Private Investment in Developing Countries: The Effects of Commodity Shocks and Uncertainty

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Abstract: The link between *ex post* discrete shocks and private investment have never been formally tested in a panel data context, while the evidence of a link between *ex ante* commodity price uncertainty and investment is weak. This paper constructs measures of discrete shocks and uncertainty using a new multi-country data set of aggregate commodity price indices, and tests the relationship between various manifestations of commodity price variability and private investment rates within the context of a canonical empirical investment model estimated on a sample of 44 developing countries. The analysis confirms theoretical predictions that positive *ex post* commodity price shocks have strong positive effects on private investment rates in low income developing countries, conditional upon the level of commodity prices. It is also shown that the prospect of uncertain future commodity prices and *ex post* negative shocks do not affect private investment rates.

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1. Introduction

The literature on the effects of commodity price variability on macroeconomic performance in developing countries has been concerned primarily with two aspects of variability, namely discrete *ex post* price shocks and uncertainty about future prices. There are strong reasons to suspect that both these manifestations of variability should have important implications for investment: The theory of temporary trade shocks shows that investment can be expected to respond strongly to discrete *ex post* commodity price shocks (Bevan, Collier and Gunning (1990a), Collier, Gunning and Associates (1999)). Similarly, recent theoretical developments support the view that investment decisions may be very sensitive to uncertainty about the future outcomes of key variables affecting investment decisions (Dixit and Pindyck (1994)). In light of the widely recognised fact that commodity prices are highly volatile, it is therefore surprising that very little empirical work has sought to quantify the link between manifestations of commodity price variability and investment decisions in developing countries, seen as particularly vulnerable to commodity price volatility. A rare empirical contribution in the uncertainty literature is Serven (1998), who is unable to find statistical evidence of a strong negative link from terms of trade uncertainty to investment. The effects of discrete *ex post* shocks on investment have never been estimated empirically, although Deaton and Miller (1995) used a VAR model to show that commodity price movements more generally are positively associated with investment in a sample of African countries.

Recent empirical evidence on growth suggests that while commodity export dependency confers both *ex post* shocks and *ex ante* uncertainty upon producing countries, what reduces their growth is not the prospect of volatile prices world prices, but the actual realisation of negative discrete commodity price shocks (Dehn (forthcoming-a)). This finding raises the interesting question whether the absence of a growth response to positive shocks can be seen as an indication that the prominence given to investment in the theory of temporary trade shocks is somehow misplaced, or, what is perhaps more likely, that the effects of positive shocks on investment are somehow dissipated and fail to result in a lasting improvement in GDP? Collier and Gunning (1996) have argued forcefully that dissipation can arise due to a combination of the policy stance at the time of the shock and policy changes made in response to shocks, lack of access to adequate savings instruments on the part of windfall recipients, and inaccessibility on the part of private agents to information about the nature of the shock. A related question is whether changes in investment alone can account for the powerful negative growth effects which precipitate from discrete negative shocks, given that an alternative avenue of adjustment is changing capacity utilisation? Finally, is the absence of a growth response to changes in future commodity price uncertainty replicated for investment?

This paper attempts to address these questions by examining the relationship between private investment rates on one hand and *ex post* commodity price shocks and *ex ante* commodity price uncertainty on the other. The framework of analysis is canonical flexible accelerator model of investment estimated on a dynamic panel of 44 developing countries. The investment model is constructed with reference to previous empirical investment models which have been estimated using data on developing countries.

The key findings are the following: First, the theoretical prediction that positive commodity price shocks have strong positive and significant effects on private investment rates in developing countries is confirmed with the proviso that positive shocks are conditioned upon the level of commodity prices. Positive shocks generally boost investment, but only up to a point. If a shock occurs at a time when commodity prices are already high, the net effect on investment rates weakens.

Secondly, uncertainty about future commodity prices does not affect investment decisions. Investors in developing countries are exposed to multiple sources of uncertainty ranging from political instability and economic policy changes to exogenous weather shocks, disease, and civil strife. In the presence of multiple sources of uncertainty, commodity price uncertainty *per se* is not critical to investors. Hence, the data shows that investors only pay attention to commodity price movements is when these take the form of extreme upwards price changes.

Thirdly, levels and first differences of commodity prices as well as large negative shocks do not affect private investment rates. The very asymmetric investment response to positive and negative shocks is possibly due to irreversibility of investment which reduces the scope for disinvesting, especially in commodity sectors where replacement investment rates are small. The implication is that adjustment to negative shocks occurs via a reduction in capacity utilisation.

The results are robust to changes in sample composition, different estimation methodologies, and different definitions of uncertainty.

The paper is structured as follows. Section 2 reviews the theoretical and empirical literature on shocks and investment, while Section 3 examines the corresponding literature which links uncertainty and investment. In section 4, a canonical empirical investment model is outlined. In section 5, the uncertainty and shock variables are introduced into the empirical framework. Section 6 discusses the empirical issues which arise in the context of dynamic panel data estimation. Section 7 presents the results, and Section 8 concludes.

2. Shocks and investment

The standard 'Dutch Disease' model has mainly focused on consumption and sectoral income distribution effects within a comparative static analytical framework suitable for evaluating long run effects ((Corden (1984), Neary (1985), Bruno (1982)). However, the premise of shock permanence, which underlies Dutch Disease models is unsuitable for developing countries for at least three reasons: First, the bulk of commodity shocks are arguably temporary rather than permanent (Deaton and Laroque (1992), Bevan, Collier and Gunning (1990a)). Secondly, a dynamic modelling approach is more suitable for describing the effects of transitory shocks. Finally, as the analytical framework switches to a dynamic one, the variables of interest also change from consumption and income distribution towards investment.

Collier and Gunning (1999a) have recently provided a theoretical illustration of the investment response to a temporary trade shock within the context of a Ramsey model.[1] The model shows that with a closed capital account adjustment to a temporary shock involves two phases: In the first phase, the capital stock increases via investment. This phase is likely to be characterised by a construction boom if investment requires both tradable and non-tradable capital good inputs. Construction booms have been widely reported during shocks ((Collier and Gunning (1999a)). In the second phase, investment is reversed. The model assigns great importance to the policy stance adopted for the capital account according to the rationale that large windfalls drive down the rate of return to capital within the domestic economy as the

[1] The original statement of mechanisms of a temporary trade shock is contained in Bevan, Collier and Gunning (1990a).

most lucrative investment opportunities are gradually exploited.[2] In such circumstances, agents in the domestic economy stand to gain from having access to foreign savings instruments, which allows them to avoid the temporary erosion of investment returns. When agents have access to foreign savings instruments, the investment dynamic involves four phases: In the first phase, savings are invested domestically to exploit the high rate of return differential with the rest of the world which exists due to the borrowing constraint. In the second phase, as the rates of return on construction and other domestic investment opportunities approach the return available on international deposits, agents switch any additional windfall savings into foreign assets to ensure a better return to the windfall than is available domestically. In phase three, as the shock dwindles away foreign assets are first repatriated, and then in phase four domestic investment is finally reversed. The savings rate which determines the size of the investment response is determined the duration of the shock (Bevan, Collier and Gunning (1990b)).

Investment in the Bevan-Collier-Gunning model is reversible, and the exact magnitude of the shock is known with certainty. Mash (1998) models discrete time investment dynamics in response to shocks of uncertain duration when investment decisions are irreversible. The model has a commodity export sector and an import competing sector, each with specific capital. Labour is fixed, but fully mobile across sectors. Once capital is installed it is irreversible. There is a delivery lag between the decision to invest and the time when new capital goods become productive. Finally, the model assumes access to a perfect capital market. Mash shows that in this framework aggregate investment responds both to the shock and to its reversal. The capital stock of the favoured sector initially expands rapidly after the favourable relative price change, while the other sector stops its replacement investment in order to let its (irreversible) capital stock depreciate. When prices are reversed at the end of the shock, the non-favoured sector then expands again, while the export sector contracts. In each period, the aggregate effect across the two sectors therefore depends on the relative size of the two sectors, the lags in delivery of capital goods, relative rates of depreciation, and the duration of the shock. In the presence of technical progress, relative capital stock obsolescence rates are also likely also to influence the aggregate effect. The main conclusion from Mash's model is that in the absence of detailed information on expectations about the duration of the shock, gestation lags, depreciation and obsolescence rates, and sector capital stock sizes, it is impossible *a priori* to determine the magnitude of the aggregate investment response to shocks.

Empirically, the effects of discrete shocks on private investment have yet to be evaluated, although the subject has been given considerable qualitative attention in Collier, Gunning and Associates (1999). Their argument, which is based on a series of individual country case studies, is that both the quantity and quality of investment is reduced during shocks due to a combination of factors, including limitations on private agents' access to foreign savings, and excessive and wrongly directed public expenditures. In another study, Deaton and Miller (1995) find that commodity prices are positively correlated with investment in developing countries, although this paper does not test whether large and small price changes have different effects, nor whether positive and negative shocks have distinct effects. Finally, in another paper which also does not explicitly examine investment, Rodrik (1999) argues that windfalls are appropriated by powerful interest groups due to a lack of

[2] In practice, the marginal efficiency of investment may also fall if investment bunching puts upwards pressure on the price of capital goods due to short run supply constraints.

agencies of restraint. This allocation mechanism, Rodrik argues, ensures that windfalls are either not invested at all or invested in projects which are sub-optimal and possibly unsustainable.

3. Uncertainty and investment

The poor empirical performance of deterministic investment models has kindled a growing interest in the role played by uncertainty (Abel and Blanchard (1986)). Once uncertainty becomes a potential determinant of investment, attitudes to risk on the part of investors become important, because firm investment decisions can only be viewed in isolation of the consumption decisions of households when there is access to a perfect market for Arrow securities. In their absence, firm owners may be averse to taking risks at firm level for fear of the repercussions such decisions have for the household's consumption. Risk aversion, however, has an unambiguous negative impact on investment, so it is arguably more interesting to assume risk neutrality on the part of investors in order to illustrate other avenues whereby uncertainty may affect investment.

Thus, assuming risk neutrality Hartman (1972) and Abel (1983) show that investment is a positive function of uncertainty whenever profits are a convex function of the stochastic variable (by Jensen's Inequality). In good states of the world, the firm (with a given capital stock) takes on additional labour, which raises the marginal product of capital more than linearly with price of output. Meanwhile, in bad states the firm can rid itself of excess labour. The profit function's convexity thus ensures that the return to capital in a good state outweighs the loss of investing in the bad state, provided the firm is able to adjust variable cost. Convexity can also result from the ability of the monopolistic firm to vary output.[3]

The Hartman/Abel models suggest that the Marshallian conditions of determining when to invest should hold on average, but actual investment typically does not occur until price exceeds long run average cost by a factor of three or four (Pindyck and Solimano (1993)). Dixit and Pindyck (1994) shows that this hurdle rate feature follows directly from the three premises: First, there is ongoing uncertainty about future outcomes, and waiting for additional information can reduce this uncertainty. Secondly, firms can postpone investment without foregoing the investment opportunity, because there is not free entry to the industry; by implication there is imperfect competition. Thirdly, investment decisions are irreversible. Jointly, these assumptions imply an opportunity cost of immediate investment over and above the long run average cost, which is the value of waiting for additional information (Bernanke (1983)). For example, a firm which invests and then cannot reverse its investment in the event of a downturn in the following period is stuck with an excessive capital stock. On the other hand, a firm which waits until the next period can avoid this predicament. The firm which waits will, however, incur an opportunity cost in terms of forgone current profits by operating with a capital stock which is below optimum size. The value to waiting arises when this opportunity cost in current profit terms is low compared to the cost of carrying out the irreversible investment and then being stuck with excessive capital in the event of a downturn. This opportunity cost, it is argued, *is* low compared to the cost of excessive

[3] Predictably, when the Hartman result is combined with risk aversion on the part of firm owners, the effect of uncertainty on investment becomes ambiguous (Zeira (1987)). This is because the convexity of the profit function raises investment in uncertainty, while the concavity of the utility function discourages investors.

investment, wherefore the net value of waiting is large and positive (Caballero (1991); Abel and Eberly (1994)).[4]

While the combination of uncertainty and irreversibility can account for hurdle rates, it is not in itself sufficient to secure a negative link between investment and uncertainty, which requires additional assumptions about imperfect competition or decreasing returns, or both. These assumptions have the effect of making the marginal product of capital a decreasing function of the level of the capital stock in conditions of irreversibility, such that the rise in profitability under uncertainty due to the convexity of the profit function is outweighed by the rise in the profitability threshold, which itself rises with uncertainty, such that the overall effect is negative (Caballero (1991)).

