 1990), Hamilton (1994, Chapter 13) and Lütkepohl (1993, Chapter 13).

4.5 Variance Decompositions

The assumption of independence of the factors of which each asset return is a function enables the results to be interpreted in terms of the contribution of each factor to the overall volatility of each asset. The volatility of currency and commodity returns can be decomposed in terms of the factors by squaring of both sides of (4.1), (4.4) and (4.5) and taking expectations. The pertinent decomposition of the variances for the commodity currencies is

(4.11) $$E\left[CE_{i,t}^2\right] = \frac{\lambda_i^2}{1-\rho_V^2} + \frac{\phi_i^2}{1-\rho_{CF}^2} + \frac{\gamma_i^2}{1-\rho_{PCF}^2} + \sigma_i^2, \quad i = 1,\dots,m.$$

where the term $\lambda_i^2 / 1-\rho_v^2$ represents the contribution of the world factor to volatility in commodity currency i, $\phi_i^2 / 1-\rho_v^2$ represents the contribution of the currency factor, $\gamma_i^2 / 1-\rho_{PCF}^2$ the contribution of spillovers from the commodity factor, and σ_i^2 the contribution of the idiosyncratic factor. Analogous to (4.11), the decomposition for the additional currencies is

(4.12) $$E\left[E_{j,t}^2\right] = \frac{\lambda_j^2}{1-\rho_V^2} + \sigma_j^2, \quad j = 1,\dots,n,$$

and for the commodity price series is

(4.13) $$E\left[PC_{k,t}^2\right] = \frac{\lambda_k^2}{1-\rho_V^2} + \frac{\delta_k^2}{1-\rho_{PCF}^2} + \frac{\beta_k^2}{1-\rho_{CF}^2} + \sigma_k^2, \quad k = 1,\dots,v.$$

Expressing these decompositions in terms of the percentage contribution that each factor makes to overall volatility provides a convenient mechanism for interpretation of the results.

4.6 Empirical Results

Table 4.1 presents the volatility decompositions expressed in equations (4.11) to (4.13) of the currency and commodity returns in terms of the contribution that each factor makes to total volatility, and Table 4.2 presents the parameter estimates of the model specified in equations (4.1) to (4.6). For all data except for the Australian dollar, the idiosyncratic factors are most important in explaining volatility of the returns. The large contribution of the idiosyncratic factors is as expected as returns data are less predictable than levels data. The common factor is most important to the British pound and the New Zealand dollar, contributing 43.95 and 32.93 percent of the volatility to these returns respectively. It is not surprising that the British pound and the New Zealand dollar are similar as they seem to be related as reflected in the Granger causality tests conducted in Table 3.5, where the hypothesis that the pound does not Granger cause the New Zealand dollar returns was rejected at the 5 percent level of significance, and the hypothesis that the New Zealand dollar does not Granger cause pound returns was rejected at the 10 percent level of significance. The common factor contributes just under seven percent to volatility of the Australian dollar, and 0.03 percent to Canada. Of the commodity returns, metals are most affected by the common factor (7.64 percent), with the other commodities less than four percent. These results are reflected in the parameter estimates reported in Table 4.2 which shows that the common factor is significant only for the Australian, New Zealand and British currencies, as well as for the metal price returns. It is also of interest to note that the signs on the parameter estimates for the commodity currencies are the same, but are opposite to those of the pound. The signs on the commodity returns are also the same as for the commodity currencies with the exception of beverage returns, reflecting that all markets excluding that for the pound and beverages are affected in the same way by the common factor.

The (commodity) currency market factor has an important role for the volatility of the commodity currencies. The contribution to volatility for Canada and New Zealand is just under 30 percent of volatility, and is about 81 percent of the volatility of the Australian dollar. The Australian dollar thus appears to dominate movements amongst the commodity currency markets, although the contribution of the factor for all three series is quite large. The parameter estimates of the currency factor are significant for the three returns series as shown in Table 4.2, and as expected, the signs of the loadings of each of the three series on the currency factor are all the same. The commodity returns factor plays a mixed role in explaining volatility in the commodity markets. Agricultural materials, beverages, and metals are most affected by the commodity factor, with a contribution of between 20 and 30 percent of volatility. Food and oil are least affected, although the parameter loading on the parameter for food is significant at the 5% level of significance. Oil is the only commodity where the commodity factor is not significant. That the oil price returns are not as strongly related to the commodity factor makes sense in that the oil industry is much different in nature than the other commodity industries, particularly in light of the role that OPEC is able to play in consciously altering supply and hence the price of oil. Similar to the case for the currency factor on the currencies, the parameter loadings on the commodity factor on all commodities are of the same sign.

Commodity Currencies or Currency Commodities?

The volatility decomposition in Table 4.1 shows that commodities are more affected by spillovers from the commodity currency factor than commodity currency returns are affected by the commodity factor.[14] This suggests that perhaps the commodity exporting nations do exhibit a small degree of market power. The commodity factor in the exchange rate markets are not significant for any country, and the contribution of commodity price movements to the exchange rate return volatilities are close to zero. These results are reinforced by likelihood ratio tests contained in Table 4.3. The joint test of the hypothesis that the parameter loadings of the commodity factor in the commodity currency returns is zero, a test of H_0: $\gamma_i = 0$, i = 1,...,m, in equation (4.1), is unable to be rejected with a p-value of 0.808. Table 4.2 shows that the estimates of the loadings of the commodity factor in the currency returns [the γ_i in equation (4.1)] are the same signs of the commodity factor in the commodity returns themselves [the δ_k in equation (4.5)]. This confirms prior expectations as commodity currencies and commodity prices tend to move in the same direction. The same is generally true of the signs of the currency factor in the currency returns and the spillovers into the commodity returns [compare φ_i in equation (4.1) and β_k in (4.5)].

The impact of the currency market factor on commodities on the other hand is slightly more important, although accounts for less than 5.5 percent of volatility for all markets. Spillovers to beverages are the least important with almost no contribution to volatility made from the currency factor. This probably reflects that Australia, New Zealand and Canada do not produce the commodities included in the beverages index, so it is not anticipated that they would have market power.[15] Spillovers from currency returns to commodities are most important for the returns of food (5.23 percent), followed by oil (2.71

[14] An additional parameterisation was also estimated whereby a factor common to the commodity currencies and commodity prices was specified to control for joint contemporaneous movements across the two types of markets. The volatility decompositions of this model were quite similar to the ones presented here. Namely, the spillover effects across the two types of asset markets were much the same.

[15] For a summary of the commodity producing countries and their principal exports, see Cashin et al. (2004).

percent), metals (2.34 percent) and agricultural materials (2.08 percent). The parameter estimates are only significant in the case of food and oil, however, likelihood ratio tests contained in Table 4.3 show that the hypothesis that the parameter loadings of the currency factor in the commodity returns are jointly zero [H_0: $\beta_k = 0$, k=1,...,v, in equation (4.5)] is rejected with a p-value of 0.092. It is peculiar that the spillovers from the commodity currencies to the oil returns are significant. However, it should be acknowledged that this result possibly reflects other aspects specific to the oil market, including (i) the widespread complementary nature of the oil in the production process of many goods, including other commodities, and (ii) the role of production decisions by OPEC in managing oil prices.

Globalisation and Latent Factors

The advantage of using the Kalman filter as the estimation methodology is that it provides a time series of each of the factors in the model. This enables an analysis of changes in the importance of each factor over time to the returns of the series in the model, which is particularly relevant in light of the discussion relating to the effects of globalisation discussed in Section 2. Section 2 concluded that increases in volatility over time may be due to the interaction between the flexibility of the economy and the commodity-currency nature of its exchange rate. The times series of each factor are not presented here, as visually the factors appear to be quite noisy due to the returns nature of the data. However, Table 4.4 presents the contribution that each factor makes to the returns of each asset over sub-periods of the sample period to assess how the relative influences of each factor has changed over time.

The first sub period considered is from the beginning of the sample (less three observations, one due to the construction of the returns data set, and two to the initialisation of the factors in the Kalman filter) to Quarter 4, 1982. This breakdown was chosen to coincide with the period prior to deregulation in the financial systems of Australia and New Zealand. The second sub period extends from Quarter 1, 1983 to Quarter 4, 1990, followed by decompositions separated into five years blocks until the end of the sample period.

There are certain patterns evident in the sub-period decompositions, although the results are quite stable over time. The commodity currency variables are all relatively more affected by the commodity currency factor over time, and spillovers from the commodity price market to currency returns become marginally less important. It is possible that the reason for the increasing importance of the currency factor is that the commodity type economies are increasingly becoming subject to inter-linkages with other economies as the level of integration increases. That this is reflected more in the currency factor than in the common factor may be because the economies considered are competing in the same markets. For the commodity returns, the commodity factor is marginally less important over time. Spillovers from the currency markets are increasingly important, although again, the effects are small relative to the impacts from other factors.

5. SUMMARY AND CONCLUSIONS

Most research, both theoretical and empirical, into the exchange rates of countries that are prominent commodity producers assumes that these rates are a function of commodity prices. Countries that are commonly thought to have "commodity currencies" include Australia, Canada and New Zealand, as well as many developing countries that are rich in natural resources. Few papers consider the opposite case of "currency commodities", whereby the value of an exchange rate of a commodity exporting country can have an impact on commodity prices. This situation can arise if a country is a large producer of a commodity and is thus able to influence world prices; another possibility is that a group of commodity exporting countries may have combined market power and are hence able to influence the world prices of commodities.

This paper considered issues surrounding the joint determination of the the prices of commodity currencies and currency commodities in both a theoretical and an empirical framework. The theoretical framework provided conditions necessary for the existence of a commodity currency and market power in commodity markets, as well as an analysis of the simultaneous workings of both effects. Three scenarios were analysed to illustrate the workings of the model. These were (i) a shift in investor sentiment towards the currency of the home country; (ii) technological change that created new alternatives for the commodity; and (iii) globalisation that injected an added degree of flexibility into the domestic economy.

