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CYCLICALITY OF THE R&D SHARE OF INVESTMENT IN THE EU OVER THE PERIOD BEFORE AND AFTER THE CRISIS

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Cyclicality of the R&D Share of Investment in the EU over the Period before and after the Crisis

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Abstract

In this paper we investigate the co-movements between the R&D share of total investment and GDP growth in different EU areas over the period 1999-2014. Our empirical analysis shows that only core countries display a common counter-cyclical mechanism leading to an increased share of R&D over prolonged downturns. The lack of any counter-cyclical pattern of R&D share over the evolution of GDP growth in periphery countries makes this area highly vulnerable to persistent recessions, with potentially harmful consequences for longer term growth. For recent EU members the evidence of R&D share pro-cyclicality should be evaluated in the light of the catching-up process still at work in this area. Our analysis suggests that any successful EU innovation policy should not disregard the potential divergence in R&D performance due to the dispersion of the counter-cyclical properties of the share of productivity enhancing activities in the different EU areas.

Keywords. R&D investment, cyclicality, European Union, economic crisis

JEL Classification: O52, O30, E32

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1. Introduction

The macroeconomic performance of the European Union is showing signs of turnaround from the 2008 financial and economic crisis. However, it is widely recognized that the "Great Recession" cannot be considered a normal cyclical downturn. Accordingly, European institutions and the overall political debate inside the EU are far from considering these early sign of recovery a reassuring prospect for a renewed path of steady growth and economic integration. There is considerable historical evidence that financial crises associated with abnormally deep recessions, may involve weak recoveries and long lasting effects on the level of output (Cerra and Saxena 2008; Haugh *et al*. 2009; Reinhart and Rogoff 2009). The recent global and sovereign crises are no exception. The major EU concern is about two interrelated issues: the impact of the crisis on the growth of potential output and its disarranging effects among different EU areas (European Commission 2013, 2014, 2015). Several recent papers analyze the consequences of the crisis on the sustainability of the common currency area with specific reference to the dualism core-periphery (Wortmann and Stahl 2016; De Santis and Cesaroni 2016; Bonatti and Fracasso 2013). These papers highlight how the macroeconomic imbalances between core and periphery EU countries, grown since the early 2000s, intensified with the worldwide crisis, revealing evident diverging trends in competitiveness, indebtedness, and economic performance. Another set of contributions, focusing on the prospects of economic integration inside the EU, analyzes the effects of the crisis on the convergence of innovation performance (Archibugi and Filippetti 2011) and labour productivity (Filippetti and Peyrache 2013). On the whole, the evidence presented in these papers shows that the crisis impacted heavily on innovation activity, but differently across EU areas, leading to increasing divergence and to widening technological gap especially between recent EU members and the mature area of the EU. The disarranging effects of the crisis on productivity enhancing activities inside the EU is also confirmed by the illuminating review of the process of European economic integration and convergence provided by Sapir (2014). With respect to the

longer term consequences of the diverging trends in innovation since the 2008 crisis, a major aspect is that the R&D activity in the EU area appears peculiarly vulnerable to external shocks involving deep recessions. This latter point calls for a deeper understanding of the cyclicality of R&D expenditure in response to changes in macroeconomic conditions.

Indeed, within Schumpeterian endogenous growth literature (Hall 1991; Saint-Paul 1993; Aghion and Saint-Paul 1998a, 1998b), the "virtue of bad times" emphasizes that over a downturn the change in the opportunity cost between capital investment and R&D expenditure should increase the incentive to undertake innovation activity. Following the line of reasoning of Aghion *et al*. (2010), the time horizon of R&D projects is longer than that of investment in physical capital. This implies that short run returns to tangible investment are more sensitive to current macroeconomic conditions than the present value of profits arising from longer term investment in R&D. Thus, over the business cycle the relative return between short and long term investment changes so that the share of resources allocated to R&D should increase. This opportunity cost effect is counterbalanced by credit market frictions. Indeed, the presence of credit market imperfections constrains both types of investment, but the longer time horizon of R&D projects introduces an additional liquidity risk on this type of investment that combined with a likely preference for internal financing, turns R&D expenditure pro-cyclical[1]. Therefore, within this theoretical framework, the degree of counter-cyclicality of the composition of investment results from the interplay between these offsetting forces and the persistence of the business cycle fluctuations. These considerations highlight the macroeconomic relevance of the cyclical dynamics of the R&D expenditure share. Indeed, as underlined by Aghion *et al*. (2010), an endogenous interdependence between composition of investment and business cycle arises with crucial

