MACROECONOMIC INSTABILITY AND THE INCENTIVE TO INNOVATE – A CROSS-COUNTRY PANEL DATA ANALYSIS

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Low levels of domestic R&D spending by the private sector result in lacking competitive advantage and can lead to low levels of development. This paper investigates the channels through which macroeconomic volatility prevents or hinders innovative investment undertakings financed by the business sector. It does so by testing various measures of volatility in the framework of a cross-country panel data analysis. The results suggest a negative impact of real, monetary and political 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.

JEL: C33, C36, O11, O3

INTRODUCTION

This paper investigates the way in which macroeconomic and political instability influences the innovative investment decision-making of business sector's agents, given that: innovation is a risky, long-term-maturity, high-budget type of investment, and, as such, it is likely to be influenced by uncertainty in the surrounding macroeconomic environment (Vidal, 2008); small and medium-sized firms, particularly in developing countries, are likely to be credit constrained, especially during recessionary phases. In addition, with regards to developing countries in particular, levels of political and macroeconomic instability are high, while levels of private innovative investment undertakings are low, something that inevitably results in lacking competitive advantage. A well-established literature exists on the relationship between uncertainty and investment. However, firstly, this literature is divided by contrasting opinions on the sign of said relationship, and, secondly, very little interest has been specifically devoted to the impact of uncertainty on 'innovative investment'. In particular, while various

microeconometric contributions exist, a well-developed macroeconomic literature on the issue is not available. This paper aims to construct a comprehensive empirical analysis of the impact that macroeconomic volatility[1] has on the domestic private sector's R&D investment, in an attempt to fulfil the aforementioned gap. At the same time, seeing as it is still quite debated whether such impact is positive or negative in nature, this paper will also provide some reconciling evidence.

The theoretical literature on uncertainty and fixed investment can be broadly divided in those who believe that the relationship between these two variables is positive, in the presence of perfect competition and constant returns (Hartman, 1972; Abel,1983; Dehn, 2000; Pindyck and Solimano,1993) and those who believe that the irreversibility of most investment projects, and especially of innovative investment,[2] will turn this relationship negative (Bernanke, 1980; Federer, 1993). In particular, Bernanke (1980) argues that a range of inaction is created, and investment will not be undertaken until the moment when the cost of postponing it exceeds the value of the information gained by waiting. Some other contributions place themselves somewhere in the middle: for instance, Sarkar (in Serven, 2003) maintains that the link between volatility and investment might exhibit threshold effects, with a positive relationship occurring at low uncertainty levels and a negative one when the uncertainty level rises beyond a critical threshold; whereas, Goel and Ram (1999) show that the 'degree' of irreversibility can change the impact of uncertainty: they find a much sharper adverse effect on R&D investments, which are likely to be highly irreversible, than on non-R&D ones. [3]

[1] 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.

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

[3]They argue that R&D investments entail expenditure on personnel, equipment and materials that are largely irreversible, owing to their project specific - and not merely firm specific or industry specific – nature.

Within and in parallel to this literature, a more recent, although rather limited, number of empirical contributions exists which analyse the impact of volatility on 'innovative' investment from a microeconomic point of view. This literature can also 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. As Blackburn (1999) explains: 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 favour of a pro-cyclical response pattern maintain that a 'cash-flow' effect exists, which financially constraints firms' activities and hinders the undertaking of innovative investment during downturns (Rafferty, 2003a; Rafferty and Funk, 2008). Those that support the counter-cyclicality of R&D investment suggest downturns influence resource allocation at the firm level according to 'opportunity-cost' criteria (Saint-Paul, 1993). In other words, 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 (1991) reorganizational capital theory. According to both, recessions have a cleansing role as they encourage firms to restructure, replace and innovate. Rafferty (2003b) reconciles these conflicting theories by suggesting that recessions might indeed have a cleansing effect, but only expansions can create the scope for the implementation of the innovation performed during recessions. Bohva-Padilla *et al.* (2009) use Slovenian firm-level data to argue that both pro-cyclicality and counter-cyclicality of R&D are confirmed. However, the first is more likely to hold for small firms which tend to experience binding credit constraints the most, whereas the second characterises non-credit constrained firms, such as MNCs or subsidised

firms. They rely on the same methodology used by Aghion *et al.* (2008), who achieved similar conclusions in their paper and confirmed the results presented by Rafferty and Funk (2008). Namely, the possibility of an asymmetry in binding constraints: in other words, they find cash-flow constraints to bind more during recessions than expansions, which results in firms' disinvestment during recessions being greater than their increase in investment during expansions. Likewise, the 'opportunity-cost' effect appears 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, during negative demand shocks.

All the above papers take up a microeconometric approach using firm-level data on private R&D investment, and then regress the latter on measures of their cash flow, sales and financial constraints. This paper, instead, investigates the relationship between volatility and R&D investment along the lines of Rafferty (2003b), Bohva-Padilla *et al.* (2009), Aghion *et al*. (2008) and Rafferty&Funk (2008) but with a macroeconomic focus in mind. And it does so, by testing the impact of different specifications of volatility and political instability on domestic private R&D investment in the framework of a macroeconomic cross-country panel data analysis. The results point very clearly towards the existence of a negative impact of political instability, real and monetary volatility on innovative investment. The findings are robust and only lose their significance when tested in a panel made up of high income OECD countries only. These results uncover the necessity of public policy interventions in support of private firms engaging in innovation in developing economies. Such interventions should aim at preventing the abandonment or avoidance of R&D investment undertakings by firms, as a consequence of the uncertainty they face. In this way, these policies can allow for continuity both in private future profitability horizons and, as a consequence, in national growth and development paths.

The structure of the paper is as follows: the econometric analysis section below will present the model, its variables, and the data sources in subsection 1. The results along with the robustness analysis are described in subsection 2 and 3; finally, the last section will illustrate some policy implications and conclude.

