Andrés Rodríguez-Pose and Callum Wilkie

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Innovating in less developed regions: what drives patenting in the lagging regions of Europe and North America

by

Andrés Rodríguez-Pose and Callum Wilkie

Department of Geography and Environment
London School of Economics
Houghton St, London WC2A 2AE, UK
e-mails: a.rodriguez-pose@lse.ac.uk, j.c.wilkie@lse.ac.uk

Abstract: Not all economically-disadvantaged – 'less developed' or 'lagging' – regions are the same. They are, however, often bundled together for the purposes of innovation policy design and implementation. This paper attempts to determine whether such bundling is warranted by conducting a regional level investigation for Canada, the United States, on the one hand, and Europe, on the other, to (a) identify the structural and socioeconomic factors that drive patenting in the less developed regions of North America and Europe, respectively; and (b) explore how these factors differ between the two contexts. The empirical analysis, estimated using a mixed-model approach, reveals that, while there are similarities between the drivers of innovation in North America's and Europe's lagging regions, a number of important differences between the two continents prevail. The analysis also indicates that the territorial processes of innovation in North America's and Europe's less developed regions are more similar to those of their more developed counterparts than to one another.

Keywords: Innovation, lagging regions, R&D, patenting, Canada, Europe, United States.

JEL classifications: R11, R12, O32, O33

1. Introduction

The spatial concentration of innovative activity in large and economically-advanced cities and regions – often to the detriment of less developed areas – is a well-documented phenomenon (e.g. Feldman and Florida, 1994; Sun, 2003; Bettencourt et al., 2007; Mitra, 2007; Crescenzi et al., 2012; Foddi and Usai, 2013; Breau et al., 2014). Yet, the processes that drive innovation within more and less developed areas, in spite of the spatial and socioeconomic similarities they often display, are far from homogeneous (e.g. Crescenzi et al., 2007; 2012; Usai, 2011; Fagerberg et al., 2014) and vary considerably from one context to another.

Because of the tendency of innovation to congregate in more socioeconomically developed centers, a great deal is known about how processes of innovation transpire in these types of environments. We know much less, however, about how innovation unfolds in economically disadvantaged contexts and, more importantly, how processes of innovation vary across them (Virkkala, 2007; Hall and Donald, 2009). This research aims to shed light on how innovation processes occur in less developed regions by examining whether processes of innovation, and the factors that impinge upon them, differ substantially across heterogeneous lagging contexts. In particular, it addresses the issue of what makes relatively less developed areas of North America more innovative than those of Europe. The notion of interregional heterogeneity warrants further attention here. No two regions, lagging or otherwise, are identical; they differ along socioeconomic, political, structural, and institutional lines. There are, however, certain axes with which we are, given the innovation-orientation of the research, more concerned. These are elaborated on throughout the paper and, especially, in the theoretical section. Briefly, our focus remains on regions' knowledge-generating efforts, their physical situation and consequent exposure to knowledge flows, their skills endowments and, critically, the way in which they vary across space and between regions. Structural factors and features relating to regions' demographic compositions, agglomeration, and industrial structures are integrated as well in the analysis.

Two related questions lie at the heart of the research: (a) what factors govern processes of innovation in North America's and Europe's economically disadvantaged regions, respectively; and (b) how do these factors differ between the two contexts. A macroeconomic investigation of provinces and states in Canada and the United States, on the one hand, and regions in Europe – the OECD's Territorial Level 2 (TL2) regions –, on the other, between 2000 and 2010 is conducted to address the two questions.

Innovation is, for reasons addressed in the model and data section, proxied in the econometric analysis by patent applications.[1] The research is, therefore, an exploration of the key factors, features, and attributes that explain interregional differences in patenting activity. Patents have, despite their problems, been frequently employed as an indicative and reasonably reliable barometer of a territory's capacity to introduce commercially viable, tangible, and applied innovations (e.g. Furman et al., 2002). The econometric analysis is therefore employed as the basis for the formulation of insights into processes of innovation in the contexts with which this research is immediately concerned and, more specifically, into the socioeconomic factors that drive, shape, and mediate these processes. These inferences must, however, be interpreted with a cognizance of the limitations associated with the use of patent statistics as a proxy for innovation and with the appropriate degree of caution they warrant. Moreover, while interesting and insightful in and of themselves, the inferences drawn from the econometric exercise should be viewed as exploratory in nature and are as much points of departure for further research and exploration as they are 'standalone' conclusions.