What are the implications of uncertainty for investment on average? Perhaps surprisingly, the effect is ambiguous. Irreversibility means that individual firm behaviour is characterised by periods of positive gross investment and zero gross investment, since firms only adjust their capital stocks in sufficiently good times.[5] In good times, firms invest less than they would in a fully reversible world in order not to be stuck with too much capital in the event of a downturn, but they only do so because they know they will be stuck with too much capital in the event of a bad outcome. On average, they therefore hold too little capital in good times and too much in bad times, and the precise outcome is essentially ambiguous.[6]

At aggregate level, firms face firm level (idiosyncratic) uncertainty and industry-wide (aggregate) uncertainty.[7] If Hartman's convex profit function result is accepted, firm specific idiosyncratic shocks have a positive effect on investment, but aggregate uncertainty is likely to affect firms differently depending on whether the industry is perfectly or imperfectly competitive. Imperfectly competitive firms can exploit the option to wait, so the firm level results carry over to the industry. For perfectly competitive firms, however, the value of the option to wait is zero, because hesitant firms will see their perceived option usurped by new entrants due to free entry, or because other incumbents expand their output. The industry supply curve therefore immediately shifts to the right, dampening any demand driven price increase. Meanwhile, the response of competitive firms to a bad state is to lower prices by moving along the supply curve, which has a definite negative impact on price. The combination of free entry and limited exit due to irreversibility therefore also introduces a payoff asymmetry to good and bad states of the world in the competitive industry. Positive shocks do not raise profits, but negative shocks lowers them, so the average payoff is reduced by uncertainty. The implication that firms invest less in good states therefore carries over from firm to industry level albeit for different reasons (Caballero and Pindyck (1996)).

Another feature which distinguishes aggregate investment from firm level investment is that the former tends to be far smoother than the action-inaction investment decisions of individual firms. Caballero (1993) and Bertola and Caballero (1994) explain this 'excess smoothness' in terms of the distribution of marginal profitability across firms. A consequence of irreversibility and firm specific shocks is that at any point in time some firms will be investing while others will not be investing. Whether or not a firm is investing depends on the

[4] Interestingly, the introduction of an option to invest creates ambiguity about the effect of the cost of capital on investment; higher interest rates raise the cost of investment, but they also reduce the incentive to wait.

[5] This result also obtains simply as a result of irreversibility as shown by Arrow (1968).

[6] Bertola and Caballero (1990) show that actual outcome depends on very specific parametric assumptions.

[7] The two are identical for the monopolist, but in all other cases firm and aggregate uncertainty are distinct influences.

firm's underlying marginal profitability of capital, which is different across all firms due to the idiosyncratic shocks. The distribution of marginal profitability reflects the difference between optimal and actual capital stocks, and its peakedness is a function of depreciation rates and other factors affecting the speed of capital stock adjustment. 'Excess smoothness' arises because the cross-sectional distribution channels parts of the energy of aggregate shocks into greater or lesser capacity utilisation by individual firms rather than wholly into investment.

A corollary of this property of aggregate investment is that when the industry faces positive aggregate shocks and more firms invest the cross sectional distribution narrows. A sequence of positive aggregate shocks therefore brings more firms near to full capacity utilisation, which means that aggregate shocks are more likely to be translated into aggregate investment effects. In contrast, a sequence of negative shocks causes firms to investment less and therefore widens the cross-sectional distribution. By implication, upside uncertainty is more likely to lead to aggregate investment shocks, while downside uncertainty is more likely to be smoothed out due to the buffering effect of a wider spread in the marginal profitability of capital across the firms in the industry.

A number of uncertainty variables have been tested in the investment literature, but the specific effects of *ex ante* commodity price uncertainty have not received much attention.[8] An important exception is the recent study by Serven (1998) who quantifies the contribution of *ex ante* terms of trade uncertainty on private investment. Using a large dynamic panel of developing countries, Serven finds that terms of trade uncertainty is not a statistically significant determinant of private investment.

4. A simple canonical empirical model of investment

There is no broad agreement about what is the 'correct' specification of the empirical aggregate private investment equation (Rama (1993)). The approach adopted in this paper is to construct a simple canonical investment equation with reference to the existing empirical literature on cross-country investment equations for developing countries, and then augmenting this model with variables which capture commodity shocks and uncertainty.

The basic theoretical framework used for the canonical model is the flexible accelerator model by Bond *et al.* (1997). The desired capital stock ($k_{i,t}$) is written as a log-linear function of output ($y_{i,t}$) and the real user cost of capital ($j_{i,t}$):

$$k_{i,t} = a + y_{i,t} + \sigma j_{i,t} \qquad [1]$$

The subscripts $i = 1,...,N$ and $t = 1,...,T$ refer to the cross-section and time series dimensions of the data, respectively. [1] is consistent with profit maximisation subject to constant returns to scale and a CES production function, and nests the possibility of a fixed capital output ratio ($\sigma = 0$). Temporarily ignoring the costs terms, differencing [1] produces the expression

$$\Delta k_{i,t} = \Delta y_{i,t} \qquad [2]$$

[8] For example, Pindyck and Solimano (1993) find a moderately negative relationship between investment and inflation, inflation variability, exchange rate variability, and interest rate variability.

where Δ is the difference operator. Unfortunately, data on the size of capital stocks are not widely available for developing countries. To resolve this problem, note first that $\Delta k_{i,t}$ can be approximated by

$$\Delta k_{i,t} \approx \frac{I_t}{K_{i,t-1}} - \delta . \qquad [3]$$

In turn, $\frac{I_t}{K_{i,t-1}}$ can be replaced by investment rates as is commonly done. The transformation of the dependent variable from investment to capital stock to investment to GDP means that right hand side coefficients will be roughly three times the magnitude of the coefficients which obtain from using capital stock ratios.[9] With these modifications, we arrive at a simple short run flexible accelerator investment specification:

$$\frac{I_t}{Y_{i,t}} = \rho\left(\frac{I_{i,t-1}}{Y_{i,t-1}}\right) + \beta_0 \Delta y_{i,t} + \beta_1 \Delta y_{i,t-1} + \gamma_0 \mathbf{X}_{i,t} + d_t + \eta_i + v_{i,t} \qquad [4]$$

In addition to time specific and country specific effects in the error term, a dynamic adjustment term has been included in [4] in recognition of the tendency towards excess smoothness in aggregate investment series in the face of aggregate shocks (Caballero (1993)). The long run relationship between investment and income can be recovered as $\left(\left[\beta_0 + \beta_1\right] / \left[1 - \rho\right]\right)$, which we expect to be unity if constant returns to scale are in evidence.

The aggregate demand terms are proxied by the growth rate of GDP and its lag. Many other studies have found that these enter the investment equation with strong positive coefficients (Vogel and Buser (1976); Fry (1980); Tun Wai and Wong (1982); Gupta (1984); Garcia (1987); Leff and Sato (1988); Love (1989); Greene and Villanueva (1991)). The possible endogeneity problems which arise from using aggregate demand as a regressor are discussed in Section 6.

The vector $\mathbf{X}_{i,t}$ in [4] captures auxiliary variables thought to influence investment in developing countries. Principal among these are the cost of capital. Jorgensen (1963) provides strong theoretical reasons to consider the cost of capital as a determinant of investment, and a number of studies, which have included the relative price of capital have found its coefficient to be significant and negative (Galbis (1979); Fry (1980); Gupta (1984); Leff and Sato (1988); Greene and Villanueva (1991)). The literature is, however, divided on which precise measure of the cost of capital is appropriate. Some studies use interest rates as an indicator of the cost of borrowing (or the opportunity cost of foregone alternative uses of the investable funds). Other studies use measures of the price of capital goods. Conceptually, however, interest rates and the price of capital goods are not the same thing, and there is no guarantee that they will move together. It was therefore decided to follow the approach of Serven (1998), who uses regressors which capture both the opportunity cost of investing (we use a

[9] Assuming a capital output ratio of 3.

measure of real domestic interest rates) and the price of capital goods in the canonical equation.

The role public investment - infrastructure provision - in private investment decision making has been examined in a number of investment equations for developing countries, including Galbis (1979), Blejer and Khan (1984), Gupta (1984), Greene and Villanueva (1991), and Oshikoya (1994). To the extent that public investment is financed by domestic borrowing, the amount of savings available for the private sector is correspondingly reduced when the government invests, thus crowding out private investment. This effect is potentially mitigated, however, by the extent of capital mobility.[10] In the extreme case of perfect capital mobility, for example, international capital will flow in as domestic interest rates rise, which causes interest rates to fall again leaving total investment unchanged, but its composition changed. On the other hand, public investment may also facilitate private investment if public and private investments are complementary. Generally, studies have found conflicting roles of public investment on private investment decision. Blejer and Khan (1984) and Gupta (1984) found a strong negative relationship between public investment and private investment using Ordinary Least Squares (OLS) and Two Stage Least Squares (TSLS) estimation methods, respectively. On the other hand, the Galbis and Greene & Villanueva studies suggest that public investment crowds in private investment, for example, by lowering private transaction costs via infrastructure provisions. Oshikoya (1994) finds some evidence that public infrastructure investment positively affects private investment, while non-infrastructure investment has a negative impact on private investment. Hence, while there is some disagreement over the direction of the effects, there is broad recognition that public investment is potentially important to private investors, wherefore this variable rightly belongs in a canonical private investment equation. We use the ratio of public investment to GDP as a regressor.

In addition to the role of aggregate demand, relative prices, and public investment, which apply to rich and poor countries alike, conventional investment equations for developing countries typically include variables thought to be of particular importance in this subset of countries. Chief among the additional regressors are policy variables. Policy is regarded as a particularly important determinant of investment in African countries, which are generally seen as more capital hostile than other regions (Collier, Hoeffler and Pattillo (1999)).