The empirical section of the paper provided an examination of quarterly real exchange rate and commodity price returns since the mid 1970s in order to uncover evidence on the existence of commodity currencies and currency commodities. The commodity currencies considered were the Australian dollar, the Canadian dollar and the New Zealand dollar, and the commodities were the IMF's indices of agricultural materials, beverages, food, metals and oil prices.[16] To uncover the simultaneous relationships between the two types of assets, a multivariate latent factor model was specified and estimated. The model decomposed volatility of the asset returns in the model into a set of independent factors consisting of a common factor, a commodity currency factor, a commodity factor and spillovers across each type of

[16] The oil price index was sourced from an alternative database due to unavailability of a long energy time series provided by the IMF.

market. Spillovers from currencies (commodities) to commodities (currencies) were modelled by the lagged impact that the factor specific to the exchange rate (commodity) returns had on the commodity (currency) returns. The model also contained an idiosyncratic factor which captured all movements not due to the joint factors. The model provided an interesting set of results that are contrary to common modelling and theoretical assumptions invoked in contemporary analysis of commodity currencies. Namely, the results suggested that there is less evidence that currencies are affected by commodities than commodities are affected by the commodity currencies. Spillovers from commodities to currencies contributed less than 1 percent to the volatility of the currency returns, whilst spillovers from currencies to commodities generally contributed between 2 and 5.2 percent to the commodities. These results suggested that commodity currencies models failing to account for endogeneity between currency and commodity returns may be mis-specified.

This research is subject to a set of caveats. First, the commodity price data is sourced from the database of the IMF. The components of the commodity prices considered (agricultural materials, beverages, food, metals and energy/oil) are not specifically tailored to the economies considered in the model. It may be better to use commodity price indices which are more representative of the commodities in which Australia, Canada and New Zealand are dominant, or to even use relevant commodity prices themselves (perhaps while also controlling for movements in world commodity markets in general through the inclusion of some generic commodity price index). Presumably the results for the joint impact of the currency markets will be stronger (as even without the country specific indices being included in the model currencies have some effect on commodity returns), and potentially there may be more evidence of spillovers from commodities to the commodity currencies. Before dismissing former empirical research, this decomposition needs to be considered.

Second, rather than examining the joint determination of currencies and commodities in a general framework with a number of currencies and commodities as adopted here, an alternative would be to assess the endogenous determination of a currency and commodity pairing. For example, one hypothesis could be that Australia is a price maker in the market for iron ore. Our model could be extended to examine this hypothesis in conjunction with the hypothesis that the price of iron ore has an impact on the Australian dollar by examining spillovers from the idiosyncratic factor specific to the exchange rate to the commodity price, and vice versa. This framework may indicate evidence of more specific sources of market power across the asset markets.

Third, little attention has been devoted to the role of the terms of trade in the model. The role of the terms of trade is probably an important element in the story linking the endogenous determination of both exchange rates and commodity prices. Some of the commodities considered are representative of the exports of the countries considered in the model and others are considered imports. It is hence feasible to establish the impact that each commodity has on the terms of trade of each country; but again it is probably more desirable to have a series of commodities less generic in nature, as well as to consider the role of other imports, not commodity based such as manufactured goods, in order comprehensively analyse this situation. Future research may explore this issue further.

Caveats aside, the research has broad implications in a number of areas. The results suggest that it is important for commodity exporters (both producers and countries) to pay attention to the co-movement of prices and currency values; there appear to be several sources contributing to the co-movement of the assets which may help analysts and traders gain a better understanding of the notorious volatility of currency values and commodity prices. Although the majority of volatility in these asset markets is as a result of idiosyncratic factors, common and market specific factors are also important. In particular, the currency factor is important for the commodity currency returns, and the commodity factor is important for most commodity returns. The results suggest that a multivariate model provides an additional edge in understanding currency or commodity price determination.

The results also suggest that in an increasingly globalised world, the definition and use of the assumption of a "small country" may need to be reassessed. Apart from the US, most countries are traditionally assumed to be small. However, the advantage or our framework is that it is possible to extract an indirect method of identifying "large countries" in international trade. If volatility in a set of markets has spillover effects on another set of markets, then collectively there is evidence of large country effects. This was the case in the paper where the currency factor jointly specific to Australia, Canada and New Zealand had effects on the commodity series. The approach makes it possible to identify 'hidden' market power even in the absence of collusion. Empirically our results show that joint market power has been increasing over time, although it appears that even those benefiting from this market power have been unaware of its existence. Knowledge of this phenomenon may be of use for companies producing and consuming commodities that are priced by formal periodic "contract negotiations" such as iron ore.

The results also have implications for risk management by producers and consumers. Within our framework with bi-directional causality, the links between exchange rates and currency prices are stronger than that implied by traditional uni-directional commodity currency models. In other words, we can account for more of the substantial volatility of currency and commodity prices by allowing for spillovers from one asset class to another. Commodity price risk cannot be assessed independently of foreign exchange risk, and vice verse. In this context, hedging of these risks assumes even more importance as part of risk management strategies by producers/consumers.

The use of factor models in jointly examining the determinants of more than one asset market is becoming a new area of research in the literature on financial market contagion (see Dungey and Martin, 2006), and also in the joint determination of bond and equity markets or other macro variables during non-crisis times. The emphasis on the latter style of models is usually on the determination of the term structure in conjunction with some other market (see Bekaert and Grenadier, 2001, Rudebusch and Wu, 2004, and Diebold et al., 2005, as examples). The application of this paper provided another example of the importance of accounting for cross-market linkages in models where economies are becoming increasingly integrated.

Although the factors derived from the latent factor models cannot specifically be mapped back to observable fundamental variables (such as macroeconomic variables, industry policies, trade agreements or other factors which may impact on exchange rates or commodity markets), the advantage is that a sense of the relative importance of each factor can be gleaned. Further, specification issues relating to the choice of such variables and indeed measuring some of these variables (such as industry policies) can be avoided. The model also has the advantage of parsimony as in each equation the impact of the common factor (which could be a composite of many common variables) can be measured by just one parameter. The feature of parsimony also has benefits for forecasting the factors and hence the exchange rates and commodity returns, although this avenue was not pursued here.

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FIGURE 2.1

THE WORLD GOLD MARKET

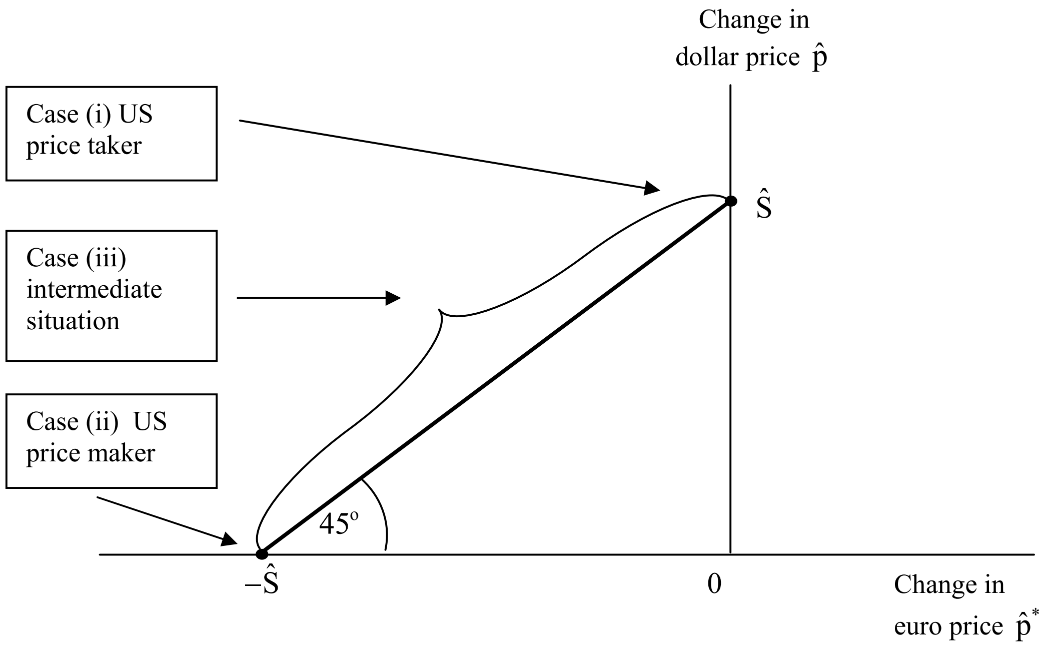
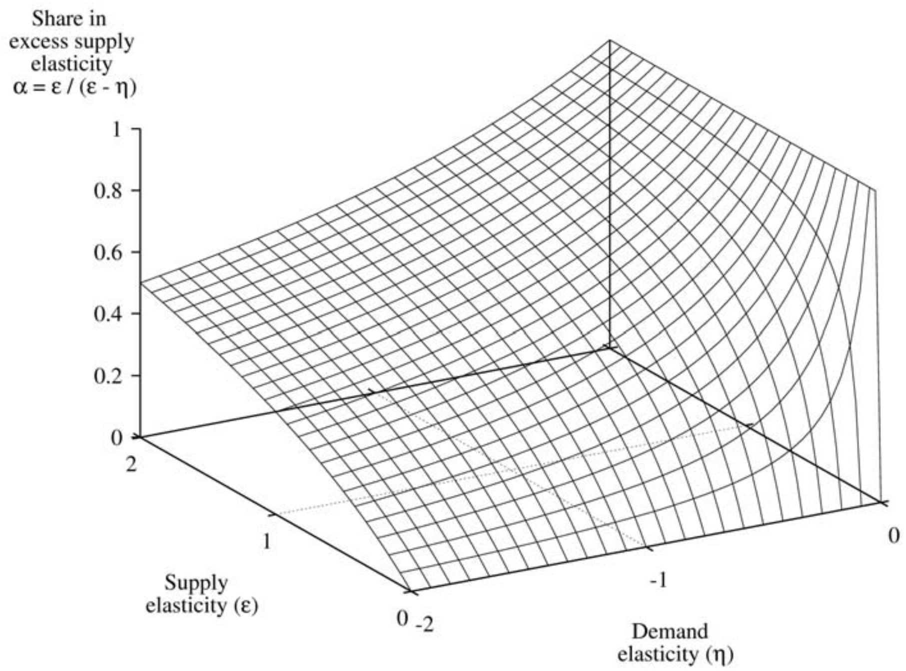