This research makes contributions of both an academic and policy-oriented nature. Generally, work on innovation in less developed contexts has consisted of in-depth, often survey-driven investigations of single countries or regions (e.g. Doloreux et al., 2007; Virkkala, 2007; Doloreux and Dionne, 2008; Isaksen and Onsager, 2010; Fitjar and Rodríguez-Pose, 2011a, b; Jauhiainen and Moilanen, 2012; Fitjar and Rodríguez-Pose 2013; Pinto et al., 2015; Stephens et al., 2013; Mayer and Baumgartner, 2014; Varis et al., 2014; Kudic et al. 2015; Pelkonen and Nieminen, 2015). While this research has shed considerable light on innovation in what are thought to be relatively disadvantaged environments, a need for systematic research to facilitate the drawing of conclusions that go from the particular to the more general remains. The cross-continent comparative approach of the paper thus aims to supplement the work that has been and is being conducted at the case-study and microeconomic level with broader macroeconomic insights,[2] with the overarching objective of contributing to the development of innovation policies for North America's and Europe's lagging regions.

The empirical analysis, covering 71 less- and 81 more-developed regions in Europe as well as 27 less- and 34 more-developed provinces and states in Canada and the United States, respectively, suggests that while there are some similarities between the factors that govern innovation in North America's and Europe's lagging regions, a number of not inconsequential differences between the two continents prevail. Of the similarities, the most prominent relate to the positive relationships between innovation and both the availability of skilled human capital and the agglomeration of economic activity, as well as to the relevance of interregional knowledge flows to the generation of innovation. Differences relate to the types of R&D expenditure that are linked to regional innovativeness and to the role of R&D knowledge flows for innovation in lagging areas. In addition, the sets of factors that mediate processes of innovation in the lagging regions of both North America and Europe seem to bear a closer resemblance those that drive innovation in their more developed neighbors in the same Continent than to those at play in their lagging counterparts on the opposite side of the Atlantic.

The remainder of the paper is structured as follows: *Section 2* addresses the motivation for the work and presents the theoretical framework within which it is situated. *Section 3* explores trends in R&D expenditure and patenting in North America and Europe. *Section 4* introduces the empirical methodology, model, and variables employed in the analysis. *Section 5* presents and interprets the results of the econometric analysis. *Section 6* concludes by summarizing the analysis and deriving a series of preliminary policy implications and avenues for future research.

2. The puzzle of innovating in lagging regions

Two tenets have increasingly come to dominate the understanding of the economic geography of innovation. The first is that more economically developed territories are more innovative than their less developed counterparts. The second is that processes of innovation and the factors that influence them are as heterogeneous as the territories in which they occur.

The intention of the following section is to engage with these two beliefs with a view to expose some of the tension between the ways in which they are often approached or applied. It is this tension that ultimately serves as the theoretical motivation for this exploratory research and the questions that guide it.

2.1. The less-/more-developed innovation dichotomy

Lagging regions are generally thought to be less innovative than more economically advanced ones. While certain economically disadvantaged areas have managed, often against the odds, to display considerable innovative capacity (e.g. Virkkala, 2007; Doloreux et al., 2007; Doloreux and Dionne, 2008; Fitjar and Rodríguez-Pose, 2011a, b; 2013; Jauhiainen and Moilanen, 2012), the dominating view is that innovation tends to cluster in a relatively limited number of well developed areas (Feldman and Florida, 1994; Sun, 2003; Bettencourt et al., 2007; Mitra, 2007; Crescenzi et al., 2007; 2012; Foddi and Usai, 2013; Breau et al., 2014).

The dynamism of more developed territories in terms of innovative activity is frequently attributed to a host of socioeconomic and institutional factors. These areas generally have an abundance of skilled human capital, better technological infrastructure and ample physical capital (Feldman and Florida, 1994; Florida, 2003, 2005; Bettencourt et al., 2007). They concentrate public organizations and private firms that benefit from the externalities associated with co-location and agglomeration. Firms reap the benefits of economies of scale, specialization and diversification and of the localized circulation of knowledge (e.g. Jacobs, 1969; Glaeser et al., 1992; Anselin et al. 1997; Audretsch and Feldman, 2004; Duranton and Puga, 2004; Andersson et al., 2005; Carlino et al., 2007). Economic centers are also understood to be more institutionally suitable for innovative activity (Rodríguez-Pose 1999, 2001). The agglomeration of socioeconomic actors is associated with the emergence of "intricate institutional systems" that support the diffusion and exchange of knowledge and the collaborations and interactions fundamental to processes of innovation (Fitjar and Rodríguez-Pose, 2011a:557).

