The Dual Role of Innovation Policy in the European Union: Short and Long Term Prospects

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Abstract

The objective of this article is to assess a potential dual role of innovation policy upon economic growth and employment. First, we look into direct, short term impacts arising from R&D expenditures, much in the sense of a multiplier effect. Second, we analyze impacts from the stage of development of National Innovation Systems (NIS) upon the macroeconomic conditions of interest, assuming that current stages of development are products of previous commitment to innovation, i.e., a structural, long term outcome of innovation policy. In order to empirically test our propositions, we have analyzed 28 EU Member States (1990-2013) through three sets of econometric (static and dynamic panel data) models. Results highlight that EU countries' governmental commitment to their respective innovation systems catalyzes current and prospective economic growth and employment levels, suggesting a complementarity between Neo-Schumpeterian and Neo-Keynesian perceptions over governmental R&D involvement. This can bring innovation efforts closer to the mainstream debate on monetary and fiscal policies and function as a criticism to austerity measures in laggard innovation systems, as this may not only affect the present economic situation, but also generate the cornerstone for a perennial state of divergence among EU Member States.

Keywords: Innovation policy; European Union; Public R&D expenditures; National Innovation Systems.
JEL: O38; B52; E61

1. Introduction

The 2008 financial turmoil had important effects in the productive structure of many developed and developing nations. In the European Union, its impacts were pervasive and affected levels of income, employment and economic growth (Fagerberg & Srholec, 2016). This situation has driven down aggregate demand, causing a lasting recession within the bloc and a slowdown in convergence trends in the EU. In its turn, macrostabilization policies, in this context of economic crisis, seemed to be largely ineffective as generators of multipliers, thus having, at best, minor impacts on the restoration of sustainable growth patterns (Tassey, 2012).

Throughout recent periods, this debate have been dominated by a clash of approaches claiming for, on the one hand, austerity measures and, on the other, economic stimuli for countries. What we notice is that, although innovation theory and policy have evolved significantly in previous decades, there is a persistent gap concerning the need for stronger insertion and coordination with other related policy (and political) frameworks (von Tunzelmann, 2004; Mytelka & Smith, 2001). We depart from the perspective that the inclusion of an innovation-driven point of view - as a form of confronting such period of recession/depression - could provide a framework of reference of great utility for public policy (Audretsch & Link, 2012). Also, we understand that it can be adequately articulated with the economic stimuli speech and theoretical background.

Our uneasiness resides in that macroeconomic policy has been largely determined by interests from bond markets (mainly represented by austerity policies and structural reforms), not allowing for necessary investments in skills, technology and innovation that can enhance long term structural capabilities in European countries (Mazzucato, 2013b; Mazzucato & Shipman, 2014). Tassey (2012, p. 2) has also raised analogous propositions, stating that "*in contrast to stabilization policies, the emphasis must be on investment in a range of productivity-enhancing technologies, as opposed to the traditional (and current) reliance on an investment component that focuses largely on conventional economic infrastructure such as transportation networks*" (Tassey, 2012, p. 2). In this article we argue that undervaluing the importance of innovation and technology investments in economic recovery processes can be significantly counterproductive for short and long term evolution and stability of economic systems.

Our research inquiry is directed towards assessing a potential dual role of innovation policy upon economic growth and employment. First, we look into direct, short term impacts arising from R&D expenditures. Second, we analyze impacts from the stage of development of National Innovation Systems (NIS) upon the macroeconomic conditions of interest. We take this stage of development as a product of previous systemic commitment to innovation at the aggregate level, i.e., a structural, long term outcome of innovation policy. Our objective is to verify the potential complementarity between these two perspectives that are intrinsically related to distinct time horizons concerning their capacity of providing a rationale for public policy when it comes to adjustments to fluctuations caused by business cycles.

To test our propositions we have analyzed 28 EU Member States throughout the 1990-2013 period. Three sets of empirical models are developed to approach variations in economic output and employment as a function of: (i) current public expenditures in R&D; (ii) structural conditions of NIS; and (iii) combined effects of these two sets of determinants. Static and dynamic panel data methods are applied. Factor analysis is used to establish proxies of NIS' stages of development. Results support the existence of a dual role of innovation policy in the European Union. The main implication is straightforward: austerity policies are expected not only to cause short term disparities among EU nations, but also to affect countries' evolutionary trajectories. As it has been pointed out elsewhere, heterogeneous environments in terms of R&D efforts shall lead to persistent productivity divergence (Fagerberg & Verspagen, 1996).

The remaining of the article is structured as follows: section 2 offers a brief discussion on the effects of the 2008 crisis upon EU countries and its latent relationship with NIS. Section 3 build upon literature to develop a framework for assessing potential complementarities of short and long term effects of innovation policy. Section 4 presents the sample and the data used in our empirical approach. Econometric models are depicted in Section 5 and results can be found in Section 6. Section 7 concludes with final remarks and implications for policy and research.

2. The European Union and the Innovation Effects of the Crisis

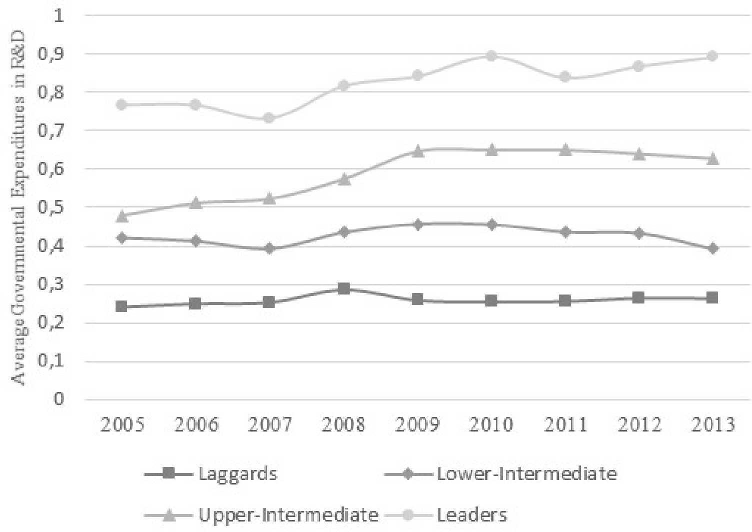
The financial crisis that took place in 2008 had significant structural effects in economies throughout the world. In Europe, stagnation and recession are still present in several nations, leading to fiscal pressures and the application of austerity measures. One of the key areas for governmental intervention concerning the recovery from this situation is related to initiatives in the realm of science, R&D and innovation[1].

