In addition the simulations have highlighted possible reasons why the empirical investment literature (see Serven, 1997) has found it difficult to establish a clear relationship between investment and the terms of trade. Such a relationship will exist in the underlying sense that comparing steady states the terms of trade will determine the relative size of the two capital stocks and their combined steady state (replacement) investment will change with that (albeit in an ambiguous direction since relative depreciation rates will be important). In the presence of marked changes in commodity prices, however, investment data will tend to be dominated by changes between steady states rather than the latter themselves. The analysis above shows very clearly that investment in the short run is likely to be a positive function of the absolute change in the terms of trade rather than its level and if price changes are frequent and large such short run effects are likely to predominate. Furthermore the results also indicate that aggregate investment may respond more or less, or not at all, to either upward or downward price movements and the nature of such asymmetries may differ across countries since they depend on relative sector sizes and investment lags.

We turn now to a brief examination of some empirical evidence for aggregate investment at the time of the late 1970s coffee and cocoa shocks. This evidence is intended to be indicative rather than conclusive. It was noted above that domestic price controls were in place in many countries at that time and hence the emphasis on relative price changes in the theory above may be less relevant for this period. For this reason we show Collier and Gunning’s (1999)\textsuperscript{7} attribution of these shocks as "private", "public" or "mixed" which are based on whether the change in world prices largely fed through into domestic prices.

Figure 4 shows both aggregate investment and (where available) private investment for the countries shown, each of which had a four year positive commodity price shock 1976-79\textsuperscript{8} and hence the four year shock simulations of Figure 1 are the natural point of comparison with the theoretical results. Most striking about the charts of Figure 4 is how much more variable is investment generally in the "private" pair of charts at the top, even though they are themselves less jumpy than the theory results which is natural since the model above abstracted from adjustment costs. In addition the private shocks are consistent with the theory since they show some of the "twin peaks" tendency of Figure 1. The total investment/private investment split is helpful here also since the time path of total investment in the top two charts is seen to be driven largely by changes in private investment which is the concern of the theory work. There is some tendency for public investment (the gap between the two lines) to fall towards the end of the period which is to be expected since a fall in export prices is likely to lead to falling revenues.

The mixed shock cases of the middle charts show much less variation over time, aggregate and private investment in Colombia showing some response after the end of the shock in 1979, while aggregate investment in Senegal is unresponsive. The public shock cases of the lower charts show no response to the end of the shock and while private investment is not available for these countries it is likely, given the public nature of the shock, that the aggregate picture is being driven by public investment.
FIGURE 4: EMPIRICAL EVIDENCE, 4 PERIOD SHOCKS

"PRIVATE" SHOCKS

Kenya
Investment/GDP (indices)

Costa Rica
Investment/GDP (indices)

"PUBLIC" SHOCKS

Ghana
Investment/GDP (indices)

Côte D'Ivoire
Investment/GDP (indices)
3. Feedback Effects From the Investment Response to the World Commodity Price

The material above has been concerned with the investment response to a given, exogenous commodity price shock. Given the information that it has generated about the possible investment (and hence supply) dynamics during and after a shock a question arises as to what that supply response, if repeated across a sufficient number of producers in a world market, might imply on the reverse causation for the time path of the world price. It should be emphasised that the empirical modelling of commodity prices has proved difficult and controversial and requires complexity that is well beyond the scope of this paper. The literature on commodity prices does not appear, however, to have analysed the implications of the irreversible investment response in commodity sectors to large price movements which is the potential contribution of this paper. In particular the nature of the investment response during a shock determines in part the supply response which may affect the world price. In addition, and perhaps more importantly, the nature of irreversible capital is that after the end of a positive price shock, the commodity sector capital stock (and hence to an extent supply, allowing for much quicker movements of labour away from the commodity sector) will tend to fall slowly constrained by depreciation and hence the post-shock level of supply will tend to be higher and thus the world price lower, than before the shock, at least for a few periods until depreciation has restored a steady state.

To illustrate these effects we suppose that the commodity price is determined by:

\[ P^t_x = P_x(1+s)Q_x^{-\frac{1}{\gamma}} \]  

(12)

In this expression \( P_x \) or \( P_x(1+s) \) corresponds to the commodity price before/after and during respectively the exogenous price shock analysed above but we now allow the actual \( P_x \) that obtains over time to depend also on the level of commodity output \( Q_x \) as well as the price elasticity of demand, \( \gamma \). Hence the source of the price shock, \( s \), remains exogenously imposed but we now allow for a feedback effect from output to the world price while still abstracting from all other sources of price movements. We make the extremely strong assumption that all producing countries are identical in their investment and supply responses, essentially to allow a simple translation between the single country results above and world output which is what influences the world price. Clearly this is unrealistic but our purpose is to illustrate the possible effects generated by the model, particularly in relation to the shape of the price path rather than its exact level, and in that sense a simple exercise of this kind may still be informative. Also for illustrative purposes we assume that the commodity supply responses follow those of the model which amounts to ignoring the further feedback effect from the different price path to different supply responses. The effect of a proper simultaneous determination of output and price may however be seen in general terms from the simulations that follow.

