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Macroeconomic uncertainty and private investment in developing countries - an empirical investigation — Source link

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Published on: 30 Nov 1999 - Social Science Research Network (The World Bank)

Topics: Return on investment, Investment strategy, Real interest rate, Exchange rate and Financial market

POLICY RESEARCH WORKING PAPER 2035

Macroeconomic Uncertainty and Private Investment in Developing Countries

An Empirical Investigation

Luis Servén

Economic uncertainty can affect investment through different channels, some of which operate in mutually opposing directions, so the sign of its overall effect is ambiguous and can be assessed only empirically. This paper presents a thorough empirical assessment of the investment-uncertainty link in developing countries.

The World Bank
Development Research Group
Macroeconomics and Growth
December 1998

Summary findings

The impact of uncertainty on investment has attracted considerable attention in the analytical and empirical macroeconomic literature. In theory, however, uncertainty can affect investment through different channels, some of which operate in mutually opposing directions. So the sign of its overall effect is ambiguous and can be assessed only empirically.

To thoroughly assess the impact of macroeconomic uncertainty on private investment, Servén uses a large panel data set on developing countries. He draws a distinction between sample variability and uncertainty, constructs alternative measures of the volatility of innovations to five key macroeconomic variables (inflation, growth, the terms of trade, the real exchange rate, and the price of capital goods), and examines their association with aggregate private investment.

He then adds these constructed measures to an empirical investment equation that is estimated using alternative panel data econometric methods, allowing for simultaneity, country-specific effects, and parameter heterogeneity across countries.

The results underscore the robustness of the link between investment and uncertainty. Virtually all of the volatility measures in the paper show a strong negative association with investment ratios. In addition, the regression estimates indicate that uncertainty has an adverse direct impact on investment, over and above any indirect effects that might also be at work. This finding is particularly robust in the case of real exchange rate volatility, which invariably has a robust negative effect on investment, regardless of econometric specification.

This paper — a product of Macroeconomics and Growth, Development Research Group — is part of a larger effort in the group to understand the determinants of private investment decisions. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Hazel Vargas, room I8-138, telephone 202-473-8546, fax 202-522-2119, Internet address hvargas@worldbank.org. The author may be contacted at lserven@worldbank.org. December 1998. (33 pages)

Macroeconomic Uncertainty and Private Investment in LDCs: An Empirical Investigation

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* A preliminary version of this paper was presented at the LACEA meetings in Bogotá, October 1997. I am grateful to conference participants for useful comments; to Michael Gavin, Norman Loayza and Fabio Schiantarelli for helpful discussions; and to Charles Chang for excellent research assistance.

1. Introduction

The impact of uncertainty and instability on investment, a topic of obvious concern for policy-makers, has attracted considerable interest in the analytical and empirical literature. From the analytical perspective, theoretical work has pointed out a number of different channels through which uncertainty can impact on investment, under various assumptions about risk aversion, adjustment costs to investment and other factors (see Caballero, 1991 and Abel and Eberly, 1994). Some of these effects operate in mutually opposing directions, however, and hence the sign of the investment-uncertainty relationship is indeterminate on *a priori* grounds.

Relative to the analytical literature, empirical studies on uncertainty and investment are less abundant, and mostly confined to a few single-country studies focusing on the U.S. and U.K., plus a handful of cross-country papers. On the whole, they are not conclusive in their assessment of the impact of uncertainty on investment, although the majority does find a negative association between both variables. In most cases, however, these studies use naive measures of sample variability rather than uncertainty, often ignore important investment determinants, and/or fail to account for the likely simultaneity between investment and its determinants—including uncertainty itself. As a result, in many cases it is not entirely clear whether any empirical association between uncertainty an investment reported by these studies operates directly or through third-variables relevant for investment (such as output growth or the cost of capital), and whether such association can be given a causal interpretation.

This paper provides a thorough empirical re-examination of the link between macroeconomic uncertainty and aggregate private investment using a large set of cross-country time-series macroeconomic data for developing countries. The paper makes an attempt at separating simple variability from uncertainty, by constructing alternative measures of the dispersion of the innovations to a number of relevant macroeconomic variables; lays out the stylized facts concerning their empirical association with investment; and assesses their impact on private investment performance using an econometric framework encompassing other conventional determinants of investment, and applying a range of estimation techniques that control for issues such as simultaneity, country-specific effects and parameter heterogeneity.

The paper is organized as follows. Section 2 presents a brief overview of the analytical and empirical literature on the link between uncertainty and investment. Section 3 assesses the stylized facts, looking at the co-variation between aggregate private investment and measures of macroeconomic uncertainty in developing countries using the panel data set mentioned above. Section 4 goes one step beyond and examines the investment-uncertainty relationship controlling for other standard determinants of private investment, through estimation of an empirical private investment equation using various econometric techniques. Finally, section 5 concludes.

2. Investment, Uncertainty and Instability: A Brief Overview

Economic theory has paid considerable attention to the relationship between uncertainty and investment. Taken as whole, however, the theoretical predictions are ambiguous. Depending on their underlying assumptions, some approaches predict a positive relationship, while others predict a negative one.

Much of the theoretical work on uncertainty and investment has been developed in the framework of risk-neutrality. The impact of uncertainty in standard models of risk-neutral investors-firms depends basically on the relationship between the expected marginal revenue product of capital and the uncertain variable(s)—typically the output price or the real wage. Consider, for example, the familiar scenario of the constant-returns, perfectly competitive firm in which capital is the only fixed factor, while other productive inputs (e.g., labor) can be costlessly adjusted in the face of changing output prices. Price shocks then cause the firm to alter the optimal capital/labor mix, thus making the marginal revenue product of capital rise more (or fall less) than relative output prices. In such conditions, marginal profitability is a convex function of output prices, and Jensen's inequality then implies that higher price uncertainty raises the expected profitability of capital, thereby increasing the desired capital stock and hence investment (Hartman, 1972; Abel, 1983).

A recent, but rapidly growing, literature has shifted the analytical focus to the adjustment costs implied by the acquisition and installation of capital, emphasizing the irreversible nature of most fixed investment projects (see Dixit and Pindyck, 1994 for a thorough discussion). This in effect makes investment adjustment costs asymmetric—larger for downward than for upward adjustment. Under appropriate conditions, this creates a range of inaction: investment takes place only when expected profitability exceeds a certain threshold.

From the preceding discussion, however, it should be clear that irreversibility *per se* is not sufficient to turn around the positive impact of uncertainty on investment following from the convexity of the profit function. Indeed, even under asymmetric adjustment costs it can be shown that optimal investment by a competitive firm continues to be a non-decreasing function of uncertainty (Caballero, 1991; Abel and Eberly, 1994). To reverse this result, it is necessary to bring in additional assumptions such as imperfect competition or decreasing returns to scale (or both). When combined with irreversibility, they can create a negative uncertainty-investment link by making the marginal revenue product of capital a decreasing function of the capital stock (Caballero, 1991). Under such conditions, the profitability threshold mentioned above rises with the extent of uncertainty, and if this effect is powerful enough it may outweigh the rise in expected profitability stemming from the convexity of the profit function, leading to reduced investment. The intuitive reason is that in this case the asymmetric nature of adjustment costs makes downside uncertainty more important than upside uncertainty: since disinvestment is costlier than investment, favorable shocks have a smaller effect on profitability than adverse shocks, and investors/firms become *ex ante* reluctant to invest to reduce the risk of being stuck *ex post* with unprofitable irreversible projects.

The assumption that the marginal profitability of capital declines with the capital stock obviously cannot apply to a constant-returns perfectly competitive firm, for which the marginal profitability of capital is, by construction, unrelated to the level of capital. However, such assumption does hold for imperfectly competitive firms and, perhaps more importantly, also for a free-entry perfectly competitive industry taken as a whole. At this industry-wide level, the distinction between aggregate and firm-specific uncertainty becomes important: the latter continues to have the positive (or non-negative) effects on firm investment described above, but aggregate shocks have an asymmetric effect, because the industry-wide impact on profitability of favorable aggregate shocks is limited by the entry of new firms, while irreversibility prevents exit when unfavorable shocks occur. As individual perfectly competitive firms are aware of this fact, higher aggregate uncertainty unambiguously raises their profitability threshold and tends to reduce firm as well as industry-wide investment (Caballero and Pindyck, 1996).