A number of different policy variables have been used in investment equations, and it is not clear *a priori* which variables to use. It is of some comfort, therefore, that policy variables tend to be highly correlated with each other (Collier and Dollar (1999)). This means that attention can be confined to a few indicators thought to be especially relevant to investment. This paper considers the share of credit to the private sector and capital account restrictions as the policy variables of choice. Private sector credit, used in investment equations by Serven and Solimano (1993), is potentially an important determinant of investment rates, because low real interest rates induce savers to not deposit their savings in banks, which are therefore unable to mediate funds towards potentially profitable investment projects. Financial repression also takes the form of non-price rationing, whereby scarce savings are pre-allocated to selected investors, usually the government. King and Levine (1993) show that investment and the share of credit allocated to the private sector are

[10] The extent to which crowding out occurs in response to budget deficits depends among on things on whether there is Ricardian Equivalence.

positively correlated, and Serven (1998) finds that private credit shares are a strong determinant of private investment in 60 developing countries. Credit availability was also shown to be a significant determinant of private investment by Vogel and Buser (1976), Fry (1980), Tun Wai and Wong (1982), Blejer and Khan (1984), Gupta (1984), Garcia (1987), Leff and Sato (1988)), and Oshikoya (1994).

We have already argued that capital account restrictions are an important determinant of investment in the context of shocks. But capital account restrictions also have a more general role. In economies with closed capital accounts, investment only takes place up to the point where domestic savings equal domestic investment at a given rate of interest. If this equilibrium interest rate is above world interest rates, as one would expect for developing countries where capital is relatively scarce, opening capital markets would *ceteris paribus* cause capital to flow in enabling a larger amount of investment than can be financed by domestic savings alone. As an indicator of the openness of the capital account, we use the capital account openness measure developed by Grilli and Milesi-Ferretti (1995). This variable, which is based on IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions*, takes the value of 1 when a restriction on "payments for capital transactions" is in place, and 0 otherwise. A drawback of the variable is that it does not measure their intensity.

The canonical investment model can be summarised as follows:

$$\frac{I_t}{Y_{i,t}} = \rho\left(\frac{I_{i,t-1}}{Y_{i,t-1}}\right) + \beta_0 \Delta y_{i,t} + \beta_1 \Delta y_{i,t-1} + \gamma_p \mathbf{X}_{i,t} + d_t + \eta_i + v_{i,t} \qquad [5]$$

where

$$\gamma_p \mathbf{X}_{i,t} = \gamma_1 \ln DomR_{i,t} + \gamma_2 \ln RPK_{i,t} + \gamma_3 \ln Pub + \gamma_4 \ln CRED_{i,t} + \gamma_5 KAR_{i,t} \qquad [6]$$

where $DomR$ are real domestic interest rates, RPK is the real price of capital goods, Pub is the ratio of public investment to GDP, $Cred$ is the share of credit to the private sector, and KAR is the dummy variable denoting capital account restrictions.

5. Introducing uncertainty and shocks into the investment equation

The canonical specification outlined in the previous section is now augmented with two additional sets of variables: The first, $VAR_{i,t}$ is a country specific measure of *ex ante* commodity price uncertainty. We consider a total of nine different versions of this variable, including three time varying definitions. The second set is a vector of dummies and variables, $\mathbf{S}_{i,t}$, which comprises the log of commodity price in levels, positive and negative shock dummies, and interaction terms between shocks and the log of commodity prices, respectively. $\mathbf{S}_{i,t}$ is intended primarily as a means of capturing *ex post* shock effects.

Both uncertainty and discrete shock variables are constructed from a geometrically weighted index of commodities similar in structure to one used by Deaton and Miller (1995). The formula describing the index is

$$DM = \prod_i P_i^{W_i} \qquad [7]$$

where W_i is a weighting item and P_i is the dollar international commodity price for the commodity i. Dollar prices measure *cif* border prices. Historical *fob* prices, which give a preferable measure of the value of a commodity to the exporting country are not generally available. The weighting item, W_i, is the value of commodity i in the total value of all commodities, n, for the constant base period j:

$$W_i = \frac{P_{ji}Q_{ji}}{\sum_n P_{jn}Q_{jn}}. \qquad [8]$$

Since W_i is country specific, each country's aggregate commodity price index is unique. As an average of the prices of the commodities exported by each country, the index is primarily suited to the study of macroeconomic rather than sectoral effects.

A geometrical weighting scheme is useful for two reasons. After taking logs a geometric index provides the rate of change of prices in first differences, which is a useful property. Also, geometrically weighted indices avoid the numeraire problem which affects deflated arithmetically weighted indices. Further details on the construction of the index can be found in Dehn (forthcoming-a).

Ex post shocks are identified by applying a purely statistical definition to each country's commodity price index. The steps are the following: First, each country's aggregate commodity price series is made stationary by first differencing the series, which removes the any permanent innovations.[11] Secondly, the remaining 'predictable' elements are removed by regressing the differenced series on its own lag, and a second lag in levels as well as a linear time trend. This error correction specification [9] is an efficient way to model an integrated process, because it removes both the 'predictable' levels and differences information which informs the data.

$$\begin{aligned} &\Delta y_{it} = \alpha_0 + \alpha_1 t + \beta_1 \Delta y_{i,t-1} + \beta_2 y_{i,t-2} + \varepsilon_{it}; \\ &t = 1,\ldots,T \end{aligned} \qquad [9]$$

The residuals from [9], ε_{it}, are then normalised by subtracting their mean and dividing by their standard deviation, and finally an extreme but essentially arbitrary cut off point is applied to the stationary normalised residuals. The base case cut off point used here puts 2.5% of the observations into each tail region, although alternative 5% and 10% cut off points are also used. Shocks can of course occur at any price level, and since it may matter to the quality and quantity of investment whether a shock occurs at a high or a low level of commodity

[11] It is assumed that the commodity price series are I(1) rather than trend stationary. In practice, determining with a high degree of confidence whether a series is a stochastic trend process or a deterministic trend process is difficult. See Leon and Soto (1995).

prices, we also allow for the shock dummies to condition on the (log of the) level of commodity prices.

Ex ante uncertainty can be measured in many different ways, and there is no consensus on what constitutes the 'correct' method of measurement. This suggests that there is merit in considering three broad alternative approaches to measuring uncertainty. The naïve approach involves treating all price movements as indicative of uncertainty by calculating the standard deviation each country's aggregate commodity price index. This is unsatisfactory on a number of counts. Most importantly, it does not control for the predictable components and trends in the price evolution process, and is therefore likely to overstate uncertainty. Both Serven (1998) and Ramey and Ramey (1995) have argued that this distinction is important.

The second approach therefore explicitly distinguishes between predictable and unpredictable components of the price series, but remains time invariant. The measure is based on the principle proposed by Ramey and Ramey (1995) that the 'predictable' components of the price series can be modelled using a selection of explanatory variables. The variance of the residuals can then be thought of as uncertainty. However, in contrast to Ramey and Ramey (1995), we do not regress commodity prices on a series of explanatory variables, but adopt instead a time series approach, whereby the first difference of real commodity prices (in logs) is regressed on as many of what can be regarded as predictable as possible. In particular, the regressors include autoregressive terms (first lag), a second lag in levels (making the regression akin to an error correction specification), plus deterministic trend terms, and dummies to pick up deterministic quarterly effects:

$$\begin{aligned} &\Delta y_{i,t} = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \beta_1 \Delta y_{i,t-1} + \beta_2 y_{i,t-2} + \gamma_1 D_t + \varepsilon_{i,t}; \\ &t = 1\ldots, T; \end{aligned} \qquad [10]$$

The three quarterly dummies, D_t, take the value of 1 for the second, third, and fourth quarters, respectively, zero otherwise. The constant captures the base period intercept. This approach treats as predictable the trend parameters, the parameters on the quarterly dummies, and on the lagged differences and levels of the dependent variable according to the argument that past values and trends can be thought of as being accumulated as knowledge by agents, wherefore uncertainty estimates must purge these known priors.

Cashin, Liang and McDermott (1999) argue that uncertainty worsened during the 1970s. If this is so, it is clearly not appropriate to maintain the assumption of homoskedasticity implicit in the two uncertainty measures considered hitherto. The third approach therefore distinguishes not only between predictable and unpredictable components of prices, but also allows the variance of the unpredictable components to vary with time. Time varying, or conditional, variances can be estimated by applying a Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model to each country's aggregate commodity price index (Bollerslev (1986)). A univariate GARCH(1,1) specification similar to that adopted by Serven (1998) is applied uniformly across countries:

$$\Delta y_{i,t} = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \beta_1 \Delta y_{i,t-1} + \beta_2 y_{i,t-2} + \gamma_1 D_t + \varepsilon_{i,t};$$
$$t = 1\ldots,T; \qquad [11]$$
$$\sigma_{i,t}^2 = \gamma_{i0} + \gamma_{i1}\varepsilon_{i,t-1}^2 + \delta_i \sigma_{i,t-1}^2$$

where σ_t^2 denotes the variance of ε_t conditional upon information up to period. The fitted values of $\sigma_{i,t}^2$ are the measure of uncertainty of y_{it}. Quarterly dummies, D_j, were included to remove possible deterministic seasonal influences on the conditional variance. Each quarterly dummy takes a value of 1 for a particular quarter, zero otherwise, and the final quarter is catered for by the constant term.

Failure to account for major structural breaks in the mean equation of [11] may result in distorted uncertainty variables as the break is relegated to the residual, which in turn informs the uncertainty measure. Likewise, large outliers in the mean equation may dominate both time invariant and time varying uncertainty measures. It is entirely conceivable, however, that agents view outliers as sufficiently infrequent and atypical to disregard their effect when evaluating future price uncertainty. Breaks may likewise be discounted. Versions of both the Ramey and Ramey and GARCH uncertainty measures were therefore constructed to take account of such possibilities. A version of the Ramey and Ramey measure therefore allows for a trend and intercept break in the commodity price series in 1973 on the hypothesis that the rise in commodity prices at this time was seen as permanent. Similarly, versions of the GARCH uncertainty measures were constructed which respectively 'dummy out' all the shocks identified above, and 'dummy out' only the first oil shock (again on the hypothesis that this was a permanent shock rather than the start of a period of greater uncertainty). Finally, conditional standard deviation measures of uncertainty (as opposed to conditional variances) were derived by taking the square root of the three GARCH conditional variance uncertainty measures on the grounds that it cannot be determined *a priori* whether agents observe the standard deviation or variance. The total number of uncertainty measures is therefore 9 (summarised in Table 1). Further descriptions of the distribution of shocks across time and their magnitude as well as the patterns of commodity price uncertainty have been described elsewhere (see Dehn (forthcoming-a) and Dehn (forthcoming-b)).

6. Issues of estimation

Estimation of dynamic panel equations such as [6] raise a number of issues. Consider the simple two-way error component dynamic panel data model

$$y_{i,t} = \alpha y_{i,t-1} + \mathbf{X}_{i,t}\beta + u_{it}$$
$$u_{i,t} = \eta_i + \lambda_t + \varepsilon_{i,t} \qquad [12]$$

where $\mathbf{X}_{i,t}$ is a row vector containing both policy variables and standard investment regressors. η_i are time invariant country specific effects. λ_t is a country-invariant term which accounts for any time specific effects not included in the regression. Finally, $\varepsilon_{i,t}$ is a random noise error term.

