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VOLATILITY AND THE INVESTMENT RESPONSE

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ABSTRACT

We use the World Bank decomposition of aggregate investment shares into their private and public components to test for the correlation between volatility and investment in a set of developing countries. We uncover a statistically significant negative correlation between various volatility measures and private investment, even when adding the standard control variables. No such correlation is uncovered when the investment measure is the sum of private and public investment spending. Indeed, public investment spending is positively correlated with some measures of volatility.

We also use the new World Bank data to redo the Ramey and Ramey (1995) test for a correlation between investment and the standard deviation of innovations to a forecasting equation for growth. While Ramey and Ramey found no significant correlation using aggregate investment data, we find a negative and highly significant relationship between innovation volatility and private investment in developing countries. These findings suggest that the detrimental impact of volatility on investment may be difficult to detect using aggregate data.

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1. Introduction

We use the World Bank decomposition of aggregate investment shares into their private and public components to test for the correlation between volatility and investment in a set of developing countries. We uncover a statistically significant negative correlation between various volatility measures and private investment, even when adding the standard control variables. No such correlation is uncovered when the investment measure is the sum of private and public investment spending. Indeed, public investment spending is positively correlated with some measures of volatility. These findings suggest that the detrimental impact of volatility on investment may be difficult to detect using aggregate data.

2. Methodology and Results

Going back to 1970, the World Bank has constructed yearly measures of private and public investment as a share of GDP for more than forty developing countries. (Glen and Sumlinski, 1995; Madarassy and Pfeffermann, 1992). We construct average private and public investment shares over the 1970-1992 period using these data.[1]

We rely on several methods to obtain volatility measures. First, we use annual data to calculate standard deviations of individual fiscal, monetary and external variables. Next, we construct an index of volatility that is a weighted average of standard deviations in fiscal, monetary and

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1 When some annual observations are missing, we construct averages using the remaining subsample.

external variables. Finally, we consider a measure of volatility that uses the standard deviation of innovations to a forecasting equation for growth.

To start, we construct a number of volatility measures based on standard deviations. Standard deviations of the residuals are calculated from first-order auto-regressive processes. With only 23 years of annual data, no attempt is made to test for more complicated auto-regressive schemes. Since the variables for which standard deviations are calculated are measured as shares or rates of change, the standard deviation measures are unit free and acceptable for cross-country comparisons.[2]

We then compute simple correlations between private investment shares and a number of volatility measures. We report results for three measures: the volatility of government consumption expenditures as a percentage share of GDP, the volatility of nominal money growth, and the volatility of the change in the real exchange rate. Table 1 displays the simple correlations between private investment shares and each of these three volatility measures. In all cases there is a negative and highly significant correlation.

We next examine the partial correlation between volatility and private investment shares while controlling for additional relevant

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2 While Dickey-Fuller tests fail to reject the hypothesis of a random walk in some cases, the power of the tests is limited. On *a priori* grounds, the variables cannot be random walks. If they are shares, they are bounded between zero and one, and if they are rates of change, they are bounded above and below by reasonable limits. We expect the policy variables to include a mean-reverting component.

variables. Many investigators have used explanatory variables such as initial real GDP per capita, initial human capital, fiscal policy indicators, monetary policy indicators, trade measures, and political indices in an attempt to establish a statistically significant relationship between investment and a particular variable in cross-section data. But as Levine and Renelt (1992) show, the results of these cross-section regressions are fragile to small changes in the conditioning information set.

Our choice of controls is influenced by the ones identified in Levine and Renelt (1992) as important for cross-country investment and growth equations. We incorporate the following control variables: (1) the initial log level of real GDP per capita, (2) the initial fraction of the relevant population in secondary schools, (3) the initial growth rate of the population, and (4) the average share of trade (exports plus imports) in GDP over the period. The first three variables are ones Levine and Renelt found to be robust across different specifications of cross-country growth equations. The fourth variable is the one they found to be most robust in cross-country investment equations.