1. MODEL AND DATA

This econometric analysis aims to test the various claims made in the literature: firstly, it verifies that a relationship between macro-volatility and R&D investment actually exists; secondly, it indicates that such relation is negative in developing countries and it assesses the magnitude of its impact; thirdly, it tests and confirms the robustness of such results. The choice of regressors included in the model specification reflects quite closely the indications contained in all World Economic Forum (WEF)'s Global Competitiveness Reports, where the competitiveness indicators forming part of the index of macroeconomic environment quality are: price stability, cost of investment financing, stability in the exchange rate, level of the savings rate, level of public spending, expectations of individuals with regard to future recessions, and accessibility to credit.

Scarcity of developing countries innovation data is a well-known problem when working with R&D analysis. For this reason, the dataset use for this analysis has been constructed by merging various indicators of business R&D, as published in the OECD STI database, in the UNESCO S&T database and in the RICYT database. Correspondence of measurement units has been checked and discrepancies have been solved prior to the dataset merge. As a result, this panel covers 15 years, from 1994 to 2008, and sums up to 309 observations. The maximum size is of 66 countries and 956 observations; however, due to missing data on one hand and to the inclusion of lags on the other, the actual estimated panel is reduced to 50 countries and 309 observations. Sub-Saharan African

countries, excluding a few exceptions[4], 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 estimation techniques used is 2SLS with fixed effects and the benchmark econometric specification is as follows:

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

where the dependent variable, y_{it}, is the share of investment in R&D financed by the domestic business sector as a % of GDP, *BusinessR&D*. The right hand side of the regression includes a vector of time-invariant country fixed effects, α_i, one 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, both being R&D investment determinants commonly used in the literature surrounding the micro and macro-economic 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.

2. THE VARIABLES

2.1 The Dependent Variable

The reason for choosing the share of domestic private R&D as the dependent variable, rather than, for instance, total R&D intensity, responds to the particular focus of this analysis, which is, as anticipated, that of assessing the reasons behind developing countries' lack of competitive advantage creation. The latter

[4] Uganda and South Africa.

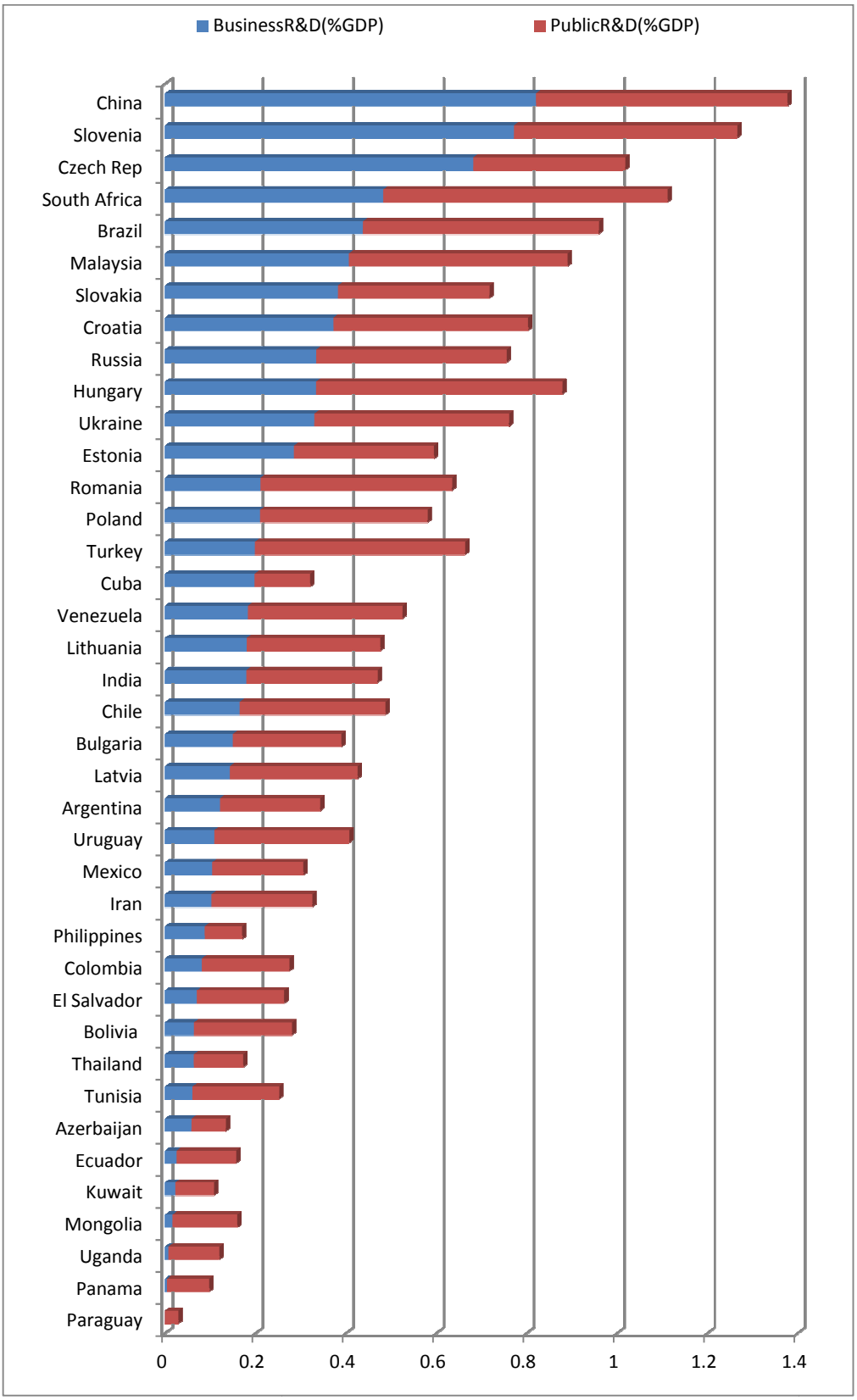
suffer from lack of innovative private entrepreneurial undertakings, in absolute terms, but especially when compared to the share of innovation carried out by the public sector (see *Figure 1*. below). *GoverR&D*, the share of publicly financed R&D, is therefore included in the regression to account for the role of public tangible and intangible infrastructure and to verify whether its impact on private R&D spending has a complementary effect or points towards the existence of a crowding out effect, instead. Most literature and the findings of this study support the first argument (see Becker&Pain, 2003 and Sameti *et al.,* 2010). The summary statistics in *Table 1.* below show that government R&D exhibits much less variation across countries in comparison to business R&D. In fact, the former varies between the 0.01% of GDP in Venezuela and the 1.18% in Iceland; the latter varies between the 0.00002% of GDP in Paraguay and the 3.40% in Israel.[5]