The recognition of macroeconomic relevance of technological change contributed to the inclusion of science, technology and innovation aspects within industrial policy frameworks. In the European Union, the release of the Lisbon Strategy in 2000 represented an institutional landmark in the agenda towards becoming a global leader in the knowledge economy. Concerted efforts related to evolutionary dynamics and innovation systems' perspective of economic development in the bloc have been taking place since the 1980s (of which the main example is the Framework Programme).

Nonetheless, the crisis has shown the fragility of innovation policies in the core of macroeconomics. A first outcome of fiscal pressures was a major reduction in public expenditures in European countries' R&D (European Commission, 2013), contrary to OECD's (2009) propositions. This is a function of budgetary constraints that have put aside the role of innovation policy and investments (OECD, 2012). The European Commission (2013) highlights that many EU Member States had larger relative cuts in

[1] The OECD (2009) proposes four key areas for governmental intervention concerning the recovery from the 2008 crisis: (i) infrastructure, (ii) science, R&D and innovation, (iii) education, and (iv) green technologies. The potential for overlaps between different dimensions is properly addressed by the OECD.

their R&D funds in comparison to other governmental investments. This action sends a message concerning the long term, evolutionary, character that is usually attributed to innovation policies. Hence, Science, Technology and Innovation are not governmental priorities during contraction cycles. But this is only part of the story. Graphs 1A and 1B bring some stylized facts on governmental R&D efforts in EU economies for the period 2005-2013. As it can be noticed, R&D behavior has stagnated/declined in those countries that possess the lowest levels of governmental investments concerning innovation-related activities (Laggards). This situation also holds for those countries included in the Lower-Intermediate group, and the distance from the Leading Upper-Intermediate investors seems to be increasing since 2008.

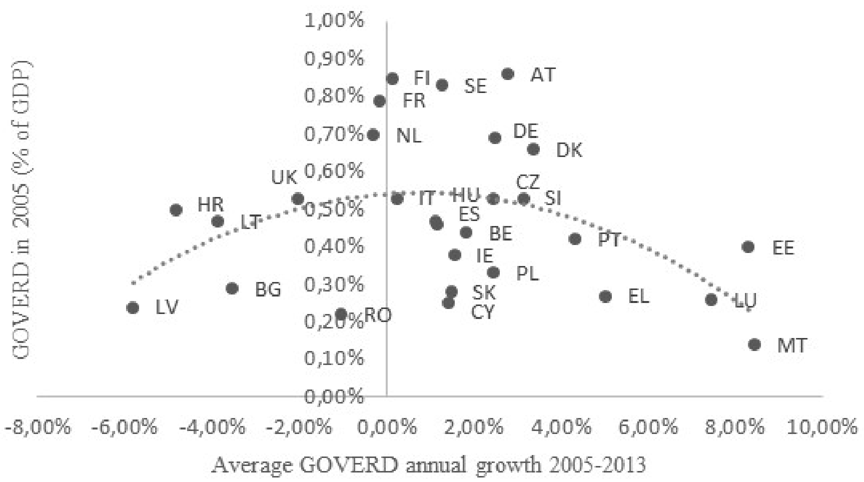


Graph 1A. Total intramural governmental R&D expenditure (GOVERD), all sectors of performance 2005-2013. Data in percentage of GDP.
Note: Countries were grouped according to their respective average levels of GOVERD (2005-2013). Laggards (up to 25th percentile): Malta, Latvia, Bulgaria, Romania, Cyprus, Slovakia and Greece; Lower-Intermediate (26th - 50th percentile): Poland, Luxembourg, Croatia, Lithuania, Ireland, Hungary, Belgium and Italy; Upper-Intermediate (51st - 75th percentile): United Kingdom, Spain, Portugal, Czech Republic, Slovenia and Estonia; Leaders (76th - 100th percentile): Netherlands, Germany, Denmark, France, Finland, Sweden and Austria
Source: Eurostat

Graph 1B provides additional support to the hypotheses of potentially divergent innovation systems in Europe (country codes can be found in Appendix I). The inverted U-shaped trend line indicates a club of converging economies in terms of governmental engagement with R&D efforts (bottom right corner of the graph), and consistently laggard NIS (bottom left corner). Although it can be argued that business enterprises R&D efforts can change this picture, this is hardly the case in a current context of depressed demand (see section 3 for a discussion on this subject). Furthermore, governmental expenditures in R&D also function as a driver for private investment (crowding-in effect) and can be directly influenced by public policy, making it an indicator of interest in our assessment.

Hence, particularly in face of the economic turmoil started in 2008 (as well as its ongoing impacts in European countries), attention must be paid to initiatives that both

(i) stimulate growth and employment; and (ii) promote economic convergence amongst nations (one of the fundamental goals of European Commission's actions). This does not seem to be the predominant dynamics in an environment that is clearly generating an increasing gap in countries' capabilities of sustaining their Science, Technology and Innovation environments.



Graph 1B. Relationship between GOVERD in 2005 (% of GDP) and average GOVERD annual growth (2005-2013)

Deliberate reductions in governmental R&D expenditures can represent potentially damaging shortsightedness from policymakers, as it does not explore the full potential of such sort of intervention. For instance, Mazzucato (2012) calls for increased R&D investments in laggard European nations, arguing that only through greater systemic capacity of generating growth these nations will be able to overcome their fiscal difficulties in a sustainable way. Nonetheless, besides long term structural shifts in the composition of economic systems, current public expenditures in R&D may also provide economies with positive multiplier effects upon their current growth trends. In sum, innovation policy represents not only the means to achieve systemic structural evolution, but also a mechanism to sustain current levels of economic output and employment through increased levels of aggregate expenditures.

