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MACROECONOMIC INSTABILITY AND THE INCENTIVE TO INNOVATE

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ABSTRACT

This paper investigates the channels through which macroeconomic instability prevents or hinders innovative investment undertakings financed by the domestic business sector. The analysis is based on a sample of 48 countries, representing all levels of development, and uses various measures of macroeconomic instability, such as political, real and monetary volatility. The results suggest a negative impact of macroeconomic instability on the share of R&D financed by the domestic business sector. These outcomes highlight the desirability of counter-cyclical policy interventions aiming to prevent the avoidance or abandonment of private R&D undertakings in unstable macroeconomic environments.

Keywords: Macroeconomic Volatility, Political Instability, R&D Investment, Innovation.

JEL Classification: C33, O11, O31, O33

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1. INTRODUCTION

Innovation, in both its public and private component, is the 'engine' of modern growth. As such, its progress is key to economic development. Nonetheless, the summary statistics of the R&D data used in this analysis appear to suggest some counterintuitive evidence in this respect. With few exceptions, in developed countries, the share of public R&D spending is lower than (or just as big as) the private share; however, in developing countries, (often very) low levels of business R&D are almost always accompanied by relatively higher levels of government R&D investment.[1]

[*Table 1 about here*]

This evidence inevitably raises the question of why the domestic private sector in developing countries refrains from engaging in high-returns R&D investment projects. We try and answer this question in what follows by focusing on a core component of R&D returns, that is, macroeconomic stability. In particular, we ask whether the domestic private sector refrains from R&D undertakings because they are too risky in uncertain macroeconomic environments such as the ones that characterise most developing countries. We do so while bearing in mind two extrinsic characteristics of R&D investment. First, innovation is a risky, long-term-maturity, high-budget type of investment, and, as such, it is likely to be largely influenced by uncertainty in the surrounding macroeconomic environment. Second, small and medium-sized firms, particularly in developing countries, are likely to be credit constrained, especially during recessionary spells.

[1] China, Malaysia, the Philippines, South Africa, Uruguay and Venezuela constitute somewhat of an exception.

While a number of studies have dealt with the implications of macroeconomic volatility[2] on private investment, with sometime conflicting results (Hartman, 1972; Abel, 1983; Dehn, 2000; Pindyck and Solimano, 1993; Bernanke, 1980; Federer, 1993; Serven, 2003, Aghion et al., 2010), only a few more recent papers have looked specifically into the link between macro-instability and innovative private investment (Aghion and Saint-Paul, 1998; Goel and Ram, 1999; Saint-Paul, 2003; Rafferty, 2003a; Barlevy, 2005; Aghion *et al.*, 2008; Rafferty and Funk, 2008; Bohva-Padilla *et al.*, 2009). Most importantly, part of the aforementioned contributions is theoretical in nature. Those which are empiric follow a microeconometric approach, utilising firm-level data and/or focusing on OECD countries only. Such focus is motivated by the well-known scarcity of R&D data availability for developing countries (Goel and Ram, 1999; Aghion et al., 2010; Agénor and Neanidis, 2011). As a result, a comprehensive analysis that adopts a macroeconometric approach and considers developing countries as well as developed countries does not exist to the author's knowledge, which is what this paper seeks to do in what follows.

The contribution of this paper is not, however, limited to the novel empirical focus. It also extends to the mixed dataset, which has been constructed by integrating private sector R&D expenditure data from various sources and databases.[3] And it includes the estimation of a multi-dimensional set of volatility indices. Specifically, to represent the multiple aspects in which instability of the macroeconomic environment manifests itself, we utilise a number of proxies for real, monetary and political instability. It is shown that they all have a negative impact on private innovation incentives. In addition to this, we also disentangle the individual effect that each one of these components has when all volatility indices are estimated at the same time. These findings qualify

[2] Uncertainty and volatility are technically defined as two different concepts. However, it is common to find them used interchangeably in the literature and we will follow this convention hereafter.

[3] Details of the dataset composition process are presented in Section 2 below.

the mixed results reported in the literature, on one hand. On the other hand, in light of the considerations previously exposed, they uncover the necessity of public policy interventions in support of private firms engaging in innovation in volatile macro-environments. Such interventions should aim at preventing the abandonment or avoidance of private R&D investment undertakings as a consequence of macro-uncertainty; so as to allow for continuity in private profitability horizons and, as a result, in national growth and development paths.

The structure of the paper is as follows: Section 2 outlines the theoretical background; section 3 presents methodological considerations, together with the variables and the data. The results along with the robustness analysis are described in section 4 and 5. Section 6 illustrates some policy implications and concludes. Finally, the data sources, the country list and some additional methodology appear in Appendix A and B.

2. BACKGROUND

The theoretical literature on uncertainty and investment can be broadly divided into two strands. Some studies describe the relationship between these two variables as positive (Hartman, 1972; Abel, 1983; Dehn, 2000; Pindyck and Solimano,1993). Others posit that tighter credit constraints during recessions and the irreversibility of most investment projects - especially of innovative investment - turn this relationship negative (Bernanke, 1980; Federer, 1993; Goel and Ram, 1999; Aghion et al., 2010).[4] In particular, Bernanke (1980) argues that a range of inaction is

[4] Uncertainty is defined as an increase in the variance of future return forecasts. The latter will be higher when the future maturity horizon of an investment is long and/or when it is uncertain, which is particularly the case in R&D investments. Furthermore, investing in the proximity of the technological frontier requires

created in the presence of uncertainty, and that investment will not be undertaken until the moment when the cost of postponing it exceeds the value of the information gained by waiting. In addition, Goel and Ram (1999) show that the 'degree' of irreversibility of an investment project can change the impact of uncertainty: they find a much larger adverse effect on R&D investments, which are likely to be highly irreversible, than on non-R&D ones. In this sense, they argue that R&D investment entails expenditure on personnel, equipment and materials that is largely irreversible, owing to its project-specific and not merely firm-specific or industry-specific nature. This implies that it will be much more difficult, if not impossible, to dispose of the variable and fixed capital acquired in order to carry out a specific R&D project, in the face of adversities. Aghion et al. (2010) find that, when credit markets are imperfect and liquidity constraints are tight enough, long-term investment will tend to be pro-cyclical.[5]