In addition to the control variables, the investment equation includes a measure of volatility. We first enter the fiscal, monetary and external volatility measures sequentially. The results are displayed in equations (1)-(3) of Table 2. We then construct an index of volatility that is a weighted average of the three individual volatility measures, where the weights are determined optimally to maximize the explanatory power of the regression. Equation (4) of Table 2 shows the results of the investment equation when this index is used as the volatility measure. Because heteroskedasticity may be important across countries, the standard errors for the coefficients in Table 2 are based on White's (1980) correction method.[3]

The results indicate a negative relationship between volatility and private investment in all cases. Moreover, the coefficient on the volatility measure is significant at the 5 percent level. It is notable that the correlation between the various volatility measures and investment is *not* statistically significant when the average investment share is measured by total (public and private) investment rather than just private investment. (See Table 3.) This result may be due to the fact that public and private investment spending are determined by different factors. Indeed, the partial correlation between public investment and volatility as measured by the fiscal or monetary variable turns out to be positive and highly significant, as shown in Table 4.

These findings can be rationalized in various ways. For example, if public investment is determined by a benevolent planner, it may increase in periods of heightened volatility to compensate for the reluctance of the private sector to invest. If public investment is a mechanism for

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3 Since each volatility measure is a constructed variable measured with error, each should be instrumented in the estimation. A number of instruments were tried, such as the frequency of coups, revolutions and assassinations, measures of market distortions and inflation variance, but typically the instruments were not highly correlated with the volatility measure. The mean and variance of the variable were the most promising instruments but none of the results was substantively changed by using them. We report results obtained without instrumenting.

distributing political rents in a rent-seeking society, then public investment may increase in periods of political instability. Thus political instability triggers both the drop in private investment and the rise in public investment. Whatever the correct interpretation, the findings suggest that testing for a negative link between volatility and investment using aggregate investment data may lead to biases due to aggregation problems.

Ramey and Ramey (1995) use a panel of 92 rich and poor countries over the 1960-1985 period in order to explore the relationship between volatility and growth. They find that their particular measure of volatility lowers growth but is not significantly related to investment. Since we have uncovered a strong negative correlation between our measures of volatility and private investment, we reexamine their claim using their methodology on our data of developing countries.

We start by examining the relationship between growth and volatility where volatility is measured as the standard deviation of innovations to a forecasting equation for growth. For the analysis, we use the specification in Ramey and Ramey (1995):

(1a) $$\Delta y_{it} = \lambda \sigma_i + \theta X_{it} + \varepsilon_{it}$$

(1b) $$\varepsilon_{it} \sim N(0, \sigma_i^2), \qquad i = 1,\ldots,I \quad t = 1,\ldots,T$$

where Δy_{it} is the growth rate of output per capita for country i in year t, expressed as a log difference; σ_i is the standard deviation of the residuals, ε_{it} ; X_{it} is a vector of control variables and forecasting variables; and θ is a vector of coefficients assumed to be common across countries. The residuals ε_{it} are specified to be normally distributed and represent the deviation of growth from the value predicted based on the variables in X. The variance of the residuals, σ_i^2, is assumed to differ across countries, but not across time. The standard deviation of the residuals is the volatility measure.

The control variables included in X are the same as those used by Ramey and Ramey, who in turn select those judged important by Levine and Renelt. We use (1) initial log of real GDP per capita, (2) initial human capital as measured by secondary school enrollment, (3) the initial growth rate of the population, and (4) the average (public and private) investment fraction of GDP over the period.[4]

In addition, we follow Ramey and Ramey (1995) by including forecasting variables in our growth equation. These are (1) two lags of the log level of real GDP per capita, (2) a time trend and a time trend squared, (3) a time trend that starts in 1983 after the onset of the debt crisis, and (4) a dummy variable for 1983 and after. These forecasting variables permit various configurations for the estimated trend in GDP. Ramey and Ramey use similar forecasting variables, but they look for a possible break in the trend in 1974, after the first oil shock. Given that

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4 We also considered an alternative specification where the investment fraction in the initial year of the sample is the fourth control so there is no future information in any of the control variables when forecasting equation (1a). The correlations between the generated volatility measure and private, public and total investment were essentially identical to those reported below.

our data does not start until 1970, we look for a possible break in 1983, after the onset of the debt crisis.