Table 1. Summary Statistics

VARIABLE	MEAN	ST. DEV.	MIN	MAX	OBS.
BUSINESSR&D	0.667	0.691	0.000028	3.40	681
GOVERR&D	0.454	0.256	0.01	1.18	691
GDP_{PC}	12630	11858	215.32	56624.7	956
INTRATE	9.35	11.93	0.034	130.78	803
EXCHRATE	273	960	0.03	11786	863
BALANCE	-0.93	4	-21.5	23.5	601
TRADEOPEN	0.89	0.61	0.15	4.38	935
POLINSTABILITY	4.71	5.09	0	21	827
LOGGDPCOV	0.31	0.28	0.0002	2.79	898
INTRATECOV	0.521	2.13	0.0005	45.9	750
EXCHRATECOV	0.06	0.09	0	0.84	863

[5] The countries with the lowest levels of private R&D spending in the panel are Paraguay, Panama and Uganda; those with the highest levels are Israel, Finland and Sweden. The highest levels of public R&D are recorded in Iceland, Israel, the US and Sweden; the lowest in Venezuela, Bolivia, Colombia, Uruguay and the Philippines.

Figure 1. Private vs Public R&D Spending Shares – Developing and Transition Economies



Furthermore, the data shows a pattern behind the relation between public and private R&D spending: with few exceptions, in developed countries, the share of public R&D spending is lower than (or just as big as) the private share; whereas in developing countries, (sometimes very) low levels of business spending in research are always accompanied by relatively higher levels of government spending.[6] This evidence inevitably raises the question of whether the domestic private sector is refraining from engaging in high-returns R&D activities because they are too risky in uncertain macroeconomic environments.

2.2 Endogenous Controls and Low-Growth Trap Evidence

The variables included, along with *GoverR&D*, in $X_{j,it-2}$ are lagged to account for their endogeneity. The second lag is used and the vector also contains: *LogGDP*, that is, nominal GDP per capita (in logs), an interaction of *LogGDP* per capita with a dummy variable, *HI*, which takes the value of 1 if the country is a high-income one according to the World Bank Atlas classification system and zero if it isn't.[7] The level of GDP per capita represents a control for the level of development of a country.[8] Its interaction term, *LogGDPhi*, has been included to reflect the existence of an L-shaped pattern, resembling that of a low-growth trap, exhibited by the data when plotting business R&D expenditure against GDP per capita (see *Figure 2.a.* below). Separating the effect of GDP per capita according to countries' development levels allows us to account and correct for this pattern found in the data; in particular, the threshold value after which the horizontal line becomes

[6] China, Malaysia, the Philippines, South Africa, Uruguay and Venezuela constitute an exception in this sense.

[7] The relevance of human capital and educational levels to the innovation process has been highlighted by both theory (Lucas, 1988; Mankiw, Romer&Weil, 1992; Acemoglu&Zilibotti, 2001) and empirics (Wang, 2010); the reason why this control is not included in our analysis is because its very high correlation levels with GDP would bias the results of the coefficients on both variables.

[8] Most literature uses nominal GDP. We do the same after having tested the Spearman Correlation Coefficient between Real and Nominal GDP per capita, which confirms a very high correlation coefficient of 0.968.

upward sloping occurs somewhere around 8. Considering now *Figure 2.b.*, which plots the relationship between GDP per capita and business R&D when only high income countries are retained, it can be noted that the data starts indeed at around 8. This suggests that the nearly horizontal line in *Figure 2.a.* corresponds to the developing countries contained in the panel; and also that very low levels of private R&D spending correspond to situations of underdevelopment, represented by low values of GDP per capita.

Figure 2.a.

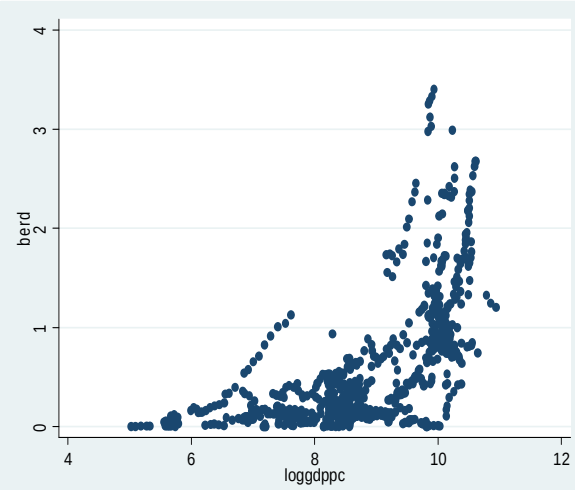
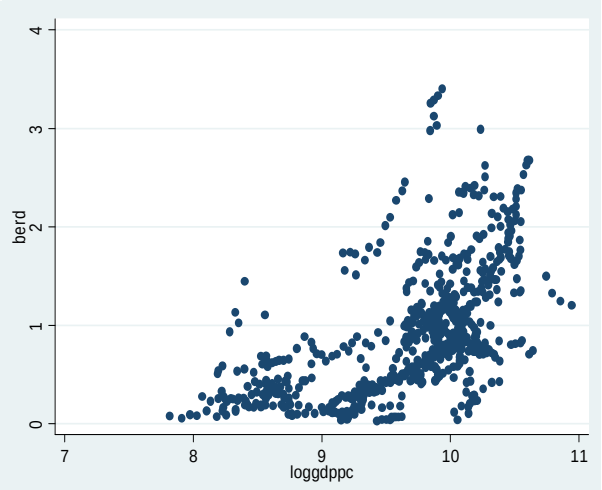


Figure 2.b.