A more recent number of contributions analyze the impact of volatility on 'innovative' investment. This literature can again be divided into two main strands, depending on whether they maintain that R&D investment follows a pro-cyclical or counter-cyclical response pattern to macroeconomic fluctuations. It is crucial for policy-makers to determine which one holds. In fact, as put forward in Blackburn (1999), if business cycles increase inventive activity, a policy attempt to smooth out the business cycle might reduce productivity growth and long-run growth. But if business cycles decrease inventive activity, then attempts to smooth out the business cycles can improve productivity growth and long-run growth. Those that argue in favor of a pro-cyclical response pattern maintain that a 'cash-flow' effect exists, which financially constrains firms' activities and hinders the undertaking of innovative investment during downturns (Rafferty, 2003a;

plenty of funds and firms worry equally about probability of success and size of the investment (Canitrot, in Katz, 1987).

5 The authors explicitly identify R&D investment as a long-term type of investment.

Rafferty and Funk, 2008; Aghion *et al.*, 2008; Bohva-Padilla *et al.*, 2009, Aghion et al., 2010). Barlevy (2005) adds to this that, although credit constraints certainly account for part of the pro-cyclicality, knowledge spillover effects play their part too. In particular, diffusion and implementation by imitators tends to takes place during recessions when the time to reverse engineer the spllied-over idea before the next boom is longer. Therefore, private innovators will refrain from incurring spillover risks and will tend to invest in R&D during booms instead. Those that support the counter-cyclicality of R&D investment suggest that downturns influence resource allocation at the firm level according to 'opportunity-cost' criteria (see Saint-Paul, 1993). Specifically, recessions lower expected sales. As a consequence, the opportunity cost of undertaking R&D activities in terms of foregone profits, is lowered as well. Therefore, firms will find it profitable to allocate resources to R&D during recessions and to the shop-floor during expansions. This approach is informed by the Schumpeterian view of the business cycle and by Hall's reorganizational capital theory (1991). According to both, recessions have a cleansing role as they encourage firms to restructure, replace and innovate. In this respect, however, Aghion and Saint-Paul (1998) specify that such set-up will only hold when productivity enhancing investment is costly but this cost does not hinder current production activities. In fact, when the costs are higher and may disrupt current production, pro-cyclicality holds instead. Furthermore, Aghion et al. (2008) and Rafferty and Funk (2008) show that the existence of an asymmetry in binding constraints causes cash-flow constraints to bind more during recessions than expansions. This results in firms' R&D disinvestment during recessions being greater than their increase in R&D investment during expansions. Likewise, the 'opportunity-cost' effect is shown to bind more during booms than slumps. As a result, firms will tend to relocate resources away from R&D and towards the productive compartment when positive demand shocks occur, but the opposite is unlikely to happen (to the same extent), during negative demand shocks. Relying on the same methodology used by Aghion et al. (2008), Bohva-Padilla et al. (2009) additionally prove that both pro-cyclicality and counter-cyclicality of R&D are confirmed. The first, however, is more likely to hold for small and medium-sized firms, which tend to experience binding credit constraints the most; whereas, the second characterises non-credit constrained firms, such as MNCs or subsidised firms. It follows, therefore, that for small and/or credit-constrained firms, as well as for all enterprises exposed to the negative impact of downturns, counter-cyclical mechanisms need to be in place in order to maintain their incentive to innovate.

3. Model and Data

The econometric analysis aims to test the various claims made in the literature, as to the direction and size of the impact that macro-volatility has on private R&D investment. The choice of regressors included in the model specification has taken into account and sought comparison with a variety of stability/instability indicators used in the literature, and with various control variables which have been used by the literature on the determinants of innovative investment. The dataset has been constructed by merging various databases reporting measures of business R&D for both developed and developing countries (OECD STI, UNESCO S&T, RICYT – see Appendix A for details).[6] As a result, our panel covers 15 years, from 1994 to 2008, and 66 countries, so that the maximum sample includes 956 observations. Due to missing data, however, the actual estimated panel is reduced to 48 countries and 288 observations. Sub-Saharan African countries, excluding

[6] Correspondence of measurement units has been ensured and discrepancies have been solved prior to the dataset merge. This has been achieved by making sure the overlapping sections of the various databases were rebased in the currency denomination year of the one that contained the most variables. Moreover, the unit of measurement has been homogenized across the various sources and million dollars have been used as the base unit. Finally, where data discrepancies were encountered, the formally identical data definition has been explored in detail to subtract the components which made measures different in practice.

Uganda and South Africa, do not collect secondary data on innovation at all. Therefore, the panel suffers from an underrepresentation of African countries that needs to be acknowledged. All the sources used for the collection of the dataset and the country list are shown in Appendix A.

The benchmark econometric specification is as follows:

$$y_{it} = \alpha_i + \delta_t + \sum_{j=1}^{j} \beta_j X_{j,it-2} + \sum_{l=1}^{l} \gamma_l Z_{l,it} + \sum_{m=1}^{m} \theta_m V_{m,it} + \varepsilon_{it} \quad (1)$$

where the dependent variable, y_{it}, is *BusinessR&D*, the share of investment in R&D financed by the domestic business sector, calculated as a % of GDP. The right hand side of the regression includes a vector of time-invariant country fixed effects, α_i, a vector of time-varying common effects, δ_t,, and the error component ε_{it}. The $X_{j,it-2}$ and $Z_{l,it}$ vectors contain, respectively, lagged endogenous control variables and exogenous control variables in levels. Finally, the vector of $V_{m,it}$ is formed by volatility measures, the impact of which is the object of this analysis.