Likewise, several factors constrain the innovative capacity of less developed areas. Most prominent among them are socioeconomic and institutional deficiencies and geographic isolation. These contextual deficiencies relate to the weakness of the 'local economic fabrics', insufficient stocks of human and physical capital, and the absence of the formal and informal institutions that would normally function as the backbone of 'innovation prone' environments (Rodríguez-Pose, 2001:280-281). These shortcomings are thought to stifle the generation, local circulation, and application of knowledge. Physical isolation, on the other hand, places many of these areas beyond the geographic limits of knowledge spillovers emanating from more innovative territories (e.g. Moreno et al., 2005; Sonn and Storper, 2008; Rodríguez-Pose and Crescenzi, 2008), and in doing so, bars them from absorbing and exploiting economically useful knowledge generated elsewhere.

Stated simply, the resource endowments, socioeconomic fabrics, institutional infrastructures and, in some cases, the geographic/physical 'situations' of lagging regions differ vastly from those of their more economically advanced counterparts. More relevantly here, these differences tend to be reflected in and are ultimately responsible for their respective – often radically different – innovative capacities. The contextual conditions in lagging regions, in particular, are generally thought to be less conducive to the development and sustenance of robust innovative capacities. It is on this basis of these observations that the first implicit hypothesis of this research is formed: namely that because economically-disadvantaged regions tend to be characterized by structural, socioeconomic, and institutional fabrics that are *less conducive* to innovation than those of their more developed counterparts, processes of innovation in lagging regions, if and when they unfold, will stand in stark contrast to those transpiring in more economically developed areas.

2.2 Regional innovation as a contextually contingent process

The understanding of innovation processes and of what shapes them has evolved considerably from the earliest linear models (e.g. Maclaurin, 1953). Processes of innovation are now commonly considered as not only complex and dynamic, but also influenced by a variety of socioeconomic, institutional, and political characteristics unique to the environments in which they take place (Edquist and Chaminade, 2006: 125-126).

While investment in R&D expenditure and knowledge generation have long been associated with the generation of innovative output (e.g. Grilliches, 1979), other research has teased out links between a multitude of factors and innovative capacity. These include, but are not limited to: the supply and quality of human capital (Romer, 1990; Glaeser, 1999; Andersson et al., 2005; Crescenzi, 2005; Lee et al., 2010; Pater and Lewandowska, 2015); the skills composition of pools of labor (Florida, 2002; Ottaviano and Peri, 2005; Storper and Scott, 2009; Özgen et al., 2011); the agglomeration of economic activity and the knowledge-related externalities associated with it (Duranton and Puga, 2004; Storper and Venables, 2004); the capacity to absorb non-local knowledge (Bathelt et al., 2004); and local institutions and their quality (Rodríguez-Pose and Di Cataldo, 2015). These analyses often reveal pronounced differences between the factors that affect innovation, their relative importance and, critically, in how they interact with one another across geographies.

Consequently, innovation processes differ depending on the context in which they take place. The territorially-specific nature of regional innovation becomes evident in comparative analyses, which have unveiled great diversity in the territorial dynamics of innovation between places. Recent empirical research has revealed, for example, that the exact set of factors that influence processes of innovation in the United States, the European Union, India, and China, respectively, and, perhaps more importantly, the extent to and manner in which these factors do so, varies considerably across these four areas of the world (Crescenzi et al. 2007; 2012).

The research's second hypothesis is founded on this notion that processes of innovation are highly contingent on local context. More specifically, it is posited that while less developed areas may, as mentioned earlier, share some broad similarities, processes of innovation in what remain heterogeneous regions *will not* transpire in the same or perhaps even similar ways.

2.3 Do lagging areas innovate in the same way?

While the cross-context diversity of processes of innovation is increasingly acknowledged, an implicit tendency to presume that all economically disadvantaged environments a) innovate less and b) that they do so in relatively homogenous ways remains. Lack of agglomeration, poor accessibility, and weak socioeconomic and institutional endowments curtail innovation and offer limited alternatives for technological change. Hence, innovation policies tend to be similar for all lagging areas, regardless of local conditions. But is this truly the case? Do these regions, irrespective of geography and context innovate less and, more importantly, do they do so in similar ways?