Even in this case, however, the theoretical predictions of the irreversibility approach concern the *ex-ante* investment decision, and hence refer mostly to the short-term. In the longer term, a "hangover effect" (Abel and Eberly, 1995a,b) comes into play: higher degrees of irreversibility and/or uncertainty make it more likely that firms will *ex-post* find themselves stuck with excessive capital, in effect making the long-run capital stock and investment higher than they would have been otherwise.

It may be worth noting also that factors analogous to irreversibility can in fact contribute to a *positive* investment-uncertainty link, at least in theory. For example, if firms have the option of abandoning unprofitable projects, investment adjustment costs also become asymmetric, but in the opposite direction to that implied by irreversibility: with the possibility of abandonment, *upside* uncertainty is the one that matters, since the impact of adverse shocks can be mitigated by shutting down those projects revealed *ex-post* as unprofitable, and hence higher uncertainty actually hastens investment—provided the cost of abandoning projects is not too high (Bar-Ilan and Strange, 1996).

So far the discussion has been limited to the risk-neutral case. An alternative approach takes as starting point the case of risk-averse agents facing limited diversification possibilities in the context of imperfect capital markets. Along these lines, Zeira (1990) presents a model of optimal capital accumulation by perfectly competitive risk-averse investors/firms facing uncertain relative prices. In this framework, uncertainty has an ambiguous impact on investment: on the one hand, it tends to raise investment through the convexity of the profit function mentioned earlier; on the other hand, higher uncertainty discourages investment due to investors' risk aversion. The net effect depends on the concavity of the utility function (describing the extent of investors' risk aversion), the convexity of the profit function, and the distribution of risk.

Both the risk-neutral and risk-averse cases above fit into the standard neoclassical expected utility model. A third approach is that of 'disappointment aversion,' which has been recently advocated by Aizenman and Marion (1995) and departs from the expected utility paradigm by assuming that agents' preferences attach more weight to adverse outcomes than to favorable ones – a notion first developed by Gul (1991) that has had some success in explaining individuals' behavior in certain controlled experiments. Aizenman and Marion show that, under appropriate assumptions concerning the degree of disappointment aversion, this approach can yield a considerably stronger negative impact of uncertainty on investment than that suggested by the conventional expected-utility framework.

In turn, the empirical literature on the relationship between uncertainty and investment is still considerably more scarce than its theoretical counterpart. Most empirical studies, particularly those using macroeconomic data, adopt a non-structural approach, in which various uncertainty proxies are appended to otherwise conventional reduced-form investment equations.[1]

Along these lines, a few studies have examined the impact of uncertainty on U.S. and U.K. investment. Federer (1993) finds a negative effect on U.S. equipment investment, while Driver and Moreton (1991) and Price (1995, 1996) find a likewise negative effect on U.K. manufacturing investment. In turn, Goldberg (1993) explores the impact of real exchange rate uncertainty on U.S. industry-level investment. She finds basically no effects at the aggregate level, while at the subsector level her results vary in sign and significance.

Cross-country empirical studies using aggregate data are somewhat more abundant. Hausmann and Gavin (1995) report a negative association between an index of macroeconomic volatility—which combines real GDP and real exchange rate volatility—and the aggregate investment/GDP ratio, using a large sample of developing countries. By contrast, Bleaney (1996) finds that measures of volatility (including for example the variability of the real exchange rate) affect adversely growth performance in developing countries, but not aggregate investment. A similar result is obtained by Ramey and Ramey (1995), who also use aggregate investment data.

In turn, Aizenman and Marion (1995, 1996) report a negative cross-country correlation between various indicators of economic instability (such as the volatility of the terms of trade, inflation and the real exchange rate) and private investment. They further show that these

[1] Several studies using firm-level data adopt a similar perspective. For example, a recent paper by Bell and Campa (1997) examines the impact of volatility on investment in a data set comprising US and European firms in the chemical sector, with volatility measured by the standard deviations of the rates of change of the real exchange rate, the relative price of oil and overall market capacity. Somewhat surprisingly, the results indicate that the first of these factors has a negative impact on investment, while the other two have a positive effect. In turn, Ghosal and Loungani (1996) estimate the impact of output price uncertainty on investment using panel data for US manufacturing firms. They find a negative effect in those industries characterized by a higher degree of product market competition. Finally, Guiso and Parigi (1998) examine the effects of future demand volatility on a cross-section of Italian firms, and they find a consistent negative impact of demand uncertainty on firm investment.

volatility measures contribute significantly to explain the performance of private investment across countries in a reduced-form regression framework. Total (i.e., private plus public) investment, however, is unrelated to instability indicators in their sample.

A more structural approach is followed by Bertola and Caballero (1994), who implement empirically a model that follows explicitly from the aggregation of individual firms' irreversible investment rules; Caballero (1993) applies a similar approach to developing country data. These two studies illustrate the asymmetric response of aggregate investment to positive and negative shocks, and its strong dependence on initial conditions: after a deep recession, for example, many firms are likely to be well below their investment thresholds, and therefore the responsiveness of aggregate investment to positive incentive changes can be very limited.

Most of the cross-country empirical studies are confined to the cross-section dimension, ignoring the time-series variation in the data. There are a few exceptions, however. Servén and Solimano (1993) estimate a private investment equation using panel data on a group of developing countries including as regressors the standard deviations of inflation and the real exchange rate; they find some evidence that these measures of variability affect investment negatively. In turn, Pindyck and Solimano (1993) test for the effects of uncertainty on aggregate investment following the irreversibility approach. Using panel data for industrial and developing countries, they construct proxies for the profitability threshold, and examine its relation with the volatility of profitability itself. They also estimate reduced-form investment regressions including volatility indicators such as the standard deviations of inflation and the real exchange rate; the latter is found to have negative impact on investment.[2] More recently, Darby, *et al.* (1998) estimate simple investment specifications, extended to include a measure of real exchange rate variability, separately for five OECD economies, and they find a consistently negative effect, either in the short or the long run or both.

It is worth noting two general problems affecting many of these reduced-form empirical studies. The first, most basic difficulty concerns the very measurement of uncertainty, which in

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[2] By contrast, the standard deviation of the inflation rate has no significant effect. Instead, Pindyck and Solimano find that the inflation rate itself is negatively associated with investment. However, their ensuing interpretation of the inflation level as a measure of uncertainty is disputed by Eberly (1993).

most studies is proxied by sample variability.[3] Yet it is quite obvious that variability does not amount to uncertainty, except when events are unpredictable, and therefore more accurate measures of uncertainty would be provided by the dispersion of the *innovations* to the variables of interest.

The second problem has to do with the interpretation of the empirical link between uncertainty and investment reported by several studies. In many cases they ignore other important investment determinants such as real interest rates and/or capital goods prices, which leaves unanswered the question whether uncertainty has an independent effect on investment—i.e., if it matters for investment decisions once other standard determinants of capital accumulation are accounted for. Further, because in a macroeconomic equilibrium the variables summarizing volatility (typically second moments of inflation and/or relative prices) are determined simultaneously with investment, it is often unclear whether the empirical results of these studies identify causation or simply co-movement of the two sets of variables.[4] A particular aspect of this problem concerns the use of cross-section data on countries that may be very diverse, raising the possibility that the empirical findings could be distorted by heterogeneity biases—i.e., unmeasured country-specific factors affecting both economic volatility and private investment.[5] I attempt to tackle these problems below.