Starting with the endogenous controls, $X_{j,it-2}$ contains the share of publicly financed R&D, *GoverR&*D. This is included to account for the role of public tangible and intangible infrastructure and to verify whether its impact on private R&D spending has a complementary or a crowding out effect. As public and private R&D can be co-determined, $GoverR\&D_{t-2}$ enters the regression in the form of its second lag; which serves to correct for the potential endogeneity bias on its coefficient. The same applies to all the other variables contained in $X_{j,it-2}$. The other variables included in this vector are *LogGDP*$_{t-2}$, that is, GDP per capita (in logs), and its interaction with the dummy *HI*.[7] This takes the value of 1 if the country is a high-income country, according to the World Bank Atlas classification system, and zero otherwise.[8] GDP per capita is included to control for the level of development of the countries in our panel. Its interaction term, *LogGDPhi*$_{t-2}$, on the other hand, has been included to control for the possible non-linearity of the relationship between the level of development of an economy and its private innovative spending.[9]

The $Z_{l,it}$ vector contains exogenous control variables The real interest rate, *IntRate*[10]is routinely used as a determinant of investment in the literature (Rafferty, 2003b; Aghion *et al.*, 2008; Rafferty and Funk, 2008; Bohva-Padilla *et al.*, 2009; Becker and Pain, 2003; Escaleras&Thomakos, 2008). The type of interest rate considered is the lending interest rate charged to businesses by commercial banks, with a maturity of 3 months to 1 year. The choice of this type of interest rate over the short term rate (1 month to 3 months) or long term rate (around 10 years) aims to target medium-term investment decision dynamics. A measure of trade openness (*TradeOpen*), calculated as the sum of exports and imports as a % of GDP, is also included. We expect this variable to have an impact related to the contribution of international exchange to the

[7] The relevance of human capital and educational levels for the innovation process has been highlighted by both theory (Lucas, 1988; Mankiw, Romer and Weil, 1992; Acemoglu and Zilibotti, 2001) and empirics (Wang, 2010). The reason why such a variable is excluded from our analysis is due to its high correlation with GDP.

[8] The list of HI countries is available in Appendix A

9 This hypothesis of a non-linear pattern is confirmed by a visual inspection of the data in our sample and by a plot of LogGDPt-2 against BusinessR&D. In particular, the plot suggests that the positive effect of the level of development on private innovation sets in after a certain income threshold and only exists in HI countries.

[10] Its square, *IntRateSq*, is also included to capture potential non-linear effects.

ease and pace of innovation and technological progress. This variable has been included in previous studies and tested as one amongst the most relevant determinants of innovative investment (Smolny, 2003; Sameti *et al.*, 2010). Finally, this vector also contains *ExchRate*, the nominal exchange rate level, together with the interaction between the latter and an *EMU* dummy, which takes the value of one only for those countries which joined the European Monetary Union (EMU), in the year they switched currency regime. The level variable is meant to take into account the impact of a currency appreciation/depreciation, which would be brought about by changes in export and/or import capacities. The interaction, instead, controls for the structural break taking place when the EMU regime is adopted, by correcting for the switch in measurement units.[11]

Finally, the $V_{m,it}$ vector contains various measures of volatility that cover and proxy for all aspects of macroeconomic instability. They represent indicators of volatility associated with real, monetary, and political variables proxying for the overall soundness of the macroeconomic environment. Specifically, the $V_{m,it}$ vector contains: a measure of overall government deficit/surplus, named *Balance*. *Balance* proxies for the quality of public account management. While, strictly speaking, this does not represent a coefficient of instability, it does give a measure of fiscal reliability, and it has been used in other studies in the same way (Burnside and Dollar, 2000; Fisher, 1993). In other words, the way a government keeps its finances, accumulates its debt load, and maintains the manageability of its budget are all indicators of the soundness and reliability of its policies. *PolInstab* is an indicator of political and institutional stability named 'State Fragility Index' in the Polity IV database. The index is constructed as a weighted average of

[11] Most EMU countries joined the currency union in 1999; the rest of the EMU countries in our sample have joined the union between 2001 and 2007. When the switch takes place LCU denominated exchange rates turn to euro denominations, therefore the EMU dummy is needed to take into account the break and to avoid biasing the estimation.

various political legitimacy and economic effectiveness indicators. In particular, its score is higher for countries where the occurrence of wars, coups d'état and short-lasting political regimes is more frequent. The rationale for including a measure of political stability relates to the likelihood with which a political regime change influences the macroeconomic environment as a whole, by switching policy, tax and incentive regimes, and by shifting around economic targets and priorities at the national level (Fosu, 1992; Alesina et al., 1996). Also, more so in developing countries where this happens rather openly, corruption and rent-seeking behaviors influence the allocation of resources (Alesina et al., 1996): if the group/coalition in power changes, the whole network of interactions, resource allocation and power relations can change, thereby bringing an abrupt alteration in investment profitability and opportunities. The vector also includes *ad hoc* measures of real and monetary volatility, which have been constructed using the coefficient of variation of real interest rate (*IntRateCoV*), exchange rate (*ExchRateCoV*), and GDP per capita (*LogGDPCoV*). The volatility of the interest rate, along with that of the exchange rate, is used to proxy for the volatility of the monetary policy framework. Moreover, the volatility of the exchange rate is also used to proxy for the level of international volatility. In particular, this is meant to capture the fact that a great part of the innovation performed in developing countries is not sold domestically. Once again, the interaction between the volatility of the nominal exchange rate and the *EMU* dummy (*ExchRateCoVEmu*) controls for the structural break induced by the European Union membership, as explained in the above section. In this case, however, the interaction is used to measure and account for the increased stability that the introduction of the common currency regime has introduced in the nominal exchange rate levels of the EMU countries. Finally, the volatility of GDP per capita is intended to proxy for the instability in the real sector of the economy. In other words, the coefficient on this volatility index measures the variability in the level of overall savings and aggregate demand.