The objective is to recover consistent estimates of the coefficient on the lagged dependent variable as well as the coefficients on the other regressors. A range of dynamic panel data estimators are available, and each estimator has very different qualities (Judson and Owen (1996)). Hsiao (1986) shows that pooled OLS estimation of [7] results in omitted variable bias arising from correlation between the country specific effects, η_i, and the lagged dependent variable, $y_{i,t-1}$. The dependent variable is, of course, a function of η_i, but the time invariance of η_i means that the lagged dependent variable is also a function of η_i. The resulting positive correlation between the lagged dependent variable and a component of the error term causes the estimate on the lagged dependent variable to be upwardly biased. This problem can be avoided by using a Fixed Effects Within Groups (FE(WG)) estimator. The FE(WG) estimator transforms the data by subtracting the time series mean of each variable, thereby sweeping out the country specific effects. The transformation does not, however, remove any (negative) correlation between the lagged dependent variable and the time varying component of the error term as shown by Nickell (1981). This residual 'Nickell Bias' means that the FE(WG) estimator yields a downwards biased and inconsistent estimate of the coefficients on the lagged dependent variable in [12]. Only when the time series dimension approaches infinity does the Nickell bias approach zero, but this is never the case in developing country macroeconomics data wherefore the Nickell bias must be taken seriously. By virtue of the fact that the biases go in opposite directions, the OLS and FE(WG) estimates define the upper and lower limits of the coefficient on the lagged dependent variable in otherwise well-specified equations, and we would expect an unbiased estimate of the coefficient ρ in [6] to lie within the interval $\rho_{OLS} \geq \rho_{unbiased} \geq \rho_{FE(WG)}$ (Hoeffler (1998)).

If the right hand side variables in [6] are endogenous to investment, both OLS and FE(WG) estimators will yield biased and inconsistent estimates. As alluded to earlier, this might be the case if, for example, aggregate demand is endogenous to investment via the multiplier. There are several ways to address the problem. One is to estimate a system of simultaneous equations, but this usually introduces problems of identification, which can only be solved by introducing further variables which themselves may be endogenous, and so on. Another method is to instrument for the endogenous variables. Instruments may be external or internal. External instruments are often difficult to find given the general scarcity of data. Moreover, there is no guarantee that external instruments are particularly efficient. It has therefore become common practise use internal instruments to avoid the Nickell bias problem. The Anderson and Hsiao (1982) estimator thus utilises the second lag of the endogenous variable as an instrument. As long as the error term is not serially correlated, this instrument is valid. If serial correlation is present, however, higher order lags may be necessary. While Arrelano (1989) has shown that levels instruments are more efficient than differences in the Anderson-Hsiao estimator, the use of instruments in the Anderson-Hsiao estimator is generally not particularly efficient. An alternative approach is the Differenced GMM estimator (DIF-GMM) of Arrelano and Bond (1991), which allows for a wider range of internal instruments to be used. Each available instrument is weighted by the inverse of its variance, which means that a more efficient estimate of the endogenous variable is obtained.

The validity of the choice of instruments in the DIF-GMM estimator is determined in part by the relationship between current and past errors and in part by the relationship between the errors and the dependent variable. In all cases, it is assumed that the errors are serially uncorrelated and independent across cross-section units. Provided that this condition is met, three classes of instruments can be identified depending on the relationship between the regressors and the errors, where the distinction is made between exogenous, endogenous, and predetermined variables. When the regressors are strictly exogenous to the error term such that $E(x_{i,t}\varepsilon_{i,s}) = 0$ for all s, t, then all past, present, and future values of $x_{i,t}$ are valid instruments for the differenced equations. When the regressors are predetermined with respect to the error term, which means that $E(x_{i,t}\varepsilon_{i,s}) = 0$ for $t \geq 2$, then the second and higher order lags of $x_{i,t}$ are valid instruments for the differenced variable. Finally, when $x_{i,t}$ is endogenous, such that current shocks and $x_{i,t}$ are correlated ($E(x_{i,t}\varepsilon_{i,s}) \neq 0$ for $s \leq t$ and $E(x_{i,t}\varepsilon_{i,s}) = 0$ for $s > t$), then only values of the endogenous variable lagged two periods or more are valid instruments.

The Anderson-Hsiao and DIF-GMM estimators have distinct advantages over the OLS and FE(WG) estimators, but in the context of the present analysis they may not constitute preferred estimator for the following reasons: First, the required first differencing of the data throws away much of the information contained in the data.[12] The severe constraints on the availability of annual macroeconomics data for developing countries suggests that available data should be used as efficiently as possible. Secondly, when a series is close to a random walk then lagged levels instruments used in the DIF-GMM estimator are poor instruments, because the past values of a near white noise stationary growth variable have little forecasting power.

In these circumstances, Blundell and Bond (1998) have shown that a SYS-GMM estimator, which uses the variables both in differences and levels produces consistent estimates in the face of heterogeneity, endogenous variables, and country specific effects (see also Arrelano and Bond (1991)). Instrumentation for the differenced equation follows the same rules as those already discussed in the context of the DIF-GMM estimator, i.e. suitably lagged levels of the endogenous variables. Additionally, for the levels equation it is required that each regressor, $x_{i,t}$, satisfies the condition that $E(\Delta x_{i,t}\eta_i) = 0$, and that initial values conform to the requirement that $E(\Delta y_{i,2}\eta_i) = 0$. If this is the case, then the first lag of the differenced dependent variable and the first difference of the regressors can be used as instruments in the levels equation. The first of these conditions implies that the regressor in levels can be correlated with the country specific effects as long as the first difference is not. When this holds, the second condition also holds provided that sufficiently many realisations of the levels process have taken place. Generally, the validity of the instruments can be determined using the Sargan test, which assesses the orthogonality between instruments and the residuals, and by testing for first and second order serial correlation of the residuals, which indicates the extent of the correlation between country specific effects and error components.

Data Sources and Description

The data on private and public investment per GDP is based on data collected at the World Bank by Serven (1998) (which is an updated version of the data set by Serven (1996)). Investment data should be interpreted with some caution, and private investment data even more so. This is because private investment data is produced as a residual, which therefore

[12] The loss referred to here is the information contained in the level, not the loss of the first observation to differencing.

contains not only private investment's own measurement errors, but errors from the measurement of total and public investment. Additionally, it has not been possible to take account of differences in depreciation rates across individual countries in the sample due to lack of data. There are good reasons to expect such differences to exist. For example, the procurement of spare parts for the maintenance of capital stocks in some countries may be more difficult due to various import restrictions, thus leading to a more rapid deterioration of capital stocks in those countries (Ndulu and O'Connell (1999)). Some countries may also be saddled with disproportionately many 'white elephants', which have proven incapable of surviving international competition as trade regime have become more liberal over the sample period. For example, in African countries where public investment constitutes a greater share of total investment than in other countries (see Table 3 below), the hardening of budget constraints during the 1980s will have meant that existing public sector capital stocks were particularly difficult to maintain. Finally, the unavailability of data on obsolescence rates for capital in different countries means that investment rates do not take account of the extent to which some developing countries have made swifter and more frequent leaps forward in terms of the sophistication of their capital equipment simply by virtue of having more catching up to do.

Domestic real interest rates are calculated using the formula

$$\ln\left[\frac{(1+nomR)}{1+\dot{\pi}}\right] \qquad [13]$$

where $nomR$ is the nominal interest rate and $\dot{\pi}$ is the rate of inflation. It was not possible to use identical definitions of interest rates for all countries due to data limitations. Lending and commercial bank rates have been used wherever possible and otherwise the discount rate has been used. The inflation rate is calculated as the difference in logs of CPI. Both interest rates and CPI are from *IFS*.

The share of private sector credit in GDP was calculated from *IFS* using Claims on the Private Sector and Nominal GDP. The relative price of capital variable was constructed as the investment deflator divided by the GDP deflator. The investment deflator was constructed as the ratio of nominal GDI from the World Bank in local current prices divided by real GDI, likewise from the World Bank, but in local 1987 prices. The GDP deflator was obtained from the World Bank in 1987 constant local prices. Growth rates are calculated as the annual difference in logs of World Bank real GDP in 1987 US$.

The size of the final estimation sample is restricted from three directions. First, the availability of data on investment as well as its determinants is quite limited across time as well as across countries. Secondly, GMM estimation requires a minimum of 5 consecutive observations per country to produce a reasonable number of internal instruments. This means that countries are dropped if they have fewer than 5 observations, or if the observations are not consecutive. Only 56 of the 113 countries for which shock and uncertainty variables are available satisfy the investment data availability and five 5 observations criteria. Thirdly, in order to evaluate the impact of shocks the sample should obviously contain at least 1 shock for each country within the sample period. A further 12 countries fail on the criterion for the presence of a shock within that feasible sample period.[13] The final sample therefore consists of 44 countries covering 54 positive shock episodes and 36 negative shock episodes. The panel is unbalanced with 20 African and 24 non-African developing countries. The longest continuous sample period is 22 years (1971-1992), which is available for 18 countries. The country with the shortest consecutive sample period is Panama with 7 observations.

Table 2 shows how positive and negative shocks are distributed across the sample. The average number of positive shocks per country is close to the sample average of 1.23 for Sub-Saharan African, South Asian and East Asian countries as well as mixed producers, and agricultural non-food producers.[14] The remaining classifications either have a slightly lower average number of shocks (Latin American countries and non-agricultural non-oil producers), or a somewhat higher average number of shocks (Caribbean producers and South Africa as well as oil producers). Latin American countries have on average more negative shocks than other countries, while South and East Asia have fewer. South Africa's major negative shocks did not feature within the 21 year sample period for which data was available. No Pacific countries qualify.

Table 3 shows basic descriptive statistics on the key variables. The average real private fixed investment rate in the sample of African countries is 7.94% compared to 12.06% in Middle Eastern and North African countries, and 11.60% in other developing countries. Meanwhile, public investment commands a larger share of GDP in Sub-Saharan Africa (8.31%) than in other developing countries (6.91%), excluding Middle Eastern and North African countries (14.1%).[15] The combination of relatively low private investment and relatively high public investment means that the ratio of public sector investment to private sector investment in Sub-Saharan Africa is substantially larger than in most non-oil producing countries, reflecting what others have found (Adam and O'Connell (1998)). It is also clear from Table 2 that investment exhibits considerably more variability across African countries than in other regions with standard deviations which are in all cases greater than for other regional groups. A few other points are worth noting. While there is not much discernible difference in average growth rates across regions, the variability of growth in Sub-Saharan Africa is greater. The same applies to the real price of capital goods. Additionally, real domestic interest rates and credit available to the private sector are lower in Sub-Saharan Africa than in other non-oil producing developing countries.

The lower panel of Table 3 shows full sample and regional sub-sample averages of the full range of uncertainty measures used in the analysis. Uncertainty is greater when shocks are not controlled for, suggesting that outliers or shocks may account for much of the uncertainty; the differences in the severity of uncertainty across regions is also reduced considerably when controlling for shocks, notably for the oil producing Middle Eastern and North African countries, which generally experience the greatest uncertainty. Finally, while the level of commodity prices is higher on average in Sub-Saharan Africa than in the other regions in the sample period (Index 1990=1), the standard deviation is also greater, which probably reflects the greater decline of the prices of commodities produced by African countries over the sample period.

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[13] Note that the 12 countries omitted for lack of shocks did experience shocks, but not within the sample period during which data on the other variables were available.

[14] A country is a classified as a producer of a particular type of commodity if 50% or more of its commodity exports of that type. For more details on how commodities are classified, see Dehn (forthcoming-b).

[15] It is useful to consider this last group separately due to the importance of oil to these countries.

7. Results

This section reports SYS-GMM estimates as well as OLS and FE(WG) estimates. All three estimators are used to provide an indication of the robustness of the results to different estimation methods. The pooled OLS estimator is clearly more efficient, but likely to generate highly biased coefficients by virtue of ignoring both country specific effects and possible endogeneity of the right hand side variables.[16] The FE(WG) estimator addresses the first of these criticisms. In modelling country specific effects, the fixed effects specification was only accepted if fixed effects were not rejected in favour of random effects according to Hausman and Breusch-Pagan tests. The Hausman test asks if there are significant differences in the slope coefficients between a GLS (Random Effects) and the FE(WG) estimator, while the null hypothesis of the Breusch-Pagan test is that the variance of the country specific effects is zero.