Relying on a comparison between North America and Europe, this paper sets out to assess whether all lagging regions are functionally the same from an innovation perspective. Two related research questions inform the analysis: a) what are the socioeconomic factors that influence processes of innovation in North America's and Europe's lagging regions, respectively? And b) how do these factors differ between the two contexts?

Our focus on North America and Europe is motivated by a belief that the two economies are, in several relevant respects, sufficiently different to justify the comparison, but also sufficiently similar for such an exercise to be meaningful and interesting. The differences between the two economies are, as elaborated throughout the paper, numerous and range from subtle to significant. In terms of similarities, there are three of particular note that make the comparison worthwhile. First, the United States and Canada, on the one hand, and Europe, on the other, are part of the so-called ‘Triad’ of innovative economies and thus among what can be considered a first generation of leaders in the knowledge-generation and innovation spaces.[3] Second, both areas have served as engines for global economic growth and are, relatedly, at reasonably similar points in their respective development trajectories. Finally, capital and labor can move freely between states in the United States, provinces in Canada and between member states of the EU.[4] This is not to say that the economic relationships between European countries are identical to those between American states or Canadian provinces. It does, however, render a comparison – i.e. between nations and states/provinces – that in other contexts might be less appropriate, meaningful, relevant, and useful.

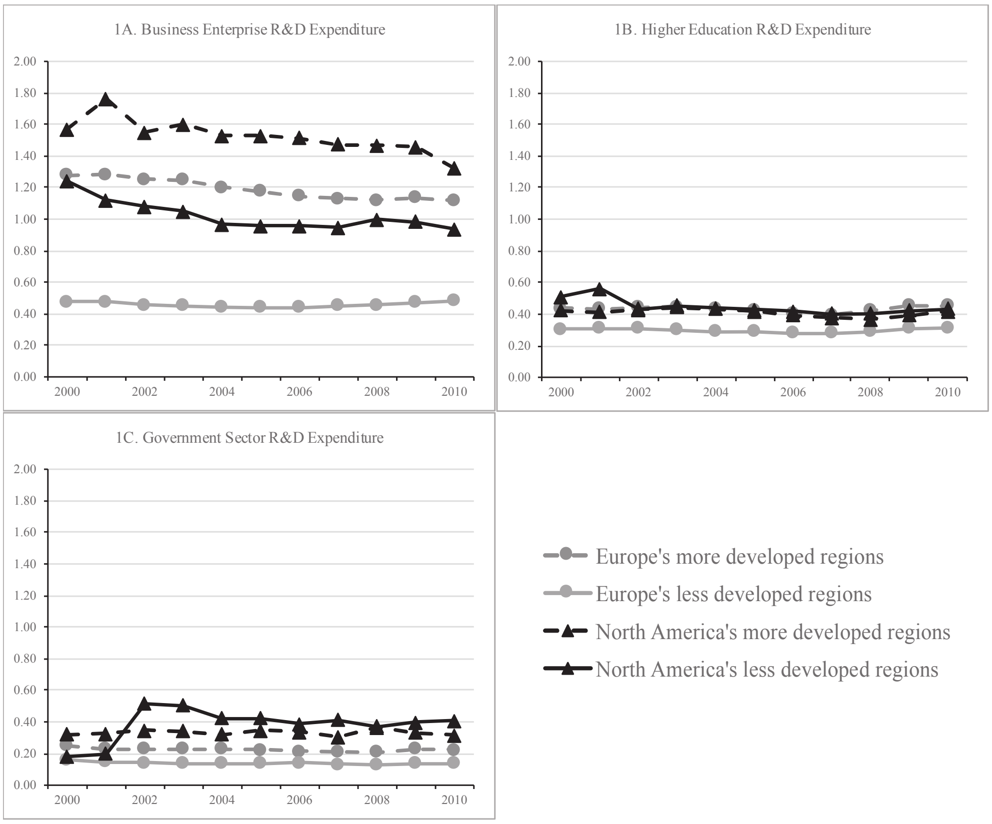
The regions that compose the continents with which we are concerned have been categorized purely in accordance with their respective levels of economic development. More specifically, ‘less-developed’ or ‘lagging’[5] regions are, for the purposes of the analysis, defined as those below a given threshold in terms of relative wealth in 2010: 90% of the average regional GDP per capita in Canada, the US, and Europe, respectively.[6]