This evidence points in the direction of a low growth trap situation as a consequence of which, in poorer countries, the levels of private sector's innovative investment depend on the level of domestic development, but the latter is itself dependent on innovative investment. This vicious cycle disappears after a certain threshold of economic development is reached as suggested by *Figure 2.b.*, which plots an upward sloping line corresponding to the HI country group.

2.3 The Exogenous Control Variables

The $Z_{l,it}$ vector contains exogenous control variables. In particular, the real interest rate, *IntRate*; its square to capture non-linear effects; a measure of trade openness (*TradeOpen*), calculated as the sum of exports and imports as a % of

GDP; a measure of government internal deficit/surplus, named *Balance*. The first is one of the main determinants of investment and it has been used extensively in the literature as such (Rafferty, 2003b; Aghion *et al.*, 2008; Rafferty&Funk, 2008; Bohva-Padilla *et al.*, 2009;[9] Becker&Pain, 2003; Escaleras&Thomakos, 2008). The second has also been included in numerous studies and tested as one among the most relevant determinants of innovative investment (Smolny, 2003; Sameti *et al.*, 2010;). *Balance* is meant to proxy for the quality of public accounts 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). 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 for the countries that joined the European Monetary Union (EMU), in the year they switched currency regime, and zero in all other years and for all other countries. This interaction is meant to control for the structural break taking place when the EMU regime is adopted, and it corrects for the switch in measurement units.

2.4 The Volatility Variables

Finally, the $V_{m,it}$ vector contains: *PolInstab,* an indicator of political and institutional instability named 'State Fragility Index' in the Polity IV dataset, and constructed as a weighted average of various political legitimacy and economic effectiveness indicators. In particular, the State Fragility Index is higher for countries where occurrence of war and short-lasting political regimes are frequent.

In addition, the vector includes some *ad hoc* measures of macroeconomic volatility, the impact of which is the object of this analysis. These measures have

[9] These studies operate in a microeconomic context and along with sales include in their regression specification firms' financial constraints, as our model is macroeconomic in nature we can consider the level of interest rate to represent the same type of constraints considered by the micro-literature.

been constructed using the coefficient of variation of interest rate (*IntRateCoV*), that of the exchange rate (*ExchRateCoV*) and that of GDP per capita (*LogGDPCoV*).[10] The volatility of the interest rate is used to proxy for the volatility in the monetary policy framework, along with the volatility of the exchange rate, and that of inflation rate, which, however, is also meant to proxy for the quality of public macroeconomic management, just like *Balance* does. The volatility of GDP per capita, instead, is a proxy for instability in the real sector of the economy. The volatility of the exchange rate is also used to account for 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. Therefore it is important to include a measure of international instability in the analysis. Finally, the interaction between the volatility of the nominal exchange rate and the EMU dummy (*ExchRateCoVEmu*), once again, controls for the structural break induced by the European Union, 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 has introduced in the nominal exchange rate levels of the EMU countries.

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[11] 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*. A great part of the literature agrees now on the coefficient of variation 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

[10] The robustness analysis will include the coefficient of variation of the inflation rate

[11] 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.

C.o.V. creates a discounted relative measure which allows taking into account co-movements between similar countries, due for example to the effect of common business cycle patterns (Klomp & de Haan, 2009). 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 results' robustness using the C.o.V. first, and then the standard deviation. The standard deviation is calculated according to the following formula:

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

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

v

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

3. THE RESULTS

Initially, the panel is estimated with simple fixed effects; subsequently, 2SLS with fixed effects and an exactly identified equation are used. This is done to compare the gains in terms of unbiasedeness achieved through the use of Panel IVs. Outliers have been dealt with in the first place; they result in a loss of no more than thirteen observations in the benchmark regression. In addition, since the C.o.V is a measure of dispersion of a probability distribution and the latter cannot be negative, it does not make sense to take into account negative C.o.V. values, therefore all C.o.V. measures in the regression have been restricted to values greater than zero. The regression results for simple FE and 2SLS are reported in *Table 2.* and *Table 3.* below.

Table 2.

	FE				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
LogGDP$_{t-2}$	-0.248	-0.25	-0.114	-0.09	**-0.3**
	(0.18)	(0.18)	(0.19)	(0.2)	(0.23)
LogGDPHI$_{t-2}$	0.58***	0.51***	0.45**	0.44**	**0.52****
	(0.178)	(0.18)	(0.19)	(0.21)	(0.21)
GoverR&D$_{t-2}$	0.215**	0.23**	0.238**	0.24**	**0.24****
	(0.11)	(0.11)	(0.11)	(0.12)	(0.12)
IntRate	-0.005*	-0.006**	-0.006***	-0.007**	**-0.007*****
	(0.002)	(0.002)	(0.007)	(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				-0.00007	**-0.00007**
				(0.00008)	(0.00008)
ExchRateEmu				-0.026	**-0.018**
				(0.043)	(0.043)
TradeOpen	0.084	0.121	0.126	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*	-0.138**	-0.16*	**-0.18*****
		(0.056)	(0.058)	(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.	321	321	316	293	293
N. Groups	57	57	57	53	53
R^2	0.29	0.29	0.30	0.28	0.25

*** significance at the 1% level **significance at the 5% level *significance at the 10% level

Table 3.