As argued, it is not realistic to assume that all the right hand side variables are exogenous. The SYS-GMM model therefore instruments for the lagged dependent variable, the growth terms, credit to the private sector, the price of capital goods, and domestic interest rates. In instrumenting for these variables, the efficiency of the estimates is invariably reduced. There is therefore a trade off: Relinquishing the potentially biased FE(WG) or OLS estimators in favour of the unbiased SYS-GMM estimator also means adopting a less efficient estimator, but when the bias is small, the FE(WG) may in principle be the preferred estimator on a mean squared error criterion.

Table 4 reports the estimates for the canonical private investment model. The model specification satisfies the basic requirements of a baseline model. The expected signs and coefficient magnitudes are broadly in line with expectation, notably for the FE(WG) and SYS-GMM models. The effect of public investment on private investment is statistically indistinguishable from zero, indicating that aggregate public investment neither substitutes for nor complements private investment. There is evidence in the OLS and FE(WG) models that accelerator effects work strongly in developing countries, a result also found by Oshikoya (1994). The signs on the coefficients are in most cases similar across different estimators, and coefficient estimates tend to be of the same order of magnitude as well. Interest rates are not significant in the canonical model, but enter the regressions with the correct sign. The price of capital goods and capital account restrictions are significant with the correct sign. Finally, private credit is important in the OLS model, but not significant in the FE(WG) and SYS-GMM models.

The coefficient on the lagged dependent variable using the SYS-GMM estimator falls within the upper and lower range limits defined by the pooled OLS and FE(WG) estimates, but is closer to the latter, which indicates that country specific effects matter considerably in this regression. Meanwhile, time effects do not have much effect as substantiated by the F and Wald tests for pooling across the time dimension which cannot be rejected within conventional confidence levels. It is also noteworthy that the SYS-GMM model supports a constant returns to scale production function by virtue of the unity long run relationship between growth and investment ([0.25+0.12]/[1-63]=1).

Both Hausman and Breusch-Pagan tests indicate that fixed country specific effects can not be rejected in favour of random effects. Hence, this and subsequent tables report only the FE(WG) results. Attention is drawn to the insignificance of the growth variables in the SYS-

[16] Each model includes time dummies.

GMM model, which is a general result, which is most likely due to poor instrumentation. Past levels and differences are poor correlates of current values of the growth variables, so it is not surprising that the Sargan tests consistently indicate that instrumentation in this and the following equations presented below is not optimal. There is also some evidence of second order serial correlation. This could be indicative of correlation between the errors and some unknown omitted explanatory variable. The error term is bound to contain elements of unobserved country specific effects by virtue of the fact that the levels equation in a SYS-GMM model is estimated as a pooled model.

Table 5 reports the preferred shock augmented model based on the full sample of 819 observations and 44 countries. The shock and commodity price variables enter the regressions with a one period lag after it was found that current values were not significant. This lag can be explained quite easily. Most obviously, it may take time to plan investment projects. Moreover, payments to producers are often delayed substantially from the time the product is sold in the main markets in USA and Europe. Meanwhile, domestic financial markets operate poorly, so that agents are often unable to borrow for investment purposes against expectations of future income. Another potential explanation is that if capacity utilisation is below optimum for a large number of firms, the initial response to increased demand among the bulk of firms is to use up spare capacity first, and then only subsequently to engage in expansion of the capital stock (buffer effect for aggregate investment).

In the preferred model, the coefficient on the lagged dependent variable again falls within the required range defined by the OLS and FE(WG) estimates, and the long run coefficient indicates constant returns to scale. The positive shock dummy indicates that investment rates on average increase during shocks compared to non-shock periods. The full effect of shocks is, however, conditional upon the level of commodity prices at which the shock occurs. The negative interaction term between the shock dummy and the level of prices means that for a given shock magnitude the higher the level of commodity prices at the time of the shock the lower the investment rate. This is an interesting result, which lends support to a theoretical prediction (which has also found empirical validity in the context of the Kenyan coffee boom) that large shocks depress the marginal efficiency of investment (Collier and Pattillo (2000), Bevan, Collier and Gunning (1990a)). As these authors have argued, the depression of the marginal efficiency of investment can come about through a combination of rising domestic costs and the exhaustion of profitable domestic investment opportunities during a positive windfall. Such effects are clearly likely to be more prevalent when shocks occur at a time when commodity prices are already high, because capacity is then nearer to full utilisation compared to periods when export revenues are low and demand consequently depressed.

Figure 1 illustrates the relationship between a shock and investment rates, conditional upon the level of prices. The figure is based on the coefficients from the SYS-GMM model. The figure shows the percentage change in (log) investment rate on the vertical axis and the level of (log) commodity prices on the horizontal axis. The downwards sloping schedules are drawn for a shock of a given size, and describe the relationship between the change in investment rates and shocks, conditional upon the price level. The bold line depicts this relationship for a shock at the 2.5% cut off. The range on the X-axis is defined over the maximum and minimum values of commodity prices in the sample. The mean is 0.17 and the standard deviation is 0.32, such that 2 standard deviation bands are located at -0.55 and 0.89, respectively. It is evident from Figure 1 that the downward sloping schedule is in the positive region for the majority of price realisations. This means that shocks usually increase investment rates relative to non-shock periods. The exception is when shocks occur at a time when commodity prices are already high in which case they tend to reduce investment rates relative to what they would have been in non-shock periods.

How is this result to be interpreted? *A priori*, it is expected that the bulk of a transitory windfall is saved and invested, wherefore investment should increase proportionately more than GDP. The observed fall in investment rates during shocks which occur at times when prices are high is therefore surprising. Indeed, even if domestic investment opportunities are exhausted, this would only imply that investment rates level off at a high level commensurate with the minimum return available on foreign assets. One interpretation is that agents face restrictions on access to foreign savings instruments which are not adequately modelled using the rather crude capital account restrictions variable. If so, agents may opt to consume rather than to invest the marginal unit of windfall, boosting GDP at the expense of investment.

An alternative explanation for falling investment rates is that governments tax windfalls above a certain magnitude. Collier and Gunning (1996) have argued that governments often fail to save windfalls, and even when they save early on they then fail to lock into the savings decision, proceeding to spend the windfall rapidly. Windfall spending typically involves a considerably element of consumption for political reasons, and governments often end up with widened fiscal deficits after the end of the shock (Schuknecht (1996))[17]. The promise of future taxation to re-establish balance in government finances after the shock may cause private investment rates to drop. Note, however, that while investment rates fall, they never become negative, because the change in investment rates never exceeds the mean investment rate for any region.

What is the effect on the shock-investment relationship of changing the cut off point for identifying shocks, given that the cut-off point was chosen arbitrarily? Figure 1 therefore also shows investment-price level schedules for shocks defined according to 5% and 10% cut-offs (thin and dotted lines, respectively). The main effect of moving to a less extreme cut off point is to pivot the schedule to a flatter slope, thus reducing the investment effects at low levels of commodity prices while increasing them at higher levels relative to the 2.5% cut off. This is indeed what one would expect in light of the previous results which show that only large changes in commodity prices are significant. As the cut off point is reduced, non-shocks are included in the sample of shock episodes which tends to erode the negative effects of shocks at large price levels and increasing the positive effects at low price levels equally so.

Two further aspects of Table 5 are worthy of attention. The first is that uncertainty does not feature in the preferred model. One potential reason is that the measure used for measuring uncertainty is unsuitable. It is obviously impossible to test all conceivable uncertainty measures, since this is an infinite set. However, a total of 9 different uncertainty measures were attempted and none of them were robustly statistically significant.[18] Hence, while it may be possible to develop alternative measures of commodity price uncertainty

[17] Deaton and Miller (1995) point out that it is difficult to distinguish clearly between investment and consumption expenditures in public spending.

[18] The only exception was the standard Ramey and Ramey time invariant uncertainty measure, which returned a positive significant coefficient (at 10%) when applied to the full sample in the pooled OLS model (but not in the SYS-GMM model). The sign changed and the coefficient became completely insignificant, however, when oil countries were dropped, which suggests that the Ramey and Ramey time invarying uncertainty measure may be driven by large positive oil shocks. Moreover, it is unclear how a time invarying uncertainty measure should be interpreted vis-à-vis unobserved country specific effects.

which are significant in this model, it is likely that significance will be highly dependent on the precise specification of uncertainty used, and hence unlikely to be very robust.

Another potential explanation for the insignificance of uncertainty is that agents are somehow able to hedge against the risk imparted by future commodity price uncertainty. This explanation only seems credible to the extent that countries and agents have access to market based risk management tools. These instruments require considerable financial resources to which, it seems reasonable to assume, only multinational corporations have access. In particular, small scale agricultural producers as well as many developing country governments do not generally have access to the financing required to utilise such tools (International Task Force on Commodity Risk Management in Developing Countries (1999)).

In order to determine if the insignificance of the uncertainty variable is driven by those countries in the sample whose exports are extracted and traded by creditworthy multinationals, two further sets of regressions were run. The first excludes non-agricultural non-oil countries (effectively excluding countries heavily dependent on mining), and the second excludes oil producers as well as non-agricultural non-oil producing countries. For each of these sub-samples, we use the GARCH based uncertainty measure which ‘dummies’ out the effects of the first oil shock, since this measure performs best among the available alternatives. Table 6 shows the four relevant regressions. Regression 1 is the canonical model augmented only with (the best performing) uncertainty variable estimated over the full sample. Regression 2 adds the shock terms and is also estimated over the full sample. Regressions 3 and 4 are similar to Regression 2, but are estimated over the samples which exclude oil producers, and oil and mining exporters, respectively. In each case, it is clear that uncertainty is not a significant determinant of private investment. We take this to imply that hedging is unlikely to be the reason for the insignificance of commodity price uncertainty, since uncertainty remains insignificant even when we consider only those countries which presumably do not have access to market based hedging.

The result that commodity price uncertainty does not impact on private investment is compatible with the findings from growth regressions (Dehn (forthcoming-a)). Hence, while intriguing, the result is neither inconsistent with theoretical priors nor with other results in the literature. The effects of risk aversion and convex profit functions may, for example, simply be cancelling each other out, or commodity price uncertainty *per se* may not be the most important source of uncertainty in the eyes of investors. Serven (1998) finds that (a) terms of trade uncertainty has no significant impact on private investment, and (b) real exchange rate uncertainty is the dominant source of uncertainty.

The second noteworthy feature of the preferred specification in Table 5 is that negative shocks do not appear to matter to private investment. In other words, positive and negative shocks have highly asymmetric effects on investment. To examine the robustness of this finding further, a number of additional regressions were run (shown in Table 7). In the simplest case, the commodity price and shock variables in the preferred model were replaced by the change in commodity prices variable, which does distinguish neither between positive and negative shocks nor between large and small changes in prices (Regression 1). This variable was never significant, even when the change was conditioned upon the level of commodity prices. When the square of the change in commodity prices was added (conditioning on levels, Regression 2) the same result obtained. Similarly, the level of commodity prices and its square was also tried on the hypothesis that a simple quadratic relationship may provide a better explanation than the shock dummy (Regression 3). This specification, which also imposes symmetry between positive and negative shocks, was firmly rejected by the data. Large shocks therefore have special significance, possibly because small price changes are not sufficient to raise the rate of return above the required hurdle rate. In this view, smaller changes in prices may engender an expansion in capacity utilisation among firms operating within their production possibility frontiers, but not by enough to produce a statistically significant aggregate private investment response. These results underscore the general conclusion that it is big positive shocks conditioned upon the level of commodity prices that matter.

