Macroeconomic instability and the incentive to innovate

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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 private sector. The analysis is based on a sample of 48 countries, representing all levels of development, and it estimates various measures of macroeconomic instability, such as political, real and monetary volatility. The results suggest a negative impact of instability on the share of R&D financed by the 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

1. INTRODUCTION

Small, credit-constrained firms and, in general, all enterprises that for the nature of their business are exposed to the negative impact of macroeconomic instability may see their incentive to invest in costly innovation projects vanish in the face of uncertainty. In this respect, it is often argued that

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adequate levels of tangible and intangible infrastructure are key to the development of a thriving entrepreneurial sector, in that they provide the basic support for firms to progress past the start-up phase. This paper argues that in uncertain environments not only the level of infrastructural support is important but also its timing. In other words, if one is willing to agree on innovation being crucial to the generation of competitive advantage, counter-cyclical technology policies need to be implemented to maintain the private sector's incentive to innovate, in the face of uncertainty. More concretely, when exploring the summary statistics (see *Table 1* below) for the data used in this analysis, it is apparent that, with few exceptions, developed countries' share of public R&D is lower than (or just as big as) the private share; whereas in developing countries (often very) low levels of business spending in R&D are accompanied by higher levels of government spending.[2]

[*Table 1 about here*]

This inevitably raises the question of why the domestic private sector refrains from engaging in high-return R&D activities, despite the fact that a higher public effort in the provision of infrastructural support and background takes place. While a number of explanations have been related to structural and historical factors, this paper seeks to answer that question from a different point of view, by bearing in mind two extrinsic characteristics of R&D investment. Firstly, innovation is a risky, long-term maturity, high-budget type of investment (Katz, 1987). Secondly, small and medium-sized firms, particularly in developing countries, are often credit-constrained, especially during recessions (Aghion et al., 2010). Based on this evidence, it is straightforward to hypothesise that R&D may therefore be largely influenced by uncertainty in the surrounding environment, and that firms' undertakings of costly and/or risky innovative plans are likely to be

[2] China, Malaysia, the Philippines, South Africa, Uruguay and Venezuela present some peculiarities, the discussion of which, however, goes beyond the scope of this paper.

hindered in uncertain macro-environments. These claims are supported by the findings of my empirical analysis for the country sample considered. The identification of the most appropriate policy tools to tackle these challenges is beyond the scope of this paper and a separate literature exists concerning the issue. What is being argued on the basis of this paper's findings is that appropriate technology policies should aim to prevent the abandonment and/or avoidance of R&D undertakings as a consequence of uncertainty. The adoption of a counter-cyclical approach can smooth out negative phases so as to allow for continuity of private profitability horizons.

In terms of the contribution of this paper: a number of studies have previously dealt with the implications of macroeconomic fluctuations on macro-performance,[3] however, some adopted a more general focus on the effects of volatility on overall private investment, with conflicting results (Hartman, 1972; Abel, 1983; Dehn, 2000; Pindyck and Solimano, 1993; Bernanke, 1980; Federer, 1993; Serven, 2003, Aghion et al., 2010). But only a few looked at the specific link between downturns and innovative private investment, in the form of R&D expenditure (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). Conflicting results arise in this sub-set of the literature too. In addition, all these papers take into account specifically the impact of recessions and crises on private R&D; but not on the impact of volatility in the occurrence of such crises, which is instead the focus of the present study. On the other hand, due to scarcity of developing country secondary data on innovation (Goel and Ram, 1999; Aghion et al., 2010; Agénor and Neanidis, 2011), most empirical studies take up a microeconometric approach, using firm-level data or examining OECD-based firms only. This paper adopts, instead, a macroeconometric approach. Further to this, an additional contribution is the construction of a

[3] 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.

comprehensive mixed dataset that includes both developed and developing countries.[4] Finally, a multi-dimensional set of volatility indices is estimated. Specifically, to detangle the contemporaneous aspects in which instability of the macroeconomic environment manifests itself, I utilise a number of proxies for real, monetary and political instability and estimate a separate specific impact for each one of those. All are shown to bear an individual negative impact on private innovation incentives, which still holds even when all other dimensions of instability are included in the estimation at the same time.