3. Short and long term perspectives of innovation policy

Heterodox economic approaches recognize innovation as a central feature of business cycles (Fagerberg, 2003; Witt, 2002). However, in order for innovation to happen, agents are bound to weigh their expectations concerning market conditions for new products and processes (Dosi, 1988; OECD, 2012). In this regard, the structure of market incentives – demand contractions or expansions - is of utmost importance in defining the current microeconomic behavior of firms (Geroski & Walters, 1995; Filippetti & Archibugi, 2011). Intuitively, the willingness to invest in innovative activities decreases in periods of economic recession (Archibugi et al, 2013), as "*during major recessions, the economic landscape is characterized by huge uncertainties about* *the direction of technological change, demand conditions, and new market opportunities*" (Archibugi et al, 2012, p. 19). Hence, increases in aggregate demand seem to be important drivers of technological change dynamics (Lucchese, 2011; von Tunzelmann, 2004).

These conditions set the stage for cumulative trends and feedback loops, linking long term prospects of innovation systems to current innovative behavior of agents (Paunov, 2012). These conclusions are in line with theoretical formulations concerning the dynamics of aggregate demand *vis-à-vis* corporate investment and the role of multipliers (as in Keynes, 1934; 1937). Based on the idea of demand-pull as a core driver for innovative output, von Tunzelmann (2004) and Paunov (2012) propose that expansionary fiscal policy (stimulation of productive investment) is likely to sustain innovation systems' evolutionary paths. This comes as a result of public funds acting as stabilizers of firms' innovative behavior in the short term.

However, the relationship between demand conditions and innovative output show signs of a bidirectional nature. Kleinknecht and Verspagen (1990) and Verspagen (2002) defend the existence of a mutual dependence between these constructs. This proposition offers a hint of self-reinforcing effects, where macroeconomic policy demand management may spur innovations, but over time innovations may also increase aggregate demand. In a similar vein, Dosi et al (2012) found strong complementarities between technology and monetary/fiscal policies. These interdependencies are mainly related to the inclusion of innovation policy as short-run instruments to deal with output and unemployment fluctuations.

This comes in addition to the usual, long-run, evolutionary orientation of technology policies. Dosi et al (2010, p. 1765) refer to this assumption as connecting "*Schumpeterian theories of technology-driven economic growth with Keynesian theories of demand generation*". The core argument rests in the incapacity of technological engines of growth alone to sustain economic systems in a growth path with low levels of employment. A complementary set of tools broadly represented by Keynesian "demand-generating" policies is needed.

In order to create sustainable rates of productivity growth, governments should consider developing strategies aiming at investments in technology (Tassey, 2012). Tassey has exposed a similar view in earlier works (Tassey, 2010; 1992), where he defends the importance of an institutional framework that addresses issues related to public and private interactions concerning the provision of an adequate technological infrastructure. This comes primarily from Tassey's concern with the inefficiency of "pure market" solutions and his call for technology-based growth policies. A very similar position is sustained in Mazzucato’s “Entrepreneurial State” (Mazzucato, 2013a). Both arguments loosely rely on what we understand as a combination of short term multipliers and evolutionary policies (with its goal oriented towards structural aspects of innovation systems). Similar conclusions can also be found for the case of developing countries in Paunov (2012).

We recognize that expenditures in R&D are linked to a linear view of innovation processes. They do not necessarily translate into effective outcomes, as there are systemic aspects involved in innovation dynamics (Edquist & Zabala-Iturriagagoitia, 2015; Archibugi & Filippetti, 2011). Nonetheless, it functions as a key indicator for the evaluation of the overall quality of innovation systems (as demonstrated in Castellacci & Natera, 2013). Also, leaving systemic aspects aside, expenditures in R&D stimulate demand in the short term and supply in the long term (OECD, 2009). Unfortunately, few innovation policies addressed the issue of demand uncertainty throughout the crisis (OECD, 2012), thus allowing the emergence of a hostile market environment for innovation-oriented projects. This situation is particularly dramatic in laggard innovation systems. As previously shown in Graphs 1A and 1B, there is a downward or stagnant trend of investments in R&D performed by some laggard economies in the EU (an aspect already pointed out in earlier research by Archibugi & Filippetti, 2011; Filippetti & Archibugi, 2011; Archibugi et al, 2012).

In this regard, it is known that consolidated institutional structures of NIS can compensate for demand variations and sustain agents' innovative investments (Filippetti & Archibugi, 2011; Paunov, 2012). This has set the stage for a growing divergence in economic input in EU nations. These economic shocks are likely to widen and perpetuate innovation systems' disparities and their respective capacities of generating growth (Mazzucato, 2012). An example of this perverse lock-in is represented by structural impacts upon the demand-side of laggard countries, considering that "*rising inequalities and labor market hysteresis both within and between countries or regions [...] can have deleterious effects on aggregate demand and hence on the demand-pull incentive to innovation*" (von Tunzelmann, 2004, p. 98). The solution proposed by von Tunzelmann (2004) is to create an economic environment that is conducive to growth via a combination of: i) short term, demand-side policies; and ii) long term, supply-side initiatives.

Based on the theoretical framework designed in this section and in the current situation of sluggish growth in the EU (together with its impacts upon economic growth, convergence and employment) we establish a set of hypotheses to be tested empirically in our assessment:

H_1: National Innovation Systems' stage of development influences the capacity of generating economic growth and sustaining employment levels.

H_2: Current governmental R&D efforts function as an instrument to sustain levels of economic output and employment.