3. Knowledge generation and innovation in the lagging regions of North America and Europe

Prior to delving into the econometric analysis, let us consider both the basic ‘inputs’ to and ‘outputs’ of the innovation process in North America and Europe. The input we focus on is R&D expenditure. R&D investment is by no means the only input to processes of innovation. It is, however, intimately linked to the generation and absorption of the “economically useful knowledge" (Audretsch and Feldman, 2004) and is the only input for which there is reliable and comparable data at the regional level for both North America and Europe. For output we consider patent applications – again a not uncontroversial measure of innovation (see footnote 1) – but the only one for which comparable data exist.

Figure 1 illustrates R&D expenditure trends in business enterprise (*Figure 1A*), higher education (*Figure 1B*) and government sector (*Figure 1C*) R&D in both the lagging and the more developed regions of North America and Europe. Three inferences can be drawn from the figures.

Figure 1. *Average regional R&D expenditure by sector as a percentage of GDP, 2000-2010*



Authors' elaboration: Source OECD, Regional Database (http://stats.oecd.org).

First, business enterprise is the most prominent type of R&D investment across North American and European regions, regardless of level of development (*Figure 1A*). There are, however, considerable differences in business R&D expenditure across different types of territories. North America's more developed regions invest considerably more in business enterprise R&D than their lagging counterparts. In 2010, for example, the continent's more developed regions spent 1.32% of their GDPs on business enterprise R&D. Its lagging regions, by comparison, directed an average of only 0.94%. A much greater gulf exists in Europe. In 2010, business enterprise R&D expenditure accounted for 1.12% of the GDP of its more developed regions and only 0.48% of its economically disadvantaged ones.

Second, the balance between private and public R&D varies considerably between the two continents and between their less developed regions in particular (*Figures 1B* and *1C*). In North America's lagging regions, the public effort represented 45% of the 1.8% of GDP invested in R&D. In Europe, the involvement by the private sector was less prominent, and public investment was 0.5% of GDP in a total investment in R&D which has hovered around 1% of GDP.

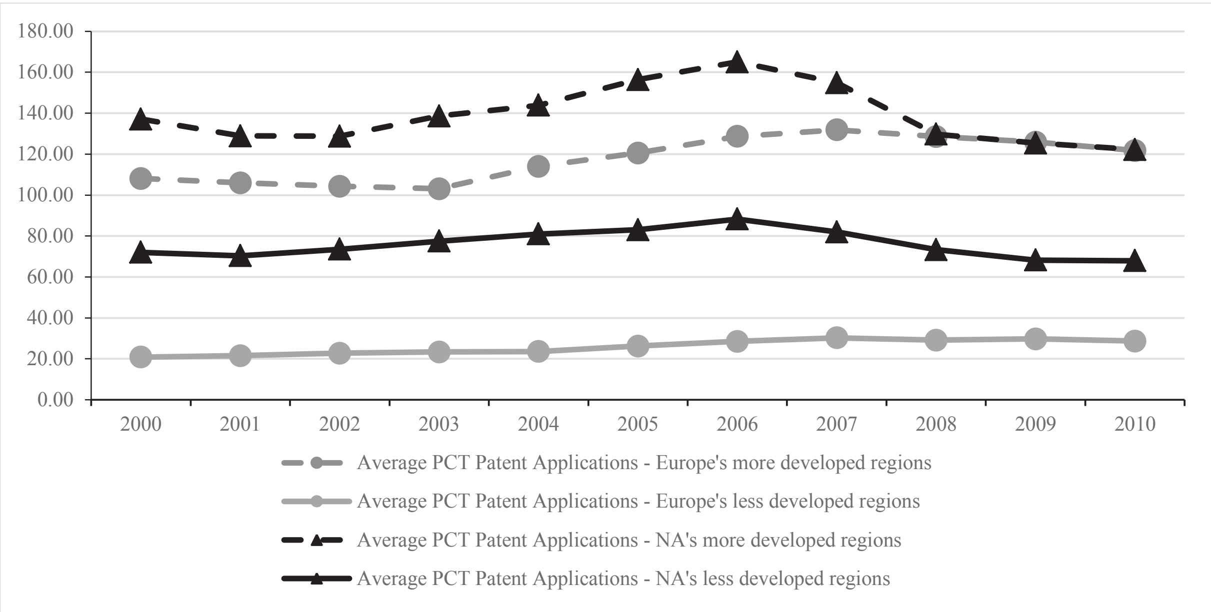
Third, levels of public R&D investment in North America's lagging regions – that is both higher education and government R&D – are comparable to those in its more developed regions (*Figures 1B* and *1C*). In 2010, higher education R&D expenditure accounted for an average 0.43% of GDP in lagging regions and 0.42% in more advanced ones (*Figure 1B*). Likewise, the continent's more developed regions spent, on average, 0.32% of their GDPs on government sector R&D, while their less developed counterparts directed 0.41% of GDP to these activities