3. The Empirical Facts

To explore the empirical relation between investment and economic uncertainty, I make use of a large cross-country time-series data set, comprising 94 developing countries and spanning the years 1970 to 1995, for a combined total of over 2,200 annual observations. The

[3] There are some exceptions, however. For example, Federer (1993) proxies uncertainty by the risk premium implicit in the term structure of U.S. interest rates, while Driver and Moreton (1991) use the dispersion of growth and inflation forecasts from a survey of UK forecasting firms. In this regard, the two papers closest in approach to the present one are Goldberg (1993), who uses the variability of ARMA-based exchange rate forecasts for the U.S., and Price (1995, 1996), who employs a GARCH-based approach to assess growth uncertainty.

[4] The main exception is Goldberg (1993), who uses an instrumental-variable estimation procedure.

[5] For example, economies specialized in labor-intensive agricultural products tend to have lower investment ratios than manufacturing-based economies, and the relative price structure of the former could be also more volatile that that of the latter due to their greater exposure to factors like climatic phenomena. This would tend to create the illusion of a negative cross-country relationship between investment and volatility, even if they were in fact completely unrelated in a causal sense.

cornerstone of the data is the information on private fixed investment drawn from the World Bank databases, which is constructed by subtracting from total fixed investment the part attributable to the public sector. Whenever the data allow, the latter is defined as inclusive of local governments and public enterprise investment, drawing from Jaspersen, Aylward and Sumlinski (1995); investment by these entities is therefore excluded from private investment. However, this is not always feasible with the existing information, and hence some unavoidable degree of heterogeneity across countries in the definition of private and public investment is likely to remain in the data. Finally, the panel is unbalanced, with some countries lacking observations for several sample years.

Table 1 presents some basic statistics on constant-price private investment as a ratio to real GDP, for the full sample as well as its separate time-series and cross-section dimensions. The table reveals considerable variation in private investment ratios, although the variation is substantially larger across countries than over time, in a proportion of nearly two to one—a likely reflection of the persistent contrast between the high private investment levels of some East-Asian countries and the very low levels of many African countries.[6] In both dimensions of the data, the mean investment ratio exceeds its median value, due to the presence of a few large values at the upper end of the distribution; nevertheless, the difference between mean and median is rather small.

3.1 Measuring uncertainty

Using the above investment data, I first examine the association between private investment and measures of economic uncertainty. Unlike in much of the existing macroeconomic literature, the explicit aim here is to separate sample variation from uncertainty, because the former may overstate the latter by including not only truly unpredictable innovations to the variables of interest, but possibly also (cyclical) movements partly predictable from their own past.

Rather than selecting *a priori* the 'right' variable whose volatility is to be examined (as done in much of the empirical literature), I work with five key macroeconomic variables:

[6] The full-sample and cross-section minimum values of the private investment ratio shown in Table 1 correspond to Chad.

inflation, the relative price of capital goods, the growth of output (measured by real GDP), the real exchange rate and the terms of trade.[7] The first three variables are related to the aggregate profitability of capital: inflation is often taken as a summary measure of the overall macroeconomic stance, and hence the volatility of its unpredictable component can be viewed as an indicator of overall macroeconomic uncertainty (e.g., Eberly, 1993). In turn, the relative price of investment goods (measured here by the fixed investment deflator relative to the GDP deflator) is closely related to the user cost of capital, and hence the volatility of its innovation can be viewed as a good indicator of the uncertainty on aggregate investment profitability. Thirdly, the volatility of output growth is taken here to represent the unpredictability of demand, which has attracted attention in recent microeconomic work on investment under uncertainty (e.g., Guiso and Parigi, 1998).

In turn, the terms of trade and the real exchange rate are related to the relative profitability of investment in different economic sectors—exportables versus importables, in the case of the terms of trade, and home-market versus foreign-market oriented activities, in the case of the real exchange rate. *Ceteris paribus,* increased volatility of these variables makes price signals less informative about the relative profitability of investment across sectors, likely hampering investment decisions.[8]

For each of these variables, I construct seven sample-based measures of dispersion of their respective unpredictable innovations; for simplicity, I henceforth refer to these constructs as 'uncertainty measures'. The first one is perhaps the closest conceptually to the notion of uncertainty, and is given by the conditional variance of the innovation to each of the variables of interest, constructed using the generalized autoregressive conditional heteroskedasticity (GARCH) specification of Bollerslev (1986). More specifically, I estimate the following univariate GARCH(1,1) model:

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[7] Some of these variables are also included in the cross-section analysis of Aizenman and Marion (1995). However, none of the other empirical studies mentioned in the text takes into consideration the level or the variability of the relative price of capital as an investment determinant.

[8] These variables are of course mutually related. Inflation volatility is typically reflected in relative price variability, while the volatility of the real exchange rate and the terms of trade should both be reflected in the price of capital goods if investment has a significant import content (as is the case in most developing countries). As will become clear below, the variables do in fact contain a good deal of common information.

$$y_{it} = \alpha_0 + \alpha_1 t + \beta_1 y_{i,t-1} + \varepsilon_{it}\,; \qquad t = 1,\dots,T; \tag{1}$$

$$\sigma_{it}^2 = \gamma_{i0} + \gamma_{i1}\varepsilon_{it-1}^2 + \delta_i \sigma_{it-1}^2 \tag{2}$$

where σ_t^2 denotes the variance of ε_t conditional on information up to period t. For each of the five variables of interest, I estimate the two-equation model (1)-(2) *separately* for each country i (where i = 1,...,94) in the sample.[9] I take the fitted σ_{it}^2 from equation (2) as the measure of uncertainty of y_{it}.

The other six uncertainty measures are more rudimentary. All are based on the 1-step ahead forecast errors of two univariate auto-regressive models, using respectively one and two lags of the dependent variable, plus a constant and a time trend. However, to ensure that the forecasts use no more information than available at the time that they are formulated, they are computed from recursive estimation of the auto-regressions. As with the GARCH estimates, this is done separately for each country in the data set. More compactly, for each of the five variables above and each country i, I estimate recursively a modified version of (1):

$$y_{it} = \alpha^{\tau}{}_0 + \alpha_1{}^{\tau} t + \beta_1^{\tau} y_{i,t-1} + \beta_2^{\tau} y_{i,t-2} + \varepsilon_{it}\,; \qquad t = 1,\dots,\tau; \tag{1'}$$

in two variants, one imposing $\beta_2 = 0$ and the other without this restriction. The superscript τ on the coefficients indicates the changing sample size used in the recursive estimation of (1'). Estimations are performed for $\tau = T_0,\dots,T$, where T_0 denotes the initial sample set aside to start the recursive procedure. Hence for each country and variable, the above equation is estimated a total of $T\text{-}T_0$ times in each of the two specifications. It is easy to see that this involves running a very large number of regressions; however, unlike with the GARCH model, the regressions are linear and hence the process is computationally feasible.[10]

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[9] For these regressions, the relative price variables were expressed in logs, while the GDP growth and inflation rates were measured as first differences of the log of GDP and its deflator, respectively. In the case of the inflation rate, the trend term in (1) was rarely significant and was therefore dropped from the model. For the GARCH regressions, I used observations for 1965-95 on the five dependent variables.

[10] The initial sample size T_0 was set at 6, and hence the recursive estimation starts in 1970. In practice, this amounts to some 25 regressions per country for each of the five dependent variables and each of the two auto-regressive specifications—a total around 25,000 regressions. Clearly, this recursive approach would be computationally prohibitive in the nonlinear setting of the GARCH model.

Using the recursive parameter estimates from (1'), I construct the 'naïve' uncertainty measures as (i) the time-varying standard deviation, and (ii) the mean absolute value, of the one-step ahead forecast errors. Both statistics are calculated over 3 consecutive years—the current year plus the preceding two; to test the robustness of the results to this choice of time horizon, in the case of the AR(1)-based forecast errors I also use a 5-year horizon to compute the standard deviation and mean absolute deviation of the one-step forecast errors. Notice that in each case this procedure yields *annual* observations on the relevant uncertainty measure. Combining the two dynamic specifications (first- or second-order autoregression) with the selected measure of variability (standard deviation or mean absolute value), and the 3 or 5-year averaging horizon (with the latter used only for the AR(1) specification, to preserve sample sizes) of the forecast errors, I thus obtain a total of six 'naive' uncertainty measures in addition to the GARCH-based one.