H_1 represents the long term, supply-side perspective of our propositions, related to structural conditions of National Innovation Systems. It translates into the idea that the current stage of development of a given NIS is a function of previous frameworks of institutions and policies addressing Science, Technology and Innovation. Although we recognize that quantitative indicators can represent but a partial view of the systemic character of innovation, we also believe that such assessment offers a robust proxy for the institutional commitment towards the construction of knowledge-intensive societies and its correspondent level of innovative activity.

H_2 stands for our perception of the short term, demand-side multiplier effects of expenditures in R&D, i.e., benefits arising from sustaining innovation efforts throughout business cycles. This hypothesis contains our main criticism towards austerity measures (particularly during economic downturns).

4. Sample and Data

This section contains the description of variables and the methodological procedures of the empirical assessment. The sample consists of the 28 European Union Member States (see Appendix 1 for the list of countries) observed throughout the period 1990-2013. The extension of this timeframe allows dealing with relatively robust approximations of evolutionary trends in NIS without incurring in excessive missing data issues, also including information after the occurrence of the 2008 financial crisis.

Table 1 describes the analytical variables used in our approach. These variables can be divided into four groups. The first one consists in variables representing the different elements of the NIS: R&D expenditures, Patent, Scientific and technical journal articles, Education, Institutions[2] and Internet users[3]. In this group we have also separated Governmental R&D from Business Expenditures in R&D in order to capture the differential effects arising from these investments[4]. The second group of variables is composed by vectors of output, i.e., indicators of GDP and employment. The third group of variables comprehends Gross capital formation and Labor with the aim of developing the basic structure of production functions in econometric estimations. The fourth group includes control variables concerning the macroeconomic foundations of EU Member States, offering extensions for the basic production function: inflation, interest rates, and inward FDI. Population is used as an intermediary variable that allows calculations of per capita levels in other variables.

Table 2 presents Descriptive statistics for the sample. The identification of country/year representing minimum and maximum values for each indicator is also presented. Coefficients of variation (C.V.) allow the identification of main aspects of heterogeneity amongst EU Member States. For the purpose of our assessment, it is worth noticing the strong variations in RDGDP and EDU, fundamental components of NIS. Strong diversity is also observed for fundamental macroeconomic indicators, such as GDP growth, inflation, interest rates, capital formation and Inward Foreign Direct Investments. Hence, although we are dealing with a panel composed mostly by developed nations, economic heterogeneity can be underscored as a strong trait of the European bloc.

Table 1. List of variables

	Variable description	Acronym	Source
Group 1	Governmental R&D expenditures in millions of euros	RDGOV	Eurostat, 2015

[2] The proxy used for "Institutions" identify the institutional quality of countries. This is included as a dimension of innovation systems as there is an expectation that institutions drive the efficiency in the relationship between innovation inputs and outputs.

[3] In this case, the penetration of internet among the population is used as a proxy for the "knowledge society" and infrastructure development.

[4] Although we understand that R&D expenditures from private firms is also a function of the institutional landmark of innovation policy.

	Business R&D expenditures in millions of euros	RDBUS	Eurostat, 2015
	Total R&D Expenditure as a % of GDP	RDGDP	World Bank, 2015
	Patent. Number of patents per capita	Pt/p	Eurostat, 2015
	Scientific and technical journal articles per capita	Jour/p	World Bank, 2015
	Education enrollment in tertiary Education(%Total)	EDU	World Bank, 2015
	Institutions. Composed Index[1]	Inst	World Bank, 2015
	Internet User Users per 100 habitant	Internet	World Bank, 2015
Group 2	GDP. Constant US$ 2005	GDP	World Bank, 2015
	Unemployment. % of Total labor force	Unem	World Bank, 2015
Group 3	Gross Capital Formation. % of GDP	K	World Bank, 2015
	Labor. % of Active Population	L	World Bank, 2015
Group 4	Inflation. % of GDP	Inf	World Bank, 2015
	Interest Rate. %	Ir	World Bank, 2015
	Inward Foreign Direct Investment. % of GDP	IFDI	Unctad, 2015
	Total Population	P	World Bank, 2015