	2SLS				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
LogGDP$_{t-2}$	-0.26	-0.27	-0.176	-0.18	**-0.41**
	(0.17)	(0.18)	(0.18)	(0.19)	(0.26)
LogGDPHI $_{t-2}$	0.56***	0.46***	0.44***	0.44**	**0.51*** **
	(0.17)	(0.173)	(0.17)	(0.18)	(0.17)
GoverR&D $_{t-2}$	0.67*	0.74**	0.76**	0.79**	**0.82****
	(0.34)	(0.35)	(0.34)	(0.38)	(0.37)
IntRate	-0.005*	-0.005**	-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				-0.00006	**-0.00005**
				(0.0001)	(0.0001)
ExchRateEmu				0.0004	**0.007**
				(0.05)	(0.04)
TradeOpen	0.09	0.15**	0.14*	0.213**	**0.23****
	(0.07)	(0.08)	(0.08)	(0.094)	(0.09)
Balance	0.016**	0.016***	0.019***	0.02***	**0.021*** **
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)
LogGDPCoV		-0.132**	-0.18***	-0.206***	**-0.21*** **
		(0.056)	(0.06)	(0.06)	(0.065)
IntRateCoV			-0.012***	-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.	315	315	309	288	288
N. Groups	51	51	50	48	48
R^2	0.30	0.31	0.33	0.34	0.346

*** significance at the 1% level **significance at the 5% level *significance at the 10% level

Real volatility, monetary volatility and political instability are added one at a time in each set of results and column (5) in *Table 3.* presents the benchmark results. The negative coefficient on the levels of GDP per capita is confirmed by both econometric estimators, as well as its insignificance. Along the same lines, both FE and 2SLS report the significance of the level of development measured by GDP per capita when interacted with the HI dummy. This confirms the low-growth trap pattern suggested by the data, which has been previously described in Section 2.2 and illustrated in *Figure 2.a.*

Both estimators find a positive impact of public innovation spending; however, while in the FE table, *GoverR&D* is not significant, its coefficient turns significant at the 1% level when endogeneity is corrected for in the 2SLS specification. The negativity and significance of real interest rate is confirmed by both estimators, as well as the positivity and significance of its square. *TradeOpen* has the same magnitude in both sets of results as well as a positive impact on private R&D spending. However, it is only significant in the 2SLS panel. This result is in line with the findings of Smolny (2003), Sameti *et al.* (2010), and Wang (2010) and it provides evidence for a beneficial effect of international openness and exports. The positive and significant coefficient of public account surpluses, *Balance*, is evident in both tables; however it appears to be slightly bigger in magnitude in *Table 3*. The positive impact of lack of deficit on R&D investment by the business sector can be interpreted in terms of increased confidence of private agents in the macroeconomic environment. As already mentioned, Burnside and Dollar (2000) have also used a measure of deficit to proxy for the quality of public macroeconomic management; and the latter appears as one the main components of a successful innovation and development agenda according to all WEF's Competitiveness Reports.

LogGDPCoV and *IntRateCoV* have the same magnitude in both sets of results and in both are shown to have a negative impact and to be significant at the 1%

level. *ExchRateCoV* and its interaction term are never significant. Political Instability is also negative in sign; and it is significant at the 10% in the benchmark regression, reported in column (5) of the 2SLS table.

Two points deserve particular attention: firstly, *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. Moreover, it has to be emphasised that the volatility measures retain their significance despite the inclusion of time controls. The time controls correct for the effect of both common shocks and the business cycle, but even when the latter have been controlled for, real, monetary and political instability retain their significance.

These results with respect to the volatility measures can be interpreted as a confirmation of the microeconometric findings reported by Rafferty (2003a), Aghion *et al.* (2008), Rafferty and Funk (2008), and Bohva-Padilla *et al.* (2009). In fact, real volatility can be seen as a proxy for the variability in aggregate demand/sales, whereas interest rate variability can be seen as a proxy for the change in financial constraints faced by firms. With regards to the measure of political instability, the results are in line with the arguments of Fanelli and Frenkel (1995), who warn that the biggest risk implied by volatility lays in its recurrence and persistence, which lead economic agents to change expectations and behaviours as a response. In particular, the two Argentine economists maintain that lack of confidence in the institutions and rigidities in private responses lead authorities to overshoot their policy measure. However, overshooting itself is likely to cause disappointment when the targets are not met. Rodrik (1989), for instance, argues that uncertainty on policy stability acts as a tax on investment. In fact, expectations are based on the subjective probability attached to policy reversal and on the magnitude of investment irreversibility. On these grounds, "*policy reforms that appear desirable on standard economic grounds will backfire when they introduce doubts as to their likely survival*" (1989:20).

4. ROBUSTENESS ANALYSIS

In order to check the robustness of these findings, firstly, we add an additional volatility measure to the 2SLS benchmark regression. Secondly, we test this new expanded model using the standard deviation as an indicator of volatility, for the reasons explained in section 2.4. Thirdly, we estimate the same regression again, this time using an OECD country panel and, finally, we add a number of regressors in order to show that the impact of the benchmark volatility indicators on *BusinessR&D* is robust to the inclusion of additional controls.

Column (1) of *Table 4.* below, reports the results for the expanded regression where the C.o.V. of the inflation rate is included. The level of inflation is included too, as well as its square, in order to capture non-linear effects. *InflationCoV* is not significant. However, an unexpected result is the positive and significant coefficient of inflation. This is a very robust result and both the significance and the sign of the coefficient hold in all regression where inflation appears. The literature is divided on the nature of the impact that inflation has on growth and investment: some studies point out that threshold effects exist (Pindyck and Solimano, 1993); other show that price instability is detrimental to price allocation mechanisms and, in this way, to both investment and growth (see Grimes, 1991); finally, some other prove that the relationship between inflation, investment and/or growth is positive. In particular, Grimes (1991) reports some of the main contributions in this respect: the Tobin-Mundell theory and the standard Philips curve predictions;[12] and Dotsey and Sartre (2000) argue that price instability leads to higher precautionary savings, which result in turn in higher investment rates (see Neanidis&Savva, 2010, for a review). Column (3) reports the results of the expanded regression estimated on a panel of OECD economies. This reduced panel covers a longer period: 28 years,

[12] According to which higher inflation is linked to higher employment and activity levels.