3.2 Uncertainty and private investment: the empirical facts

The next step is to investigate the empirical association between these uncertainty measures and private investment performance. Table 2 summarizes the correlation between the different constructed measures and the private fixed investment/GDP ratio, both in the full sample and its separate cross-section (i.e., using country averages) and time-series dimensions. Each column in the table corresponds to one economic variable, and each row to one particular method, among those described earlier, of measuring the volatility of its unpredictable component. To limit the potential impact of outliers I use Spearman rank correlations rather than simple correlations; in fact, however, both turn out to present a very similar picture.

The most striking aspect of Table 2 is the remarkable uniformity of the correlations between investment and the various forms/measures of uncertainty. In the full sample, they are all negative and significantly different from zero. They are also of roughly similar magnitude, not only across the different uncertainty indicators associated with a given variable (i.e., along a given column in the table—which is hardly surprising since the seven volatility measures try to capture the same phenomenon),[11] but also across the different economic variables (i.e., along

[11] For each of the five economic variables (inflation, the terms of trade, the real exchange rate, the relative price of capital and the GDP growth rate), the seven uncertainty measures are very strongly positively correlated with each

each row in the table). Interestingly, the GDP growth-related measures seem to be the least closely associated with investment, while the opposite is true for the real exchange rate and terms of trade-based measures.

In turn, the cross section correlations (middle section of Table 2) are again all negative, larger in absolute value than their full-sample counterparts in every case (with the only exception of the GARCH-based indicator associated with the relative price of capital), and significantly different from zero with few exceptions. Interestingly, the cross-section correlations of private investment with the various real exchange rate-based measures are similar to that reported by Aizenman and Marion (1996), equal to -.34; however, the cross-section correlation of the investment ratio with inflation- and terms-of-trade uncertainty in Table 2 is much larger than found by these authors in their sample.[12]

Finally, the bottom section of Table 2 shows the time-series correlations, derived from the 'within' dimension of the data (i.e., deviations from country averages).[13] They remain all negative with only two exceptions, but their size is generally much smaller (under .1 in absolute value). Further, most of the indicators associated with the terms of trade, and all of those associated with GDP growth, cease to show a significant association with the private investment ratio. By contrast, the uncertainty indicators associated with the real exchange rate and the relative price of capital continue to be negatively related with investment.

The similarity in sign, and even magnitude, of the pairwise correlations between investment and the volatility of the unpredictable component of each of the five variables under consideration raises the natural question of the extent to which the latter contain common information. Table 3 provides an answer. It shows the full-sample correlation between the volatility of the different economic variables, using two of the seven volatility measures developed earlier (the others, not reported to save space, offer a similar picture). The general

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other, in both the cross-section and the time-series dimensions—although more strongly so in the former (where the correlations average around 0.8) than in the latter dimension (where they average around 0.6).

[12] Aizenman and Marion (1996) find no significant cross-section association between the volatility of these two variables and the private investment ratio.

[13] The table presents contemporaneous correlations. However, a very similar picture emerges if the uncertainty indicators are instead lagged one year.

message from Table 3 is that the volatilities of the different variables are all positively correlated with each other, and very significantly so. Interestingly, inflation volatility seems particularly strongly associated with the volatility of the remaining variables.

In view of this fact, I finally construct a summary measure of macroeconomic uncertainty by extracting the first principal component of the five GARCH-based volatility measures (obviously, the same could be done with the other 'naïve' measures). The full-sample rank correlation of the resulting summary indicator of uncertainty with the private investment ratio is -.295 (standard error of .025), while its cross-section and time-series counterparts are -.324 (.115) and -.087 (.025) respectively, all different from zero at any reasonable confidence level.[14]

In summary, while the various uncertainty measures presented in this section are admittedly crude—they follow from simple univariate processes—the above results are on the whole strongly supportive of the negative association between uncertainty and private investment, and agree with those recently reported for example by Aizenman and Marion (1996) using a cross-section of countries. As shown above, however, the negative association remains present in the time-series dimension of the data, at least for real exchange rate and price of capital volatility.

In any case, these results refer only to pairwise correlations. They do not clarify whether economic uncertainty has a direct impact on investment after controlling for standard investment determinants, or just an indirect one operating through the latter.[15] I turn to this issue in the next section.

4. Econometric Estimation

To address this issue, I next specify an empirical investment equation and estimate it using the data just described. I use a simple empirical specification relating the (log of) real private investment to a set of conventional determinants, to which I add uncertainty measures introduced in the previous section. Rather than throwing away potentially valuable information

[14] The first principal component thus constructed accounts for over 50 percent of the overall variance of the five individual indicators. The largest weights correspond to the conditional variances of innovations to the real exchange rate and the relative price of capital goods.

by averaging the annual data at an arbitrary phase length (e.g., five or ten year averages), I choose to work with the yearly information. This means that inertia, very likely present in the annual data, needs to be taken into consideration. Hence the model to be estimated is of the form:

$$I_{it} = f\left(I_{it-1}, \mathbf{x}_{it}, \sigma_{it}\right) + u_{it} \tag{3}$$

where I is the log of private fixed investment at constant prices, $\mathbf{x}$ is a set of standard private investment determinants, σ is a set of uncertainty indicators, u is a random disturbance, and the subscripts $i=1,..., N$ and $t = 1,...,T$ respectively refer to the cross-section and time-series dimension of the data.

Among the $\mathbf{x}$ variables, I include the current and lagged levels of (the log of) real GDP, to capture the conventional accelerator effect, and variables measuring the user cost of capital. The latter include the relative price of capital goods, measured by the (log of the) ratio of the investment deflator to the GDP deflator, and the real interest rate, measured as $ln[(1+i)/(1+\pi)]$, where i denotes the nominal interest rate and π is the GDP inflation rate;[16] both regressors should exert a negative effect on investment. However, in view of the pervasive role of interest rate controls and non-price rationing mechanisms in developing-country financial markets—that may render observed interest rates uninformative as to the true marginal cost of funds—I also add to the specification a measure of the overall tightness of credit markets, namely the flow of private credit relative to nominal GDP;[17] for this variable one should expect to find a positive effect on private investment.

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[15] For example, Ramey and Ramey (1995) and Aizenman and Marion (1996) find that measures of volatility have a detrimental effect on output growth. Through the conventional accelerator effect, this would in turn translate into a negative investment impact.

[16] Two alternative measures of the inflation rate were used to construct the real interest rate: (i) the current inflation rate, and (ii) a simple average of the current plus one-period ahead inflation rates. The empirical results were similar in both cases; those reported below use the second of these definitions. In both cases, a few outlying observations showing real interest rates in excess of 50 percent (in absolute value) were discarded from the sample, as they raised suspicions as to the accuracy of the raw data.

[17] Alternative specifications used instead the (log of the) real private credit stock or its first difference, with qualitative results similar to those reported below.

To these conventional investment determinants I add the measures of macroeconomic uncertainty described earlier. Of the seven alternative sets of measures, I choose the conditional variances of the innovations to the five variables of interest as obtained from the GARCH procedure, because they are closest in spirit to the notion of uncertainty. I report empirical experiments using all five individual measures simultaneously as well as experiments using only their first principal component. However, some empirical experiments using instead the 'naïve' measures of dispersion of the forecast errors derived from the univariate auto-regressive estimates presented earlier yielded qualitatively similar results.

4.1 Methodological issues

Empirical implementation of equation (3) using the cross-country time-series data set summarized earlier raises some methodological issues, which can be easily illustrated using a linear version of (3):

$$I_{it} = \lambda I_{i,t-1} + \mathbf{X}_{it}\beta + u_{it}, \qquad u_{it} = \alpha_i + \varepsilon_{it} \tag{3'}$$

where $\mathbf{X}_{it}$ = ($\mathbf{x}_{it}'$, σ_{it}') is a (row) vector comprising both the standard regressors and the uncertainty measure(s), α_i denotes a time-invariant country-specific disturbance possibly correlated with the columns of $\mathbf{X}$, ε_{it} is random noise, and the parameters of interest are λ and the (column) vector β.