The structure of the paper is as follows: Section 2 outlines a brief theoretical background. Section 3 presents model, variables and data. The results along with the robustness analysis are described in section 4 and 5. Section 6 illustrates some policy implications and concludes. Finally, data sources, country list and all methodological considerations 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 investment projects - especially of innovative investment - turn this relationship negative (Bernanke, 1980; Federer, 1993; Goel and Ram, 1999; Aghion et al., 2010).[5] In particular, Bernanke (1980) argues that a range of inaction is created in the

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

[5] Uncertainty is defined as an increase in the variance of future return forecasts. The latter is higher when the future maturity horizon of an investment is long and/or uncertain, which is particularly the case in R&D investments.

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. Goel and Ram (1999) show that the impact of uncertainty is much larger on R&D investment. This is because the latter is highly irreversible due to its large share of expenditure on personnel and equipment which is project-specific and not merely firm-specific or industry-specific in nature. 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.[6] Other contributions place themselves somewhere in the middle: for instance, Sarkar (in Serven, 2003) maintains the link between volatility and investment exhibits threshold effects, with a positive relationship occurring at low uncertainty levels and a negative relationship taking place when the uncertainty rises beyond a critical threshold.

A more recent number of contributions analyses the impact of the business cycle on 'innovative' investment. While this literature can provide some useful insights for the objectives of this paper, it has to be said that its specific focus overlooks the second moment of the business cycles, that is, its volatility, and concentrates on the analysis of the troughs only. 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. Those that argue in favor of the first maintain that a 'cash-flow' effect exists, which financially constrains firms' activities and hinders the undertaking of innovative investment during downturns (Rafferty, 2003a; 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 account for part of the pro-cyclicality, knowledge spillover effects play their part too. In particular, diffusion and

Furthermore, investing in the proximity of the technological frontier requires plenty of funds and firms worry equally about probability of success and size of the investment (Canitrot, in Katz, 1987).

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

implementation by imitators tends to takes place during recessions when the time to reverse engineer the spilled-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, instead, 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 in recessions. 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. Aghion and Saint-Paul (1998), however, specify that such set-up only holds if innovation costs are not very high s to interfere with current production activities, in which case innovation will be pro-cyclical. Along the same line, Aghion *et al.* (2008) and Rafferty and Funk (2008) show that the existence of an asymmetry in binding constraints causes cash-flow constraint effect to bind more during recessions than expansions. This results in firms' disinvestment during recessions being greater than their increase in investment during expansions. Likewise, the 'opportunity-cost' effect is shown to bind more during booms than slumps. As a result, firms 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) show that both pro 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 only, such as MNCs or subsidised firms.

3. DATA AND MODEL

The dataset used for this analysis 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). [7] The panel covers 15 years, from 1994 to 2008, and the baseline 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 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 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 it also includes various control variables which have been used by the literature on the determinants of innovative investment. The benchmark econometric specification is as follows:

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

[7] 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.

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. These represent standard R&D investment determinants commonly used in the literature surrounding the micro and macroeconomic determinants of innovation. Finally, the vector of $V_{m,it}$ is formed by volatility measures, the impact of which is the object of this analysis.

I estimate a simple Fixed Effects (FE) model first, and then a 2SLS-FE model, which constitutes the preferred estimation set. The FE model only deals with time invariant country specific fixed effects and, in that context, I take care of the endogeneity of the $X_{j,it-2}$ vector variables by lagging (second lag) all the variable contained in the vector. However, as explained in Pesaran (2004) and Baltagi (2005), in this context, cross sectional dependence can be a problem. If such cross-sectional dependence is caused by the presence of common factors, which are unobserved but uncorrelated with the included regressors, then the standard FE estimator is consistent. However, if the unobserved components that create interdependencies across cross-sections are correlated with the included regressors, the FE estimators will be biased and inconsistent A solution is the estimation of IV FEs, that is, two stage least squares with FE (2SLS-FE), provided there is not an issue of weak identification (De Hoyos and Sarafidis, 2006). When estimating 2SLS, the entire set of exogenous (or internal) instruments - the lags of the endogenous variables - is used to proxy for the whole set of endogenous variables. Whereas all the exogenous variables, contained in this case in vector $Z_{l,it}$, are used as instruments for themselves (external instruments).