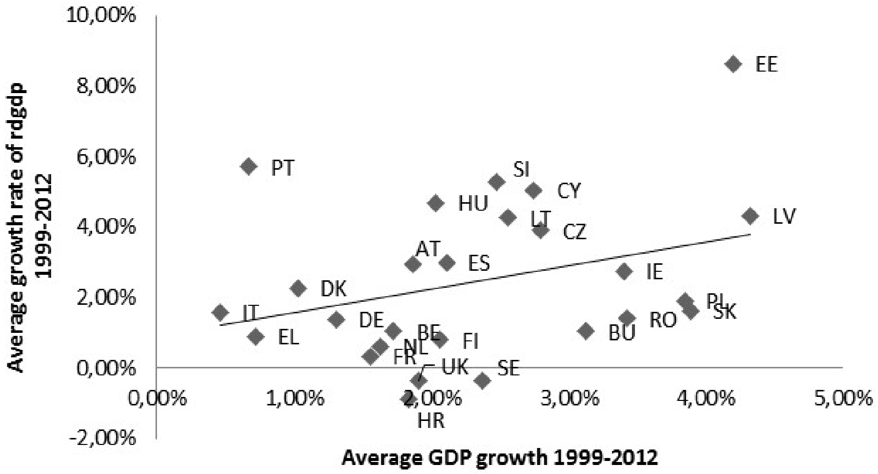
Source: own elaboration

Table 2. Description of data

Variable	Valid N	Min.	ID	Max.	ID	Mean	Std. Dev.	C.V.
RDGOV	576	0.58	MT, 2007	12,100.00	DE, 2013	1,034.15	1,951.77	1.89
RDBUS	571	1.05	LT, 1998	53,790.10	DE, 2012	4,719.44	8,878.29	1.88
RDGDP	445	0.22%	CY, 1998	4.13%	SE, 2001	1.41%	0.88	62.94
PT/p	611	0.0000	RO, 1992	0.0006	UK, 2005	0.0001	0.0001	1.36
EDU	629	4.79%	LU, 1991	116.6%	EL, 2012	48.95%	20.79	42.46
Jour/p	601	0.000	EE, 1992	0.0011	SE, 2001	0.0004	0.0003	0.78
Internet	627	0.00	BE, 1990	94.78	SE, 2013	34.74	30.34	0.87
Ins	360	2.190	HR, 1996	4.486	FI, 2004	3.589	0.501	0.14
GDPg	624	-14.81%	LT, 2009	11.7%	EE, 1997	2.32%	3.62	156.44
Unem	620	0.60%	EE, 1990	27.3%	EL, 2013	8.98%	4.37	48.68
IFDI	617	0.00%	RO, 1990	322.1%	LU, 2009	41.83%	43.95	105.07
K	619	0.60%	EE, 1990	27.30%	EL, 2013	8.99%	4.36	48.55
L	647	138,552	MT, 1990	42,490,517	DE, 2011	8,491,737	10,639,041	1.25
Inf	625	-0.10%	LV, 2009	958.5%	BG, 1997	0.08%	43.19	51453.40
Ir	459	-70.43%	BG, 1997	93.94%	BG, 1996	4.99%	7.57	151.60

Source: own elaboration

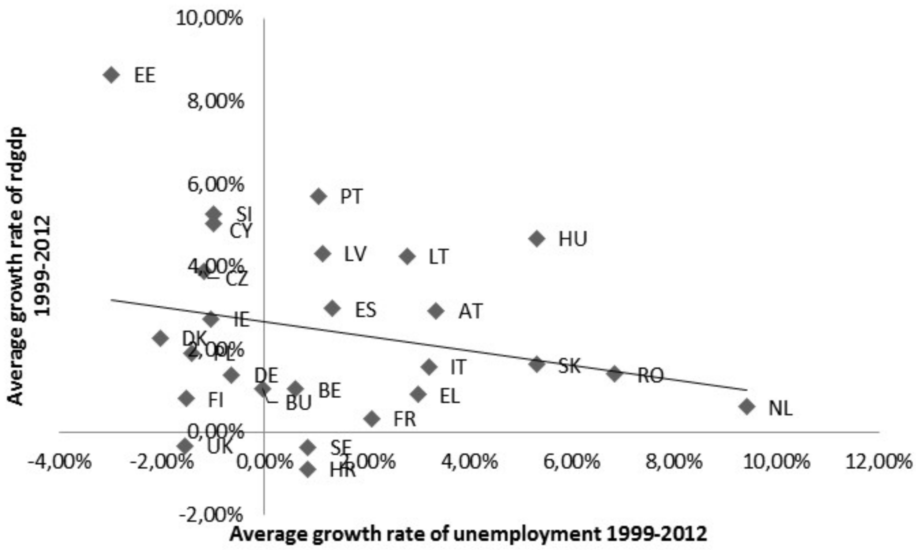
Taking a closer look at some of the main variables of interest, relevant relationships can be drawn. In graph 2 we offer a perspective of the relationship between average growth rates in RDGDP and average GDP growth in the period 1999-2012 (country codes can be found in Appendix I). Although it can be noticed that this relationship is far from perfect - outlining the non-linear character of R&D expenditures and innovative results - it is also true that there are hints suggesting that countries with steeper growth trends in R&D investments (% of GDP) are associated with higher levels of overall economic growth. This is not, however, the case of Portugal, a country that has increased its levels of R&D expenditures but that has faced sluggish growth throughout the period. On the other hand, Latvia has achieved a perfectly proportional condition of growth in GDP and in R&D investments.



Graph 2. Relationship between growth rates in RDGDP (1999-2012) and average GDP growth (1999-2012)[5].

A similar picture is verified in graph 3, where we address the relationship between average growth rates in RDGDP and average growth rates in unemployment in the period 1999-2012. The trend follows the expected pattern with significant noise in the association between variables. The situation is particularly unsatisfactory for the case of Hungary, a country that has increased somewhat substantially its R&D efforts, but with significant growth in its levels of unemployment. The UK is the only country that has performed negative growth patterns in both dimensions. As in the evaluation between RDGDP and economic growth, Estonia also presents an extremely positive behavior, with a substantial average rate of decreasing unemployment. The next step in our assessment is to formalize these propositions and the content of our research hypotheses into a set of econometric models that allows achieving a deeper comprehension of the phenomena under investigation.

[5] We did not apply longer timeframes because of missing data issues. Also for this reason, Luxembourg and Malta are not represented in this analysis.



Graph 3. Relationship between growth rates in RDGDP (1999-2012) and growth rates in unemployment (1999-2012)[6].

5. Econometric Approach

The first step in the econometric approach deals with the construction of NIS dimensions through factorial analysis. This procedure allows to combine a set of different elements present in the NIS. The factor analysis reduces the set of existing variables to a set of non-observable hypothetical or theoretical factors which summarize most of the information contained in the original set of variables[7]. The strength of this technique allows avoiding discriminatory selection of different proxies. The factor analysis in our sample includes indicators of different aspects of the NIS: Patents, Publications in scientific Journals, Education, Institutions, R&D Expenditures and Internet users. Results have grouped the variables into two factors (Table 3): (i) *Technological factor (TECH)*, composed by R&D expenditures, Patents and Scientific and technical journal articles, representing a basic input/output structure of innovation systems; and (ii) *Institutional and Infrastructure factor (IINS)*, comprehending education, institutions and internet users. The combination of these two factors offers a multidimensional perception of the dynamics involved in the functioning of economic and productive systems concerning innovative activities.

[6] We did not apply longer timeframes because of missing data issues. Also for this reason, Luxembourg and Malta are not represented in this analysis.

[7] A similar procedure is undertaken by Fagerberg et al. (2007) and Fagerberg and Srholec (2016) for estimation of technology and capacity competitiveness.