Equation (3') poses a dynamic error-components model whose estimation has been extensively discussed in the literature. Even in the absence of any other complications, it is well known that simple-minded estimators such as fixed effects (in panels of short time dimension) and OLS are inconsistent. The present case poses the added complication of simultaneity, as some or all of the columns of $\mathbf{X}_{it}$ may be jointly determined with investment. This is particularly likely for real GDP, but may apply as well to the cost-of-capital variables and the uncertainty measure(s).

The standard approach to estimation of (3') involves first-differencing the equation to remove the time-invariant disturbance:

$$\Delta I_{it} = \lambda \Delta I_{it-1} + \Delta \mathbf{X}_{it}\beta + (\varepsilon_{it} - \varepsilon_{it-1}) \tag{4}$$

Estimation of (4) requires an instrumental variable procedure to correct for the endogeneity of the columns of **X** as well as the correlation between the lagged difference of the dependent variable and ε_{it-1}. While strictly exogenous instruments are in general hard to come by, it is often possible to construct 'internal' predetermined instruments using lagged values of the right-hand side variables. In particular, if one is willing to assume that $E[\varepsilon_{it} \mid \mathbf{X}_{is}] = 0$ for $t > s$ (but not otherwise), then second and higher-order lags of the columns of **X** can be used as instruments in the estimation of (4). This condition is likely to hold if ε_{it} is serially uncorrelated, in which case the second- and higher-order lags of the endogenous variable are likewise valid instruments. Using these internal instruments, a GMM estimator can be constructed; see Arellano and Bond (1991).[18] Below I use this approach to compute what I label the *difference estimator*.[19]

This approach, however, has drawbacks. First, differencing the equation removes the long-run (cross-country) information present in the levels of the variables. Second, if the columns of **X** display persistence over time, their lagged levels will be poor instruments for their differences.

Under additional assumptions, it is possible to construct an alternative GMM estimator that overcomes these problems. Specifically, if one is willing to adopt the 'stationarity' assumption that $E[\alpha_i \mid \mathbf{X}_{it}] = E[\alpha_i \mid \mathbf{X}_{is}]$ and $E[\alpha_i \mid I_{it}] = E[\alpha_i \mid I_{is}]$ for all t and s, then the original specification in levels (3') can be estimated without need of any transformation, using suitably lagged *differences* of the dependent and independent variables as instruments—an almost exactly symmetric case with the use of lagged levels of the variables as instruments for the first-difference specification (4) above. Specifically, if ε is serially uncorrelated, once-lagged differences of the regressors are valid instruments. Combining the level and first-difference specifications, one can construct a *system* GMM estimator that outperforms the difference estimator; see Arellano and Bover (1995) and Blundell and Bond (1997). Finally, as long as the

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[18] Provided the time dimension of the data is long enough, this approach can easily accommodate the case of serially correlated ε_{it}: with autocorrelation of order k, regressors lagged k+2 periods become valid instruments.

[19] It should be noted, however, that if T is sufficiently large the GMM estimator of λ is biased, although less so than the within estimator as long as $T < N$ (as will be the case here). For a thorough discussion see Alvarez and Arellano (1998).

model is overidentified,[20] validity of the assumptions underlying both the difference and the system estimators can be tested through Sargan tests of orthogonality between the instruments (i.e., the lagged levels and/or differences of the regressors) and the residuals, and through tests of second- or higher-order residual autocorrelation (Arellano and Bond, 1991; Blundell and Bond, 1997).[21]

So far I have ignored the possibility of parameter heterogeneity. However, if the parameters differ across countries, so that instead of (3') the true relation is of the form $I_{it} = \lambda_i I_{i,t-1} + \mathbf{x}_{it}\beta_i + u_{it}$, then pooled estimation imposes the invalid equality restrictions $\beta_i = \beta_j$ and $\lambda_i = \lambda_j$ for all i and j, and will lead to inconsistent estimates. Specifically, under plausible conditions the pooled estimate of λ converges asymptotically to 1, overstating the true degree of persistence, while the pooled estimate of β converges to zero, understating the impact of the remaining regressors (Robertson and Symons, 1992).

In these conditions, and provided the time dimension of the data is large enough, an alternative is to estimate the model separately for each country and compute an average of the individual-country estimates (Pesaran and Smith, 1995).[22] Thus, to examine the robustness of the pooled estimation results, below I follow this approach to compute individual-country OLS and 2SLS estimates.

4.2 *Empirical implementation*

Data limitations are severe and deserve explicit mention. Even for the simple empirical specification above, the samples for which *all* of the regressors are available are substantially smaller than those underlying the pairwise correlations reported in Section 3 above. Further, for the instrumental-variable regressions below, each country in the regression sample must possess

[20] This is almost invariably the case in a panel of at least moderate time dimension, in which a large number of lags of the regressors are typically available as instruments. In fact, use of all available instruments (as suggested, for example, by Anh and Schmidt 1995) leads to severe small-sample downward bias of the GMM estimator and its estimated standard errors; see Ziliak (1997) and Altonji and Segal (1994). For this reason, the GMM estimates below use only a subset of the available instruments.

[21] Notice that if the original ε_{it} are serially uncorrelated, differencing will induce first-order (but no higher-order) serial correlation of the transformed disturbance in (4).

[22] See Baltagi and Griffin (1997) for a recent implementation of this approach in the context of a dynamic model. A third, intermediate option is to combine the pooled and heterogeneous estimates; see Maddala, *et al.* (1997).

a sufficient number of observations in the time dimension to allow the construction of instruments for the endogenous variables using their lagged values, along the lines described earlier. I set this required number of annual observations at 10, which yields an unbalanced panel consisting of 60 countries and a total of 876 observations. The number of observations per country ranges from the required minimum of 10 to a maximum of 23.

Using this sample and the empirical specification described above, Table 4 presents various pooled estimates of the basic model using all five uncertainty indicators simultaneously.[23] The first column reports OLS estimates, which ignore the potential endogeneity of the regressors as well as the possible presence of country-specific effects. The estimated coefficient on the lagged dependent variable is close to 1, while the remaining coefficients are in general very small; both results accord with theoretical predictions. Nevertheless, the signs of the coefficients on the standard investment determinants appear reasonable: GDP growth and credit availability have a positive effect on investment, while the opposite applies to the relative price of capital and the real interest rate. Interestingly, the estimates reveal no long-run effect of the *level* of real GDP on investment. In turn, neither the credit measure nor the real interest rate carry significant coefficients. Among the uncertainty indicators, only that associated with the real exchange rate carries a significant coefficient, of negative sign.

The second column reports fixed-effects estimates. As noted earlier, in short panels they are inconsistent due to the presence of a lagged dependent variable, although the severity of the problem in a heavily unbalanced panel such as the present one is unclear. In any case, their sign pattern is very similar to that of the OLS estimates, but the coefficient on the lagged dependent variable is considerably smaller, and the private credit flow now is found to have a significant positive impact on investment. The estimated coefficients of the uncertainty indicators do not display any substantive changes.

The third and fourth columns of Table 4 report the difference and system GMM estimates, respectively, that attempt to correct for both endogeneity and unobserved country-specific effects. The regressions assume that all the explanatory variables are endogenous, and in

[23] All specifications include a set of year dummies, which in general were highly significant.

consequence they are all instrumented. For the standard investment determinants, I use their lagged values as instruments. However, this is not possible with the GARCH-based uncertainty indicators, because their construction uses future as well as past information; for these, I use as instruments lagged values of the other 'naïve' uncertainty indicators, which as explained earlier are constructed from the recursive estimates of the univariate auto-regressive processes and therefore are based on current and past information only. In particular, I use the 3-year standard deviation of the forecast errors derived from the AR(1) specification. Finally, as additional instrument I use the log terms of trade.[24]

The difference-GMM estimates in column 3 again show a sign pattern mostly similar to that already described, but their magnitude is in most cases considerably larger. Precision is poor, however, and among the standard investment determinants only the relative price of capital carries a significant (negative) coefficient. Among the uncertainty indicators, growth volatility now has a marginally significant negative coefficient (of quite large magnitude), while real exchange rate volatility retains its negative and significant parameter estimate. The Sargan test provides no evidence of misspecification, while the serial correlation tests point to first- but no second-order autocorrelation of the residuals, in accordance with the assumptions underlying the selection of instruments.