[1] The issue has been extensively investigated on an empirical ground, both at macro and at micro level. This conspicuous body of diversified evidence shows that the potential counter-cyclicality of innovation activity is constrained by several factors related to countries' financial and industrial structure. The presence of credit market frictions may offset the opportunity cost effect (Ouyang 2011; Aghion *et al*. 2010, 2012; Lopez-Garcia *et al*. 2013; Männasoo and Meriküll 2014). In addition to credit market frictions, other papers show that the opportunity cost effect may be influenced by other factors: the size of firms (Brown *et al*. 2012), firms' ownership type (Beneito *et al*. 2015) and the industrial structure (Fabrizio and Tsolmon 2014; Barlevy 2007).

consequences for longer term growth. In particular, a weak counter-cyclical reaction of the R&D share of total investment to an economic downturn slackens the accumulation of productive knowledge relative to physical capital. The deficient support to the core engine of growth tends to prolong the duration of the economic downturn, triggering a potential vicious circle. The magnified persistence of the recession may inhibit the opportunity cost effect, since the latter arises when the time horizon of R&D projects goes beyond the expected duration of the recession. This reinforces the pro-cyclical pattern of the composition of investment, further weakening the endogenous mechanism able to restart a growth path, which, in turn, further amplifies the persistence of the recession. Indeed, the above theoretical analysis envisages an endogenous mechanism lying behind the medium term effects of the crisis on potential output and its disarranging impact among different areas, which are issues of major concern in the economic and political debate inside the EU.

These considerations motivate our empirical analysis aimed at investigating the degree of counter-cyclicality of the share of productivity enhancing activities, measured as R&D expenditure over total investment, in the whole EU area and for specific groups of countries, over the period 1999-2014. The country sample consists of 25 EU members and its partition follows the core-periphery dualism with the addition of the group of those central and eastern Europe countries that joined the EU since 2004. The periphery countries are almost unanimously identified in literature as Ireland, Greece, Spain, Italy and Portugal, while the core consists of those countries with strengthened roots in the history of the EU and with a mature stage of economic development[2]. The empirical analysis starts with a general outline of evidence before and after the 2008 crisis, showing that the R&D share of total investment is generally higher in the post-crisis period. In order to gain a deeper insight into this descriptive evidence we explore the co-movements between R&D share

[2] Although at institutional level the core-periphery dualism is not explicitly mentioned, the EU recognizes a set of states, whose macroeconomic conditions make them particularly vulnerable to the long lasting effects of the crisis. These vulnerable states consists of the periphery countries as recognized in the core-periphery literature with the addition of Cyprus, and Slovenia (European Commission 2014).

and GDP growth by decomposing the time series into cyclical and trend components[3]. On the one side, this analysis clarifies some important differences among groups of countries. On the other side, it motivates the choice of an Error Correction Mechanism estimation strategy. Indeed, both short and medium term fluctuations are recognizable inside our sample period, recommending an estimation method able to take into account short and long run dynamics within the same econometric framework[4].

The estimated correlation between the R&D share of total investment and GDP growth offers a clear picture of the heterogeneity inside the EU area. Only core countries display a common counter-cyclical pattern of the R&D share along the medium term evolution of GDP growth. As for the periphery countries, the absence of any common long term relation between R&D share and GDP growth emphasizes a noticeable heterogeneity within this group of countries, while in the group of the central and eastern Europe countries even a positive correlation between R&D share and GDP growth arises. This latter result may be partly ascribed to the transitional dynamics driving these countries towards the stage of development of the core area. Accordingly, our results may suggest that the 2008 crisis impacted in this area by shifting downward the catching up process. As far as periphery countries are concerned, the estimation results indicate some early signs of warning. Indeed, while in the core the reallocation of investment towards innovation activities may effectively contribute to revert the economic downturn to the previous path of growth, the lack of any countercyclical response of the share of productivity enhancing activities within periphery countries may not only delay the economic recovery, but it is likely to foster a divergence process inside the EU.

[3] Wälde and Woitek (2004) investigate the degree of counter-cyclicality of the R&D expenditure with respect to GDP growth for G7 countries by decomposing the time series into cyclical and trend components according to different filtering procedures.

[4] An estimation strategy based on an Error Correction Mechanism specification is also employed by Rafferty (2003) and Rafferty and Funk (2004) that investigate the R&D response to demand fluctuations for a sample of US firms.