FIGURE 2.2

THE SHARE OF SUPPLY IN THE EXCESS SUPPLY ELASTICITY



$$\alpha = \frac{\varepsilon}{\varepsilon - \eta}\ , \ \varepsilon \in [0, \infty),\ \eta \in (-\infty, 0]$$

FIGURE 2.3

COUNTRY SIZE, THE EXCHANGE RATE AND COMMODITY PRICE

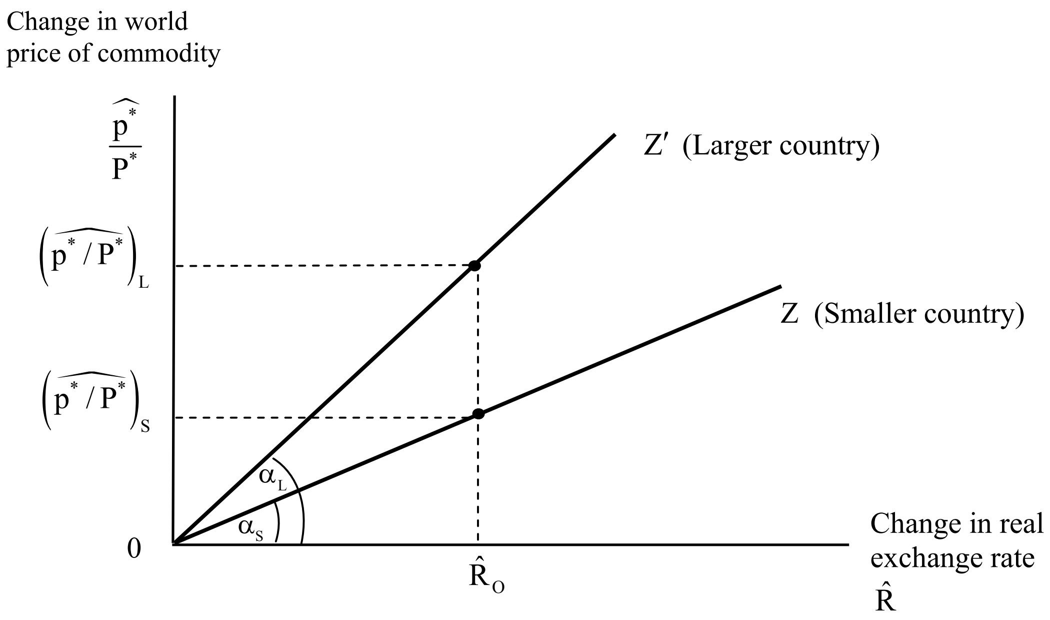


FIGURE 2.4

WORKINGS OF THE COMMODITY MARKET

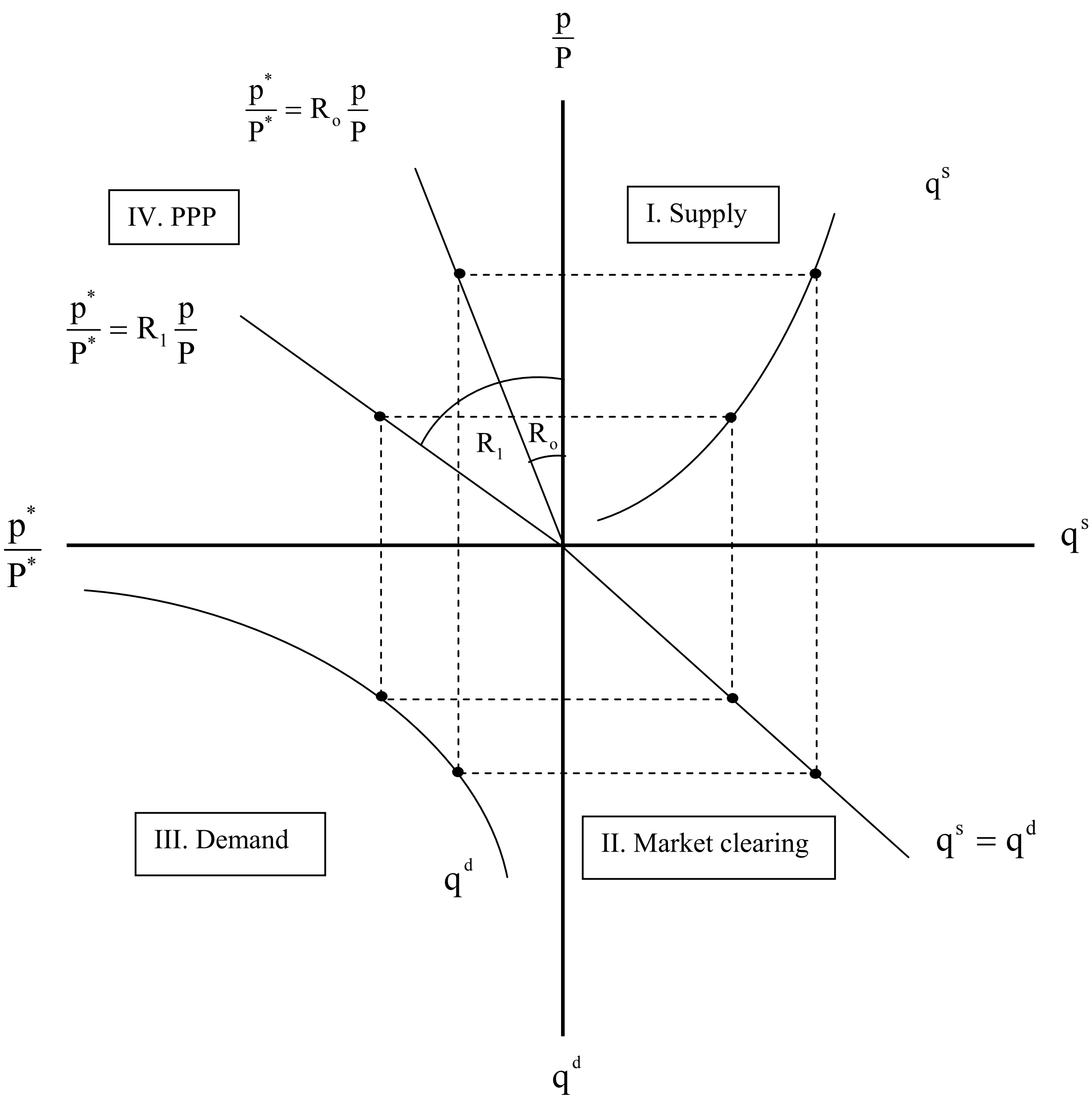


FIGURE 2.5

MARKET POWER, COMMODITY PRICE AND EXCHANGE RATE

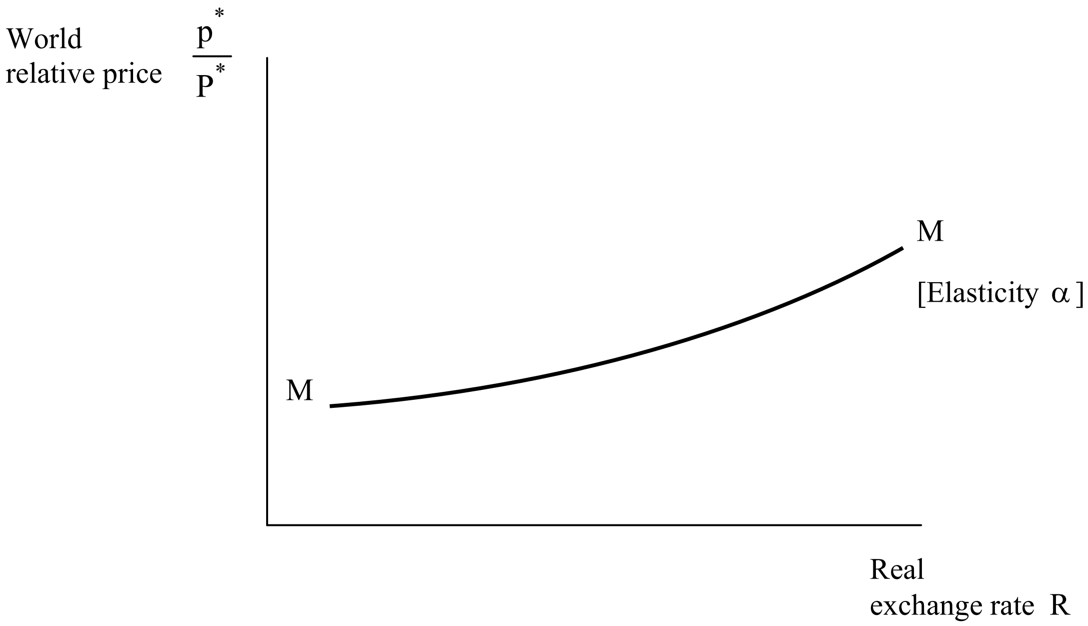
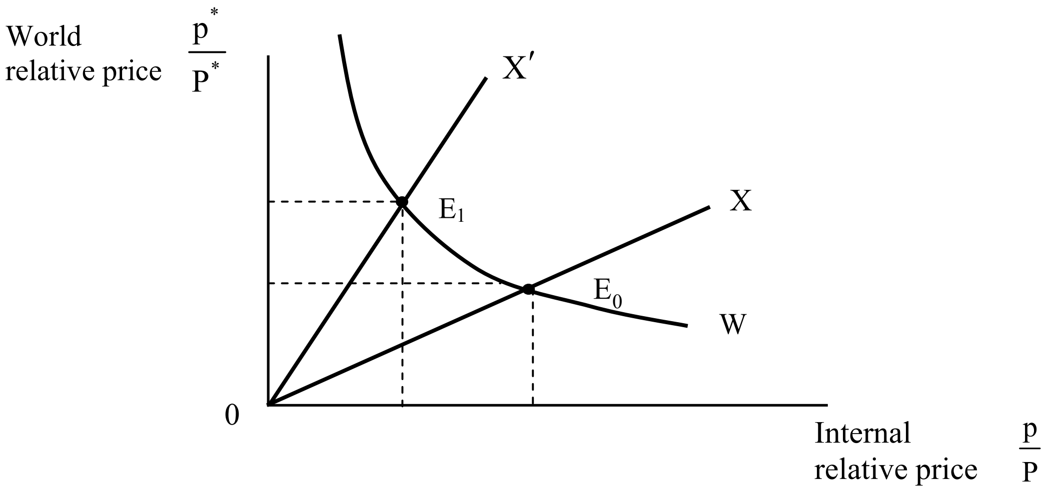