Unlike the estimates in columns 2 and 3, which only make use of the time-series dimension of the data, the system-GMM estimates in column 4 exploit the cross-section dimension as well. On the whole, the system estimates are quite precise. All of the conventional investment determinants carry significant coefficients of the anticipated sign, and their magnitude is in most cases larger than obtained with the preceding estimation methods. Interestingly, the system estimates imply a long-run output elasticity of private investment close to unity (a Wald test shows that the coefficients on current and lagged GDP are significantly different from each other at the 5 percent level). In turn, the implied long-run elasticity with respect to the price of capital is of similar magnitude but opposite sign. Another remarkable fact is that both the credit variable and the real interest rate carry significant coefficients, suggesting

[24] Specifically, the difference estimator in column 3 uses as instruments the second and third lags of the standard regressors and the 'naïve' uncertainty indicators cited in the text, plus the current and three lagged values of the log terms of trade (all expressed in levels). The system estimator in column 4 adds as instruments for the level regression the lagged first difference of all these variables.

the simultaneous presence of price and quantity effects on investment stemming from financial markets. Regarding the five uncertainty indicators, four of them carry negative coefficients, although only those on inflation and real exchange rate volatility are significantly different from zero at conventional levels. Finally, the diagnostic tests (Sargan and second-order autocorrelation) reveal no evidence against the validity of the instruments used by the system-GMM estimator.

Overall, these results show a robust negative impact of real exchange rate uncertainty on private investment, and less clear-cut effects of the remaining uncertainty indicators. While this is in broad agreement with results reported by some earlier studies (e.g., Servén and Solimano, 1993; Pindyck and Solimano, 1993; Darby, *et al*, 1998), it might partly reflect the already-mentioned fact that all five indicators share a good deal of common information, which suggests an alternative empirical approach based on a summary measure of uncertainty encompassing the unpredictable components of all five macroeconomic variables. To explore this track, Table 5 presents pooled estimates of an alternative specification using the first principal component of the five GARCH-based uncertainty indicators as the summary statistic of macroeconomic uncertainty.

A quick column-by-column comparison of Tables 4 and 5 reveals very little difference concerning the estimated coefficients of the conventional regressors for each of the four specifications. The only exception is the real interest rate, whose system-GMM estimated coefficient (column 4) is now insignificantly different from zero, in contrast with the last column of Table 4. As for the summary uncertainty indicator, it carries a negative coefficient regardless of estimation method, and significantly different from zero in every case except for the OLS estimate. As before, the diagnostic statistics are, on the whole, supportive of the difference and system-GMM estimates.

Among the alternative econometric specifications reported in Tables 4 and 5, the GMM estimates in columns 3 and 4 of the tables are superior on theoretical grounds in view of their ability to correct for both endogeneity and unobserved country-specific effects. On the basis of such estimates, the unambiguous conclusion is that uncertainty has a significant negative impact on private investment.

This conclusion, however, is based on the heroic assumption of identical parameters across countries, which underlies the pooled estimates discussed so far. Thus, in the remainder of this section I examine the robustness of the above results to allowing for parameter heterogeneity across countries. To do this, I estimate equation (3') above *separately* for each country. Unlike the standard panel context, which typically assumes a fixed time dimension and a large cross-section dimension, this procedure requires a large value of *T*, which is unavailable for many of the sample countries, and thus I restrict the analysis to those countries possessing a sufficient number of annual observations. Specifically, in order to rerun the regressions in Tables 4 and 5 at the individual-country level with no less than 5 degrees of freedom in every case, I set the required number of annual observations at 18. This leaves a total of 30 countries and 661 data points.[25]

Table 6 reports the averages of individual-country estimates thus obtained. Symmetrically with the time effects included in the pooled estimation, the individual estimates include a time trend, reported at the bottom of the table. To take into account the varying sample size across countries, the averages are computed weighting the individual-country estimates by their respective number of observations. Standard errors are in turn constructed under the (admittedly unrealistic) assumption that the individual-country estimates are independent.

Columns 1 and 2 in Table 6 respectively present average OLS and 2SLS estimates of the specification including the five uncertainty indicators (i.e., the specification employed in Table 4).[26] While the individual-country estimates (not reported to save space) are fairly disperse, the pattern that emerges appears sensible. Two striking results are the considerably lower degree of persistence—as measured by the coefficient of the lagged dependent variable—and the much larger magnitude of several coefficients, both relative to the pooled estimates presented earlier. Concerning the standard investment determinants, the qualitative pattern of the average OLS estimates is similar to that obtained with the pooled GMM estimates—positive effects of real output and credit availability (although the latter is not significant), and negative effects of the

[25] Pooled estimates computed on this reduced sample are very similar to those reported in Tables 4 and 5.

[26] The 2SLS estimates in columns 2 and 4 of Table 6 use as instruments the current and lagged value of the log terms of trade, plus the first lags of all the regressors, and the first lags the real exchange rate, the relative price of capital, the inflation rate and the 'naïve' uncertainty indicators used as instruments in the pooled GMM regressions.

real interest rate and the price of capital goods—but the implied long-run output elasticity of private investment is now well above unity, and lagged GDP ceases to be significant. In turn, the uncertainty variables carry large coefficients (in absolute value), which are significant and negative in the cases of real exchange rate and price of capital volatility. The bottom of the table reports the Wald test of equality across countries of all parameters except constant and trend (which amounts to allowing for unrestricted country and time effects); the pooling restrictions are overwhelmingly rejected.

Column 2 presents average 2SLS estimates of the same specification. The qualitative pattern is similar, although precision is extremely poor—a reflection of overparameterization, small sample sizes and/or poor instrument quality—and only two of the parameter estimates are significant at the 10 percent level. The pooling restrictions cannot be rejected in this case, although in view of the lack of precision of the estimates the result is not particularly encouraging.

Columns 3 and 4 turn to the condensed specification using the summary measure of uncertainty given by the first principal component of the five individual uncertainty indicators in columns 1 and 2. The average OLS results in column 3 are quite similar to those in column 1, although the coefficient of the lagged dependent variable nearly doubles in size and is much closer to the GMM pooled estimate. The parameter estimates of the conventional investment determinants continue to follow the same sign pattern, and they are all significant except for the credit variable. Most importantly, the summary uncertainty measure carries a large negative coefficient, significant at the 5 percent level. Finally, column 4 presents the average 2SLS estimates. They are very similar in sign, magnitude and statistical significance to the average OLS results in column 3, with the only exception of the uncertainty indicator itself, whose coefficient becomes considerably larger in absolute value while remaining significantly negative. Finally, as shown at the bottom of the table, the pooling restrictions are clearly rejected for both the OLS and 2SLS estimates.

To summarize the empirical experiments in this section, the econometric results consistently reveal a significant negative effect on private investment of measures of macroeconomic uncertainty, after controlling for other standard investment determinants. Moreover, this finding holds when controlling for country-specific effects, simultaneity, and/or parameter heterogeneity (or all simultaneously). Indeed, the only exception are the pooled OLS estimates in the first column of Table 5, where the uncertainty measure carries a negative but insignificant coefficient. On the other hand, there are considerable differences across specifications concerning the estimated magnitude of the impact of uncertainty on investment. In general, the pooled GMM estimates and, especially, the heterogeneous estimates yield the largest effects.