Table 4.

	2SLS		
	(1)	**(2)**	**(3)**
LogGDP $_{t-2}$	-0.378	0.11	-0.58**
	(0.28)	(0.22)	(0.26)
LogGDPHI $_{t-2}$	0.53***		0.62***
	(0.165)		(0.18)
GoverR&D $_{t-2}$	0.9**	0.86***	0.84**
	(0.39)	(0.17)	(0.38)
IntRate	-0.006**	0.05**	-0.006**
	(0.002)	(0.024)	(0.002)
IntRate^2	0.00006**	-0.004**	0.00008***
	(0.00002)	(0.001)	(0.00003)
ExchRate	-0.00007	0.0003***	-0.00001
	(0.0001)	(0.00008)	(0.00007)
ExchRateEmu	-0.026	0.04	-0.008
	(0.046)	(0.04)	(0.03)
TradeOpen	0.213**	-0.21	0.2***
	(0.09)	(0.2)	(0.07)
Balance	0.019***	0.006	**0.016*** **
	(0.006)	(0.005)	(0.005)
LogGDPCoV	**-0.21*** **	0.21	
	(0.06)	(0.14)	
IntRateCoV	**-0.012*** **	**-0.021*** **	
	(0.004)	(0.008)	
ExchRateCoV	**0.014**	-0.37*	
	(0.13)	(0.22)	
ExchRateCoVEmu	**0.09**	0.56**	
	(0.18)	(0.25)	
PolInstab	**-0.037** **		**-0.04*** **
	(0.017)		(0.013)
XConst		-0.1	
		(0.08)	
Inflation	0.017***	-0.06***	0.013***
	(0.005)	(0.01)	(0.004)
Inflation^2	-0.0002*	0.002***	-0.0001
	(0.0001)	(0.0006)	(0.0001)
InflationCoV	**-0.00003**	0.002	
	(0.0002)	(0.001)	
LogGDPStDev			**-0.195*** **

			(0.006)
INTRATESTDEV			-0.006**
			(0.003)
INFLATIONSTDEV			0.004
			(0.003)
EXCHRATESTDEV			-0.001***
			(0.0003)
N. Obs.	282	321	305
N. Groups	47	22	49
R^2	0.375	0.97	0.37

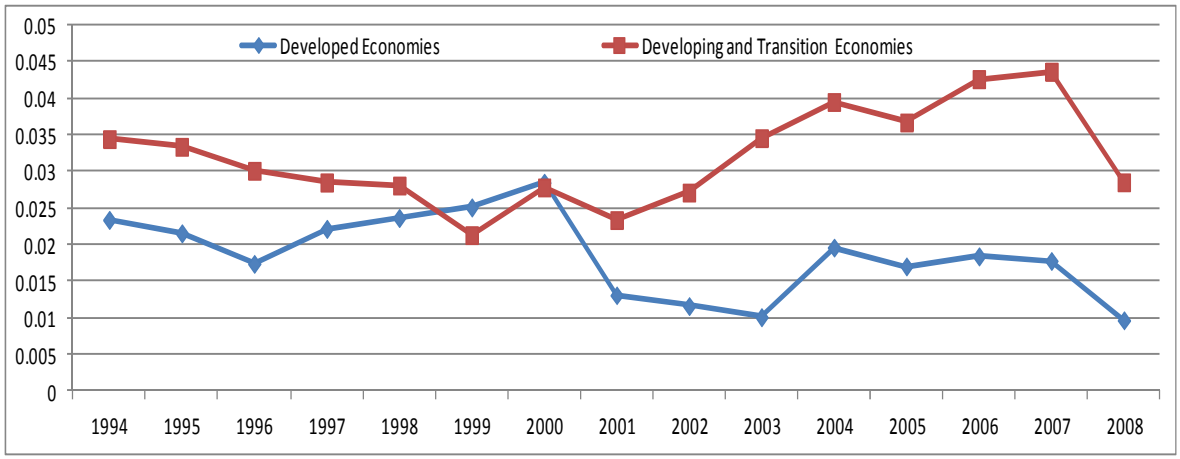
*** significance at the 1% level **significance at the 5% level *significance at the 10% level

from 1981 to 2008, it counts 22 countries and sums up to 321 observations.[13] As anticipated, this is done in order to estimate the impact of volatility conditional on various structural differences existing between developing and developed economies, that is, diversities in the quality of public macroeconomic management, level of sheer development, size of firms and extent to which firms are credit-constrained. This test intends to assess the argument according to which the type of production landscape can influence the impact that volatility has on the amount of domestic private R&D spending; a view which has been put forward in the previously reported literature (Bohva-Padilla *et al.*, 2009). The results reported in Column (3) are in line with the main findings of this literature for what regards real volatility. To the contrary, with respect to monetary volatility, the volatility of exchange rate turns marginally significant at the 10% and its impact is negative in nature. What is more its interaction term, *ExchRateCoVEmu,* is also significant and it exhibits a positive coeffiicient, which confirms the initial hypothesis that, after joining the EMU, levels of exchange rate volatility have been sizably lowered. Moreover, monetary volatility as proxied by the volatility of the

[13] Sweden and Switzerland country fixed effects have been excluded from this panel, as their larger than average *BusinessR&D* and *LogGDP* values represent regression outliers. The two countries have not been excluded from the regression, however their country dummies have. This allows us to interpret all the other country dummies in comparison to the excluded ones and indeed they are all negative.