We estimate the model in (1) jointly using the same maximum-likelihood procedure as in Ramey and Ramey. The time period begins in 1972 and runs through 1992, resulting in a panel of 966 observations for the 46 developing countries in the sample. As shown in Table 5A, volatility enters the estimated growth equation with a negative coefficient that is statistically significant. Ramey and Ramey obtain a similar finding.

We now check whether this particular volatility measure is significantly related to investment. Ramey and Ramey find that in the simple bivariate specification, "innovation volatility appears to have a negative relationship with investment and is significant at the 10-percent level" in their 92-country sample but is not significant in their 24-country OECD sample. However, once the control variables are included in the investment equation, "the effect is no longer significant" even in the bigger sample (Ramey and Ramey, 1995, p. 1145).

Table 5B shows the results of cross-country regressions of the average private investment share on innovation volatility for our set of 46 developing countries. In the simple bivariate specification, we find a negative relationship between innovation volatility and private investment spending that is statistically significant at the 5-percent level. The second row shows that the strong negative relationship between volatility and private investment continues to hold even after the control variables are included in the investment equation. Thus, while Ramey and Ramey find little impact of innovation volatility on investment, we uncover a negative and highly significant relationship between volatility and private investment after controlling for other factors.

It is important to emphasize that we use a different investment measure than Ramey and Ramey. We use the average *private* investment share of GDP rather than the average *total* (public and private) investment share. Our use of the private investment measure explains why our sample size is smaller and may also explain why our results are stronger. Indeed, as shown in Table 5C, the correlation between innovation volatility and *total* investment is negative but not statistically significant.[5]

We next construct innovations by allowing for country-specific coefficients on the forecasting variables in (1a). We follow the procedure in Ramey and Ramey (1995) by estimating separate growth forecasting equations for each country, containing a constant term, two lags of GDP, and the four trend variables. We then calculate the standard deviation of the innovation for each country from the estimated residuals of the country-specific growth equations. The correlations between this standard deviation and the various investment measures are qualitatively the same as those reported in Table 5. The volatility measure is negatively and significantly correlated with private investment, but it is uncorrelated with either total investment or with public investment.

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5 Ideally we would like to have enough data to determine how much of the difference in results is due to the level of disaggregation in the investment measures, the mix of countries in the sample and the time period chosen. These data are not currently available, however.

3. Conclusion

We believe that the finding of a statistically significant negative partial correlation between a number of volatility measures and private investment lends support to the view that volatility has important detrimental effects on developing countries. Moreover, to the extent that these effects operate through an investment channel, they may be undetected when tests utilize aggregate investment data.

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Table 1: Correlation Between Volatility and Private Investment

Volatility Measure	Correlation	t-Statistic
government consumption as a share of GDP	-0.44	-3.37
nominal money growth	-0.46	-4.14
real exchange rate	-0.34	-3.80

Measures: investment measured as the average share of private investment in GDP over the 1970-1992 period or available sub-period; government consumption volatility measured as the standard deviation from an AR1 process of government consumption as share of GDP, 1970-1992; money growth volatility measured as the standard deviation from an AR1 process of nominal M1 growth; real exchange rate volatility measured as the standard deviation from the average change in the effective real exchange rate.

Countries = 47. Sample: Argentina, Bangladesh, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cote D'voire, Dominican Republic, Ecuador, Egypt, El Salvador, Figi, Ghana, Guatemala, Guyana, Haiti, India, Indonesia, Iran, Kenya, Korea, Madagascar, Malawi, Malaysia, Mali, Mauritius, Mexico, Morocco, Nepal, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Singapore, South Africa, Sri Lanka, Tanzania, Thailand, Tunisia, Turkey, Uruguay, Venezuela, Zimbabwe.