A great part of the literature agrees on the coefficient of variation (C.o.V.) being a more robust indicator with respect to the standard deviation (SD); as not only the latter is an absolute measure, but it also is very sensitive to noise in the data (see Mobarak, 2005; Klomp & de Haan, 2009). To the contrary, the division by the mean implied by the C.o.V. creates a discounted relative measure, which allows to take into account co-movements between similar countries, due for example to the effect of common business cycle patterns (Klomp & de Haan, 2009).[12] Nonetheless, there is still much controversy as to which of the two measures is more appropriate when different variable specifications are used. For this reason, we test the CoV results' robustness using the SD.

Macroeconomic volatility does not enter the regression specification in lagged form because it is extremely unlikely that such a small component of GDP such as innovative investment financed by the private sector can cause real, monetary, and/or political instability, as measured by the CoV of the variables reported above.[13] All the other variables are divided, as already said, in endogenous and exogenous ones. Just to reiterate, for the former, their own second lag has been used as a way of instrumentation. This choice has been made both in the simple Fixed Effects (FE) model, which we estimate first, and in the 2SLS-FE model, which constitutes our chosen estimation technique. In the next section, the results of the simple FE panel are followed by those of the 2SLS-FE panel, in order to compare the gains in terms of unbiasedness achieved by means of the second technique. To be more specific, the FE model only deals with time invariant country specific fixed effects and, in that context, we take care of the endogeneity of the $X_{j,it-2}$ vector variables by lagging all the variable contained in that vector. In the 2SLS-FE panel, instead, the advantages of the fixed effects methodology are coupled with a different instrumentation technique. The latter is structured in two stages of estimation and the entire set of exogenous (or internal) instruments is used to proxy for

[12] Appendix B contains technical details on the construction of these volatility measures.

[13] The average private R&D spending in our sample is just about 0.7% of GDP (see Table 1)

the whole set of endogenous variables. At the same time all the exogenous variables in vector $Z_{l,it}$ are used as instruments for themselves (external instruments).

3. RESULTS

The benchmark regression reported in equation (1) is estimated in its basic, more parsimonious, form first and then in its extended form when all volatility indices are included. The results of the FE estimator are reported in *Table 2*, while the results of the 2SLS - FE estimator appear in *Table 3*. We start with column (1) of *Table 2*, which reports the results of the most basic regression specification estimated, that includes: GDP per capita and its HI interaction, public R&D, the interest rate and its square, the exchange rate and its EMU interaction, trade openness and budget deficit. Subsequently, as we move to the next columns, real volatility, monetary volatility and political instability indices are added one at a time in each set of results; this is done in order to examine their individual as well as their joint effect on private innovative spending. Column (5) appears in bold type because it reports our benchmark regression specification as detailed in equation (1).

[*Table 2 about here*]

As we can see in *Table 2*, the non-interacted level of development is never significant, regardless of the regression specification being estimated, whereas $LogGDPhi_{t-2}$ takes on the expected positive sign. One possible interpretation of this result is that the level of a country's economic development is relevant when explaining private innovate investment only after a certain threshold value of GDP per capita. $GoverR\&D_{t-2}$ also has a positive sign and retains its high significance throughout the estimation set, a result which points in the direction of a complementary rather than a crowding out effect of public R&D. This result confirms the findings of Becker and Pain (2003) and Sameti *et al.* (2010). The real interest rate shows a negative but diminishing effect on innovative investment. This is to be expected if the interest rate is taken to represent the cost of borrowing capital by private enterprises. The level of the nominal exchange rate as well as its interaction with the EMU dummy are never significant, and equally insignificant turns out to be the volatility of the exchange rate and the interaction term of the latter with EMU, as shown in column (4) and (5). The degree of openness to trade has a positive and significant impact on *BusinessR&D* at the 10% level. This result is in line with both the empirical literature (Smolny, 2003; Sameti *et al.*, 2010; Wang, 2010) and the theoretical literature (Porter, 1990; Lundvall, 1992; Nelson, 1993) that show how international openness is likely to result in a positive impact on technological progress, due to increased external exposure and interaction. Turning to the examination of the instability indicators, *Balance* has a very highly significant positive impact on *BusinessR&D*. The magnitude of this impact increases further as we move from left to right in the table. We can interpret this coefficient to signify that in our panel there is evidence of a positive relationship between improved fiscal performance and innovative investment. Moving our attention now to the CoV macro-volatility indices, column (2) reports the results of the inclusion of real volatility only. *LogGDPCoV* enters the regression with a negative sign, as expected, and an absolute coefficient of 0.1, which actually increases in both significance and magnitude as more volatility indices get added and reaches 0.18 in column (5). A sizably lower but still very significant and negative impact is born by the monetary volatility index and by the political instability index.[14]All these results remain substantially the same when endogeneity is taken into account, via the use of 2SLS with fixed effects (*Table 3*).

[14] A quantitative interpretation of the C.o.V. indices is given in the next paragraph, when the results of the 2SLS-FE preferred estimation technique are described.