Figures 5-7 below (which correspond to the same cases as Figures 1-3) give the results of taking the earlier supply responses and using them to determine the endogenous price path. In each case the upper line is the simple exogenous price path used earlier while the lower line shows how this changes if the output response alters the price by means of the equation above. The gap between the two lines therefore depends on the supply response of the commodity sector. For the simulations we use a price elasticity of demand of two. Increasing this parameter reduces the gap between the lines but our main interest as before is in the shape of the endogenous price
path rather than its exact level and hence the general conclusions drawn are not sensitive to this assumption. Similarly if we allowed for the full simultaneous determination of output and price the lower line would move towards the upper line (since the output response would be lower given expectations that the world output response would lower the commodity price) but again its general shape would not change greatly.

Considering Figure 5 it may be seen that a smaller initial $K_x/K_m$ gives rise to a bigger supply response (a larger gap between the two lines). This is because the commodity sector has a larger pool of labour from the M sector to draw on (more formally the commodity sector can expand employment without wages rising a steeply as if the M sector were smaller) which both increases the immediate supply response due to labour reallocation while also raising the investment response due to the beneficial cross effect on the return to capital of a greater labour movement. Also the supply response and "endogenous" effect on price is smaller for the longer investment lag cases since the commodity sector capital stock both rises less and after a longer delay.

These factors (together with the price elasticity of demand) determine the size of the feedback effect from supply to price but perhaps of greater interest is that the S-shape endogenous price path is broadly similar across the different cases (and in Figures 6-7 except that it is compressed or shrunk according to the duration of the shock). During the shock there is an immediate supply response from labour reallocation and this is followed by an expansion of the commodity sector capital stock (slowly in the 4 period lag cases) which further raises output such that the initial price peak is not sustained. Investment jumps up quickly and then gradually as the M sector capital stock depreciates (shown most clearly in Figure 5(e)) so the supply response builds up at a declining rate over time. After the shock the irreversible nature of the commodity sector capital stock means that its level (and hence in part the output of the commodity) falls only gradually. After the shock there is an immediate reallocation of labour back to the M sector but X sector output nevertheless remains higher (and thus the endogenous price lower) for some time until depreciation allows $K_x$ to reach its steady state.

Once again it should be emphasised that commodity price determination is a difficult area and its proper modelling requires consideration of numerous factors not included above, but to the extent that other factors generate price shocks of the kind examined in the earlier section the feedback effects shown here will exert some influence. Of particular note, perhaps, is that the irreversibility model predicts an overhang of low prices after the end of a positive shock.
FIGURE 5: WORLD COMMODITY PRICE, 4 PERIOD SHOCK

LARGE INITIAL Kx/Km

a) 1 period X sector delivery lag

b) 4 period X sector delivery lag

SYMmetric INITIAL Kx/Km

c) 1 period X sector delivery lag
d) 4 period X sector delivery lag

SMALL INITIAL Kx/Km

e) 1 period X sector delivery lag
f) 4 period X sector delivery lag
FIGURE 6: WORLD COMMODITY PRICE, 2 PERIOD SHOCK

LARGE INITIAL $K_x/K_m$

a) 1 period X sector delivery lag

b) 4 period X sector delivery lag

SYMmetric INITIAL $K_x/K_m$

c) 1 period X sector delivery lag
d) 4 period X sector delivery lag

SMALL INITIAL $K_x/K_m$

e) 1 period X sector delivery lag
f) 4 period X sector delivery lag
FIGURE 7: WORLD COMMODITY PRICE, 6 PERIOD SHOCK

LARGE INITIAL $K_x/K_m$

a) 1 period X sector delivery lag

World Commodity Price: 6 Period Shock Index (pre-shock period 0 = 100)

b) 4 period X sector delivery lag

World Commodity Price: 6 Period Shock Index (pre-shock period 0 = 100)

SYMMETRIC INITIAL $K_x/K_m$

c) 1 period X sector delivery lag

World Commodity Price: 6 Period Shock Index (pre-shock period 0 = 100)

d) 4 period X sector delivery lag

World Commodity Price: 6 Period Shock Index (pre-shock period 0 = 100)

SMALL INITIAL $K_x/K_m$

e) 1 period X sector delivery lag

World Commodity Price: 6 Period Shock Index (pre-shock period 0 = 100)

f) 4 period X sector delivery lag

World Commodity Price: 6 Period Shock Index (pre-shock period 0 = 100)