Table 3. Rotated components matrix

	Components	
	Technological factor (TECH)	Institutional and infrastructure factor (IINS)
RDGDP	.718	.495
PT/p	.873	.111
EDU	.294	.607
Jour/p	.890	.081
Internet	.286	.839
Ins	-.065	.708

Source: own elaboration

The next step deals with the econometric models *per se*. Three groups of models are developed according to their function concerning our evaluation of innovation policy effects on economic growth and employment.

5.1. Model 1 – National Innovation Systems' stage of development effects on economic growth and employment

In order to test our first hypothesis, Model 1 addresses the effects of NIS' stage of development upon economic growth. The goal is to verify the current impacts of vectors that are derived from long term evolutions of innovation systems. This model consists in an extended production function based on the impacts of dependent indicators upon the panel dynamics of GDP variations over time.

$$\text{M1.1. } Log\ Y_{it} = \beta_1 TECH_{it} + \beta_2\ IINS_{it} + \beta_3 logL_{it} + \beta_4 logK_{it} + u_{it}$$

$$\text{M1.2. } Log\ Y_{it} = \beta_1 TECH_{it} + \beta_2\ IINS_{it} + \beta_3 logL_{it} + \beta_4 logK_{it} + V_{it} + u_{it}$$

Where *Y is* GDP, *Tech* and *IINS* are the *Technological* and *Institutional and Infrastructure* factors obtained in the factor analysis. The subscript "i" identifies each country in the sample, while "t" represents each time period. These variables are used as representations of the current conditions of NIS' stage of evolution. Additionally, *L* is labor and *K* is capital. Finally, *V* is a vector that includes the following controls: Inflation (Inf), Inward foreign direct investment (IFDI) and Interest rates (Ir). Inflation and interest rates allow controlling for monetary conditions of economies, while IFDI contains important information on the level of trust of international markets concerning the host market, as well as it offers a complement for the evaluation of capital input. These comments on the extensions of production functions also apply to the remaining econometric models in our analysis. *u* is the error term.

We have also checked the structural effects taking unemployment as the dependent variable. The fundamental structure of these models follows the same pattern as M1.1 and M1.2. We have excluded *L* because of its direct connection with the employment conditions in countries. *K* was also excluded because of latent collinearirty with the NIS factors. This complementary view of the structural effects of innovation policy is depicted in the following equations:

$$M1.3.\ Log\ Y_{it} = \beta_0 + \beta_1 TECH_{it} + \beta_2\ IINS_{it} + u_{it}$$

$$M1.4.\ Log\ Y_{it} = \beta_0 + \beta_1 TECH_{it} + \beta_2\ IINS_{it} + V_{it} + u_{it}$$

Where, *Y* is unemployment, *TECH* and *IINS* are the technological and institutional and infrastructure factors obtained in the factor analysis. *V* is a vector that includes Inflation (Inf), Inward foreign direct investment (IFDI) and Interest rates (Ir). The subscript “i” identifies each country in the sample, while “t” represents each time period. u_{it} is the error term.

5.2. Model 2 – Short term effects of R&D efforts on economic growth and employment

The second model of our assessment aims at testing our second hypothesis. This approach seeks to verify short term, direct economic impacts of current public expenditures in innovation-related activities upon growth and employment. We have also addressed the potential contributions of business expenditures in R&D in order to capture the differential contributions between public and private investments in innovation. This procedure aims at distinguishing the marginal contribution of these sources of investment. Hence, the proposed structure of this model is oriented to allow us to identify potential influences that unravel, we expect, as a function of multipliers introduced by innovation efforts.

$$M2.1.\ Log\ Y_{it} = \beta_0 + \beta_1 RDGOV_{it} + V_{it} + u_{it}$$

$$M2.2.\ Log\ Y_{it} = \beta_0 + \beta_1\ RDBUS_{it} + V_{it} + u_{it}$$

Where, *Y* is GDP and Unemployment and, RDGOV is the governmental expenditure in R&D and RDBUS is the expenditure of business in R&D. *V* is a vector of control variables that includes Inflation (Inf), Inward foreign direct investment (IFDI) and Interest rates (Ir). The subscript “i” identifies each country in the sample, while “t” represents each time period. *u* is the error term.

5.3. Model 3 – Combined dynamics of innovation policy short and long term effects on economic growth and employment

In this equation we develop an assessment that incorporates simultaneously the short (R&D efforts) and long (NIS’ stages of development) term effects of innovation policy on economic growth and employment. This proposition unites both justifications for current governmental involvement with innovation systems and the importance of its continuation over time (in order to create an economic environment conducive to innovation and growth). This model allows a closer scrutiny of partial results identified in the previous sets of models.

$$M3.\ Log\ Y_{it} = \beta_0 + \beta_1 TECH_{it-1} + \beta_2\ IINS_{it-1} + \beta_3\ RDGOV_{it} + V_{it} + \eta_{si} + \upsilon_{dt} + \varepsilon_{it}$$

Where, *Y* is estimated as GDP and Unemployment. *TECH* and *IINS* are the technological and institutional and infrastructure factors obtained in the factor analysis. In this case, the NIS factors are lagged in order to explore evolutionary effects of the NIS. RDGOV is the governmental expenditure in R&D. V is a vector of control variables that includes Inflation (Inf), Inward foreign direct investment (IFDI) and Interest rates (Ir). The subscript "i" identifies each country in the sample, while "t" represents each time period. Finally, η_{si}, υ_{dt}, ε_{it} are the specificities related to dynamic effects of the technique used.

We have applied Panel Data in each static version for our first and second sets of models (fixed or random effects were assigned according to Hausman test results). The third model is addressed via Dynamic Panel Data in order to capture specifically the evolutionary effects of the NIS applying a lag structure. Dynamic panel allows to correct the inherent endogeneity of the model due to the path dependence and the cumulative process that characterizes innovation activity and the evolution of innovation systems (Dosi, 1988; Castellacci, 2008). This method has two key advantages to test our hypothesis: the inclusion of time-series effects and the consideration of variables' individual effects. (Arellano and Bond, 1991; Arellano and Bover, 1995; Roodman 2006:2009:2012). Estimations' results of the econometric assessment are presented in the next section.