Domestic private R&D spending has been chosen as the dependent variable to examine whether recurrent economy-wide fluctuations affect the incentive and willingness of the private sector to invest in innovation. As discussed previously and as visible in Table 1, developing countries suffer from lack of innovative entrepreneurial undertakings, in absolute terms, but especially when these are compared to the relative share of innovation carried out by the public sector. The latter has therefore been included in the regression specification, in the $X_{j,it-2}$ vector. To be more specific, the share of publicly financed R&D, *GoverR&*D, 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 crowding out effect. As public and private R&D can be co-determined, *GoverR&D* enters the regression in the form of its second lag. The same applies to all the other variables contained in $X_{j,it-2}$.The other variables included in this vector are *LogGDP*, that is, GDP per capita (in logs), and its interaction with the dummy *HI*.[8] This takes the value of 1 if the country is a high-income country and zero otherwise.[9] GDP per capita is included to control for the level of development of the countries in the panel. Its interaction term, *LogGDPhi*, 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.[10]

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[8] 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 variable is excluded from this analysis is because of its very high correlation with GDP.

[9] According to the World Bank Atlas classification system. The list of HI countries is available in Appendix A

[10] The hypothesis of a non-linear pattern is confirmed by a visual inspection of the data and by a plot of $LogGDP_{t-2}$ against BusinessR&D. 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.

The $Z_{b,it}$ vector contains exogenous control variables which represent commonly used determinants of private R&D spending. One of these is the real interest rate, *IntRate*[11]. The use of the latter as a determinant of investment is common (Rafferty, 2003b; Aghion *et al.*, 2008; Rafferty and Funk, 2008; Bohva-Padilla *et al.*, 2009; Becker and Pain, 2003; Escaleras&Thomakos, 2008). The 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. I expect this variable to have an impact related to the contribution of international exchange to the 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 on the level of innovative investment performed. Such indirect impact would be brought about by changes in export and/or import patterns, to which the considerations on *TradeOpen* also apply. The interaction, instead, controls for the structural break taking place when the EMU regime is adopted, by correcting for the switch in measurement units.[12]

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

[12] Most EMU countries in my sample joined the currency union in 1999; the rest between 2001 and 2007. When the switch takes place, LCU denominated exchange rates turn to euro denominations. The EMU dummy takes into account the break to avoid biasing the estimation.

3.1 Volatility Vector: Variables and Construction

Finally, the $V_{m,it}$ vector contains measures of real, monetary, and political instability which proxy 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). *PolInstab* is an indicator of political and institutional stability named 'State Fragility Index' in the Polity IV database. Its score is higher for countries where the occurrence of wars, coups d'état and short-lasting political regimes is more frequent. The reason for including such measure is that political regime changes influence 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 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. In particular, variability in the interest rate influences the cost of capital; whereas fluctuations in the exchange rate affect the export/import incentives of firms. 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.

The interaction between nominal exchange rate volatility and the *EMU* dummy (*ExchRateCoVEmu*) is meant to capture the increased stability that the introduction of the common currency has introduced in the nominal exchange rate. Finally, the volatility of GDP per capita is intended to proxy the instability in the real sector of the economy and the variability in the level of overall savings and aggregate demand.

A great part of the literature agrees now on the coefficient of variation (C.o.V.) being a more robust indicator with respect to the standard deviation; 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).[13] Nonetheless, there is still much controversy as to which of the two measures is more appropriate. For this reason, I test the results' robustness using the C.o.V. first, and, then, the standard deviation. Macroeconomic volatility does not enter the regression specification in lagged form because it is unlikely that such a small component of GDP such as innovative investment financed by the domestic private sector can cause real, monetary, and/or political instability.

4. 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.* Starting with column (1) of *Table 2*, the most basic regression specification estimated includes:

[13] Appendix B contains the technical details on the construction of these volatility indicators.

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, moving from left to right to the next columns, real volatility, monetary volatility and political instability indices are added one at a time in each set of results. Column (5) appears in bold type because it reports the benchmark regression specification as detailed in equation (1).

[*Table 2 about here*]

As visible in *Table 2*, the non-interacted level of development is never significant, regardless of the regression specification, whereas *LogGDPhi* takes on the expected positive sign. One possible interpretation of this result is that the level of a country's GDP per capita is relevant in explaining private innovate investment only after a certain threshold value of economic development. *GoverR&D* also has a positive sign 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. I can anticipate that this is also the case for 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 of significance. 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 shows 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 positive impact on

BusinessR&D, which indicates that a positive relationship between improved fiscal performance and innovative investment exist in the sample considered. The magnitude of this impact increases when moving from left to right in Table 2. Moving the focus now to the C.o.V. 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. Its coefficient increases in both significance and magnitude as more volatility indices get added. Both the monetary volatility index, *IntRateCoV*,.[14] and the political instability index, *PolInstabI* also enter the regression with a negative coefficient.