Sources: Penn World Tables, Version 5.6a; Glen and Sumlinski (1995); Madarassy and Pfeffermann (1992); IMF International Financial Statistics (1995); Inter-American Development Bank

Table 2: Relationship Between Private Investment and Volatility Measures

Variable	(1)	(2)	(3)	(4)
n	43 countries	43 countries	43 countries	43 countries
c	0.1057 (1.27)	0.0757 (1.01)	0.0260 (0.29)	0.0820 (1.03)
volatility	-1.6732 (-3.97)	-2.9171 (-5.26)	-0.2375 (-3.44)	-2.6796 (-6.29)
volatility measure	govt. spending	money growth	real exchange rate	index
initial per capita GDP	-0.0043 (-0.37)	0.0064 (0.62)	0.0114 (0.84)	0.0087 (0.78)
initial school enrollment rate	0.1003 (1.44)	0.0701 (1.13)	0.0666 (0.75)	0.0619 (0.96)
initial population growth rate	0.8876 (0.76)	0.1816 (0.17)	0.9017 (0.77)	0.1183 (0.11)
avg. trade share of GDP	0.0470 (1.78)	0.0452 (2.03)	-0.0069 (-0.19)	0.0263 (1.21)
$\bar{R}^2$	0.21	0.33	0.15	.39

Notes: Dependent variable is the average share of private investment in GDP. Numbers in parentheses are heteroscedastic-consistent t-statistics. In the optimally-weighted index of (4), the weight attached to volatility in money growth exceeds 90 percent. Sample size reduced to 43 countries because of missing data.

Sources: Penn World Tables Version 5.6a; Glen and Sumlinski (1995); Madarassy and Pfeffermann (1992); World Bank World Tables; IMF International Financial Statistics (1995); Inter-American Development Bank; Barro (1991) data.

Table 3: Relationship Between Total Investment and Volatility Measures

Variable	(1)	(2)	(3)	(4)
n	43 countries	43 countries	43 countries	43 countries
c	-0.0825 (-0.77)	-0.0816 (-0.81)	-0.0980 (-1.03)	-0.0960 (-1.02)
volatility	-0.4358 (-0.54)	-1.0928 (-0.94)	-0.1086 (-1.27)	-0.9350 (-1.59)
volatility measure	govt. spending	money growth	real exchange rate	index
initial per capita GDP	0.0132 (0.88)	0.0158 (1.13)	0.0180 (1.31)	0.0207 (1.55)
initial school enrollment rate	0.1870 (2.17)	0.1777 (2.04)	0.1751 (2.15)	0.1650 (2.04)
initial population growth rate	2.5967 (2.10)	2.2936 (1.82)	2.5366 (2.13)	2.1769 (1.84)
avg. trade share of GDP	0.0575 (1.55)	0.0602 (1.78)	0.0386 (1.28)	0.0439 (1.33)
$\bar{R}^2$	0.24	0.26	0.34	0.28

Notes: Dependent variable is the average share of total investment in GDP. Numbers in parentheses are heteroscedastic-consistent t-statistics. In the optimally-weighted index of (4), the weight attached to volatility in money growth exceeds 90 percent. Sample size reduced to 43 countries because of missing data.
Sources: Penn World Tables, Version 5.6a; Glen and Sumlinski (1995); Madarassy and Pfeffermann (1992); World Bank World Tables; IMF International Financial Statistics; Inter-American Development Bank; Barro (1991) data.