On the whole, the various estimates reported here also provide a consistent picture concerning the more conventional investment determinants. Private investment is found to be negatively affected by real interest rates and the relative price of capital goods, and positively by real output and credit availability. As before, the specifics regarding size and significance of the coefficients vary across estimators, in some cases considerably so. For example, the degree of persistence appears grossly overstated by the pooled OLS estimates, and is much more modest in the heterogeneous estimates; both results accord with theoretical predictions. In contrast, the heterogeneous estimates yield the largest long-run output effects. Further, the real interest rate coefficient is in most cases significantly negative in the heterogeneous-coefficient regressions, while in the pooled regressions it is usually insignificant. This suggests that diversity in financial-market arrangements across countries might be the cause of the frequent failure to detect significant real interest rate effects in developing-country empirical investment equations.

5. Concluding Remarks

The impact of uncertainty on investment has long intrigued economists. Different theoretical models make opposing predictions about its sign, which is therefore an empirical matter. In turn, empirical studies based on aggregate data often use potentially misleading measures of uncertainty, fail to control for other standard investment determinants, and in many cases are subject to possible heterogeneity and simultaneity biases.

This paper has re-examined empirically the investment-uncertainty link, using a large macroeconomic data set for developing countries. Rather than focusing on the sample variability of any one arbitrarily-chosen variable (e.g., inflation or the real exchange rate), the paper constructs alternative measures of uncertainty based on the dispersion of the innovations to five key macroeconomic variables: three related to the macroeconomic environment and the aggregate profitability of capital—growth, inflation and the relative price of investment goods—and another two more closely related to the relative profitability of different economic sectors—the terms of trade and the real exchange rate.

Using these constructed measures, the paper has explored the stylized facts concerning the association between private investment and macroeconomic volatility indicators and has investigated the impact of uncertainty on private investment in a regression framework, controlling for other standard investment determinants.

Simple correlations reveal a significantly negative association between the constructed uncertainty measures and private investment. Further, this applies virtually without exception to each one of the uncertainty indicators on all five economic variables considered in the paper.

The paper has gone one step beyond by adding these uncertainty measures to an otherwise standard empirical equation for private investment, which was estimated using alternative econometric procedures variously allowing for simultaneity, country specific effects and parameter heterogeneity across countries. On the whole, the estimation yields satisfactory results concerning the standard investment determinants included in the equation: in general, the estimates show significant output and cost-of-capital effects, with the latter captured by the relative price of capital, the real interest rate and/or the availability of credit to the private sector. Interestingly, allowing for parameter heterogeneity across countries generally reveals a significant negative impact of the real interest rate on private investment, in contrast with the lack of significance found with most pooled-estimation methods in the paper. Finally, the results also show that private investment displays significant persistence over time.

Most importantly, the negative association between macroeconomic uncertainty and investment remains present in these multivariate regressions, pointing to the existence of a direct impact of uncertainty on private investment over and above any other indirect effects that may be at work. In particular, real exchange rate volatility is found to have a robust negative effect on investment regardless of econometric specification, in broad agreement with some earlier studies based on both micro and macro data. Likewise, a summary measure of macroeconomic uncertainty encompassing the volatility of the five variables of interest listed above also has a consistently negative effect on private investment. The fact that these results hold after taking account of the likely simultaneity between investment and volatility, as well as after controlling for unobserved country-specific effects and even parameter heterogeneity, indicates that the relationship is causal rather than merely coincidental—higher uncertainty leads to lower private investment.

While these results are encouraging, some caveats are in order. The measures of economic uncertainty used in the paper are based on very simple forecasting procedures that could be improved considerably, for example by employing multivariate—rather than univariate—forecasting methods making better use of the available information. Also, the magnitude of the estimated effects of uncertainty varies considerably across specifications, and becomes much larger when allowing for parameter heterogeneity—an issue that could deserve further scrutiny. Perhaps most importantly, the paper has not attempted to disentangle the mechanisms behind the negative effect of uncertainty on investment, which could reflect investment irreversibility, limited risk diversification possibilities, or other factors. Some of these questions could be addressed empirically: for example, if lack of access to risk diversification is the main issue, then the adverse investment impact of uncertainty should be consistently larger in countries (and periods) with less developed financial systems. These issues, however, are beyond the scope of this paper.

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Table 1

Table 1

**Private Investment/GDP Ratio:
Descriptive Statistics**

Sample	Full	Between[a]	Within[b]
Mean	0.1251	0.1236	0.0000
Median	0.1065	0.1140	-0.0068
Standard deviation	0.0715	0.0583	0.0420
Variance	0.0051	0.0034	0.0018
Minimum	0.0014	0.0172	-0.1550
Maximum	0.4488	0.2865	0.2436
Number of observations	2226	94	2226

a. Country averages.
b. Deviations from country averages.

Table 2

Rank Correlation between the Private Investment/GDP Ratio and Selected Uncertainty Indicators

Volatility Measure	Uncertainty Source: Inflation rate	Relative price of capital	Real exchange rate	Terms of trade	GDP Growth
1. Full-sample correlations					
Conditional variance from GARCH(1,1)	**-0.217**	**-0.212**	**-0.240**	**-0.282**	**-0.150**
3-period standard deviation of AR(1) forecast errors	**-0.157**	**-0.137**	**-0.173**	**-0.213**	**-0.123**
5-period standard deviation of AR(1) forecast errors	**-0.161**	**-0.188**	**-0.187**	**-0.233**	**-0.161**
3-period standard deviation of AR(2) forecast errors	**-0.102**	**-0.146**	**-0.142**	**-0.213**	**-0.094**
3-period MAD of AR(1) forecast errors	**-0.203**	**-0.160**	**-0.168**	**-0.239**	**-0.129**
5-period MAD of AR(1) forecast errors	**-0.211**	**-0.196**	**-0.182**	**-0.244**	**-0.144**
3-period MAD of AR(2) forecast errors	**-0.160**	**-0.177**	**-0.172**	**-0.222**	**-0.113**
2. Cross-section correlations					
Conditional variance from GARCH(1,1)	**-0.256**	**-0.196**	**-0.302**	**-0.394**	**-0.196**
3-period standard deviation of AR(1) forecast errors	**-0.295**	**-0.215**	**-0.345**	**-0.294**	**-0.262**
5-period standard deviation of AR(1) forecast errors	**-0.265**	**-0.241**	**-0.324**	**-0.301**	**-0.211**
3-period standard deviation of AR(2) forecast errors	-0.141	**-0.216**	**-0.325**	**-0.282**	-0.141
3-period MAD of AR(1) forecast errors	**-0.301**	**-0.216**	**-0.311**	**-0.327**	**-0.221**
5-period MAD of AR(1) forecast errors	**-0.291**	**-0.213**	**-0.319**	**-0.309**	**-0.216**
3-period MAD of AR(2) forecast errors	-0.179	**-0.205**	**-0.332**	**-0.313**	-0.167
3. Time-series correlations					
Conditional variance from GARCH(1,1)	**-0.078**	**-0.105**	**-0.056**	**-0.053**	-0.034
3-period standard deviation of AR(1) forecast errors	**-0.080**	**-0.089**	**-0.075**	-0.022	-0.026
5-period standard deviation of AR(1) forecast errors	**-0.068**	**-0.086**	**-0.096**	-0.025	-0.041
3-period standard deviation of AR(2) forecast errors	-0.028	**-0.097**	**-0.045**	**-0.060**	0.038
3-period MAD of AR(1) forecast errors	**-0.083**	**-0.074**	**-0.084**	-0.012	-0.016
5-period MAD of AR(1) forecast errors	**-0.073**	**-0.103**	**-0.103**	-0.017	-0.020
3-period MAD of AR(2) forecast errors	**-0.053**	**-0.064**	**-0.091**	-0.032	0.014

Note: Each entry in the table shows the simple correlation between the private investment/GDP ratio and one specific measure of the volatility of the innovation to the variable at the top of the column. The correlations shown in bold are statistically significant at the 5 percent level.