Finally, encompassing tests were carried out for competing specifications of shocks (Regression 4).[19] The strategy is to ask whether the preferred positive shock measures reject the symmetric measures, and whether the symmetric measures reject the positive shock terms. It is possible that both may reject (implying that there is information in both measures but to different extents), that neither will reject (implying that the data cannot discriminate between the two), or that one specification will reject the other (giving a clear-cut decision). The last result was obtained according to which commodity prices in levels, the positive shock dummy and the positive interaction term jointly reject the symmetric response (composed of the level of commodity prices, the change in commodity prices, and the interaction term between the two), thus confirming that the asymmetrical approach to modelling shocks is superior.

The robustness of the results to changes in the sample was also explored. Priors suggest three alternative sample definitions. First, commodity shocks are likely to matter more to less diversified economies and to economies with greater restrictions on access to international capital markets. We may therefore expect to find that shocks matter particularly to low income countries and less or not at all to middle income countries. Secondly, African countries are among the most heavily commodity dependent economies in the world wherefore shocks may matter more here than in other regions. Thirdly, the oil shocks in the 1970s are always dominant in discussions of trade shocks and it is therefore natural to control for oil shocks when trying to determine the general validity of shocks as determinants of private investment. Table 8 shows the results of estimating the preferred model on alternative sample specifications using the SYS-GMM estimator. A number of features are worth drawing attention to:

First, regression 1 shows that commodity price movements and shocks do not appear to matter to Middle Income countries (defined as countries with income per capita in excess of US$1900 in both 1970 and 1990). Secondly, while investment rates in non-Sub-Saharan African countries are sensitive to commodity price movements, there is no evidence to suggest that these countries are particularly affected by shocks (regression 4). Thirdly, oil is not driving the shocks result, which can be verified from regression 3, which shows that the shock variables remain significant after dropping oil countries (defined as countries for which oil constitutes more than 50% of total commodity exports). Finally, Sub-Saharan Africa is significantly affected by shocks as are low income countries more generally of which the majority are, of course, Sub-Saharan African countries (regressions 2 and 5).

These partial sample results are less stable than the full sample results, partly because of smaller sample size. This may account for a number of peculiar differences which emerged when different estimators were used. For example, when the FE(WG) estimator is applied to non-SSA countries sample, the shock variables become significant, although this result is not

[19] For convenience, the test results are based on the FE(WG) results. The similarity of coefficient magnitudes and significance suggests a similar result based on the SYS-GMM estimator.

forthcoming with the OLS or SYS-GMM estimators (not shown). Similarly, whereas the lagged growth term is positive in the FE(WG) and OLS models, the coefficient on this variable is negative in the SSA sample when using the SYS-GMM estimator. Perhaps this indicates income gains are more quickly reversed in SSA, a result which is compatible with the findings in Dehn (forthcoming-a).

Pesaran and Smith (1995) have showed that pooling of dynamic panels may result in inconsistent results if parameters are not constant. In order to test for poolability, we conducted Chow tests. Critical values can either be obtained from a normal F table, which assumes that the test is centred on zero, or from a non-centred MSE table on the argument that it is preferable to balance the negative bias effects of illegitimate pooling against the positive efficiency benefits of a larger sample when deciding if pooling is justified. Critical values have been developed for the MSE criterion by Goodnight and Wallace (1972) and Wallace and Toro-Vizcarrondo (1969). Unfortunately, pooling is rejected on both the strict F criterion and on the MSE criterion for the preferred model, but poolability cannot be rejected at the 5% level on the MSE criterion if uncertainty terms and negative shocks are added back into the model. Their inclusion does not change the coefficients from the preferred regression however, which we take as an indication that negative shocks and uncertainty may matter not in terms of their effects on coefficient size but rather in terms of their effects on the coefficient's standard error.

It should be noted, however, that Chow tests are invalid in the presence of groupwise heteroskedasticity. Our results only correct for simple heteroskedasticity, not for groupwise heteroskedasticity. While it is possible in some circumstances to correct for groupwise heteroskedasticity, our attempts were unsuccessful because it was not possible to identify the unknown sources of heteroskedasticity. We also failed to successfully implement the approach recommended by Pesaran and Smith (1995) and used by Serven (1998), which involves estimation of coefficients of the preferred regressions specification for *each* individual country and then generating a weighted average of the coefficients and standard errors (where the weights are the number of observations for each country). The reason for failure is undoubtedly the shortness of the time series available for each country. Unlike Serven who applies the methodology to a model with 9 parameters our model has 16 parameters and a maximum sample size of just 22 observations per country. The implication is that it cannot with confidence be ruled out that the results suffer from the inconsistency problems highlighted by Pesaran and Smith (1995).

8. Conclusion

Deaton and Miller (1995) find that commodity prices have strong effects on investment using an extended VAR framework, although they also make the point that a clear distinction between consumption and investment in their model cannot be justified due to the quality of the data. Our results are compatible with their findings and subject to their *caveat*.

Where our results depart from Deaton and Miller (1995) is that we are able to be more specific about the particular manifestations of commodity price movements which matter to investors. By comparing various different specifications of commodity price movements, including levels, first differences, large and small price changes, and positive and negative price changes, we have been able to establish two main conclusions:

First, commodity price uncertainty does not appear to matter to investment rates in developing countries. We interpret this to mean that commodity price uncertainty is not the main concern of investors, perhaps because this particular source of uncertainty is perceived as less damaging than other sources of uncertainty. This finding is compatible with the findings of Serven (1998).

Secondly, isolated extreme manifestations of commodity price changes, or shocks, matter to investment rates, especially in low income countries. In particular, we have demonstrated a fundamental asymmetry in the effects of small and large price changes and positive and negative large price changes. Positive shocks have a strong positive effect on investment rates conditional upon the level of commodity prices. When shocks occur at times when prices are already high, there are mechanisms - possibly to do with capital constraints or government intervention - which ensure that investment rates decline.

Negative shocks on the other hand appear not to affect investment rates. This is curious given that Dehn (forthcoming-a) finds that growth responds strongly to negative shocks. Growth can, of course, change dramatically without changes in investment. Easterly *et al.* (1993), for example, point out that growth rates are far less persistent than investment rates, so all growth variation cannot possibly be accounted for by variation in investment. But if countries do not adjust to negative shocks by disinvesting, how do they adjust? One possibility is that they *do* adjust, but that the absence of an investment rate response is simply an artefact of the way investment data is collected in *National Accounts*. Investment data are often constructed on the assumption that the import content of investment projects stays constant during the shock. However, the powerful relative price changes which accompany temporary trade shocks may undermine the validity of this assumption. The import content of investment projects is likely to rise during shocks if short run supply constraints cause the price of non-tradable capital goods to rise. Similarly, during negative shocks non-tradable capital prices fall relative to imported capital goods prices. To the extent that agents respond to relative price changes by switching between imported and domestic capital goods, the assumption of a fixed import ratio in investment projects results in an overestimate of investment during positive shocks and an underestimate of disinvestment during negative shocks[20]. Unfortunately, we have no alternative sources of investment data which enable us to control for this effect, it is only possible to note that a bias from this source may contribute to the observed absence of an investment response to negative shocks.

An alternative explanation for the absence of a negative investment response is that economies adjust by lowering capacity utilisation rather than disinvesting[21]. A sharp and lasting reduction in capacity utilisation will be reflected in GDP and hence in growth rates. The capacity utilisation argument rests on the notion that investment decisions are largely

[20] For example, suppose that an investment project is assumed to required in fixed proportion one imported input and one domestically produced unit. If positive shocks shift relative prices in favour of imports, and agents respond buy importing a bigger proportion of their total investment expenditures, then the domestic investment response will be over-estimated, because it is determined with reference to the amount of imports which is now larger. Similarly, during a negative shock if agents switch to more domestic capital intensive methods, which are now cheaper relative to imported capital, then capital imports will underestimate the disinvestment during negative shocks, because the 1:1 ratio between imported and domestic capital is no longer maintained.

[21] Negative shocks could conceivably cause the rate of technical progress to slow down, for example by reducing the willingness of investors to adopt new and better technologies, but one would expect such innovations to be embedded in new equipment and hence at least partly reflected in lower investment. This we do not find, however.

irreversible, because if investments were reversible firms would simply get rid of excess capital during negative shocks, and the investment response to positive and negative shocks would be entirely symmetrical. Not only is a greater share of the exports of developing countries are subject to commodity price uncertainty, but these countries also have thinner second hard markets for investment goods, and very limited mechanisms for outright sale of going concerns (Collier and Gunning (1999b)). The case for regarding investment in developing countries as irreversible is therefore quite strong.

The remaining consideration pertains to depreciation and/or obsolescence rates for capital stocks. High depreciation and obsolescence rates shorten the duration of irreversibility constraints, so the suitability of the irreversibility argument hinges in part on the assumption that depreciation rates and obsolescence rates are fairly low in those sectors affected by negative shocks. *A priori*, depreciation rates are likely to be lower for structures and buildings than for investments in machines and equipment with moving parts. Obsolescence rates are driven by the rate of technical progress, wherefore they are lower in sectors which use less dynamic technologies. Commodity sectors are mainly agriculture and mining. Agriculture is generally regarded as a sector which has seen little technical progress in all but a few of the poorest developing countries (Ghatak (1987))[22], and the record of technical innovation in agriculture in Africa has been particularly bad (Timmer (1988)). It is also largely a non-equipment intensive activity which uses labour intensive production technologies. For these reasons, we would expect depreciation and obsolescence rates to be low in agriculture, particularly in Africa. Meanwhile, in the mining sector the resale potential for capital is likely to be low once installed, although depreciation rates for mining equipment will probably be greater than for agricultural equipment due to the equipment intensity in mining. On the other hand, the sector is not particularly dynamic in terms of technical progress. On balance, one would therefore expect irreversibility constraints to bind the hardest in agriculture, followed by mining sector followed by manufacturing. This provides broad support for the argument that adjustment to negative shocks in commodity sectors is not so much by ceasing to undertake replacement investment as by reducing capacity utilisation.

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[22] The exception is the adoption of Green Revolution technologies in Asia, but that experience has not be replicated in other regions of the world.