[*Table 3 about here*]

All these results remain substantially the same in the 2SLS-FEs estimation (*Table 3*). The lack of significance of *LogGDPpc* carries over, as well as the 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 is the increased magnitude of *GoverR&D*'s coefficient. In particular, the coefficient on public R&D in the benchmark regression specification in column (5) indicates that a 1% point increase in *GoverR&D* will lead to an increase in private R&D spending of 0.82% points. This is a non-trivial impact if one considers that the average private spending in R&D in the developing countries subsample of this study is of about 1.12% of their GDP (see *Table 1*). The impact of the interest rate, that of the exchange rate and that of 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 is common 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,

[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.

appears to have again a positive impact on private innovation. In this panel, a 1% point increase in trade openness, measured as the sum of exports and imports over total GDP, leads to an increase of about 0.2% points in *BusinessR&D*. The coefficient of *Balance* confirms the importance of the quality of the macroeconomic environment for private innovative undertakings, although the actual impact size in this sample is not big. The estimate suggests that a 1% point increase in surplus (or decrease in deficit) leads to a 0.02% point increase in innovation spending. Coming to the macro-instability indicators, the results indicate that a one standard deviation increase in the coefficient of variation of output results in a very sizable decrease of about 20% points in private R&D spending. It is easier to appreciate the magnitude of this impact if one considers that the value of *BusinessR&D* in this sample ranges between a minimum of 0.000028% and a maximum of 3.40% of GDP (*Table 1)*. In the case of monetary volatility, one standard deviation increase in the C.o.V. of *IntRateCoV* leads to a decrease of 1.2% points in *BusinessR&D*. These results are in line with the findings of the microeconometric literature reported above (Rafferty, 2003a; Aghion *et al.*, 2008; Rafferty and Funk, 2008; Bohva-Padilla *et al.*, 2009), which also identify a negative impact of both real and monetary volatility on the R&D spending financed by the firms considered in their panels. Finally, *PolInstab* appears with a very similar coefficient to the one estimated using simple FE. Here, a 1 point increase in political instability - as measured by Polity IV's "State Failure Index", which ranges from 0 to 21 - leads to a 2.7% points decrease in *BusinessR&D*, again a non-trivial impact. This type of relationship is in line with the results of Barro (1991), Fosu (1992), Alesina *et al.* (1996), and Fosu (2003), who show empirically that a negative relation exists between political instability and economic growth. My 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 spells lays in their recurrence. In fact, the latter leads economic agents to change expectations and behaviors as a response. In particular, Rodrik (1989) argues that expectations are based on 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 the case of R&D investment. Such combination is likely to be the underlying factor behind the detrimental impact that political instability has on *BusinessR&D* in my 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. Moreover, their significance is increased by the addition of new volatility indices and they retain their significance across the specification sets despite the inclusion of time controls, which are used to correct for the effect of both common shocks and the business cycle. As a final remark, note that the Anderson LM statistic for the under-identification test always rejects the null of under-identification. More importantly, the Wald F statistic used to test for weak identification takes a value of around 10 in all regressions of Table 3. Such value conforms to the rule of thumb according to which a statistics of 10 is enough to consider weak identification not an issue in the panel. This represents an important concern to address because, if instruments are weak, 2SLS may result in standard errors which are too small. Finally, a Sargan statistic for the test of over-idintification is not reported because my regression is exactly identified.

5. Robustness Analysis

To check the robustness of my findings, I, first, substitute the standard deviation to the coefficient of variation for all volatility indicators . Secondly, I include a number of additional controls in order to verify whether the C.o.V. measures retain the same impact. Finally, I use a sample of high-income countries only, to examine the differential impact of volatility in a sample with higher level of economic development. This is done because high-income countries are likely to exhibit lower financial constraints, better developed financial markets, improved ability to cope with volatility on the part of the private sector, or even the capacity of the private sector 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; Dehn, 2000; Pindyck and Solimano, 1993) and by Schumpeter-inspired creative destruction theories (Hall, 1991; Saint-Paul, 1993).