Table 3

Full-Sample Rank Correlation Among Measures of Uncertainty of Various Economic Variables

a. GARCH(1,1) conditional variances

Variable	Variable: Inflation rate	Relative price of capital	Real exchange rate	Terms of trade
Inflation rate	1.000	--	--	--
	--	--	--	--
Relative price of capital	0.397	1.000	--	--
	(0.023)	--	--	--
Real exchange rate	0.356	0.294	1.000	--
	(0.022)	(0.024)	--	--
Terms of trade	0.396	0.281	0.275	1.000
	(0.023)	(0.024)	(0.024)	--
GDP growth	0.344	0.272	0.247	0.259
	(0.022)	(0.024)	(0.022)	(0.024)

b. 3-period standard deviations of AR(1) forecast errors

Variable	Variable: Inflation rate	Relative price of capital	Real exchange rate	Terms of trade
Inflation rate	1.000	--	--	--
	--	--	--	--
Relative price of capital	0.342	1.000	--	--
	(0.024)	--	--	--
Real exchange rate	0.400	0.247	1.000	--
	(0.022)	(0.024)	--	--
Terms of trade	0.331	0.318	0.198	1.000
	(0.024)	(0.024)	(0.024)	--
GDP growth	0.278	0.225	0.220	0.212
	(0.022)	(0.024)	(0.022)	(0.024)

Note: Standard errors in brackets.

Table 4

Pooled Estimates of the Investment Equation
(dependent variable: log of real private investment)

Equation	1	2	3	4
Estimation method	OLS	Fixed effects	First differences GMM	System GMM
Constant	0.005	-0.001	0.072	-1.841**
	(0.005)	(0.005)	(0.070)	(0.455)
Lagged private investment[a]	0.868**	0.633**	0.536**	0.566**
	(0.053)	(0.046)	(0.090)	(0.075)
Real GDP[a]	0.091**	0.065**	0.876	1.827**
	(0.024)	(0.026)	(0.756)	(0.652)
Real GDP lagged[a]	-0.092**	-0.061**	-1.002	-1.339**
	(0.024)	(0.027)	(1.047)	(0.649)
Relative price of capital[a]	-0.020**	-0.040**	-0.627**	-0.433**
	(0.006)	(0.010)	(0.254)	(0.143)
Credit flow to priv. sector/GDP	0.019	0.041*	1.078	3.169**
	(0.016)	(0.023)	(1.029)	(0.975)
Real interest rate	-0.014	-0.014	-0.194	-0.521**
	(0.010)	(0.010)	(0.334)	(0.247)
Inflation uncertainty[b]	-0.180	-0.118	-0.740	-9.605**
	(0.134)	(0.091)	(5.578)	(4.617)
Terms-of-trade uncertainty[b]	0.030	-0.024	0.637	-1.955
	(0.044)	(0.033)	(4.643)	(2.727)
Real exchange rate uncertainty[b]	-0.029**	-0.059**	-2.119**	-1.493**
	(0.012)	(0.018)	(0.609)	(0.395)
Price of capital uncertainty[b]	0.011	0.002	0.104	0.367
	(0.008)	(0.009)	(0.319)	(0.249)
GDP growth uncertainty[b]	1.205	0.459	-25.855*	-19.986
	(0.837)	(0.576)	(15.458)	(13.047)
Wald test of joint significance (p-value)	0.000	0.000	0.000	0.000
Time effects (p-value)	0.001	0.001	0.002	0.000
Sargan test (p-value)	NA	NA	0.418	0.851
1st-order autocorrelation (p-value)	NA	NA	0.002	0.001
2nd-order autocorrelation (p-value)	NA	NA	0.187	0.256
Number of observations	876	816	816	816

Notes: All regressions include a set of year dummies. Standard errors (in brackets) are heteroskedasticity consistent. One (*) and two (**) stars denote statistical significance at the 10 and 5 percent level, respectively.
a. Expressed in logs.
b. Measured by the conditional variance from GARCH (1,1) estimates.

Table 5

Pooled Estimates of the Investment Equation
(dependent variable: log of real private investment)

Equation	**1**	**2**	**3**	**4**
Estimation method	**OLS**	**Fixed effects**	**First differences GMM**	**System GMM**
Constant	0.007	-0.001	0.108**	1.806**
	(0.005)	(0.005)	(0.052)	(0.299)
Lagged private investment[a]	0.880**	0.636**	0.590**	0.666**
	(0.053)	(0.046)	(0.073)	(0.051)
Real GDP[a]	0.086**	0.063**	0.604	1.778**
	(0.024)	(0.027)	(0.428)	(0.335)
Real GDP lagged[a]	-0.087**	-0.061**	-1.072*	-1.377**
	(0.024)	(0.027)	(0.585)	(0.353)
Relative price of capital[a]	-0.016**	-0.044**	-0.682**	-0.491**
	(0.005)	(0.011)	(0.201)	(0.088)
Credit flow to priv. sector/GDP	0.019	0.050**	0.874	2.931**
	(0.017)	(0.025)	(0.612)	(0.640)
Real interest rate	-0.011	-0.008	-0.242	-0.019
	(0.009)	(0.011)	(0.267)	(0.161)
Uncertainty[b]	-0.053	-0.152**	-2.719**	-1.513*
	(0.041)	(0.060)	(1.054)	(0.778)
Wald test of joint significance (p-value)	0.000	0.000	0.000	0.000
Time effects (p-value)	0.000	0.001	0.013	0.000
Sargan test (p-value)	NA	NA	0.388	0.204
1st-order autocorrelation (p-value)	NA	NA	0.002	0.000
2nd-order autocorrelation (p-value)	NA	NA	0.443	0.655
Number of observations	876	816	816	816

Notes: All regressions include a set of year dummies. Standard errors (in brackets) are heteroskedasticity consistent. One (*) and two (**) stars denote statistical significance at the 10 and 5 percent level, respectively.
a. Expressed in logs.
b. First principal component of the conditional variances of inflation, the terms of trade, the real exchange rate, the relative price of capital, and the GDP growth rate, each obtained from a univariate GARCH(1,1) model.

Table 6

Heterogeneous Estimates of the Investment Equation
(dependent variable: log of real private investment)

Equation	1	2	3	4
Estimation Method	Average OLS	Average 2SLS	Average OLS	Average 2SLS
Constant	13.178**	-21.805	-13.930**	-13.260**
	(5.270)	(23.785)	(3.073)	(4.143)
Lagged private investment[a]	0.153**	0.047	0.298**	0.292**
	(0.060)	(0.262)	(0.046)	(0.058)
Real GDP[a]	1.874**	2.134*	1.805**	1.825**
	(0.365)	(1.237)	(0.266)	(0.375)
Real GDP lagged[a]	-0.318	0.166	-0.205	-0.261
	(0.410)	(1.171)	(0.265)	(0.350)
Relative price of capital[a]	-0.506**	-0.508	-0.339**	-0.361**
	(0.139)	(0.463)	(0.100)	(0.142)
Credit flow to private sector/GDP	0.835	1.641	0.812	1.222
	(0.744)	(1.995)	(0.603)	(0.834)
Real interest rate	-0.711**	-1.472	-0.530**	-0.533**
	(0.284)	(1.509)	(0.191)	(0.271)
Inflation uncertainty[b]	31.440	120.998		
	(27.269)	(138.850)		
Terms-of-trade uncertainty[b]	-7.357	4.830		
	(15.088)	(32.884)		
Real exchange rate uncertainty[b]	-10.538**	-19.604*		
	(3.963)	(11.600)		
Price of capital uncertainty[b]	-29.747**	-40.835		
	(11.051)	(25.564)		
GDP growth uncertainty[b]	5.215	18.741		
	(40.243)	(139.515)		
Uncertainty[c]			-15.509**	-24.120**
			(6.807)	(11.515)
Time trend	-0.005	-0.010	-0.020**	-0.018
	(0.014)	(0.036)	(0.008)	(0.011)
Test of pooling restrictions (p-value)	0.0013	0.9997	0.0000	0.0001
Number of observations	661	661	661	661

Notes: One (*) and two (**) stars denote statistical significance at the 10 and 5 percent level, respectively.
a. Expressed in logs.
b. Measured by the conditional variance from GARCH (1,1) estimates.
c. First principal component of the conditional variances of inflation, the terms of trade, the real exchange rate, the relative price of capital, and the GDP growth rate, each obtained from a univariate GARCH(1,1) model.

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