The paper is organized as follows. In the next section we illustrate the data, some descriptive evidence and the empirical methodology used. The following section presents the estimation results. Then, we offer a general discussion of the empirical findings and gather some final conclusions and policy implications.

2. Empirical model

In the empirical analysis we examine whether the share of investment in productivity enhancing activities displayed any countercyclical pattern in response to the evolution of GDP growth inside the EU before and after the 2008 financial crisis.

2.1 Data and Descriptive Evidence

The country sample consists of 25 EU countries over the period 1999 to 2014. In order to evaluate whether countercyclical mechanisms operated differently across the EU area, we partition the whole sample (EU25) into three groups of countries labelled Periphery, Core and Recent. Following a conspicuous body of literature, the sample of periphery countries includes Italy, Ireland, Greece, Portugal and Spain. In the core we include those countries with strengthened roots in the history of the EU and with a mature stage of economic development: Belgium, France, Germany, Netherlands, Denmark, United Kingdom, Austria, Finland and Sweden. Finally, in the Recent sample we consider those countries that joined the EU since 2004: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Bulgaria and Romania. All data come from the Eurostat database. We employ data on total intramural R&D expenditure, total gross fixed capital formation and real GDP. As a measure of the composition of investment we consider the ratio between R&D expenditure and total investment.

Table 1 describes the empirical pattern of the R&D share, and of the growth rates of real GDP, real R&D and real investment before and after the 2008 crisis. Each column reports the average values over periods 1999-2007 and 2008-2014 for EU25, Core, Periphery and Recent. The significance of the difference between the average values in the two periods is tested by a *t*-test. The impact of the crisis reveals a common pattern. In all country samples the drop in GDP growth after 2007 is associated with a reduction in the growth rates of both types of investment and with an increase in the R&D share. Overall, this evidence suggests a lower pro-cyclicality of R&D with respect to total investment. However, remarkable differences emerge inside the EU area. Comparing core and periphery, only a modest and not significant decrease in R&D growth appears in core countries, while inside periphery R&D growth significantly drops by more than six percentage points. A notable reduction in both R&D and total investment growth rates is shown in the Recent sample. However, the drop in investment growth is highly significant, while the reduction in R&D growth by eight percentage points appears not significant, signalling a high cross-country variability. In addition, the high average GDP growth in the Recent sample before the crisis is sustained by a fast accumulation of both physical and knowledge capital, suggesting a macroeconomic dynamics affected by a fast catching-up process. In all country samples, the behaviour of share of R&D investment before and after the crisis reflects the stronger pro-cyclicality of total investment.

INSERT TABLE 1 HERE

2.2 Trend and cyclical components

The macroeconomic consequences of the crisis cannot be viewed as a short term phenomenon over the business cycle. A protraction of the recession beyond the normal duration of a downturn characterizes our sample period, with higher growth till 2007 and lower growth between 2008 and 2014. This implies that the correlation between GDP growth and R&D share depends both on transitory fluctuations and on a persistent evolution of growth recognizable as a medium term trend/cycle[5].

Figure 1 illustrates the short and long term properties of the time series inside our sample period. For all country samples the average cross-section real GDP growth and R&D share are decomposed into cyclical and trend components by using the Hodrick-Prescott filter[6]. Indeed, the trend component shows that both GDP growth and the R&D share followed a non-stationary evolution between 1999 and 2014. On the whole, the graphical presentation of the decomposition between short and medium term components confirms the general picture outlined in Table 1: the R&D expenditure tend to be less pro-cyclical than total investment, resulting in a countercyclical R&D share. In addition, the decomposition neatly highlights relevant differences between groups of countries. In the core, both trend and cyclical components of GDP growth and R&D share move in opposite directions, while a less clear picture emerges in the EU25 and periphery samples, where negative co-movements of the two variables appear only in the short term dynamics. Finally, in the Recent sample the steady rise in the R&D share does not seem to follow the evolution of medium term growth fluctuations, while an unclear pattern characterises the cyclical components.

INSERT FIGURE 1 HERE

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[5] The notion of "medium term" cycle, i.e. fluctuations that cover a time span longer than what is normally considered business cycle, is recognized in literature (see Comin and Gertler 2006). The time span of our data do not allow any inference on the transitory or permanent nature of the observed medium term evolution yet.

[6] The smoothing parameter λ is set equal to 30.