[*Table 4 about here*]

Starting with the model where the standard deviation has been substituted to the C.o.V. in column (1) of *Table 4*, the results show that both *LogGDPpc* and *LogGDPpcHI* are significant, albeit of different sign. This points in the direction of a negative effect which very low levels of development bear on private innovative investment. Public sector spending in R&D retains its positive coefficient, confirming its complementary role. All the results previously reported with regards to the interest rate, its square, the exchange rate and its EMU interaction term, *TradeOpen*, and *Balance* remain intact. Although this result may not be considered as robust, when international volatility is measured with the standard deviation, *ExchRateStDev* gains explanatory power[15]. Suh finding seems counter-intuitive at first, as it suggests that a depreciation will decrease innovative investment.[16] This can, however, be interpreted to represent the import-intensive nature of innovation in a great part of the countries in my sample. In other words, lower purchasing power will result in decreased input imports and R&D investment. Both *LogGDPStDev* and *IntRateStDev*, instead, retain their significance and negative sign, even though the magnitude of both coefficients

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15 as opposed to *ExchRateCoV*

[16] For some similar 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).

coefficients is now smaller when compared to the results of column (5) in *Table 3*. *PolInstab*, instead, retains its significance and appears with a slightly increased coefficient magnitude.

Moving now to column (2) of *Table 4*, I present the set of results deriving from the inclusion of a number of additional regressors. *Democracy* is taken from Polity IV, and its score ranges from 10 (very democratic countries) to 0 (autocratic regimes). The fact that it appears to be insignificantly different from zero could be indicating that political instability is a more important factor than the institutional background in explaining investors' confidence and willingness to fund innovation projects. Specifically, the degree of democracy vs. autocracy could be related either positively or negatively to R&D investment. However, what is more likely to impact the undertaking and continuation of long-term, high-budget projects is the instability in the alternation of democracy over autocracy and vice versa, as well as the probability of discontinuation of public policies. In addition to *Democracy*, 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 innovation investment funded by the business sector. The insignificance of this measure in my sample is a debatable result; nonetheless, Wang's (2010) analysis of the determinants of fixed investment confirms it. Finally, the amount of high-tech exports as a percentage of overall GDP has also been included, and it has been instrumented with its second lag to account for its likely endogeneity. I would expect the quantity of high-tech exports to be positively related to the amount of innovation performed by the exporting country. However, once again, this control appears with an insignificant coefficient. The result could be due to the fact that not all countries where a high percentage of high-tech exports is recorded do actually invest more in innovation. In many cases,[17] it is rather outsourcing, Export Protection Zone agreements, and the like what accounts for the high

17 e. g. Mexico, Costa Rica and many others

volumes of high value added exports. As a result, the relationship between *HighTechExp* and *BusinessR&D* can be blurry, something which is reflected in my own findings. With regards to the impact these additional control variables have had on my volatility measures, it is possible to see from column (2) of *Table 4* that their significance has not been altered 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. The results shown in Column (3) lend some support to the findings of the literature that posits the pro-cyclicality of innovative investment (see Saint-Paul, 2003). In particular, the positive coefficient exhibited by real volatility represent some mild evidence (it is only significant at the 10% level) of the Schumpeterian creative destruction argument. On the contrary, the monetary volatility index retains its negative impact, probably because financial markets' responsiveness is much more flexible. The positive sign exhibited by the level of real interest rate, instead, seems puzzling at first. 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.[18] This Polity IV variable attaches a higher score to more democratic countries, and a score of zero to autocratic regimes. The variable appears to be insignificant in the sample considered. Similarly, the level of personal income loses explanatory power and this is likely to be

[18] *PolInstab* cannot be used in this regression due to the different time coverage of the HI 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.

due to the much more homogenous range of GDP per capita levels in this panel. An interesting result is the fact that, even in this sample, the amount of public R&D financed by the government retains a positive impact on *BusinessR&D*. *TradeOpen* is not included due to the fact that all high-income countries in this panel are internationally open to the same degree. *Balance* turns insignificant, which is potentially explained by the higher confidence investors place in the public finances of developed countries. *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.

6. POLICY IMPLICATIONS AND CONCLUSIONS

This paper has studied the impact of macroeconomic instability on private innovative investment in the form of R&D. The innovation of the paper has been fourfold. Firstly, a focus on the second moment of the business cycle has been used, whereby the impact of volatility on innovation is analysed rather than simply that of recessions. Secondly, a macroeconometric approach has been adopted; thirdly a comprehensive mixed developed-developing economies panel has been constructed. Finally, indices of real, monetary, and political instability have been tested according to various econometric and economic specifications. This analysis makes it is possible to detangle the specific impact of each type of volatility component and the negative impact the latter have 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.