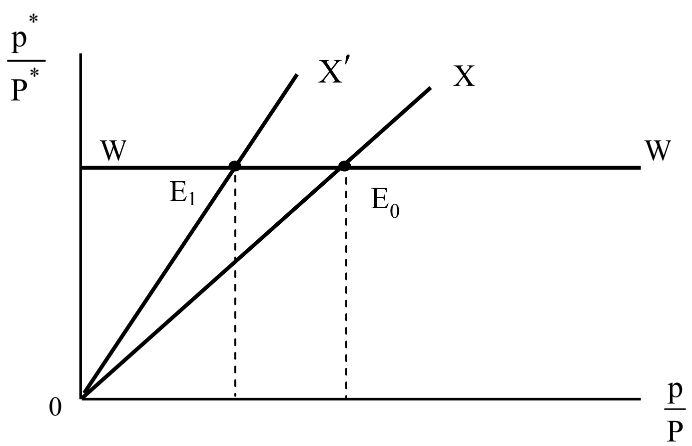
FIGURE 2.6

IMPACT OF APPRECIATION ON COMMODITY PRICES

A. The General Case



B. The Small-Country Case



C. The Large-Country Case

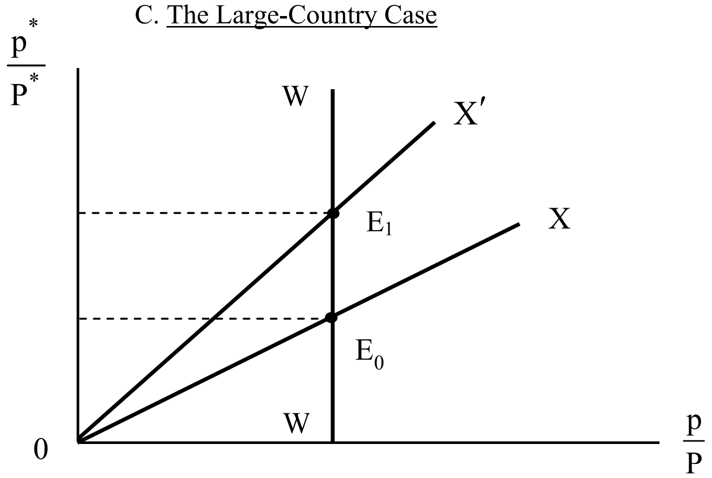
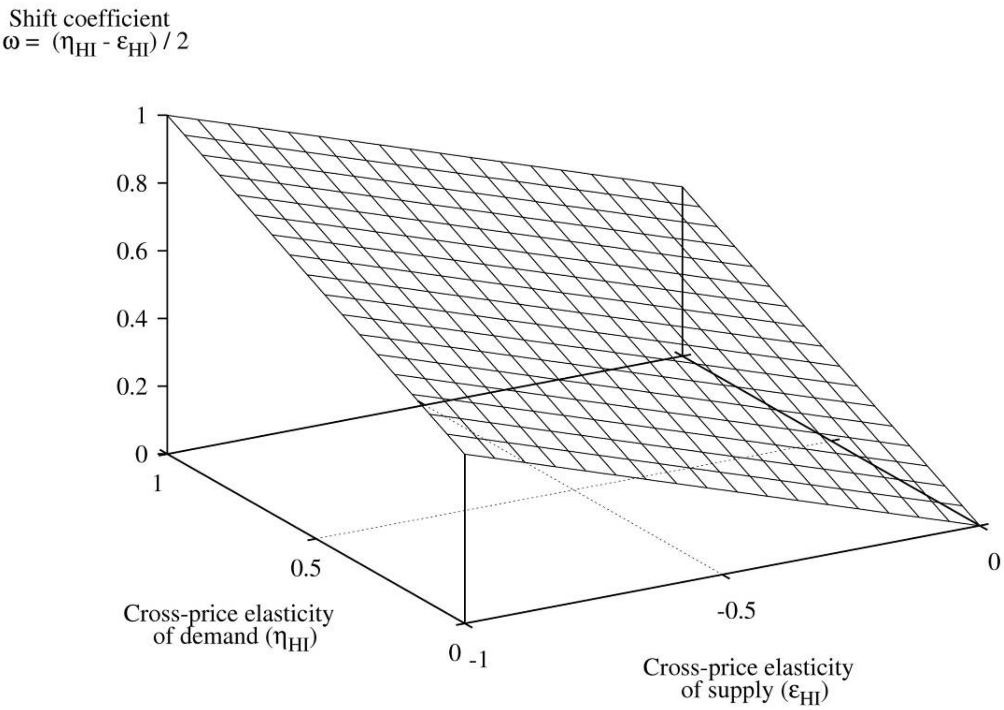


FIGURE 2.7

THE SHIFT COEFFICIENT



$$\omega = \frac{\eta_{HI} - \varepsilon_{HI}}{\varepsilon_{HH} - \eta_{HH}}\ ,\ \varepsilon_{HH} = 1,\ \eta_{HH} = -1,\ \varepsilon_{HI} \in [-\varepsilon_{HH}, 0],\ \eta_{HI} \in [0, -\eta_{HH}]$$

FIGURE 2.8

THE RECIPROCAL COMMODITY-CURRENCY RELATIONSHIP

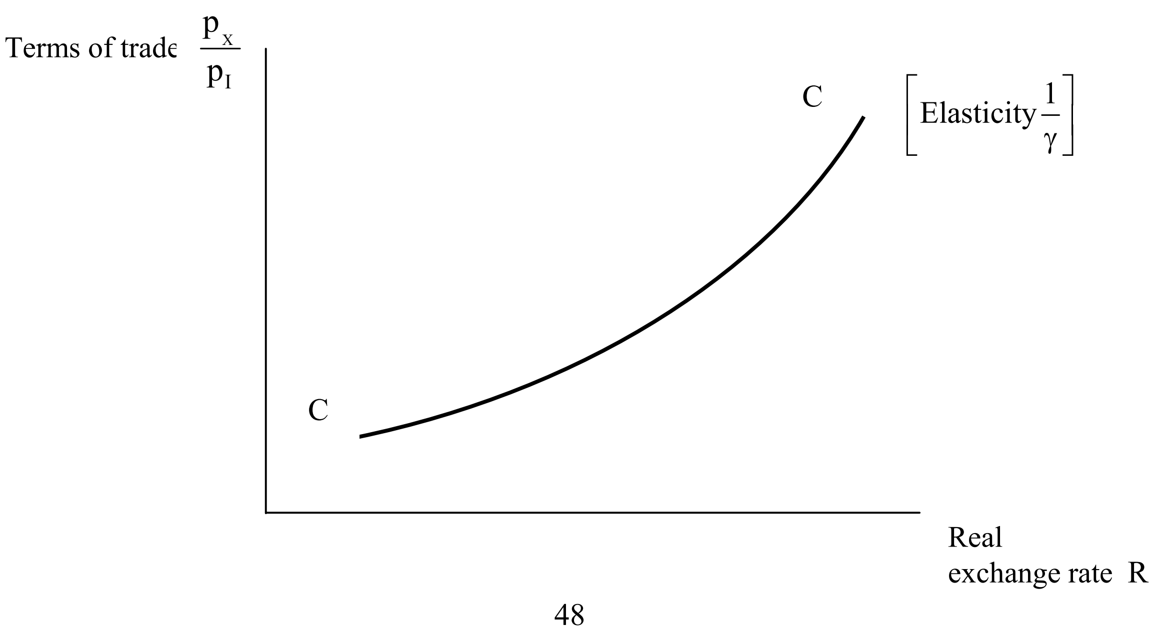
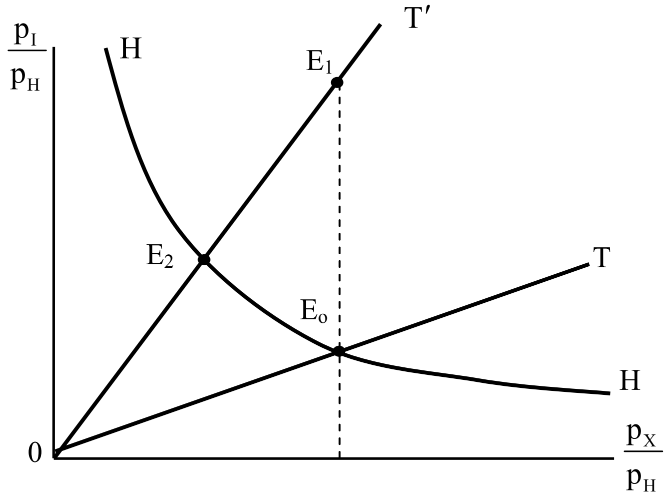