2.3 Econometric Model

To gain a deeper understanding of the evidence presented so far, our estimation strategy relies upon dynamic panel data models capable of isolating short term effects from longer term ones. A suitable and widely used approach is the Autoregressive Distributed Lag (ARDL) proposed by Pesaran *et al*. (1997, 1999). There are several advantages in employing the ARDL approach. Firstly, it allows estimating both short and long run parameters within the same econometric framework. Secondly, it can be applied even if variables are non-stationary or mutually cointegrated (Pesaran and Shin 1999). Finally, long run relationships among variables can be efficiently detected even in small samples (Ghatak and Siddiki 2001).

The ARDL (p,q) dynamic panel specification can be re-parametrised into the following Error Correction form

$$\Delta rd_{it} = \varphi_i(rd_{it-1} - \beta_i g_{it-1}) + \sum_{j=1}^{p-1} \gamma_{ij} \Delta rd_{it-j} + \sum_{j=0}^{q-1} \delta_{ij} \Delta g_{it-j} + \mu_i + D_i + \epsilon_{it} \qquad (1)$$

where rd_{it} is the R&D share of total investment and g_{it} is the GDP growth rate. Notice that in (1) the β_i parameter refers to the long run relation between rd_{it} and g_{it}, while γ_{ij} and δ_{ij} capture short run dynamics and μ_i controls for country-specific fixed effects. The parameter φ_i represents the speed of adjustment of the error correction process and must be significantly negative to ensure that the variables display reversion to a stationary equilibrium relationship. In addition, a dummy variable D_i - taking value one for years 1999-2007 and zero otherwise - is introduced in order to capture any difference between the pre- and post-crisis period. A far as the lag selection is concerned, Loayza and Ranciere (2006) recommend employing a common lag structure across the

panel cross-sections whenever the analysis of the short run parameters is also of interest. Given the time dimension of our panel, we limit the lag structure to one[7].

Equation (1) is estimated by two different estimators: the Mean Group (MG) estimator of Pesaran and Smith (1995), and the Pooled Mean Group (PMG) estimator proposed by Pesaran *et al*. (1999). Both estimators provide consistent estimates, despite possible endogeneity, since lags of independent and dependent variables are included (Pesaran *et al*, 1999). The MG estimator imposes no cross-country restriction. The model is fitted separately for each country and the mean of short and long run coefficients is consistently estimated by simply averaging on a country basis. The PMG estimator combines both pooling and averaging. In this case short run parameters, speed of adjustment and intercepts can differ across countries, whereas log run coefficients are restricted to be equal across countries[8]. The choice between the two estimators is carried out through the information provided by the Hausman test. The latter compares the MG estimator (consistent under both the null and the alternative hypothesis) with the PMG estimator (efficient and consistent under the null hypothesis, but inconsistent otherwise). If the Hausman test fails to reject the null hypothesis, then the more efficient PMG estimator is selected. If the null is rejected, it indicates that the MG and the PMG produce different estimations. In this case, since the efficient estimator is doubtful, the consistent estimator (MG) is preferred.

[7] Notice that the PMG estimator, which is employed in our regressions, has been shown to be robust to the choice of lag order (Pesaran *et al*. 1999 and Martinez-Zarzoso and Bengochea-Morancho 2004). This greatly reduces any concern about the ARDL lag structure.

[8] The Dynamic Fixed Effects (DFE) estimator can also be used. The DFE estimator allows only the intercepts to vary over countries, while it constrains long and short run coefficients and the speed of adjustment to be homogeneous. However, Pesaran *et al*. (1999) points out that the DFE estimator can produce inconsistent results, unless the coefficient homogeneity actually holds. Moreover, Baltagi *et al*. (2000) underlines that in case of small sample size, the DFE model is subject to a simultaneous equation bias, due to the endogeneity between the error term and the lagged dependent variable. For these reasons, we neglect this estimator in our analysis.

3. Estimation Results

The results of the PMG and MG estimations are reported in Table 2 for the four samples EU25, Core, and Periphery and Recent. We recall that the coefficient β captures any stationary relationship over the medium term between the R&D share of total investment and GDP growth, while φ reflects the speed of adjustment to the equilibrium value. The parameter δ measures the short run impact of GDP growth changes on the composition of investment and the dummy variable *D* captures any change in the R&D share due to a break between the pre and post-crisis periods. At the lower end of Table 2 we report the statistics of the Hausman test.