[*Table 3 about here*]

In fact, the lack of significance of the estimate on $LogGDP_{t-2}$ carries over to this analysis, as well as the very strong positive impact that the level of development has on private R&D spending when interacted with *HI*. The one result that is cconsiderably different from the simple FE set of results is the coefficient of $GoverR\&D_{t-2}$, which from about 0.2 in *Table 2* reaches a coefficient of 0.82 in the benchmark regression specification in column (5). This indicates that a 0.5% increase public R&D will lead to a 0.41% increase in private R&D spending, which is quite high, considering that the average private R&D spending in our sample is just about 0.7% of GDP (see *Table 1*). The impact of the interest rate and that of the exchange rate and its interaction with *EMU* carry over from *Table 2*. The same stands for the impact of *ExchRateCoV* and its interaction term *ExchRateEMU.* Note that the lack of significance of such variables in our sample is reflected in the literature; where much of the evidence on the relationship between exchange rate regimes and export volumes is rather inconclusive (see Wang and Barrett, 2007 for a review). *TradeOpen*, on the other hand, appears to have again a quite substantial positive impact on private innovation. In our panel, 0.5% increase in trade openness, measured as the sum of exports and imports over total GDP, leads to a 0.11% increase in *BusinessR&D*. The coefficient of *Balance*, once again, confirms the importance of the quality of the macroeconomic environment for innovative undertakings by the private sector. The estimates of the 2SLS model suggest that a 1% increase in surplus (or decrease in deficit) leads to a 0.02% increase in innovation spending. It is easier to appreciate the magnitude of this impact if one considers that the value of *BusinessR&D* in our sample ranges between a minimum of 0.000028% and a maximum of 3.40% of GDP (*Table 1)*. With regards to the volatility measures, the increase in one standard deviation of the real volatility CoV results in a decrease of about 0.2% points in private R&D spending. In the case of monetary volatility, as proxied by the CoV of the real interest rate, one standard deviation increase in the CoV of *IntRateCoV* leads to a decrease of

0.012% points in *BusinessR&D*. These results are in line with the microeconometric literature reported above (Rafferty, 2003a; Aghion *et al.*, 2008; Rafferty and Funk, 2008; Bohva-Padilla *et al.*, 2009), which finds a negative impact of both real and monetary volatility on R&D spending. Finally, *PolInstab*, also appears with a very similar coefficient to the one estimated using simple FE. That is, a 1 point increase in political instability, as measured by the Polity IV "State Failure Index", leads to a 0.027% decrease in *BusinessR&D*. This type of relationship is in line with the results of Barro (1991), Fosu (1992), Alesina *et al.* (1996), and Fosu (2003). Our results also reflect the arguments put forward by Rodrik (1989) and by Fanelli and Frenkel (1995), who warn that the biggest risk implied by political instability lays in its recurrence and persistence, which leads economic agents to change expectations and behaviors as a response. In particular, Rodrik (1989) shows that uncertainty on policy stability acts as a tax on investment. In fact, expectations are based on both the subjective probability attached to policy reversal and on the magnitude of investment irreversibility. The former is very high in developing countries, while the latter is very high for R&D investment. This combination is therefore likely to be the cause of the detrimental impact that political instability has on *BusinessR&D* in our findings.

It has to be emphasised that all volatility measures, with the exception of the exchange rate volatility index, appear in the result set with robustly negative coefficients, regardless of whether they are tested on their own or jointly. Indeed, their magnitude increases with the inclusion of additional volatility indices and controls. Furthermore, they retain their significance across the different estimation techniques and regression specification sets, despite the inclusion of time controls, which are used to correct for the effect of both common shocks and the business cycle.[15]

[15] Also note that *LogGDPCoV* is the volatility of the log of GDP per capita, and not of GDP per capita in levels. However, even with this specification, the effect of real volatility is highly significant.

4. ROBUSTNESS ANALYSIS

In order to check the robustness of these findings, we, firstly, test the same model of the benchmark regression in column (5) of *Table 3* using the standard deviation as an indicator of volatility rather than the coefficient of variation. Secondly, we include a number of additional controls to the benchmark model, and, finally, we restrict the sample to a set of high-income countries, so as to examine the differential impact that volatility has on the amount of private spending in R&D, conditional on a higher level of economic development. This is done because higher levels of economic development are likely to be also reflected in lower financial constraints, more developed financial markets and better ability of the private sector to cope with volatility and recessions, or even its capacity to benefit from such fluctuations. As anticipated, the latter hypothesis has been put forward by part of the literature reported above (Hartman, 1972; Abel,1983; Hall, 1991; Saint Paul, 1993 Hall, 1991; Pindyck and Solimano,1993; Saint-Paul, 1993; Dehn, 2000). This hypothesis is supported by our own panel's results.

Starting with the model where the SD has been substituted to the CoV, we are going to focus on column (1) of *Table 4* first.

[*Table 4 about here*]

The results show now that both $LogGDP_{t-2}$ and $LogGDPhi_{t-2}$ are significant, albeit of different sign, pointing in the direction of a negative effect of very low levels of development on innovative investment by the private sector. All the results previously reported with regards to public R&D, the interest rate and its square, exchange rate levels and their EMU interaction term, trade openness and balance remain intact. When real, monetary and international volatility are measured with the

SD, all three measures are significant. In fact, the exchange rate level gains significance, although this result cannot be considered as robust. In addition, the finding seems to be counter-intuitive as it suggests that a depreciation will decrease innovative investment.[16] This can be interpreted to represent the import-intensive nature of innovation in developing countries. In other words, lower purchasing power of a developing country's currency will result in decreased capital good and input imports. This will in turn lead to lower innovative investment. Both *LogGDPStDev* and *IntRateStDev*, instead, retain their significance and negative relationship with private R&D spending, even though the magnitude of both volatility coefficients is now smaller when compared to the results of column (5) in *Table 3*. Finally, the index of Political Instability retains its significance and appears with a slightly increased coefficient magnitude.

Moving now to column (2) of *Table 4*, we present the set of results deriving from the inclusion of a number of additional regressors. *Democracy* is taken from the same Polity IV dataset from which *PolInstab* is taken. This indicator attaches a score of 10 to very democratic countries and 0 to autocratic regimes. This control is meant to proxy for the quality of institutions; however, it appears to be insignificantly different from zero. Such result could be a sign of political instability being a more important determinant of investors' confidence and willingness to fund innovation projects than the quality of the institutional background. A measure of property rights protection is also included; which is an index constructed by Economic Freedom of the World (EFW). This control is added to test whether physical and intellectual property right security has any impact on the amount of innovative investment undertaken by the business sector. The insignificance of this measure is debatable; nonetheless it confirms Wang's (2010) results in his analysis of the

[16] For evidence of a negative impact of exchange rate volatility on agricultural productivity, see Barrett *et al.* (2006). For evidence of a positive relation between exchange rate volatility and overall fixed investment, see Escaleras and Thomakos (2008).

determinants of fixed investment. Finally, a variable measuring the amount of high-tech exports as a %GDP has also been included. This variable has been instrumented with its second lag to account for its likely endogeneity. Once again this control appears with an insignificant coefficient in column (2). It does not, however, alter all other volatility indices and control variables. In fact, it is possible to see in column (2) of *Table 4* that the volatility measures' significance and their magnitude have actually increased following the inclusion of these new regressors.