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Figure 1: The effects of shocks on investment conditional upon the level of commodity prices

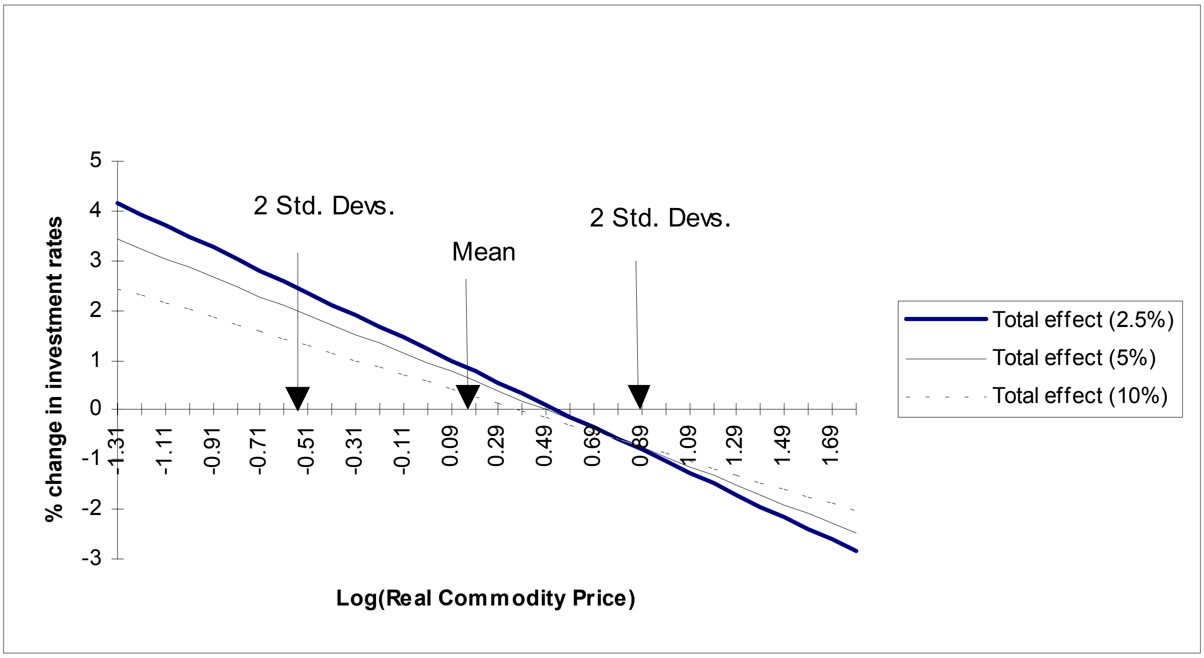

Table 1: Uncertainty and variability measures

No.	*Nature of variable*	*Description*	*Predictable element*	*Permanent effects dummied out*
I	Time varying uncertainty	GARCH conditional variance of one step ahead forecast error	LDV, T, T^2, QD	
II	Time varying uncertainty	Garch conditional variance of one step ahead forecast error dummying out first oil shock	LDV, T, T^2, QD	1973Q3-1974Q2
III	Time varying uncertainty	Garch conditional variance of one step ahead forecast error dymmying out all shocks	LDV, T, T^2, QD	2.5% positive and negative shocks
IV	Time varying uncertainty	Garch conditional standard deviation of one step ahead forecast error	LDV, T, T^2, QD	
V	Time varying uncertainty	Garch conditional standard deviation of one step ahead forecast error dymmying out first oil shock	LDV, T, T^2, QD	1973Q3-1974Q2
VI	Time varying uncertainty	Garch conditional standard deviation of one step ahead forecast error dummying out all shocks	LDV, T, T^2, QD	2.5% positive and negative shocks
VII	Time invariant uncertainty	Ramey & Ramey unconditional standard deviation	LDV, T, T^2, QD	
VIII	Time invariant uncertainty	Ramey & Ramey unconditional standard deviation	LDV, T, QD	Trend break and intercept break in 1973Q3
IX	Time invariant variability	Simple unconditional standard deviation		

(Note: 'LDV' , 'T', 'T^2', and 'QD' denote lagged dependent variable, linear time trend, trend squared, and quarterly dummies)

Table 2: Distribution of shocks across sample

	Obs	*Countries*	*Positive Shocks*	*Negative Shocks*	*Positive shocks per country (average)*	*Negative shocks per country (average)*
Full sample	819	44	54	36	1.23	0.82
Sub-Saharan Africa	333	17	25	11	1.47	0.65
Middle East and North Africa	48	3	3	3	1.00	1.00
Latin America	213	13	10	17	0.77	1.31
South Asia	86	4	5	2	1.25	0.50
East Asia	97	5	7	2	1.40	0.40
Pacific	na					
Caribbean	21	1	2	1	2.00	1.00
South Africa	21	1	2	0	2.00	0.00
Agricultural foodstuff producers	337	19	20	15	1.05	0.79
Agricultural non-food producers	82	5	6	4	1.20	0.80
Non-agricultural non-oil producers	119	6	5	4	0.83	0.67
Oil producers	237	12	20	11	1.67	0.92
Mixed producers	44	2	3	2	1.50	1.00

Table 3: Sample descriptive statistics

	Full sample	Sub-Saharan Africa	Middle East and North Africa	Others
obs	*819*	*333*	*48*	*438*
n	*44*	*17*	*3*	*24*
Private investment to GDP	**9.97**	**7.94**	**12.06**	**11.60**
	(1.95)	*(2.42)*	*(1.43)*	*(1.50)*
Public investment to GDP	**7.77**	**8.31**	**14.10**	**6.91**
	(1.81)	*(1.93)*	*(1.48)*	*(1.66)*
Growth	**0.03**	**0.03**	**0.04**	**0.03**
	(0.06)	*(0.08)*	*(0.05)*	*(0.05)*
Domestic interest rates	**2.36**	**2.16**	**2.02**	**2.56**
	(1.28)	*(1.19)*	*(1.22)*	*(1.30)*
Real price of capital goods	**0.01**	**0.01**	**0.01**	**0.01**
	(1.35)	*(1.40)*	*(1.20)*	*(1.33)*
Share of private sector credit	**0.22**	**0.16**	**0.20**	**0.29**
	(2.06)	*(1.96)*	*(2.19)*	*(1.88)*
I	**0.01**	**0.01**	**0.02**	**0.01**
	(0.02)	*(0.01)*	*(0.02)*	*(0.02)*
II	**0.01**	**0.01**	**0.01**	**0.01**
	(0.02)	*(0.02)*	*(0.01)*	*(0.01)*
III	**0.01**	**0.01**	**0.01**	**0.00**
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*
IV	**0.09**	**0.09**	**0.12**	**0.08**
	(0.04)	*(0.04)*	*(0.04)*	*(0.05)*
V	**0.08**	**0.08**	**0.09**	**0.08**
	(0.05)	*(0.05)*	*(0.03)*	*(0.04)*
VI	**0.06**	**0.07**	**0.06**	**0.06**
	(0.03)	*(0.03)*	*(0.04)*	*(0.03)*
VII	**0.08**	**0.08**	**0.10**	**0.07**
	(0.03)	*(0.03)*	*(0.02)*	*(0.02)*
VIII	**0.08**	**0.08**	**0.09**	**0.07**
	(0.03)	*(0.03)*	*(0.02)*	*(0.02)*
IX	**0.31**	**0.31**	**0.38**	**0.30**
	(0.13)	*(0.13)*	*(0.11)*	*(0.12)*
Log of real commodity prices (lagged one period)	**0.17**	**0.22**	**0.12**	**0.14**
	(0.37)	*(0.42)*	*(0.30)*	*(0.34)*

(Note: Means in bold and standard deviations in italics. *Key:I-Average conditional variance; II-Average conditional variance controlling for 1973/74 shock; III-Average conditional variance controlling for all shocks; IV-Average conditional standard deviation; V-Average conditional standard deviation controlling for 1973/74 shock; VI-Average standard deviation controlling for all shocks; VII-Ramey and Ramey unconditional standard deviation; VIII-Ramey and Ramey measure with breaks; IX-simple unconditional standard deviation)*

Table 4:

Private investment regression results: Canonical model

Dependent variable: Log of private investment to GDP
(White heteroskedasticity consistent standard errors in *(italics)*)
All regressions include time dummies

No.	***1***		***2***		***3***	
Model	***Pooled OLS Estimator***		***FE(WG) Estimator***		***SYSTEMS GMM 1-step estimator***	
Constant	0.02		-0.81	***	-0.44	
	(0.19)		*(0.28)*		*(0.56)*	
Log private investment to GDP_1 (lnpvy)	0.87	***	0.63	***	0.63	***
	(0.02)		*(0.03)*		*(0.07)*	
Log Public investment to GDP (lnpby)	-0.02		0.01		0.00	
	(0.02)		*(0.03)*		*(0.07)*	
Growth (y)	0.45	**	0.42	***	0.25	
	(0.20)		*(0.15)*		*(0.38)*	
Growth_1 (y_1)	0.33	*	0.39	***	0.12	
	(0.19)		*(0.15)*		*(0.24)*	
Log of real domestic interest rates (lndomr)	-0.08		-0.04		-0.14	
	(0.05)		*(0.10)*		*(0.16)*	
Log of real price of capital goods (lnrpc)	-0.09	**	-0.36	***	-0.34	***
	(0.04)		*(0.06)*		*(0.11)*	
Log of real private credit to the private sector (lncred)	0.04	**	0.01		0.05	
	(0.02)		*(0.03)*		*(0.03)*	
Capital account restrictions (kar)	0.00		-0.02		-0.17	**
	(0.02)		*(0.05)*		*(0.08)*	
No. countries	44		44		44	
No. observations	819		819		819	
F(regression)	132.86	***	31.07	***		
Pooling F(GMM: Wald) test across time periods	0.14				28.99	
Pooling F test across countries	3.46	***				
Parameter constancy Chow F test						
Parameter constancy Chow MSE test						
R squared	0.85		0.82			
Hausman (H0: Dif. in coef. random)			142.64	***		
Breusch-Pagan (H0: Var(u)=0)			0.18			
S.C. 1 test (H0: No 1st order serial correlation)					-3.25	***
S.C. 2 test (H0: No 2nd order serial correlation)					0.32	
Sargan test pvalue (H0: Optimal instruments)					-1.00	***
Wald test (all regressors)					232.50	***
Instrumented variables:	lnpvy_1		lnpby		y	
	y_1		lndomr		lnrpc	
	lncred					
Instruments used:	lnpvy_2		y_2		y_3	
	lndomr_1		lndomr_2		lndomr_3	
	lnrpc_1		lnrpc_2		lnrpc_3	
	lncred_1		lncred_2		lncred_3	
	(Dlnpvy_1)_1		(Dy)_1		(Dy_1)_1	
	(Dlndomr)_1		(Dlnrpc)_1		(Dlncred)_1	
	(Dlnpby)_2					

Table 5:

Private investment regression results: Preferred specification

Dependent variable: Log of private investment to GDP
(White heteroskedasticity consistent standard errors in *(italics)*)
All regressions include time dummies

No.	*1*		*2*		*3*	
Model	*Pooled OLS Estimator*		*FE(WG) Estimator*		*SYSTEMS GMM 1-step estimator*	
Constant	0.03		-0.77	***	-0.35	
	(0.19)		*(0.28)*		*(0.57)*	
Log private investment to GDP_1 (lnpvy)	0.87	***	0.63	***	0.65	***
	(0.02)		*(0.03)*		*(0.07)*	
Log Public investment to GDP (lnpby)	-0.02		0.00		0.01	
	(0.02)		*(0.02)*		*(0.08)*	
Growth (y)	0.42	**	0.39	**	0.31	
	(0.19)		*(0.15)*		*(0.41)*	
Growth_1 (y_1)	0.30		0.37	**	0.05	
	(0.18)		*(0.15)*		*(0.24)*	
Log of real domestic interest rates (lndomr)	-0.09	*	-0.05		-0.09	
	(0.05)		*(0.10)*		*(0.15)*	
Log of real price of capital goods (lnrpc)	-0.09	**	-0.35	***	-0.31	***
	(0.04)		*(0.06)*		*(0.10)*	
Log of real private credit to the private sector (lncred)	0.03	**	0.01		0.04	
	(0.02)		*(0.02)*		*(0.04)*	
Capital account restrictions (kar)	0.00		-0.01		-0.18	**
	(0.02)		*(0.05)*		*(0.08)*	
Log of Commodity prices, lagged 1 period	-0.01		0.01		-0.02	
	(0.03)		*(0.04)*		*(0.06)*	
Positive shocks, lagged 1 period	0.31	**	0.27	***	0.42	**
	(0.15)		*(0.06)*		*(0.20)*	
Positive shock and price interacted, lagged 1 period	-0.56		-0.52	***	-0.79	*
	(0.39)		*(0.10)*		*(0.42)*	
No. countries	44		44		44	
No. observations	819		819		819	
F(regression)	116.84		29.83	***		
Pooling F(GMM: Wald) test across time periods	0.14				24.24	
Pooling F test across countries	3.29	***				
Parameter constancy Chow F test			2.03			
Parameter constancy Chow MSE test			2.03	**		
R squared	0.86		0.82			
Hausman (H0: Dif. in coef. random)			138.60	***		
Breusch-Pagan (H0: Var(u)=0)			0.53			
S.C. 1 test (H0: No 1st order serial correlation)					-3.73	***
S.C. 2 test (H0: No 2nd order serial correlation)					0.13	
Sargan test pvalue (H0: Optimal instruments)					-1.00	***
Wald test (all regressors)					402.05	***