INSERT TABLE 2 HERE

The Hausman test indicates that the PMG estimator provides more efficient results in all country samples except for Periphery, where the null hypothesis is rejected at 1%. Therefore, we choose the PMG estimates for EU25, Core and Recent samples, while we rely upon the MG estimates for Periphery. The estimated coefficients for the EU25 sample show that the R&D share displays a strong countercyclical pattern inside the EU zone. As for the long term co-movements between the R&D share and the GDP growth rate, a significant negative coefficient and a significant negative speed of adjustment are obtained: a ten per cent downward shift in GDP growth translates into a 3.2 per cent increase in the R&D share of total investment. In the short run, GDP growth changes have a limited, but significant, negative effect: on average, a ten per cent decrease in growth is associated with a change in the composition of investment by only 0.3 per cent. The effect of the crisis is detected by a significant negative coefficient of the dummy variable, indicating

that the altered macroeconomic framework after 2008 determined a stair-step increase of the R&D share. However, given the magnitude of the coefficient, this effect is actually modest.

This general view dramatically changes, once the analysis considers separately the different groups of countries. Indeed, the differences among Core, Periphery and Recent samples are neatly highlighted by the estimation results. In the core the PMG results show a significant countercyclical pattern of the composition of investment both in the long and in short run. In particular, a negative response of the R&D share to medium term evolution of GDP growth emerges in the common stationary relation, which is detected by a significant negative speed of adjustment. A ten percent drop in growth is associated with an increase in the R&D share by almost five percentage points. As far as the break between pre- and post-crisis sub-periods is concerned, a negative sign emerges but weakly significant. Turning to the periphery, a different picture appears. The Hausman test strongly rejects a common pattern between R&D share and GDP growth inside this group of countries. Since the PMG estimator relies on the existence of a stationary relation between variables that is homogeneous across countries, the choice of the MG signals a dissimilar behaviour among periphery countries. This marked heterogeneity results in a non-stationary relationship linking the composition of investment to the medium term evolution of GDP growth[9]. The short run dynamics is characterized by a negative and significant coefficient and there is just a flimsy evidence of a different behaviour before and after the crisis, since the negative dummy coefficient is statistically insignificant. The estimation results show clearly the peculiarity of the Recent sample. Noticeably, in the PMG estimation a positive sign characterises the long term co-movement between the composition of investment and GDP growth. The speed of adjustment has the sign consistent with the existence of a stable equilibrium relation, but is not statistically significant. A significant effect appears in the dummy coefficient, which reveals a higher R&D share in the post-crisis period.

[9] Actually, on a single country basis, the MG estimation shows that only Spain displays a significant negative sign in the long run relationship, while a mixture of not significant, positive and negative signs characterizes the other Periphery countries.

Summarizing, the results in the EU25 sample seemingly indicate a powerful countercyclical device linking the dynamics of the R&D share to the medium term evolution of the macroeconomic conditions. However, when the analysis focuses on specific EU areas, only the core countries exhibit evidence consistent with the general view outlined in the EU25 sample, while for the two other groups of countries completely different scenarios appear. On the one side, the lack of any recognizable common long term relation linking R&D share and GDP growth emphasizes the strong heterogeneity inside the periphery. On the other side, the remarkably high growth rates in R&D and total investment combined with GDP growth rates higher than the average EU growth during the pre-crisis period inside the Recent sample reinforces the conjecture that the driving force of an ongoing transition dynamics prevents a clear emergence of the potential counter-cyclicality of the composition of investment[10].

4. Conclusions

In this paper we investigated the correlation of the share of the investment in productivity enhancing activities with the evolution of GDP growth over the period 1999-2014, by considering 25 EU members partitioned also into three samples: Core, Periphery and Recent. The purpose of the empirical analysis was to ascertain whether the economic forces driving the R&D share of total private investment were able to react counter-cyclically in response to the abnormally deep recession following the 2008 crisis.

The empirical results show that inside the core the incentives arising from the altered macroeconomic frame triggered endogenous mechanisms, leading to an increased R&D share of total investment. Following Aghion et al. (2010), the counter-cyclicality of the composition of investment may mitigate the persistence of recession, laying the basis for resurgence of growth.

[10] By using a different methodology, Männasoo and Meriküll (2015) show no evidence of pro- or counter-cyclicality of R&D expenditure at the aggregate level for the group of recent EU members over the period 2005-2013.