6. Results

Results from econometric estimations are presented in Tables 4, 5, 6 and 7. The overall assessment of models provides evidence in favor of our hypotheses. A first assessment (Table 4) concerns H_1, i.e., our approach on structural effects of NIS upon current conditions of economic growth and employment. In a first step (models 1.1 and 1.2) we notice that both factors (*Technological Factor or TECH, and the Institutional Factor or IINS*) affect GDP growth positively. Moreover, the elasticity of IINS surmounts that of TECH, suggesting that innovation systems' impacts upon economic growth are more strongly related to the knowledge and institutional conditions of European Member States. This situation pinpoints the importance of building a robust NIS structure in order to promote continuous growth in economic activity.

Additionally, L is significant in the first estimation, but once we control for a broader set of aspects, this picture changes a bit. On the one hand, K is not significant in model 1.1, but it is significant and unexpectedly negative in model 1.2. We understand this as a sign that once we control for a broad set of macroeconomic vectors and for innovation systems' conditions, traditional determinants of output (L and K) present a less relevant contribution (or even decreasing returns in the case of K) than it is expected in the traditional formulation of production functions. This result provides hints on the inadequacy of austerity measures that influence governmental behavior of reducing current efforts regarding innovation policy. The remaining models offer additional insights into these matters, highlighting the problems related to this sort of practice in terms of European nations' evolutionary trends. Control variables included in the extended function (model 1.2) perform the expected roles. Inflation and interest rates are both negatively related to economic growth in constant units. IFDI is positively associated with the dependent variable, which can be attributed to its function of capital inflows and its contributions to the knowledge infrastructure of firms[8].

Table 4. Estimation results for Models 1.1 and 1.2

GDP	M1.1.	M1.2.
TECH	0.146***	0.077**
	(0.028)	(0.033)
IINS	0.245***	0.112***
	(0.034)	(0.033)
L	1.095**	0.425
	(0.448)	(0.534)
K	-0.057	-0.123***
	(0.038)	(0.027)
Inf		-0.082***
		(0.019)
IFDI		0.176***
		(0.021)
Ir		-0.029*
		(0.018)
_cons	9.373	19.298**
	(6.829)	(8.313)
Hausman Test Chi2	17.13	28.510
	Fixed Effects	Fixed Effects
R-Square		
Within	0.7575	0.8281
Between	0.9362	0.9363
Overall	0.9227	0.8592
Observations	578	366
Groups	27	26

Robust standard errors in parentheses

Once we take into account the structural effects of innovation policy upon unemployment (Table 5), both indicators of NIS turn out to be non-significant and the model loses a relevant amount of predictive power. This outcome suggests that current stages of development in innovation systems *per se* do not seem to interfere much with short term macroeconomic shocks that affect employment. Although this is a somewhat surprising result, it may be related to the strong influence of short term financial fluctuations upon the productive structure. In other words, it is not enough for a given country “to be prepared” for unemployment pressures, it has to tackle these issues when they take place. As we will address in the upcoming estimations, this is a hint that short term multiplier effects related to innovation policy are likely to have a strategic role to play (even though innovation policy frameworks are often understood as long term tools

[8] We cannot rule out the potential endogeneity of this variable, i.e., the possibility of GDP growth attracting FDI rather than FDI influencing growth. However, this discussion lies outside of the scope of this article. For further discussions on this issue see, for example, Nair-Reichert and Weinhold (2001).

only). Hence, empirical evidence for GDP dynamics and unemployment suggesta partial acceptance of H_1.

As per the control variables, Inf is significant and negative, suggesting its role of reducing unemployment. Nonetheless, as seen in the estimations of Model 1.2, these dynamics should not be related to the promotion of economic growth. This is a potential issue of interest for future research dedicated to macroeconomic studies. IFDI is not significant in this assessment. Interest rate (Ir) is positive and significant, underscoring the important role of monetary policy upon employment conditions in European Member States.

Table 5. Estimation results for Models 1.3 and 1.4

Unemployment	**M 1.3**	**M 1.4**
TECH	-0.041	-0.043
	(0.048)	(0.081)
IINS	0.002	-0.036
	(0.029)	(0.032)
Inf		-0.106***
		(0.020)
IFDI		-0.078
		(0.065)
Ir		0.083***
		(0.019)
_cons	2.082***	2.365***
		(0.019)
Hausman Test Chi2	1.4	11.73
	Random effects	Random effects
R-Square		
Within	0.0028	0.2117
Between	0.0934	0.0126
Overall	0.0489	0.0921
Observations	620	368
Groups	28	26

Robust standard error in parentheses

The next step of the empirical analysis dedicates attention to our second research hypothesis (models 2.1 and 2.2, Table 6), i.e., the multiplier effects of current innovation policy represented by governmental expenditures in R&D. As it can be gathered from model 2.1, effects of governmental expenditures upon GDP growth surmount those perceived for the exact same model estimated with business expenditures in R&D. Nonetheless, it may be a mistake to consider RDBUS as taking place independently from RDGOV. A more robust rationale would be to attribute a significant amount of RDBUS to crowding-in effects. Moreover, marginal contributions from RDGOV are also significant (at 10%) for reducing current levels of unemployment, an aspect that is tackled more effectively by private expenditures in innovation (RDBUS). This outcome is in line with our expectations, as private firms' engagement with R&D activities may be likely to absorb more directly the idle share of the workforce. This evidence allows confirming for EU member States the validity of H_2.

Results for control variables do not differ substantially from previous assessments. Inflation maintains its negative influences upon economic growth while being positively related to unemployment reduction. IFDI has significant and positive effects upon both dependent constructs. High levels of interest rates are associated with slower GDP growth and rising unemployment.