FIGURE 2.9

RELATIVE PRICES, IMPORT TARIFFS AND THE TERMS OF TRADE

A. <u>An Import Tariff</u>



B. <u>A Terms-of-Trade Worsening</u>

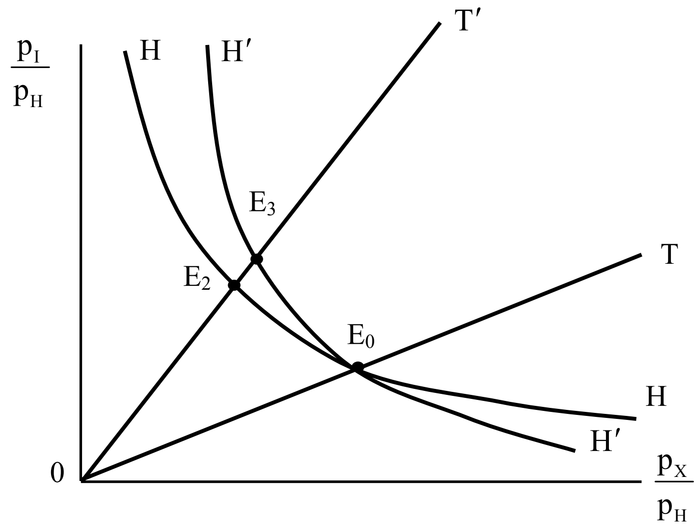


FIGURE 2.10

IMPACT OF A COMMODITY BOOM

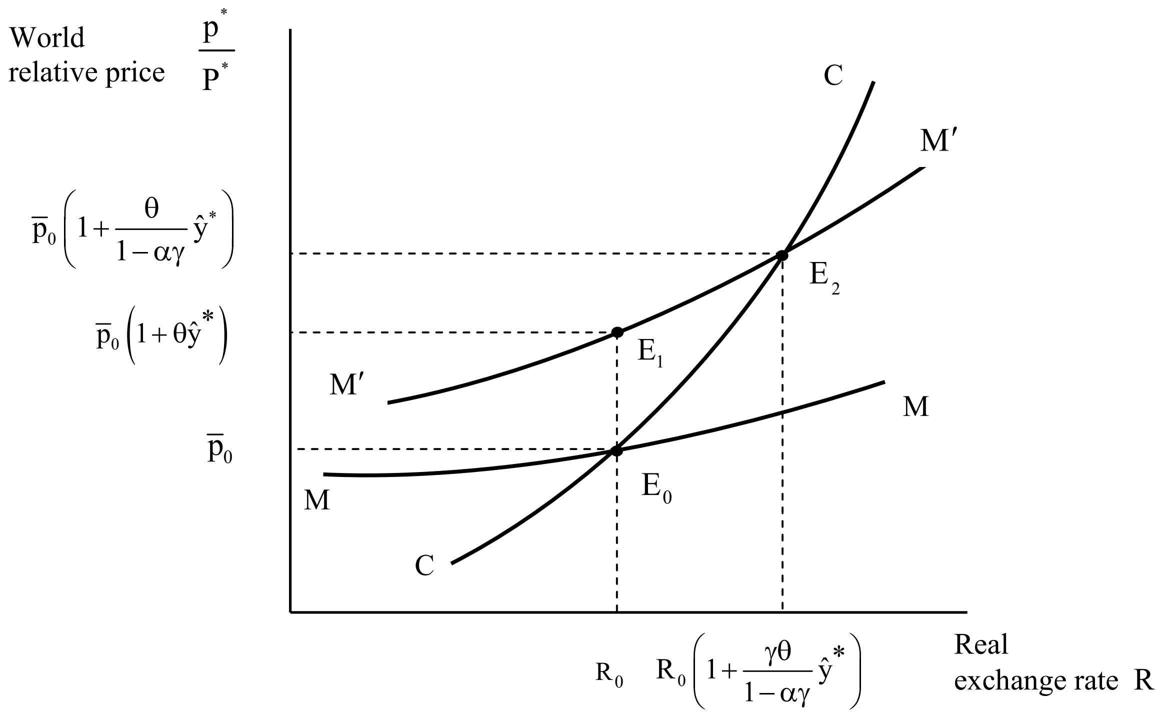


FIGURE 2.11

MORE ON A COMMODITY BOOM