Thus, the stable relation linking the share of productivity enhancing investment to the medium term evolution of GDP growth detected among core countries, may indicate an operative endogenous device able to preserve a path of steady growth in this EU area. Inside the periphery, the response of the R&D share to short run changes in GDP growth just reflects the high volatility of investment and cannot be considered evidence of an effective counter-cyclical response. Indeed, the lack of any counter-cyclical mechanism over the medium term makes the periphery area highly vulnerable to severe and persistent downturns. In case of a general economic decline, a misallocation of productivity enhancing investment may amplify the persistence of the recession, reinforcing the pro-cyclical pattern of innovation activity, which further amplifies the persistence of the recession. This progressive weakening of an endogenous mechanism able to restart a path of growth, may, in turn, start diverging trends in macroeconomic performance, with crucial consequences for cohesion, integration and stability of the whole EU area. Finally, our evidence confirms a likely convergence process at work inside the Recent sample before the crisis (Gill and Reiser, 2012). A successful "convergence machine" inside this EU area is also reported by Sapir (2014), who notices that the catching-up process continued, though at a modest pace, between 2008 and 2012. These considerations and our empirical results suggest that the crisis impacted inside this EU area by shifting downward a path of convergence, whose dynamics did not prompt any counter-cyclical device in the composition of investment.

Our selection of country samples is broadly consistent with the endogenous partition of countries based on their innovation performance, identified by Archibugi and Filippetti (2011). Thus, in the light of our results, the weakness of the convergence process in innovation activity and the early signs of divergence reported in Archibugi and Filippetti (2011) since the 2008 crisis may possibly be rooted in structural differences leading also to a dissimilar response of the R&D expenditure share to the medium term dynamics of GDP growth. Besides the different impact of the banking crisis that might have caused a more severe credit crunch inside the periphery than inside

the core, the empirical literature at firm level indicates that the counter-cyclicality of R&D expenditure may be influenced by several other factors: the size of firms (Brown *et al.*, 2012), firms' ownership type (Pilar *et al*., 2014) and the industrial structure (Fabrizio and Tsolmon, 2014; Barlevy, 2007). A detailed investigation of the incidence of these specific elements is outside the scope of our paper. What we want to highlight here is that the dissimilar behaviour of the composition of investment between core and periphery in response to the evolution of the macroeconomic framework may increase the distance between these two EU areas as a consequence of the crisis. The evidence presented here shows that the conditions for recovery to a steady growth path are weaker in the periphery area with respect to the core zone. The insufficient reallocation of investment in favour of its productivity enhancing component, may not only delay the economic recovery, but is likely to push the whole macroeconomic performance in a vicious circle with harmful medium term consequences.

Concern about the effect of the 2008 global slowdown on potential growth has been expressed by European institutions (European Commission 2009) as well as by academic research (Halmaier 2012; Ollivaud and Turner 2015). Since in a mature state of development the ultimate engine of growth relies upon the accumulation of knowledge, our empirical investigation suggests some final comments on this point. On the whole, the longer term consequences of the crisis on growth, if any, are likely to be dissimilar across different EU areas. In particular, the process of convergence at work in central and eastern Europe countries, though weakened by the 2008 crisis, represents a driving force potentially able to restart a path of fast accumulation of both knowledge and physical capital[11]. More troublesome appears the contrasting division inside the western side of the European Union. While the macroeconomic system of the core seems characterized by endogenous mechanisms able to exploit the "virtue of bad times" and to preserve potential growth, the misallocation of capital due to the weak counter-cyclical reaction of the composition of

[11] In support of this conjecture, Ollivaud and Turner (2015) show that the Great Recession appears to have little effect on growth in emerging markets.

investment among periphery countries may lay the basis for long lasting negative effects on the whole macroeconomic performance inside this area, seriously challenging any hope for a renewed process of European integration.

Finally, the discussion presented so far suggests some policy considerations. Since the Lisbon Strategy, devised in 2000, European institutions have made a huge effort to achieve a full EU innovation system in order to accomplish "the most competitive and dynamic knowledge-based economy in the world"[12]. The Innovation Union, started in 2010, sets a target of 3% of GDP invested in research and innovation and all EU countries are encouraged to converge towards it over the next ten years. To this purpose, the Innovation Union is designed to gradually remove all financial, economic and bureaucratic obstacles that prevent investment in R&D. This strategy, aimed at creating an innovation-friendly environment, is essentially based on a long run perspective, envisaging a smooth convergence towards the desired 3% goal once the factors hindering investment in innovation are gradually eliminated, namely limited access to financial resources, costly patenting, market fragmentation, outdated regulations and procedures and the failure to use public procurement strategically. In other words, this approach neglects the potential medium term impact of slowdowns in economic activity on the process of knowledge accumulation. In the light of the evidence presented in our analysis, this view suggests two policy implications. Firstly, the dispersion of the counter-cyclical properties of the innovation activity across different EU areas may represent an element of vulnerability of the convergence in R&D efforts advocated by the Innovation Union project. As already mentioned, the marked convergence in innovation activity observed in the pre-crisis period inside the EU has been replaced by significant divergence. This evidence, combined with our results, indicates the need to secure the approaching path of those countries lagging behind the innovating performance of the core area, through specific supporting measures and more effective guidelines for government counter-cyclical policies. In the spirit of the