Instrumented variables:	lnpvy_1	lnpby	y
	y_1	lndomr	lnrpc
	lncred		
Instruments used:	lnpvy_2	lnpvy_3	y_2
	y_3	lndomr_1	lndomr_2
	lndomr_3	lnrpc_1	lnrpc_2
	lnrpc_3	lncred_1	lncred_2
	lncred_3	(Dlnpvy_1)_1	(Dy)_1
	(Dy_1)_1	(Dlndomr)_2	(Dlnrpc)_1
	(Dlncred)_1	(Dlnpby)_2	pos_1
	comprice_1		

(Note: MSE pooling test based on regression including neg_1 negldm_1 and gar)

Table 6:

Private investment regression results: Uncertainty

Dependent variable: Log of private investment to GDP
(White heteroskedasticity consistent standard errors in *(italics)*)
All regressions include time dummies
Estimator: SYS-GMM

No.	*1*	*2*	*3*	*4*
Model	*Canonical with uncertainty*	*Preferred model with uncertainty*	*Sample excl. non-agro non-oil producers*	*Sample excl. non-agro non-oil and oil producers*
Constant	-0.37	-0.33	-0.73	-0.64
	(0.55)	*(0.56)*	*(0.77)*	*(0.99)*
Log private investment to GDP_1 (lnpvy)	0.65 ***	0.65 ***	0.69 ***	0.64 ***
	(0.07)	*(0.07)*	*(0.08)*	*(0.11)*
Log Public investment to GDP (lnpby)	0.03	0.01	0.02	-0.05
	(0.07)	*(0.08)*	*(0.08)*	*(0.11)*
Growth (y)	0.32	0.28	0.19	0.28
	(0.43)	*(0.41)*	*(0.42)*	*(0.52)*
Growth_1 (y_1)	0.08	0.05	0.10	0.03
	(0.24)	*(0.24)*	*(0.28)*	*(0.39)*
Log of real domestic interest rates (lndomr)	-0.13	-0.12	0.10	0.10
	(0.14)	*(0.14)*	*(0.17)*	*(0.25)*
Log of real price of capital goods (lnrpc)	-0.31 ***	-0.31 ***	-0.34 **	-0.34 **
	(0.10)	*(0.11)*	*(0.14)*	*(0.18)*
Log of real private credit to the private sector (lncred)	0.05	0.05	0.04	0.08
	(0.04)	*(0.04)*	*(0.07)*	*(0.08)*
Capital account restrictions (kar)	-0.17 **	-0.18 **	-0.09	-0.03
	(0.08)	*(0.08)*	*(0.09)*	*(0.13)*
Uncertainty (gar70)	-0.12	0.27	-0.88	-0.64
	(0.81)	*(0.91)*	*(0.61)*	*(3.00)*
Log of Commodity Prices, lagged 1 period		-0.02	0.02	0.04
		(0.06)	*(0.05)*	*(0.08)*
Positive shocks, lagged 1 period		0.41 **	0.49 **	0.44 **
		(0.20)	*(0.20)*	*(0.23)*
Positive shocks and price interacted, lagged 1 period		-0.77 *	-0.94 **	-0.86 **
		(0.43)	*(0.40)*	*(0.45)*
No. countries	44	44	38	26
No. observations	819	819	700	463
S.C. 1 test (H0: No 1st order serial correlation)	-3.31 **	-3.75 ***	-3.22 ***	-2.94 ***
S.C. 2 test (H0: No 2nd order serial correlation)	0.26	0.16	-0.38	-0.01
Sargan test pvalue (H0: Optimal instruments)	0.00 ***	0.00 ***	0.00 ***	0.00 ***
Wald test for time effects	28.28	22.23	45.53 ***	255.17 ***
Wald test (all regressors)	251.34 ***	392.34 ***	474.90 ***	140.38 ***

Table 7:

Private investment regression results: Competing shock specifications

Dependent variable: Log of private investment to GDP
(White heteroskedasticity consistent standard errors in *(italics)*)
All regressions include time dummies
Estimator: SYS-GMM

No.	***1***	***2***	***3***	***4***
Model	***Canonical with changes in commodity prices***	***Canonical with quadratic changes, conditional upon levels***	***Canonical plus quadratic terms in levels***	***Encompassing regression***
Constant	-0.41	-0.33	-0.29	-0.31
	(0.56)	*(0.55)*	*(0.55)*	*(0.55)*
Log private investment to GDP_1 (lnpvy)	0.65 ***	0.66 ***	0.64 ***	0.65 ***
	(0.07)	*(0.08)*	*(0.09)*	*(0.08)*
Log Public investment to GDP (lnpby)	0.03	0.02	0.04	0.00
	(0.07)	*(0.07)*	*(0.07)*	*(0.08)*
Growth (y)	0.38	0.32	0.35	0.47
	(0.45)	*(0.42)*	*(0.43)*	*(0.42)*
Growth_1 (y_1)	0.08	0.07	0.09	0.08
	(0.24)	*(0.25)*	*(0.23)*	*(0.24)*
Log of real domestic interest rates (lndomr)	-0.10	-0.12	-0.12	-0.08
	(0.15)	*(0.14)*	*(0.15)*	*(0.14)*
Log of real price of capital goods (lnrpc)	-0.31 ***	-0.31 ***	-0.31 ***	-0.30 ***
	(0.10)	*(0.10)*	*(0.10)*	*(0.11)*
Log of real private credit to the private sector (lncred)	0.05	0.05	0.04	0.05
	(0.04)	*(0.04)*	*(0.04)*	*(0.04)*
Capital account restrictions (kar)	-0.18 **	-0.19 **	-0.17 **	-0.20 ***
	(0.08)	*(0.08)*	*(0.08)*	*(0.08)*
ldm_1		-0.09	-0.03	0.02
		(0.10)	*(0.06)*	*(0.06)*
Dldm_1	-0.06	0.12		-0.03
	(0.08)	*(0.10)*		*(0.08)*
ldm*Dldm2_1		-0.14		0.97 ***
		(0.27)		*(0.30)*
ldm^2_1			-0.19	
			(0.19)	
pos_1				0.51 **
				(0.23)
posldm_1				-1.37 **
				(0.57)
No. countries	44	44	44	44
No. observations	819	819	819	819
Encompassing F test (Positive shocks measure)				8.37 ***
Encompassing F test (Changes based measure)				0.93
S.C. 1 test (H0: No 1st order serial correlation)	-3.30 ***	-3.62 ***	-3.73 ***	-3.71 ***
S.C. 2 test (H0: No 2nd order serial correlation)	0.22	0.21	0.25	0.37
Sargan test pvalue (H0: Optimal instruments)	0.00 ***	0.00 ***	0.00 ***	0.00 ***
Wald test for time effects	28.00	22.69	28.18 ***	27.05 ***
Wald test (all regressors)	333.08 ***	472.09 ***	379.79 ***	579.40 ***

Table 8:

Private investment regression results: Sample robustness

Dependent variable: Log of private investment to GDP
(White heteroskedasticity consistent standard errors in *(italics)*)
All regressions include time dummies
Estimator: SYS-GMM

No.	*1*	*2*	*3*	*4*	*5*
Model	*Middle Income countries only*	*Non-Middle Income countries*	*Non-oil countries*	*Non-SSA countries*	*SSA*
Constant	0.48	-0.29	0.14	0.56	-1.71
	(0.30)	*(0.83)*	*(0.66)*	*(0.30)*	*(0.94)*
Log private investment to GDP_1 (lnpvy)	0.64 ***	0.65 ***	0.58 ***	0.65 ***	0.66 ***
	(0.03)	*(0.10)*	*(0.10)*	*(0.03)*	*(0.10)*
Log Public investment to GDP (lnpby)	-0.01	-0.07	-0.09	0.01	-0.01
	(0.05)	*(0.09)*	*(0.11)*	*(0.04)*	*(0.11)*
Growth (y)	0.58 **	0.12	0.34	0.24	0.08
	(0.27)	*(0.46)*	*(0.43)*	*(0.33)*	*(0.42)*
Growth_1 (y_1)	0.42	-0.19	0.09	0.74 ***	-0.28
	(0.27)	*(0.33)*	*(0.30)*	*(0.21)*	*(0.36)*
Log of real domestic interest rates (lndomr)	-0.19 **	0.05	-0.19	-0.23 ***	0.74 *
	(0.09)	*(0.40)*	*(0.20)*	*(0.08)*	*(0.42)*
Log of real price of capital goods (lnrpc)	-0.14 ***	-0.36 **	-0.30 ***	-0.11 ***	-0.51 ***
	(0.05)	*(0.15)*	*(0.12)*	*(0.04)*	*(0.14)*
Log of real private credit to the private sector (lncred)	0.01	0.13 *	0.10 **	0.02	0.14
	(0.05)	*(0.07)*	*(0.04)*	*(0.04)*	*(0.09)*
Capital account restrictions (kar)	0.00	-0.24 ***	-0.20 **	-0.06	
	(0.05)	*(0.09)*	*(0.09)*	*(0.05)*	
Log of Commodity Prices, lagged 1 period	0.10	0.00	0.03	0.06 *	0.02
	(0.07)	*(0.07)*	*(0.08)*	*(0.04)*	*(0.09)*
Positive shocks, lagged 1 period	0.09	0.50 **	0.44 **	0.15	0.50 **
	(0.10)	*(0.21)*	*(0.19)*	*(0.12)*	*(0.25)*
Positive shocks and price interacted, lagged 1 period	-0.29	-0.90 **	-0.86 **	-0.31	-0.77 *
	(0.30)	*(0.42)*	*(0.35)*	*(0.31)*	*(0.45)*
No. countries	14	30	32	27	17
No. observations	259	560	582	486	333
S.C. 1 test (H0: No 1st order serial correlation)	-2.36 **	-3.27 ***	-3.29 ***	-3.42 ***	-3.02 ***
S.C. 2 test (H0: No 2nd order serial correlation)	-0.24	0.12	0.49	0.17	-0.12
Sargan test pvalue (H0: Optimal instruments)	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
Wald test for time effects	20.35	76.66 ***	50.03 ***	178.01 ***	45.06 ***
Wald test (all regressors)	3658.99 ***	357.98 ***	208.58 ***	720.39 ***	447.11 ***