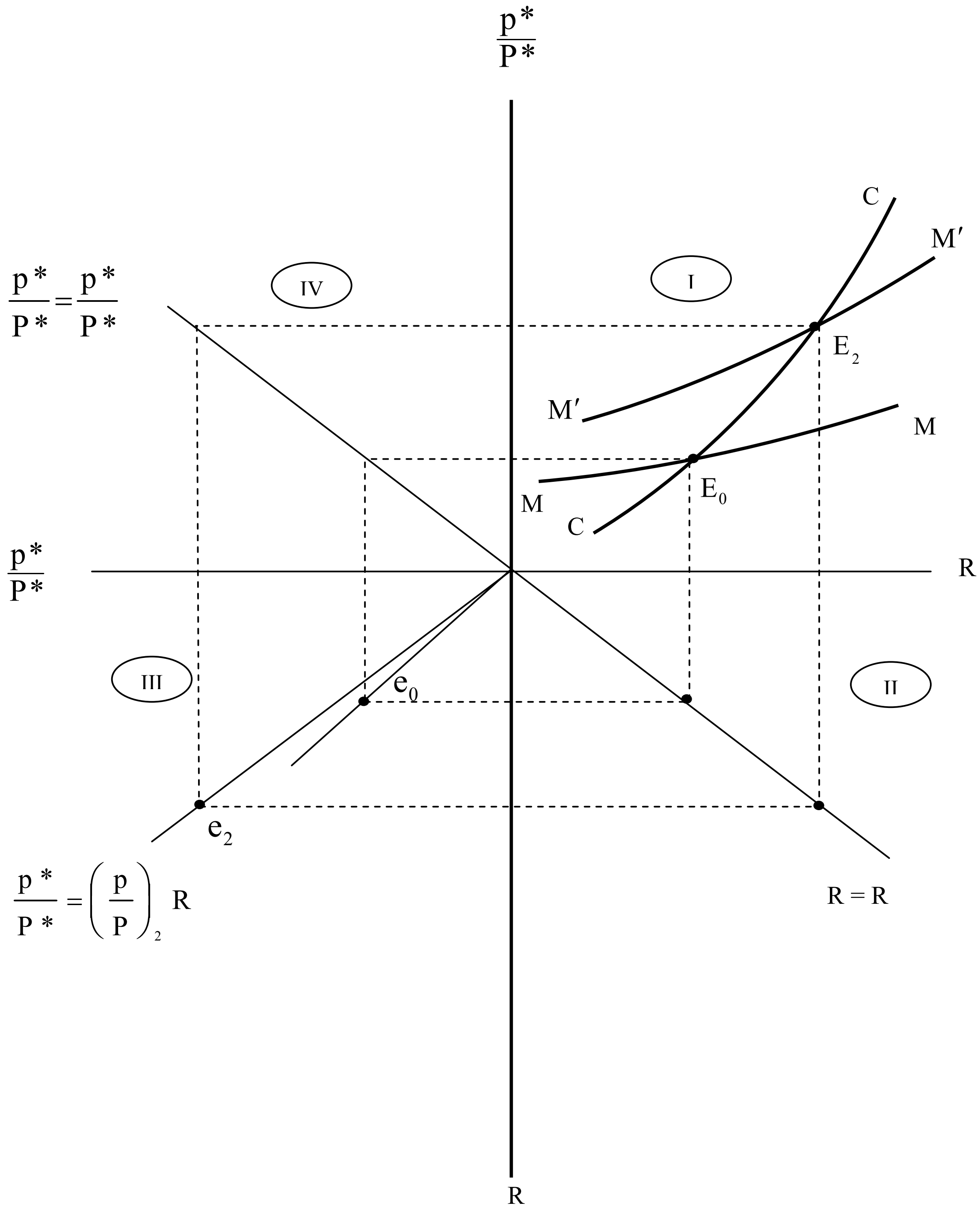


FIGURE 2.12

THE UNSTABLE CASE

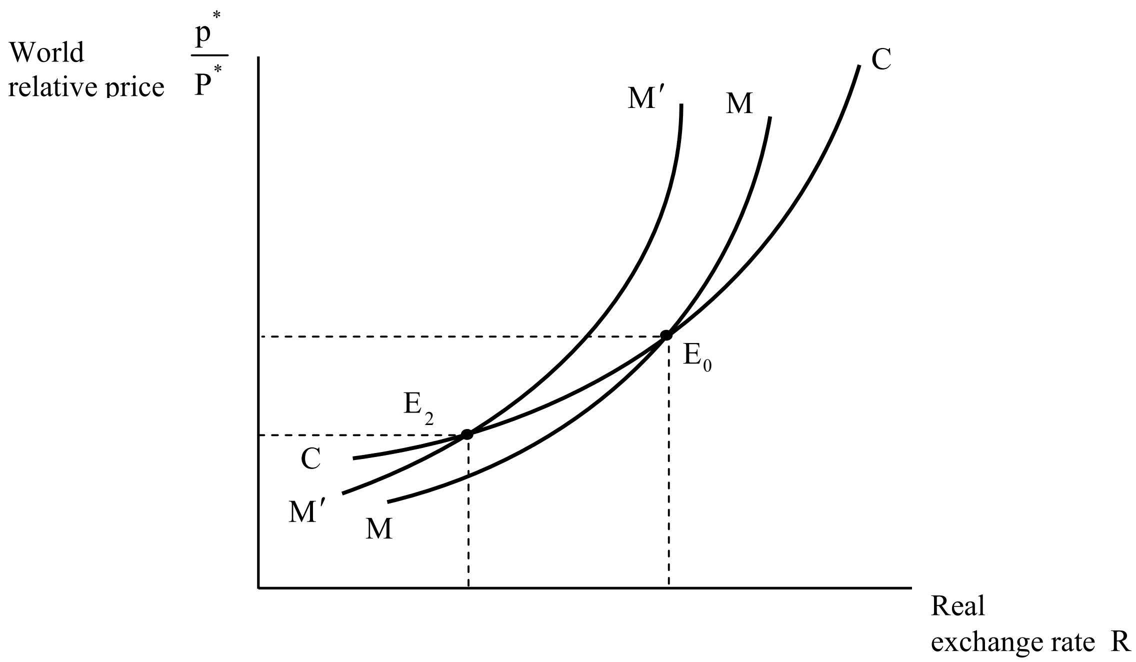


FIGURE 2.13

INTERACTIONS BETWEEN MARKET POWER AND COMMODITY CURRENCY: THE FOUR POSSIBILITIES

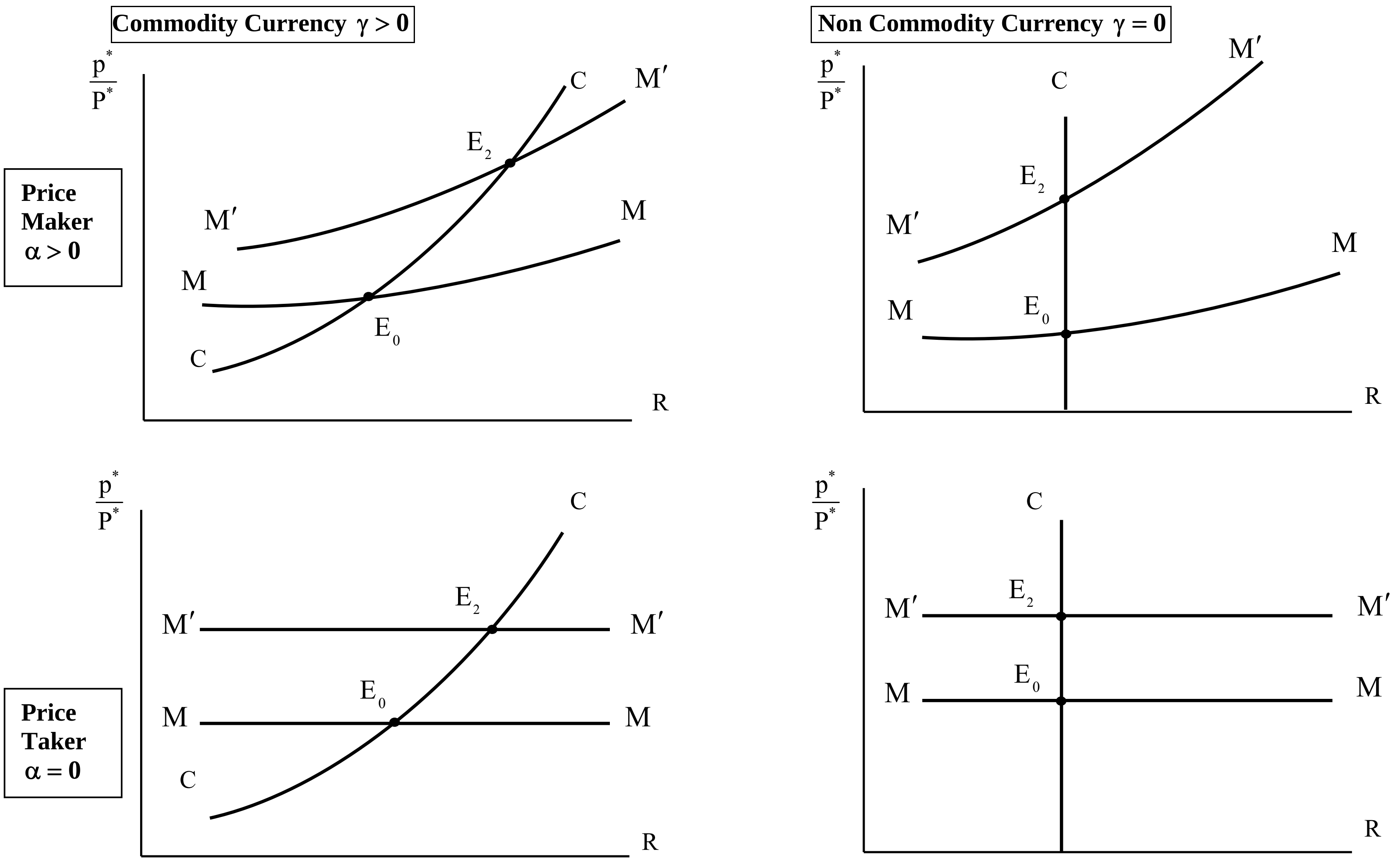
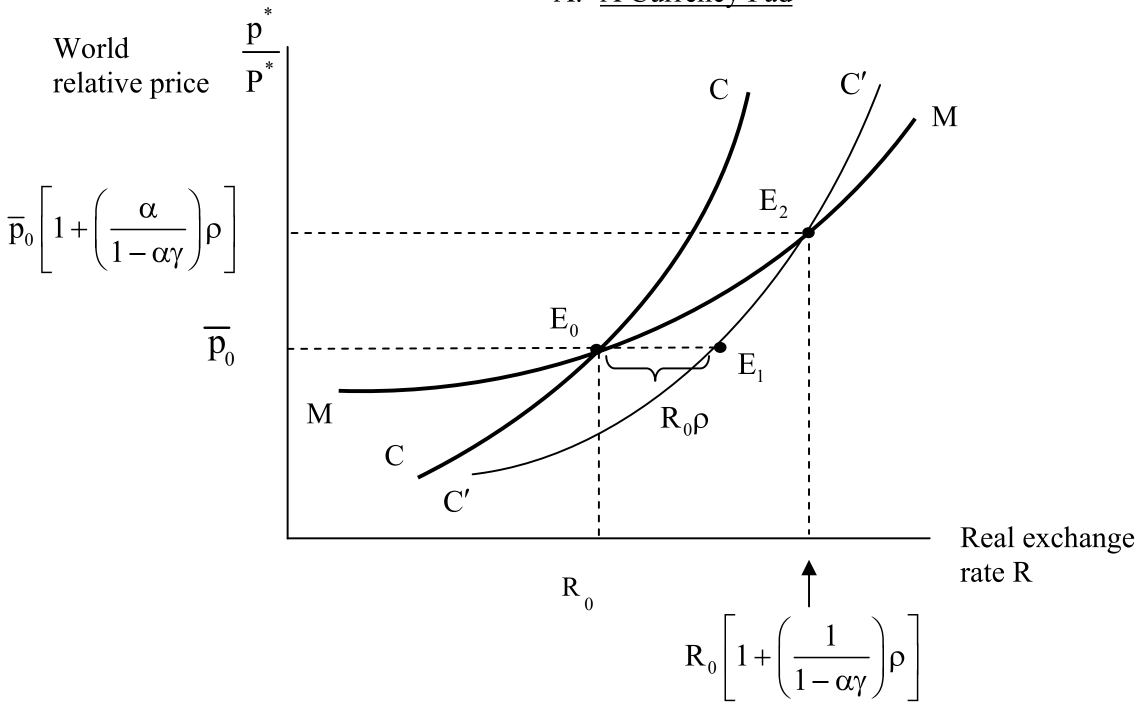