[12] Lisbon European Council, 2000. Presidency Conclusions.

Lisbon Treaty, these policy recommendations should stimulate governments to undertake strategic counter-cyclical measures by changing the composition of public spending towards a higher share of public R&D expenditure and/or by stronger economic incentives for firms' R&D activity[13]. Secondly, the results of our investigation are consistent with a considerable body of empirical literature supporting the view that, despite the fact that several factors may prevent a clear counter-cyclical pattern of innovation, the incentive prompted by the opportunity cost effect is actually recognizable in firms' behaviour (Aghion *et al.* 2010, 2012; López-García *et al.* 2013; Ouyang, 2011). This implies that a European strategy aimed at encouraging innovation might exploit the increased private incentive to undertake R&D programmes during downturns. This strategic timing of policy implementation might pursue the objective of a powerful counter-cyclical economic policy fostering at the same time a faster accumulation of productive knowledge in Europe.

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Table 1: R&D share of investment, GDP growth rate, R&D growth rate and Investment growth rate, average values

	R&D share of investment	*GDP Growth*	*R&D Growth*	*Investment Growth*
EU25				
1999-2007	3.55	3.79	11.34	6.145
2008-2014	4.66	0.87	5.87	-2.835
Difference	1.11***	-2.9***	-5.467*	-8.984***
	(0.335)	*(0.317)*	*(3.317)*	*(1.052)*
CORE				
1999-2007	7.36	2.52	3.136	2.676
2008-2014	8.20	0.79	2.183	-0.658
Difference	0.84**	-1.72***	-0.953	-3.334**
	(0.380)	*(0.323)*	*(0.948)*	*(1.031)*
PERIPHERY				
1999-2007	1.87	3.55	9.074	4.254
2008-2014	3.52	-0.44	2.490	-6.517
Difference	2.59***	-4.0***	-6.584***	-10.772***
	(0.262)	*(0.649)*	*(2.332)*	*(1.709)*
RECENT				
1999-2007	1.20	4.93	19.09	9.851
2008-2014	2.30	1.53	10.44	-2.942
Difference	1.10***	-3.4***	-8.653	-12.79***
	(0.242)	*(0.570)*	*(7.317)*	*(2.001)*

Source: Eurostat Statistics database

Note: Standard Errors in brackets: * significant at 10%, ** significant at 5%, *** significant at 1%

Figure 1: GDP Growth and R&D Share of Investment: decomposition into cyclical and trend components, Holdrick-Prescott filter