Finally, column (3) reports the results of the benchmark regression estimated on a panel of OECD economies. This reduced panel covers a longer period: 28 years, from 1981 to 2008, it counts 22 countries and sums up to 321 observations. As anticipated, this is done in order to estimate the impact of volatility conditional on the different development level attained by this high-income group of countries. An additional implication of this test is that it allows to assess whether the type of production landscape - and especially the size of the enterprises forming this landscape - influences the impact that volatility has on the share of domestic private R&D spending. Such hypothesis has been tested by part of the previously reported literature (Rafferty and Funk, 2008; Aghion *et al.*, 2008; Bohva-Padilla *et al.*, 2009), and the results shown in Column (3) are in line with both the main findings of this literature and with the strand of literature that posits the pro-cyclicality of innovative investment (see Saint-Paul, 2003). In particular, the positive coefficient exhibited by real volatility, *LogGDPCoV*, lends some evidence to the arguments inscribed in the Schumpeterian creative destruction theoretical framework. The monetary volatility index, represented by *IntRateCoV*, retains its negative impact. The positive sign exhibited by the levels of real interest rate, instead, seems puzzling at first sight. However, in light of the fact that this panel is very homogeneous and that in developed countries the risk attached to investment is much lower, this result can be interpreted to represent the rate of return on investment projects. A new indicator of political instability, *Xconst*, measures the degree of constraints put on the executive at the institutional level.[17] It attaches a higher score to more democratic countries, where the executive power is limited by other authorities and a score of zero to autocratic regimes. Because both the degree of democracy and the institutional background setting are broadly homogenous among all countries contained in this HI panel, the coefficient on this variable turns out to be insignificant. A result which is likely to be due to the lack of variation in the data. Some similar considerations can be made with regards to the level of development. In fact, the coefficient of $LogGDP_{t-2}$ appears to be non-significantly different from zero. This result is again probably attributable to the fact that there is very little variation in the level of personal income in the countries contained in this sample. An interesting result is the fact that, even in this sample, the amount of public R&D spending financed by the government retains a positive impact on *BusinessR&D*. *TradeOpen* has not been included in this regression due to the fact that all high-income countries in this panel are internationally open to the same degree. *Balance,* on the other hand, turns insignificant, which is likely to be due to the higher confidence investors place in public finances of developed countries. The level of *ExchRate* now has a positive impact on *BusinessR&D*. While its coefficient is not very high in economic terms, its significance lends mild evidence to the familiar dynamic whereby export expansions follow currency depreciations (see Wang and Barrett, 2007, for a similar argument).

5. Policy Implications and Conclusions

This paper has sought to study the impact of macroeconomic instability on private innovative investment in the form of R&D. The innovation of the paper has been threefold. Firstly, a

[17] *PolInstab* could not be used in this regression due to the different time coverage of the HI sub-sample. As already mentioned, the HI panel starts in 1981, whereas the 'State Fragility Index' by Polity IV only covers the years from 1994 onwards.

comprehensive mixed developed-developing economies panel has been constructed and a macroeconometric approach has been adopted. Secondly, various indices of real, monetary, and political instability have been tested according to various econometric and economic specifications. Their negative impact on private R&D spending has been shown to be not only robust, but also insensitive to the inclusion of additional controls and to changes in the measurement procedure. Thirdly, the macro-instability indices retain their significance both when tested individually and when tested jointly, allowing us in this way to disentangle the individual effect of each of the various macro-instability components.

It has been argued that lack of private R&D investment is likely to result in low levels of growth and development. The question of why the domestic private sector of developing countries is neglecting innovation, and therefore failing to reap the high-returns of this type of investment activity, has been asked at the outset. Innovation has been classified as a high-budget, long maturity horizon type of investment. Due to these features, uncertainty of the macroeconomic environment has been suggested as a potential answer for the lack of private R&D investment engagement exhibited by most developing countries in our sample. As mentioned above, the econometric findings reported in this paper support such hypothesis and suggest three ways in which macro-volatility can affect R&D investment. In particular, political instability, real volatility and monetary volatility are shown to have a negative impact on the share of R&D financed by the domestic business sector in a mixed panel of 48 countries. Subsequently, it has also been shown that, when the same estimation is performed on a sample of high-income countries, only monetary volatility retains a negative impact, while the coefficient of the real volatility measure is positive and signals the presence of creative destruction effects in our sample.

The above results highlight the need for counter-cyclical policy interventions aiming to prevent the avoidance or abandonment of R&D investment by developing countries' domestic firms. Vidal (2008) reports in her study of the entrepreneurial sector in Latin American countries that half of the businesses in the region fails to survive the set-up phase, and shows how abandonment of investment projects is as important a problem as the avoidance of investment altogether. Moreover, Rodrik (1989) shows in his calculations that when investment irreversibility amounts to three-quarters of the cost of installed capital, a 20% investment reversal probability due to instability calls for a 15% point public investment subsidy. The latter is needed to offset the losses due to uncertainty and it is necessary to keep alive both the investment profitability and the incentive to innovate. In conclusion, a policy implication which is possible to draw from this study is that if avoidance and/or abandonment of innovative projects are to be prevented in the face of uncertainty, policy interventions should follow a counter-cyclical pattern. In other words, they should aim at smoothing out downturns and at providing complementary infrastructure, R&D spending and innovation subsidies to firms when negative shocks hit. This would guarantee a continuity of cash flows and return opportunities over time to firms engaging in innovation in unstable macroeconomic environments.