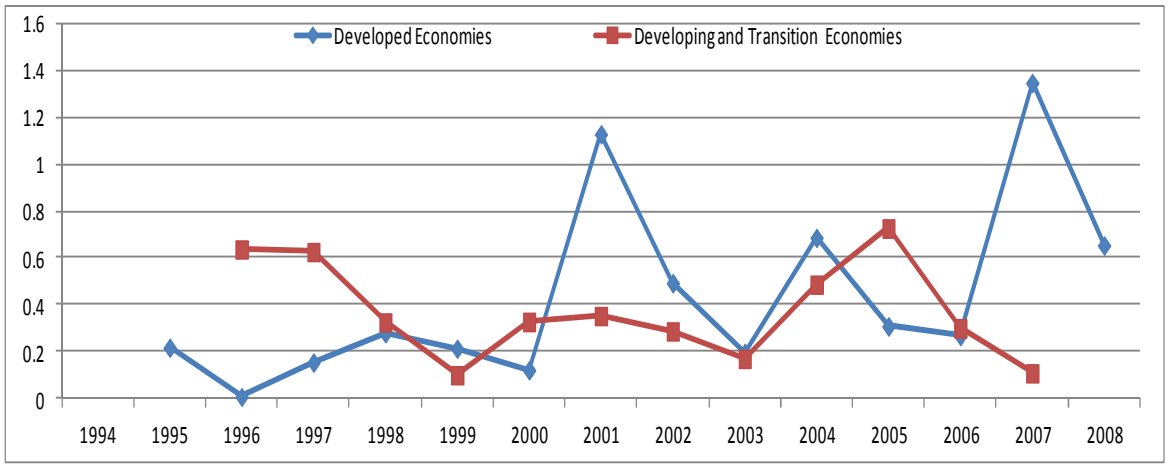
real interest rate retains its significant negative coefficient, with an even larger magnitude than the one shown in the mixed panel. These findings reflect the fact that GDP per capita levels in OECD countries are much less volatile than they are in developing countries (see *Figure 3.* below).

Figure 3. Real Volatility (GDP per capita)



In fact, their levels are also broadly the same across the countries forming this group, hence the insignificance of the *LogGDP* coefficient. On the contrary, monetary markets do retain higher levels of flexibility and responsiveness which results in comparable levels of volatility as shown in *Figure 4.* below.

Figure 4 . Monetary Volatility (Real Interest Rate)



**negative values of the C.o.V. have been excluded*

The results of column (2) show that, in the case of OECD countries, neither trade openness nor public account balances have a significantly different from zero impact on *BusinessR&D*; whereas Government R&D spending continues to have a very high and positive impact. *Inflation* and its square term now clearly point in the direction of a threshold effect pattern exhibited by the level of the inflation rate in the context of developed countries.[14] *PolInstability* could not be included in this specification, due to the fact that the 'state failure index' dataset by Polity IV starts in 1994. Testing, as a replacement, the impact of the constraints on the executive (*Xconst*) in place at the institutional level suggest that this variable is not significantly different from zero. Another finding which is not in accordance with the reduced benchmark regression set of results is the sign of the coefficient of real interest rate. However, in this OECD panel the latter can be interpreted to represent investors' considerations with regards to their rate of returns on the investment for which they have borrowed, rather than a measure of their credit constraints. In other words, the higher the interest charged the higher the expected returns on that investment. These considerations are likely to apply to OECD countries where the signals prevailing in the financial markets are reliable, but not so likely to hold in developing countries, hence the difference in sign shown in the two different panels.

In Column (3), the volatility measures are expressed in standard deviation terms rather than CoV. This alternative econometric specification confirms all previous main results, their coefficient sign and their magnitude - except for the lower magnitude of *IntRateStDev* - and adds to them the significance of the exchange rate volatility. The latter result is in line with the outcome of the OECD panel in

[14] The results suggest that low levels of inflation have a negative effect on innovative investment, but levels past the threshold positively affect private R&D spending; possibly as a result of higher precautionary savings, triggered by what is a worrisome signal for investors (for a review of this argument and of opposing views on the point see Grimes, 1991; and Neanidis and Savva, 2010).

Column (2), and it confirms Escaleras and Thomakos' (2008) findings.[15] Despite the outcomes of the last two robustness checks, it is not possible to conclude that the volatility of the nominal exchange rate is a robust instability indicator, as its significance is not confirmed by the results of *Table 3*.

Finally, *Table 5.* reports the set of results deriving from the inclusion of a number of additional regressors. The latter are added to the expanded model one at a time first, and then all at the same time in column (6). *Democracy* and *Xconst* are added in the first two columns to test the robustness of the political instability coefficient. These two variables are taken form the same Polity IV dataset from which the benchmark variable is taken, and they do not affect *PolInstab*. A measure of property rights protection is then included; which is an index constructed by Economic Freedom of the World (EFW). The insignificance of this type of measure as a determinant of fixed investment is confirmed by Wang (2010). Subsequently, a measure of fiscal imposition, *TaxRevenue*, is included and finally a variable measuring the amount of high tech exports as a %GDP, which has also been instrumented with its second lag to account for its likely endogeneity. As shown in *Table 5.*, none of these additional control regressors changes the set of benchmark results.

Table 5.

	2SLS					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
LogGDP$_{t-2}$	-0.38	-0.39	-0.39	-0.38	-0.43	-0.38
	(0.28)	(0.278)	(0.3)	(0.3)	(0.27)	(0.29)
LogGDPHI$_{t-2}$	0.54***	0.57***	0.54***	0.55***	0.45***	0.35
	(0.16)	(0.17)	(0.17)	(0.2)	(0.17)	(0.27)
GoverR&D$_{t-2}$	0.89**	0.88**	0.9**	0.9**	0.9**	0.95**
	(0.4)	(0.39)	(0.4)	(0.4)	(0.4)	(0.44)
IntRate	-0.006**	-0.006**	-0.006**	-0.006**	-0.005**	-0.005*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)

[15] The two economists calculate the volatility of exchange rate following a GARCH specification.