Table 6. Estimation results for Models 2.1 and 2.2

	GDP		Unemployment	
RDGOV	0.296*** (0.051)		-0.047* (0.026)	
RDBUS		0.254*** (0.021)		-0.057** (0.024)
Inf	-0.035 (0.023)	-0.050*** (0.015)	-0.108*** (0.022)	-0.110*** (0.020)
IFDI	0.186*** (0.029)	0.183*** (0.022)	-0.127** (0.050)	-0.120** (0.050)
Ir	-0.051* (0.030)	-0.050** (0.023)	0.088*** (0.021)	0.084*** (0.020)
_cons	23.920*** (0.294)	23.928*** (0.167)	2.782*** (0.259)	2.878*** (0.249)
Hausman test Chi2	257.240***	57.240	5.350***	5.350***
	Fixed effects	Fixed effects	Random effects	Random effects
R-Square				
Within	0.8178	0.8702	0.2538	0.2585
Between	0.8557	0.6483	0.0201	0.001
Overall	0.7936	0.6361	0.0945	0.1247
Observations	346	349	342	345
Groups	26	26	26	26

Robust standard error in parentheses

The last econometric exercise consists in the simultaneous estimation of parameters related to NIS' stages of development and short term effects of innovation policy through a dynamic panel approach (Table 7). Once we apply lags of the dependent constructs as predictors, the significance of the vectors of interest endorse the propositions contained in H_1 and H_2. In this regard, effects occurring via RDGOV are stronger than combined impacts of NIS factors (in t-1), even though these three analytical constructs are positively related to economic growth.

On the other hand, the structural conditions of innovation systems have a larger influence upon the level of employment in European nations in a direct comparison to governmental R&D expenditures. As per control variables, little variation concerning their inclusion in previous estimations is identified. These results offer a robust set of outcomes to propose that innovation policy is a two-sided phenomenon in terms of long and short term relevance. We will discuss the implications of this findings in the concluding section.

Table 7. Estimation results for Model 3

	GDP	Unemployment
TECH $_{t-1}$	0.166**	-0.200***
	(0.068)	(0.050)
IINS $_{t-1}$	0.117***	-0.124***
	(0.040)	(0.036)
RDGOV	0.689***	-0.158**
	(0.067)	(0.066)
Inf	0.051	-0.318***
	(0.084)	(0.047)
IFDI	0.089*	-0.153***
	(0.050)	(0.056)
Ir	0.189***	-0.057
	(0.045)	(0.039)
_cons	21.631***	3.938***
	(0.601)	(0.417)
Hansen Chi2	11.170	18.950
Ar(1)	-1.86**	-1.90**
Ar(2)	-1.42	-0.840
Observations	337	334
Instruments	19	19

Robust standard error in parentheses

7. Concluding Remarks

This article has dedicated attention to the relevance of innovation policy as a mechanism to sustain economic growth and employment in the short term and to establish evolutionary paths that are also conducive to virtuous macroeconomic cycles. In a moment in which some European Member States face a sluggish recovery from financial and fiscal crises, discussing the role of governmental expenditures in R&D is timely and necessary. This pertinent in a context of predominant austerity measures concerning innovation-related activities.

As a consequence, countries often fail to capture the complex effects of innovation policy in both short and long terms. Particularly in periods of economic recession, the evolutionary prospects of innovation systems are jeopardized by budget cuts in “less urgent” areas. The main issue with this perception is that countries that are capable of sustaining strong innovation systems achieve better economic outcomes, while those that can’t tend to fall behind (Fagerberg & Srholec, 2008).

This is currently the case in the European Union and these ongoing strategies may not only affect growth and employment in laggard nations, but it may also generate the cornerstone for a perennial state of divergence among EU Member States. This perception is sustained by our empirical assessment. The evaluation of hour hypotheses suggests that innovation policy positively affects the current economic conditions and it also sets the stage for more resilient productive systems. Previous research (Dosi et al, 2010) has also concluded that innovation policies' impacts are not restricted to the long term, and that systemic effects can be felt at all frequencies. The main implication of this situation is straightforward: countries' governmental commitment to their respective innovation systems catalyzes current and prospective economic growth and stability.

Our conclusion on these matters is that macroeconomic policy is biased towards financial markets interests and that this is causing a disconnection with evolutionary aspects of economic systems. As a result, business cycles are not administered properly throughout upward and downward trends. A more consistent reliance on innovation as a true engine of development is needed. Moreover, these propositions may extend to countries located outside the framework of the EU. Gathering empirical insights of the validity of our hypotheses in other nations represents a promising field of research with potential impacts for the joint management of fiscal, monetary and innovation policy. We expect that this exploratory assessment functions as a call for further investigations in this field of research.

Some limitations of this research deserve attention. First of all, our decomposition of NIS into two analytical factors can only represent a narrow perspective of the complex and extensive nature of these systems. Nonetheless, our procedures were designed to offer a relatively comprehensive view of NIS through the incorporation of six input, output and throughput variables. Moreover, the relationship between NIS indicators and the dependent variables (GDP and Unemployment) can be regarded as an indirect one, i.e., multiplier and structural effects may take place via impacts on other dimensions of the economic landscape (trademarks, patents, high-tech industrial content, etc.). However, the identification of these potential "impact paths" goes beyond the scope of this research. Qualitative case-by-case analysis of EU Member States and the co-evolution of their respective innovation systems and economic policy can also provide relevant outcomes for this field of investigation. Lastly, it is hard to identify if the timing of impacts is the most adequate under an evolutionary perspective. It was not possible to assess this aspect in this exploratory assessment, but this is an issue of great interest and it should be dealt with in future research.

Disclosure Statement

No financial interest or benefit is involved from direct applications of this research.

Appendix 1. Countries included in econometric estimations

Austria (AT), Belgium (BE), Bulgaria (BG), Czech Republic (CZ), Croatia (HR), Cyprus (CY), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovak Republic (SK), Slovenia (SI), Spain (ES), Sweden (SE), United Kingdom (UK).

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