Table 4: Relationship Between Public Investment and Volatility Measures

Variable	(1)	(2)	(3)	(4)
n	43 countries	43 countries	43 countries	43 countries
c	0.1774 (2.84)	0.1963 (4.39)	0.2478 (3.84)	0.2355 (4.33)
volatility	1.1080 (2.45)	1.9651 (5.03)	0.0006 (0.01)	0.8128 (1.49)
volatility measure	govt. spending	money growth	real exchange rate	index
initial per capita GDP	-0.0172 (-2.01)	-0.0243 (-3.35)	-0.0254 (-2.34)	-0.0291 (-2.88)
initial school enrollment rate	0.0382 (0.81)	0.0584 (1.27)	0.0502 (0.76)	0.0651 (1.05)
initial population growth rate	-0.5131 (-0.71)	-0.0336 (-0.05)	-0.7362 (-0.91)	-0.2955 (-0.36)
avg. trade share of GDP	0.0371 (1.89)	0.0379 (2.22)	0.0565 (1.79)	0.0617 (2.43)
$\bar{R}^2$	0.44	0.54	0.28	0.37

Notes: Dependent variable is the average share of public investment in GDP. Numbers in parentheses are heteroskedastic-consistent t-statistics. In the optimally-weighted index of (4), the weight attached to volatility in money growth exceeds 80 percent. Sample size reduced to 43 countries because of missing data.

Sources: Penn World Tables, Version 5.6a; Glen and Sumlinski (1995); Madarassy and Pfeffermann (1992); World Bank World Tables; IMF International Financial Statistics; Inter-American Development Bank; Barro (1991) data.

Table 5: Relationship Between Investment and Innovation Volatili

Specification	46-country sample (996 observations)
A. Growth equation (panel data; coefficient on volatility)	-0.2484 (-2.42)
B. Private investment equations (cross-section data; coefficient on volatility)	
Other variables included (besides a constant term)	
None	-0.6371 (-2.50)
Control variables	-0.6866 (-2.26)
C. Total (public and private) investment equations (cross-section data; coefficient on volatility)	
None	-0.2113 (-0.43)
Control variables	-0.3120 (-1.12)
D. Public investment equations (cross-section data; coefficient on volatility)	
None (0.89)	0.3931
Control variables	0.4024 (1.27)

Notes: In the investment equations, the control variables are the initial log real GDP per capita , the initial secondary school enrollment rate, the initial population growth rate, and the average trade share of GDP. Excluding the openness measure from the set of control variables to duplicate the control variables in Ramey and Ramey (1995) does not alter the results. Investment equations corrected for heteroskedasticity. Numbers in parentheses are t-statistics.

Table 5 uses the country-specific volatility measure generated by regressing the growth rate on four control variables (initial log real GDP per capita, initial secondary school enrollment rate, initial population growth rate, average total investment share) and six forecasting variables (one and two-period lags of log real GDP per capita, time and time squared, a post-1982 dummy and a post-1982 trend). Growth equation estimation is reported below. When the initial total investment share replaces the average share as a control in the growth equation, the coefficients on volatility and their respective t-values are almost identical to those reported in Table 5. When the country-specific volatility measure is generated from separate growth forecasting equations for each country, the coefficients on volatility and their levels of significance are qualitatively the same as those reported in Table 5.

Table 5A results based on maximum likelihood procedure using panel data.

The growth regression is:

growth = 0.0834 - 0.2484 (volatility) - 0.0082 (initial per capita GDP)
(3.24) (-2.42) (-0.97)

+ 0.0234 (initial school enrollment rate) - 0.3875 (initial population growth rate) +
(1.19) (-1.28)

0.1563 (average total investment share of GDP) +0.2330 $\log(GDP_{-1})$
(4.29) (6.98)

- 0.2354 $\log(GDP_{-2})$ + 0.0060 (trend) - 0.0008 (trend squared)+
(-6.75) (2.71) (-4.38)

0.0202 (post-1982 trend) - 0.0028 (post-1982 dummy); Log likelihood = 1,594.37.
(5.33) (-0.47)

Numbers in parentheses are t-statistics.

Sources: Penn World Tables, Version 5.6a; Glen and Sumlinski (1995); Madarassy and Pfeffermann (1992); World Bank World Tables; IMF International Financial Statistics; Inter-American Development Bank; Barro (1991) data.