IntRate²	0.00006**	0.00006**	0.00005**	0.00006**	0.00006**	0.00005**
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)
ExchRate	-0.00008	-0.00008	-0.00007	-0.0001	-0.00008	-0.00006
	(0.00009)	(0.00009)	(0.00009)	(0.00009)	(0.0001)	(0.0001)
ExchRateEmu	-0.026	-0.027	-0.028	-0.025	0.01	0.01
	(0.046)	(0.045)	(0.047)	(0.045)	(0.04)	(0.05)
TradeOpen	0.21**	0.22**	0.217***	0.21***	0.29***	0.26***
	(0.09)	(0.09)	(0.09)	(0.08)	(0.1)	(0.1)
Balance	**0.019*** **	**0.02*** **	**0.019*** **	**0.019*** **	**0.018*** **	**0.02*** **
	(0.006)	(0.006)	(0.006)	(0.007)	(0.005)	(0.006)
LogGDPCoV	**-0.21*** **	**-0.2*** **	**-0.21*** **	**-0.21*** **	**-0.28*** **	**-0.27*** **
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.08)
IntRateCoV	**-0.012*** **	**-0.012*** **	**-0.011*** **	**-0.011*** **	**-0.01*** **	**-0.01*** **
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
ExchRateCoV	0.024	0.02	0.01	0.017	0.09	0.11
	(0.14)	(0.13)	(0.13)	(0.13)	(0.14)	(0.16)
ExchRateCoVEmu	0.086	0.09	0.1	0.09	-0.01	-0.032
	(0.18)	(0.18)	(0.2)	(0.18)	(0.2)	(0.21)
PolInstab	**-0.034****	**-0.034****	**-0.036****	**-0.037****	**-0.04*** **	**-0.036****
	(0.017)	(0.017)	(0.017)	(0.017)	(0.016)	(0.017)
Inflation	0.016***	0.016***	0.017***	0.017***	0.018***	0.02***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
Inflation²	-0.0002**	-0.0002*	-0.0002*	-0.0002*	-0.0002*	-0.0003*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
InflationCoV	-0.00003	-0.00002	0.00002	-0.00002	-0.00008	-0.00003
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Democracy	0.01					-0.022
	(0.013)					(0.02)
XConst		0.036				0.06
		(0.03)				(0.06)
PropertyRights			0.003			-0.004
			(0.013)			(0.012)
TaxRevenue				0.001		-0.01
				(0.007)		(0.01)
HighTechExp$_{t-2}$					0.007	0.008
					(0.005)	(0.005)
N. Obs.	282	282	280	282	276	274
N. Groups	47	47	47	47	47	47
R^2	0.38	0.38	0.376	0.375	0.37	0.365

*** significance at the 1% level **significance at the 5% level *significance at the 10% level

5. Policy Implications and Conclusions

This paper has analysed the role played by macroeconomic and political instability in hindering and/or preventing innovative investment undertakings by the private domestic sector. It has been argued that lack of R&D investment financed by the business sector leads to low competitive advantage development and can slow down growth. It has also been shown how most R&D in developing countries is financed by the public sector. The question of why is the domestic private sector not reaping the high-returns of innovation and research spending has been asked and the uncertainty of the macroeconomic environment surrounding entrepreneurs in developing countries has been suggested as a potential answer. The econometric findings reported in this paper confirm such hypothesis and suggest three main channels of transmission linking macro-volatility to 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 developing and developed countries. These results are robust to various control checks. Finally, they also offer some reconciling evidence to the debate existing in the literature with regards to the nature of the impact that volatility has on innovative investment. In fact, the comparison between the impact of the volatility indices as shown in the mixed panel outcomes and the results of the same estimation performed on an OECD country panel suggests that only monetary volatility is still negatively affecting the levels of private R&D spending in both context, whereas real and political instability lose their significance. This lends some evidence to the conclusions put forward by that part of the literature which argues that various structural differences existing between developing and developed countries might account for the fact that volatility is sometimes found to have a negative impact on investment and sometimes it is found to have a positive one instead.

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 (2005) 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. Rodrik's (1989) calculations report that when investment irreversibility amounts to three-quarters of the cost of installed capital, a 10% reversal probability calls for a 7.5% points investment subsidy, necessary to offset uncertainty. This goes up to 15% points when the reversal probability is 20% and it rises even further when risk-aversion is introduced. As argued before, innovative investment is highly risky due to its budget requirements, its long-term maturity horizons and its mostly irreversible nature. Therefore, if avoidance and/or abandonment of innovative projects have 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 negative shocks and at providing complementary infrastructure and R&D spending when negative shocks hit. This would guarantee firms engaging in innovation in unstable macroeconomic environments a continuity of cash flows and return opportunities over time.

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APPENDIX A

I. DATA SOURCES

BUSINESS R&D	Share of total R&D spending (%) financed by the private sector	OECD.Stat MSTI Database (2010) UNESCO UIS (2010) 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	Derived using the Consumer Purchasing Index (CPI)	IMF - International Financial Series (IFS, 2010)

REAL INTEREST RATE	Lending Interest Rate (WDI and IMF's IFS series) minus Inflation	Author's calculation
OFFICIAL EXCHANGE RATE	Exchange Rate value as decided by the authorities (LCU per US$)	World Bank-WDI (2010) IMF - International Financial Series (IFS, 2010)
BALANCE	Overall internal Deficit/Surlpus (%GDP)	IMF – Government Financial Statistics (GFS, 2009)
EXPORTS/IMPORTS	Value of all goods and other market services provided to/received from the rest of the world (% GDP)	World Bank-WDI (2010) OECD National Account Statistics (2010)
TAX REVENUE	Total Tax Revenue (% GDP)	IMF - Government Financial Statistics (GFS,2010)
DEMOCRACY	Degree of democracy prevailing at the institutional level	POLITY IV Dataset (2010)
STATE FRAGILITY INDEX	Index based on state legitimacy, political instability and economic effectiveness	POLITY IV Dataset (2009)
XCONST	Institutional Constraints on the Executive	POLITY IV Dataset (2010)
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	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