APPENDIX A

I. DATA SOURCES

BUSINESS R&D	Share of total R&D spending (%) financed by the private sector	OECD.Stat Main Science and Technology Incidators (MSTI - 2010) UNESCO UIS Science&Technology (S&T - 2010) Red Indicadores Ciencias YTecnologia (RICYT - 2009)

GOVERNMENT R&D	Share of total R&D spending (%) financed by the public sector	OECD.Stat MSTI Database (2010) UNESCO UIS (2010) RICYT (2009)
GDP PER CAPITA	GDP/midyear population. Data are in constant 2000 US$	World Bank-WDI (2010)
INFLATION RATE	Rate of Inflation (CPI based)	IMF - International Financial Series (IFS, 2010)
REAL INTEREST RATE	Lending Interest Rate minus Inflation Rate	WDI and IMF's IFS series--Author's calculation
OFFICIAL EXCHANGE RATE	Exchange Rate value (LCU per US$)	World Bank-WDI (2010) IMF - International Financial Series (IFS, 2010)
BALANCE	Overall Deficit/Surlpus (%GDP)	IMF – Government Financial Statistics (GFS, 2009)
EXPORTS/IMPORTS	Trade (% GDP)	World Bank-WDI (2010) OECD National Account Stats (2010)
DEMOCRACY	I ndex of Democracy that takes the value of 10 for very democratic countries and 0 when the institutions are very authoritarian	POLITY IV Dataset (2010)
STATE FRAGILITY INDEX	Index based on state legitimacy, political instability and economic effectiveness. It takes the value of 21 for very unstable political environments and 0 for very stable ones	POLITY IV Dataset (2009)
XCONST	Institutional Constraints on the Executive. It takes the value of 7 for countries where	POLITY IV Dataset (2010)

	the power of the executive is constrained by institutional mechanisms and 0 when the government is very authoritarian	
HIGH-TECH EXPORTS	Share of High-Tech exports over GDP	World Bank-WDI (2010)
PROPERTY RIGHTS PROTECTION INDEX	Indicator of enforcement of property rights protection. It takes the value of 1 when property rights are very well protected and 7 when security of property rights is not ensured	Economic Freedom of the World (2010)

II. COUNTRY LIST

Argentina	Denmark**	Israel**	Norway**	South Africa
Australia**	Estonia*	Italy **	Panama	Spain**
Austria**	Finland **	Korea Rep.**	Paraguay	Sweden**
Belgium**	France**	Kuwait	Philippines	Switzwerland**
Bolivia	Germany**	Latvia*	Poland*	Thailand
Brazil	Greece**	Lithuania	Portugal**	Uganda
Bulgaria	Hungary*	Malaysia	Romania	Ukraine
Canada**	Iceland**	Malta*	Russia	United Kingdom**
China	India	Mexico	Singapore*	United States**
Colombia	Iran	Mongolia	Slovak Rep*	Uruguay
Cyprus*	Ireland**	Netherlands**	Slovenia*	Venezuela
Czech Rep*				

*High-Income countries (according to the ATLAS classification system)
** OECD economies included in the robustness analysis panel

APPENDIX B

The Coefficient of Variation (C.o.V.) is calculated across a two year rolling window; its measure is defined as the ratio of the standard deviation to the mean of the rolling window. A backward looking strategy has been used[18] to reflect the type of knowledge agents might have of volatility at time *t*, which is attained by comparing the volatility levels prevailed at time *t-1* with those of time *t*. The standard deviation is calculated according to the following formula:

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - x)^2} \qquad (1)$$

Whereas the C.o.V. is obtained as:

$$v = {}^{\sigma}/_{\mu}$$

Where σ is the standard deviation as defined in (1) and μ is the mean calculated across a two-year rolling window.

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[18] i.e. real volatility for year 2000 has been calculate across the two year period corresponding to 1999 and 2000; that of 2001 uses information from 2000 and 2001 and so on.

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Table 1. Summary Statistics

VARIABLE	MEAN	ST. DEV.	MIN	MAX	OBS.
BUSINESSR&D	0.674	0.7	0.000028	3.40	585
GOVERR&D	0.45	0.25	0.02	1.18	542
GDPPC	12525	11632	193.5	56639	811
GDPPCHI	11030	12382	2271.3	56639	811
INTRATE	9.7	12.7	0.128	130.7	680
EXCHRATE	288	985.7	0.03	11786	815
BALANCE	-0.88	4	-21.5	23.4	578
TRADEOPEN	0.9	0.62	0.15	4.38	803
POLINSTABILITY	4.7	5.2	0	21	741
LOGGDPCOV	0.3	0.26	0.0002	2.79	812
INTRATECOV	0.52	2.2	0.0005	45.9	675
EXCHRATECOV	0.06	0.09	0	0.84	815

Table 2.