FIGURE 2.14

IMPACT OF A CURRENCY FAD AND A COMMODITY ROOM

A. A Currency Fad



B. A Currency Fad plus a Commodity Boom

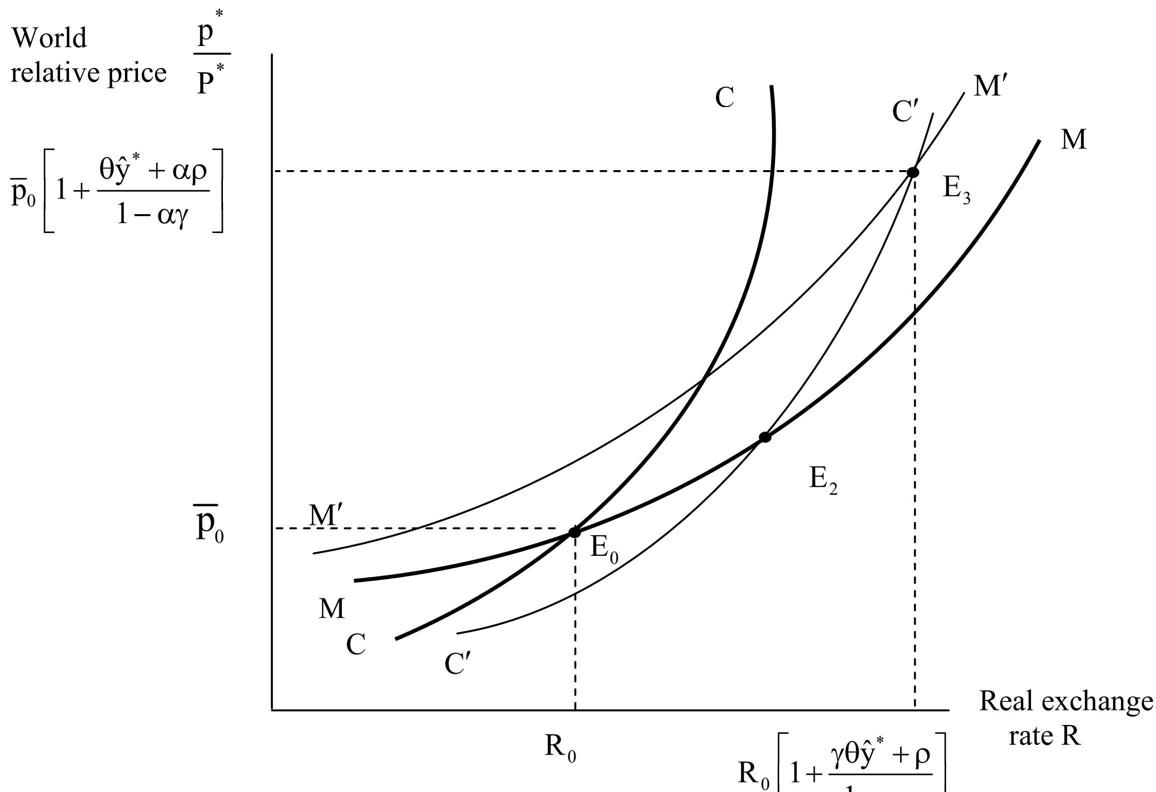


FIGURE 3.1

REAL PERCENTAGE DEMEANED CURRENCY AND COMMODITY PRICE RETURNS

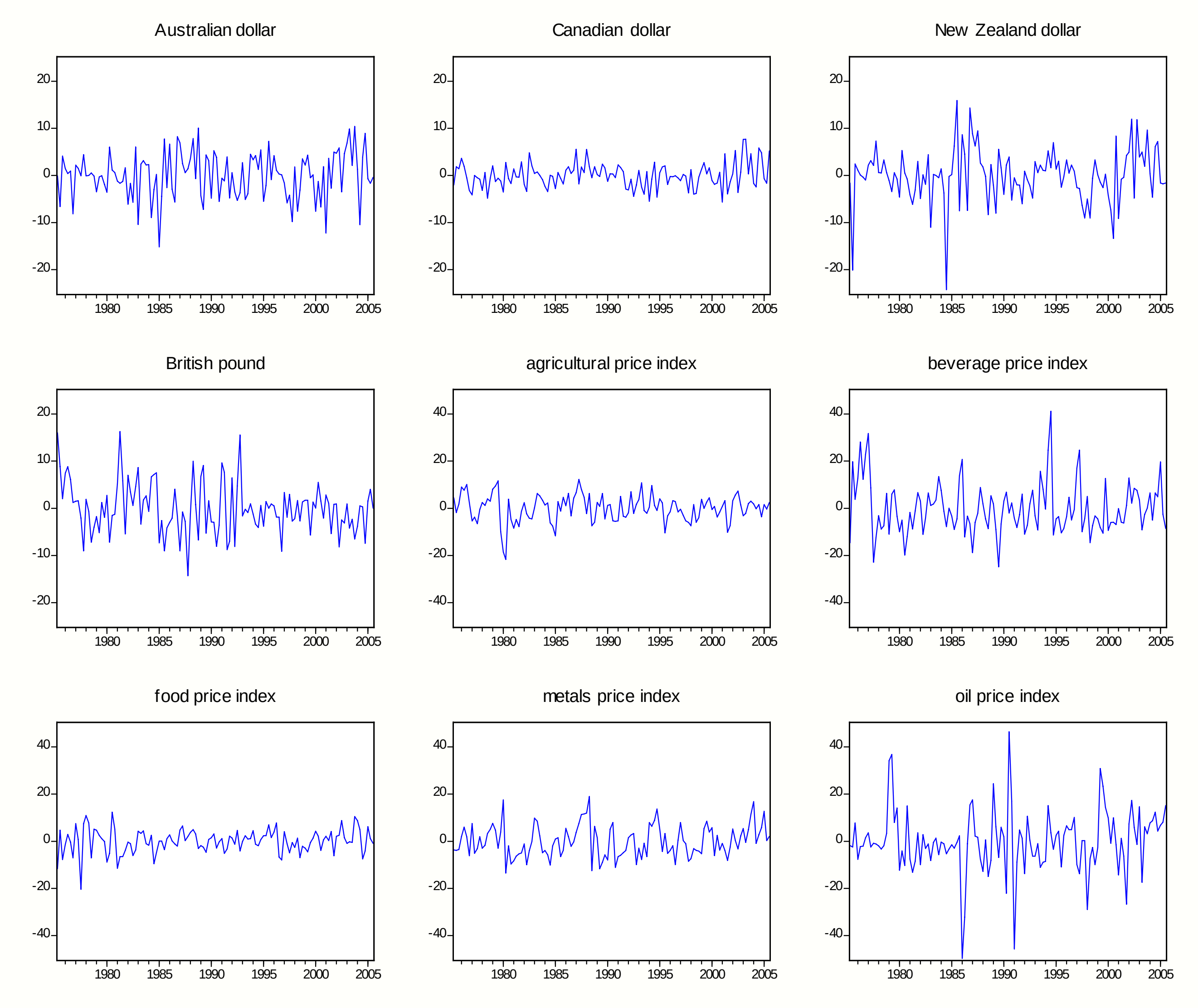


TABLE 3.1

DESCRIPTIVE STATISTICS OF CURRENCY AND COMMODITY RETURNS

	Currencies				Commodities				
	AUD	CND	NZD	GBP	AGR	BEV	FOO	MET	OIL
Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median	0.179	-0.147	0.197	0.029	0.821	-2.542	0.261	-0.863	-0.661
Max.	10.420	7.672	15.902	16.267	12.245	41.167	12.307	18.925	46.437
Min.	-15.145	-5.643	-24.213	-14.294	-21.757	-24.784	-20.342	-13.432	-49.693
Std. Dev.	4.896	2.656	5.778	5.402	5.674	10.940	5.014	6.700	13.322
Skewness	-0.342	0.429	-0.660	0.458	-0.623	0.908	-0.533	0.443	-0.164
Kurtosis	3.088	3.349	5.977	3.670	4.404	4.463	4.492	2.852	6.226
Jarq.-Bera	2.420	4.360	53.897	6.551	17.929	27.632	17.081	4.092	53.450
Probability	0.298	0.113	0.000	0.038	0.000	0.000	0.000	0.129	0.000

TABLE 3.2

CORRELATIONS (UPPER DIAGONAL), VARIANCES (DIAGONAL) AND COVARIANCES (LOWER DIAGONAL) OF CURRENCY AND COMMODITY RETURNS

		Currencies				Commodities				
		AUD	CND	NZD	GBP	AGR	BEV	FOO	MET	OIL
Currencies	AUD	23.777	0.503	0.655	-0.271	0.066	0.032	0.020	0.232	-0.005
	CND	6.488	6.994	0.298	-0.116	0.079	0.008	-0.092	0.115	0.075
	NZD	18.380	4.540	33.112	-0.454	0.203	-0.001	0.062	0.247	0.044
	GBP	-7.098	-1.645	-14.046	28.938	0.003	0.029	-0.143	-0.179	-0.224
Commodities	AGR	1.808	1.178	6.612	0.085	31.932	0.143	0.308	0.298	0.027
	BEV	-1.686	0.230	-0.041	1.709	8.829	118.712	0.142	0.226	-0.044
	FOO	-0.487	1.178	1.775	-3.850	8.688	7.703	24.933	0.298	0.027
	MET	7.558	2.036	9.501	-6.407	8.897	16.442	9.939	44.518	0.165
	OIL	-0.326	2.628	3.339	-16.004	16.920	-6.326	1.810	14.587	176.034

TABLE 3.3

CORRELOGRAMS OF CURRENCY AND COMMODITY RETURNS

	Currencies			Commodities		
Lag	Autocorr. coeffic.	Ljung-Box Q statistic	P value	Autocorr. coeffic.	Ljung-Box Q statistic	P value
	Australia			Agricultural materials		
1	-0.014	0.023	0.879	0.385	18.550	0.000
2	0.049	0.324	0.850	0.083	19.425	0.000
3	0.121	2.174	0.537	-0.108	20.907	0.000
4	0.028	2.273	0.686	-0.003	20.908	0.000
	Canada			Beverages		
1	0.069	0.592	0.442	0.307	11.746	0.001
2	0.005	0.595	0.743	-0.007	11.752	0.003
3	0.222	6.884	0.076	0.125	13.736	0.003
4	0.112	8.504	0.075	0.025	13.815	0.008
	New Zealand			Food		
1	0.080	0.796	0.372	0.079	0.786	0.375
2	0.149	3.586	0.166	-0.239	8.008	0.018
3	0.182	7.774	0.051	0.022	8.069	0.045
4	-0.032	7.903	0.095	0.124	10.033	0.040
	Great Britain			Metals		
1	0.180	4.056	0.044	0.318	12.646	0.000
2	-0.077	4.802	0.091	0.175	16.519	0.000
3	0.199	9.814	0.020	0.126	18.527	0.000
4	0.116	11.550	0.021	0.000	18.527	0.001
				Oil		
1				0.208	5.389	0.020
2				-0.130	7.533	0.023
3				0.062	8.014	0.046
4				-0.033	8.157	0.086

TABLE 3.4

LAG SELECTION CRITERIA OF A VAR OF CURRENCY AND COMMODITY RETURNS

Lag	Log L	LR	AIC	SC	HQ
1	-3,228.064	n.a.	56.086*	57.988*	56.858*
2	-3,170.768	97.112	56.488	60.291	58.032
3	-3,111.125	91.992	56.850	62.555	59.166
4	-3,032.124	109.797*	56.883	64.491	59.972

Notes: 1. * indicates lag order selected by the criterion
2. LR is the sequential modified LR test statistic (each test at 5% level); AIC is the Akaike information criterion; SC is the Schwarz information criterion; and HQ is the Hannan-Quinn information criterion.