It has been argued that lack of private R&D is likely to result in low levels of growth. The question of why the domestic private sector of developing countries is neglecting innovation and failing to reap its high investment returns 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 engagement exhibited by most developing countries in my 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.

The above results highlight the need for counter-cyclical technology policy interventions aiming to prevent the avoidance and/or abandonment of R&D investment by developing countries' domestic firms. Vidal (2008) reports in her study of the entrepreneurial sector in Latin America 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. 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% 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, while identifying the most appropriate policy tool to tackle these issues is beyond the scope of this paper, the 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 and R&D spending 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	R&D spending financed by the private sector as a % of ToT R&D	OECD.Stat MSTI Database (2010) UNESCO UIS (2010) RICYT (2009)
GOVERNMENT R&D	R&D spending financed by the public sector as a % of ToT R&D	OECD.Stat MSTI Database (2010) UNESCO UIS (2010) RICYT (2009)
REAL INTEREST RATE	Lending Interest Rate minus Inflation Rate	Own calculation
OFFICIAL EXCHANGE RATE	Nominal Exchange Rate (LCU per US$)	World Bank-WDI (2010) IMF (IFS, 2010)
BALANCE	Overall Deficit/Surlpus (%GDP)	IMF (GFS, 2009)
TRADEOPEN	(Exports + Imports) / GDP	World Bank-WDI (2010)
DEMOCRACY	0-10 Index, authoritarian regimes score 0	POLITY IV Dataset (2010)
STATE FRAGILITY INDEX	It takes the value of 21 for very unstable political environments and 0 for very stable ones	POLITY IV Dataset (2009)
XCONST	0-7 Index for institutional constraints on the executive, dictatorships score 0	POLITY IV Dataset (2010)
HIGH-TECH EXPORTS	High-Tech Exp/ Tot manufacturing Exp	World Bank-WDI (2010)
PROPERTY RIGHTS PROTECTION INDEX	1-7 Index with 1 indicating property rights are very well protected	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 (ATLAS classification) ** 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[19] 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:

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

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

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

Where σ is the standard deviation as defined in (2) and μ is the mean calculated across a two-year rolling window.

[19] i.e. volatility for year 2001 is calculated across the two year period 2000-1; that of 2002 uses 2001-2, etc.

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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 (0.18)	-0.21 (0.18)	-0.088 (0.19)	-0.09 (0.2)	**-0.3** (0.23)
LogGDPHi$_{t-2}$	0.59*** (0.18)	0.52*** (0.18)	0.45** (0.2)	0.44** (0.21)	**0.52**** (0.21)
GoverR&D$_{t-2}$	0.21** (0.11)	0.22* (0.11)	0.23** (0.11)	0.24** (0.12)	**0.24**** (0.12)
IntRate	-0.006** (0.002)	-0.006** (0.002)	-0.007*** (0.002)	-0.007** (0.002)	**-0.007***** (0.002)
IntRate^2	0.00005* (0.00003)	0.00006** (0.00003)	0.00008** (0.00002)	0.00007** (0.00003)	**0.00007**** (0.00003)
ExchRate	- 0.0001 (0.00008)	- 0.00008 (0.00008)	- 0.00008 (0.00008)	-0.00007 (0.00008)	**-0.00007** (0.00008)
ExchRateEmu	- 0.02 (0.03)	- 0.03 (0.03)	- 0.02 (0.03)	-0.026 (0.043)	**-0.018** (0.043)
TradeOpen	0.1 (0.08)	0.13* (0.08)	0.14* (0.08)	0.183* (0.09)	**0.186*** (0.1)
Balance	0.014*** (0.003)	0.014*** (0.003)	0.017*** (0.004)	0.019*** (0.004)	**0.019***** (0.004)
LogGDPCoV		-0.1* (0.05)	-0.13** (0.06)	-0.16* (0.06)	**-0.18***** (0.06)
IntRateCoV			-0.013** (0.006)	-0.0137** (0.006)	**-0.014**** (0.006)
ExchRateCoV				0.06 (0.14)	**0.13** (0.15)
ExchRateCoVEmu				-0.003 (0.23)	**-0.07** (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
Wald F	11.2	10.8	10.8	9.4	9.4
Anderson LM stat	32.1	31	31	28	27.9

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
Wald F stat	9.5	4.3	243
Anderson LM stat	28.2	18.2	82.5

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