	FE				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
LOGGDP$_{t-2}$	-0.21	-0.21	-0.088	-0.09	**-0.3**
	(0.18)	(0.18)	(0.19)	(0.2)	(0.23)
LOGGDPHI$_{t-2}$	0.59***	0.52***	0.45**	0.44**	**0.52****
	(0.18)	(0.18)	(0.2)	(0.21)	(0.21)
GOVERR&D$_{t-2}$	0.21**	0.22*	0.23**	0.24**	**0.24****
	(0.11)	(0.11)	(0.11)	(0.12)	(0.12)
INTRATE	-0.006**	-0.006**	-0.007***	-0.007**	**-0.007*****
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
INTRATE^2	0.00005*	0.00006**	0.00008**	0.00007**	**0.00007****
	(0.00003)	(0.00003)	(0.00002)	(0.00003)	(0.00003)
EXCHRATE	- 0.0001	- 0.00008	- 0.00008	-0.00007	**-0.00007**
	(0.00008)	(0.00008)	(0.00008)	(0.00008)	(0.00008)
EXCHRATEEMU	- 0.02	- 0.03	- 0.02	-0.026	**-0.018**
	(0.03)	(0.03)	(0.03)	(0.043)	(0.043)
TRADEOPEN	0.1	0.13*	0.14*	0.183*	**0.186***
	(0.08)	(0.08)	(0.08)	(0.09)	(0.1)
BALANCE	0.014***	0.014***	0.017***	0.019***	**0.019*****
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)
LOGGDPCOV		-0.1*	-0.13**	-0.16*	**-0.18*****
		(0.05)	(0.06)	(0.06)	(0.06)
INTRATECOV			-0.013**	-0.0137**	**-0.014****
			(0.006)	(0.006)	(0.006)
EXCHRATECOV				0.06	**0.13**
				(0.14)	(0.15)
EXCHRATECOVEMU				-0.003	**-0.07**
				(0.23)	(0.23)
POLINSTAB					**-0.026***
					(0.013)
N. Obs.	319	319	314	293	293
N. Groups	57	57	57	53	53
R^2	0.29	0.29	0.30	0.28	0.25

Notes: All columns report coefficient estimates based on FE. Column (5) corresponds to the specification described in equation (1).
*** significance at the 1% level **significance at the 5% level *significance at the 10% level

Table 3.

	2SLS – FE				
	(1)	(2)	(3)	(4)	(5)
LogGDP$_{t-2}$	-0.22	-0.25	-0.15	-0.18	**-0.41**
	(0.17)	(0.18)	(0.18)	(0.19)	(0.26)
LogGDPHI$_{t-2}$	0.57***	0.47***	0.44**	0.44**	**0.51*** **
	(0.18)	(0.173)	(0.17)	(0.18)	(0.17)
GoverR&D$_{t-2}$	0.64*	0.73**	0.75**	0.79**	**0.82** **
	(0.34)	(0.35)	(0.35)	(0.38)	(0.37)
IntRate	-0.005*	-0.006**	-0.006**	-0.006**	**-0.007** **
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
IntRate^2	0.00004**	0.00006***	0.00007***	0.00008***	**0.00007*** **
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)
ExchRate	-0.00008	-0.00006	-0.00005	-0.00006	**-0.00005**
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
ExchRateEmu	-0.01	-0.016	-0.006	0.0004	**0.007**
	(0.03)	(0.03)	(0.03)	(0.05)	(0.04)
TradeOpen	0.097	0.16*	0.15*	0.213**	**0.23** **
	(0.07)	(0.08)	(0.08)	(0.094)	(0.09)
Balance	0.015**	0.016***	0.019***	0.02***	**0.021*** **
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)
LogGDPCoV		-0.13**	-0.175***	-0.206***	**-0.21*** **
		(0.05)	(0.06)	(0.06)	(0.065)
IntRateCoV			-0.011***	-0.011***	**-0.012*** **
			(0.004)	(0.004)	(0.004)
ExchRateCoV				0.1	**0.13**
				(0.136)	(0.13)
ExchRateCovEmu				-0.013	**-0.034**
				(0.18)	(0.17)
PolInstab					**-0.027***
					(0.016)
N. Obs.	313	313	307	288	288
N. Groups	51	51	50	48	48
R^2	0.30	0.31	0.32	0.34	0.346

Notes: All columns report coefficient estimates based on 2SLS-FE. Column (5) corresponds to the specification described in equation (1).
*** significance at the 1% level **significance at the 5% level *significance at the 10% level

Table 4.

	2SLS – FE		
	(1)	**(2)**	**(3)**
LOGGDP $_{t-2}$	-0.57**	-0.52**	0.18
	(0.25)	(0.26)	(0.2)
LOGGDPHI $_{t-2}$	0.6***	0.47**	
	(0.17)	(0.2)	
GOVERR&D $_{t-2}$	0.7**	0.82**	0.8***
	(0.35)	(0.4)	(0.13)
INTRATE	-0.006**	-0.006**	0.07**
	(0.002)	(0.002)	(0.02)
INTRATE^2	0.00008***	0.00008***	-0.005***
	(0.00003)	(0.00003)	(0.001)
EXCHRATE	0.000	-0.00001	0.0003**
	(0.03)	(0.00007)	(0.00008)
EXCHRATEEMU	-0.01	-0.04	-0.002
	(0.03)	(0.05)	(0.15)
TRADEOPEN	0.16**	0.3***	
	(0.08)	(0.1)	
BALANCE	0.017***	0.02***	0.004
	(0.006)	(0.006)	(0.005)
LOGGDPCOV		-0.27***	0.22*
		(0.07)	(0.14)
INTRATECOV		-0.1***	-0.023***
		(0.004)	(0.008)
EXCHRATECOV		0.2	-0.3
		(0.14)	(0.27)
EXCHRATECOVEMU		-0.12	0.23
		(0.2)	(0.7)
POLINSTAB	-0.03**	-0.03*	
	(0.01)	(0.16)	
XCONST			0.1
			(0.01)
LOGGDPSTDEV	-0.017***		
	(0.6)		
INTRATESTDEV	-0.005*		
	(0.003)		

EXCHRATESTDEV	-0.001**		
	(0.0004)		
EXCHRATESTDEVEMU	0.007		
	(0.0005)		
DEMOCRACY		0.001	
		(0.01)	
PROPERTY RIGHTS		0.007	
		(0.01)	
HIGHTECHEXP $_{t-2}$		0.006	
		(0.005)	
N. Obs.	308	280	336
N. Groups	30	48	22
R^2	0.35	0.34	0.89

Notes: All columns report coefficient estimates based on 2SLS-FE. Column (5) corresponds to the specification described in equation (1).
*** significance at the 1% level **significance at the 5% level *significance at the 10% level