TABLE 3.5

BIVARIATE GRANGER CAUSALITY BETWEEN CURRENCY AND COMMODITY RETURNS

Hypothesis	F-stat.	Prob	Hypothesis	F-stat.	Prob
AUD does not Granger cause CND	0.349	0.556	NZD does not Granger cause FOO	14.590	0.000*
CND does not Granger cause AUD	2.531	0.114	FOO does not Granger cause NZD	0.383	0.537
AUD does not Granger cause NZD	0.412	0.522	NZD does not Granger cause MET	4.817	0.030*
NZD does not Granger cause AUD	0.046	0.830	MET does not Granger cause NZD	0.667	0.416
AUD does not Granger cause GBP	1.058	0.306	NZD does not Granger cause OIL	2.552	0.113
GBP does not Granger cause AUD	0.619	0.433	OIL does not Granger cause NZD	0.040	0.841
AUD does not Granger cause AGR	4.928	0.028*	GBP does not Granger cause AGR	1.968	0.163
ARG does not Granger cause AUD	0.008	0.930	AGR does not Granger cause GBP	0.954	0.331
AUD does not Granger cause BEV	0.351	0.555	GBP does not Granger cause BEV	0.513	0.475
BEV does not Granger cause AUD	0.128	0.721	BEV does not Granger cause GBP	2.748	0.100
AUD does not Granger cause FOO	11.627	0.001*	GBP does not Granger cause FOO	14.948	0.000*
FOO does not Granger cause AUD	0.021	0.886	FOO does not Granger cause GBP	0.000	0.984
AUD does not Granger cause MET	4.790	0.031*	GBP does not Granger cause MET	8.788	0.004*
MET does not Granger cause AUD	0.022	0.881	MET does not Granger cause GBP	0.778	0.380
AUD does not Granger cause OIL	5.393	0.022*	GBP does not Granger cause OIL	0.099	0.753
OIL does not Granger cause AUD	0.112	0.738	OIL does not Granger cause GBP	0.212	0.646
CAN does not Granger cause NZD	0.001	0.982	AGR does not Granger cause BEV	9.171	0.003*
NZD does not Granger cause CAN	0.049	0.825	BEV does not Granger cause AGR	0.294	0.589
CAN does not Granger cause GBP	0.001	0.970	AGR does not Granger cause FOO	2.247	0.137
GBP does not Granger cause CAN	1.763	0.187	FOO does not Granger cause AGR	1.207	0.274
CAN does not Granger cause AGR	2.243	0.137	AGR does not Granger cause MET	1.739	0.190
AGR does not Granger cause CAN	0.001	0.978	MET does not Granger cause AGR	0.622	0.432
CAN does not Granger cause BEV	1.498	0.223	AGR does not Granger cause OIL	4.183	0.043*
BEV does not Granger cause CAN	0.001	0.976	OIL does not Granger cause AGR	0.081	0.777
CAN does not Granger cause FOO	4.234	0.042*	BEV does not Granger cause FOO	0.187	0.666
FOO does not Granger cause CAN	0.678	0.412	FOO does not Granger cause BEV	1.310	0.255
CAN does not Granger cause MET	6.540	0.012*	BEV does not Granger cause MET	3.029	0.084
MET does not Granger cause CAN	0.628	0.430	MET does not Granger cause BEV	0.436	0.510
CAN does not Granger cause OIL	1.106	0.295	BEV does not Granger cause OIL	0.834	0.363
OIL does not Granger cause CAN	0.024	0.878	OIL does not Granger cause BEV	1.891	0.172
NZD does not Granger cause GBP	2.827	0.095	FOO does not Granger cause MET	0.340	0.561
GBP does not Granger cause NZD	4.230	0.042*	MET does not Granger cause FOO	6.666	0.011*
NZD does not Granger cause AGR	5.027	0.027*	FOO does not Granger cause OIL	0.682	0.411
AGR does not Granger cause NZD	0.049	0.826	OIL does not Granger cause FOO	1.746	0.189
NZD does not Granger cause BEV	0.612	0.435	MET does not Granger cause OIL	7.595	0.007*
BEV does not Granger cause NZD	1.016	0.316	OIL does not Granger cause MET	0.011	0.916

Note: * denotes significance at the 5% level.

TABLE 4.1

VOLATILITY DECOMPOSITION OF CURRENCY AND COMMODITY RETURNS
(Percentages)

Variable	Common factor	Currency factor	Commodity factor	Spillovers from: Commodities	Spillovers from: Currencies	Idiosync.
Australian dollar	6.49	80.93		0.44		12.14
Canadian dollar	0.03	29.78		0.69		69.50
New Zealand dollar	32.93	28.67		0.83		37.56
British pound	43.95					56.05
Agriculture	1.91		28.64		2.08	67.37
Beverages	2.03		23.54		0.01	74.42
Food	3.92		7.21		5.23	83.64
Metals	7.64		21.09		2.34	68.93
Oil	3.62		2.51		2.71	91.16

TABLE 4.2

PARAMETER ESTIMATES FOR CURRENCY AND COMMODITY RETURNS

(P-values in parentheses)

	Factors					
				Spillovers from		
Variable	Common	Currency	Commodity	Commodities	Currencies	Idiosync.
Australian dollar	-1.076 (0.031)	-4.337 (0.000)		-0.247 (0.579)		1.682 (0.108)
Canadian dollar	-0.042 (0.872)	-1.444 (0.000)		-0.169 (0.487)		2.209 (0.000)
New Zealand dollar	-2.847 (0.000)	-3.033 (0.000)		-0.398 (0.417)		3.478 (0.000)
British pound	3.023 (0.000)					3.905 (0.000)
Agriculture	-0.676 (0.359)		-2.298 (0.001)		-0.804 (0.143)	4.590 (0.000)
Beverages	1.359 (0.268)		-4.063 (0.002)		0.113 (0.927)	9.407 (0.000)
Food	-0.840 (0.142)		-1.001 (0.042)		-1.109 (0.030)	4.439 (0.000)
Metals	-1.593 (0.030)		-2.325 (0.000)		-1.007 (0.118)	5.474 (0.000)
Oil	-2.205 (0.124)		-1.613 (0.215)		-2.178 (0.092)	12.660 (0.000)
ρ_V	0.486 (0.008)					
ρ_{CF}		-0.058 (0.599)				
ρ_{PCF}			0.641 (0.000)			
Log likelihood	-3,390.90					

TABLE 4.3

LIKELIHOOD RATIO TESTS OF SPILLOVER FACTORS

Hypothesis	LR statistic	p-value
1. Commodity factor in commodity currency returns $\left(H_0 : \gamma_i = 0, \quad \forall\, i = 1,\ldots,m\right)$	0.969	0.808
2. currency factor in commodities returns $\left(H_0 : \beta_k = 0, \quad \forall\, k = 1,\ldots,q\right)$	9.463	0.092*

Note: * denotes significance at the 10% level.

TABLE 4.4

VOLATILITY DECOMPOSITION OF
CURRENCY AND COMMODITY PRICE RETURNS OVER TIME (Percentages)

Variable	Common factor	Currency factor	Commodity factor	Spillovers from Commodity	Spillovers from Currency	Idiosync.
1975:Q3 to 1982:Q4						
Australian dollar	13.94	79.38		2.55		4.13
Canadian dollar	0.03	13.80		1.88		84.28
New Zealand dollar	54.80	21.79		3.71		19.69
British pound	49.69					50.31
Agriculture	0.97		34.47		0.45	64.11
Beverages	1.41		38.93		0.00	59.66
Food	1.74		7.61		1.01	89.65
Metals	5.52		36.29		0.73	57.46
Oil	4.09		6.75		1.32	87.84
1983:Q1 to 1990:Q4						
Australian dollar	9.79	84.50		0.88		4.83
Canadian dollar	0.04	28.82		1.28		69.86
New Zealand dollar	39.12	23.59		1.31		35.98
British pound	53.43					46.57
Agriculture	1.74		31.57		1.33	65.36
Beverages	2.31		32.37		0.01	65.32
Food	3.87		8.64		3.65	83.84
Metals	7.49		25.08		1.62	65.81
Oil	3.41		2.87		1.80	91.91
1991:Q1 to 1995:Q4						
Australian dollar	9.26	84.73		0.86		5.15
Canadian dollar	0.04	24.60		1.06		74.31
New Zealand dollar	38.29	24.48		1.32		35.91
British pound	47.05					52.95
Agriculture	1.65		30.64		1.35	66.36
Beverages	1.92		27.68		0.01	70.39
Food	3.85		8.80		3.87	83.48
Metals	7.25		24.89		1.68	66.18
Oil	3.31		2.85		1.87	91.97
1996:Q1 to 2000:Q4						
Australian dollar	8.13	86.47		0.78		4.62
Canadian dollar	0.04	27.63		1.06		71.27
New Zealand dollar	35.67	26.50		1.27		36.56
British pound	46.17					53.83
Agriculture	1.64		31.38		1.56	65.42
Beverages	1.77		26.13		0.01	72.10
Food	3.54		8.31		4.13	84.03
Metals	6.96		24.54		1.86	66.63
Oil	2.99		2.65		1.96	92.40
2001:Q1 to 2005:Q3						
Australian dollar	6.65	88.92		0.63		3.80
Canadian dollar	0.03	27.70		0.84		71.44
New Zealand dollar	33.62	31.41		1.18		33.79
British pound	47.22					52.78
Agriculture	1.65		31.53		1.96	64.86
Beverages	1.80		26.53		0.01	71.66
Food	3.41		8.00		4.97	83.62
Metals	6.87		24.17		2.30	66.67
Oil	2.96		2.62		2.42	92.00

APPENDIX 1

DATA SOURCES AND CODES

TABLE 1A

DATA SOURCES AND CODES

Variable	Source	Code
Australian dollar AUD/USD	IMF IFS	193..AG.ZF...
Canadian dollar CND/USD	IMF IFS	156..AE.ZF...
New Zealand dollar NZD/USD	IMF IFS	196..AG.ZF...
British Pound GBP/USD	IMF IFS	112..AG.ZF...
Australian consumer price index	IMF IFS	19364...ZF...
Canadian consumer price index	IMF IFS	15664...ZF...
New Zealand consumer price index	IMF IFS	19664...ZF...
United Kingdom consumer price index	IMF IFS	11264...ZF...
US consumer price index	IMF IFS	11164...ZF...
Agricultural raw materials index	IMF IFS	00176BXDZF...
Beverages index	IMF IFS	00176DWDZF...
Food index	IMF IFS	00176EXDZF...
Metals index	IMF IFS	00176AYDZF...
Oil price index	Datastream	WDI76AADF