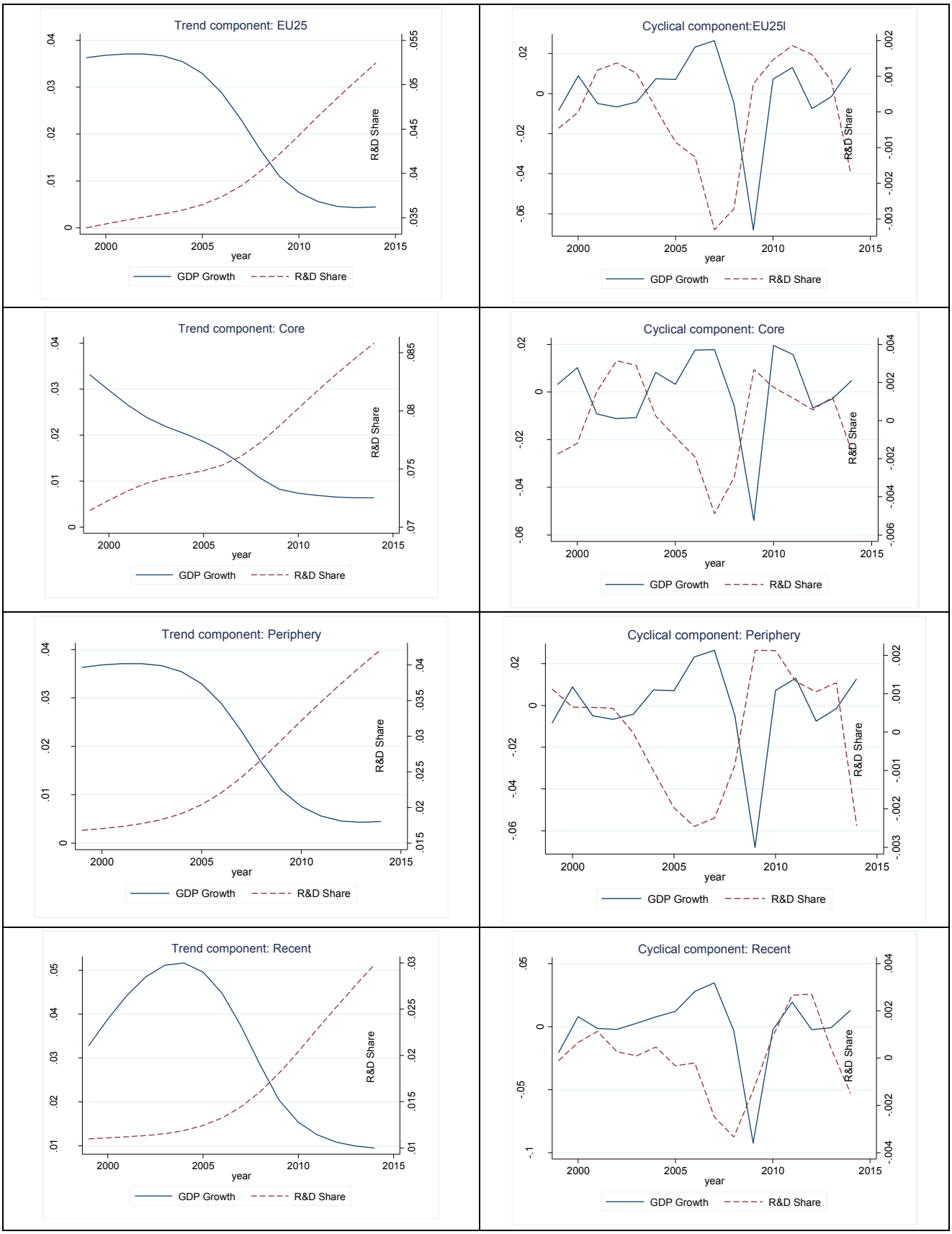

Table 2: Estimation Results of the Error Correction Model (Equation (1))

PMG Estimator				
	EU25	**CORE**	**PERIPHERY**	**RECENT**
Long-run coefficient, β	−0.321*** *(0.0556)*	−0.480*** *(0.1036)*	−0.0251*** *(0.0732)*	0.147*** *(0.0507)*
Speed of adjustment, φ	−0.147*** *(0.0263)*	−0.192*** *(0.0416)*	−0.133* *(0.0726)*	−0.052 *(0.0690)*
Short-run coefficient, δ	−0.038*** *(0.0080)*	−0.077*** *(0.0200)*	−0.034*** *(0.0093)*	−0.000 *(0.1011)*
Pre-crisis Dummy *D*	−0.0021*** *(0.0007)*	−0.0015 *(0.0011))*	−0.0021 *(0.0014)*	−0.0041* *(0.0023)*
MG Estimator				
	EU25	**CORE**	**PERIPHERY**	**RECENT**
Long-run coefficient, β	−0.342* *(0.2095)*	−1.004** *(0.4043)*	0.0174 *(0.1238)*	0.037 *(0.2712)*
Speed of adjustment, φ	−0.216*** *(0.0627)*	−0.217*** *(0.0715)*	−0.076 *(0.0977)*	−0−278** *(0.1229)*
Short-run coefficient, δ	−0.044** *(0.0116)*	−0.084*** *(0.0256)*	−0.043*** *(0.0044)*	−0.014 *(0.0090)*
Pre-crisis Dummy *D*	−0.0022*** *(0.0033)*	−0.0020*** *(0.0006)*	−0.0014 *(0.0014)*	−0.003* *(0.0016)*
Hausman statistic p-value	0.01 0.9289	1.53 0.2155	6.45 0.011	0.10 0.7493

Note: Standard Errors in brackets: * significant at 10%, ** significant at 5%, *** significant at 1%