(*Figure 1C*). By contrast, levels of public R&D in Europe's lagging regions were well below those of the more developed regions in the continent. In 2010, for example, Europe's more developed regions directed, on average, 0.45% and 0.23% of their GDPs towards higher education and government sector R&D, respectively (*Figures 1B* and *1C*). Lagging regions, on the other hand, invested 0.31% and 0.14% of their GDPs in the two types of R&D (*Figures 1B* and *1C*).

Summarizing, while North America's economically disadvantaged regions lag behind its more developed ones in terms of business enterprise R&D expenditure, the two types of regions direct, on average, similar amounts to both types of public R&D activities. The implications of this are twofold: First, differences in aggregate R&D expenditure between North America's more and less developed regions are attributable to differences in private rather than public investment. Second, lagging regions in North America are less disadvantaged in terms of R&D investment than European ones relative to their respective more advanced counterparts. That is, not only do levels of business enterprise R&D expenditure in more developed regions exceed those of lagging regions by a much greater margin in Europe than they do in North America, Europe's lagging regions also invest less, on average, in public R&D activities than their more developed neighbors. Comparable differences in public R&D investment are not observed between less- and more developed regions of North America. Overall, lagging regions in North America would seem more favorably positioned to produce innovation than their European counterparts.

On the output side, patent application trends are broadly consistent with those observed in R&D expenditure (*Figure 2*). In both North America and Europe, more developed regions are, on average, significantly more innovative than lagging ones. Moreover, there has been a degree of convergence in the innovative performance of the more advanced regions of the two continents. Between 2000 and 2006, North America's more developed regions were decidedly more innovative than their European counterparts. By the end of the period of analysis, however, the two economies' more developed regions were producing similar numbers of patents per million inhabitants. In 2010, North America's more developed regions generated, on average, 122.22 patents per million inhabitants, while in Europe the same category of regions produced a comparable 121.76 patents per million inhabitants in the same year.

Figure 2. *Average regional PCT patent applications per million inhabitants, 2000-2010*



Authors' elaboration: Source OECD, Regional Database (http://stats.oecd.org).

There remains, however, a pronounced discrepancy between the respective innovative performances of lagging regions on either side of Atlantic – North America's lagging regions are decidedly more innovative in per capita terms than their European counterparts (*Figure 2*). While the innovative gap between the two economies' less developed regions did decrease marginally between 2000 and 2010, the 28.71 patents per million inhabitants produced by Europe's lagging regions in 2010 was more than doubled by the 67.91 patents applications per million inhabitants in similarly disadvantaged regions in North America.

Part of the pronounced difference between the innovative output of North America's lagging regions and Europe's may be explicable by the classification of certain American states that were once among the country's most developed – including, for example, Michigan, Ohio and perhaps even, recognizing the former prominence of St. Louis, Missouri – as less developed areas. These states are today – and were throughout the period of analysis – lagging states. Decades-long processes of economic decline and, more recently, the global financial crisis that transpired in the latter part of the 2000s reversed the economic fortunes of what once were prosperous states. It is possible, however, that the economic dynamism these states achieved largely on the back of more industrial, manufacturing-type activities in the early- to mid-20th century endowed these regions with an above average innovative capacity some of which has proved resilient to the processes of economic decline by which they have been plagued. It is unlikely, however, that the gulf between the innovative capacities of lagging regions in the two continents is explicable entirely by the long-since-passed economic success of a small handful of states and the 'legacy effects' with which it is possibly associated. That said, this history should not be overlooked and needs to be acknowledged as part of the efforts to understand the differences between North America and Europe's lagging regions.

In short, *Figures 1* and *2* reveal sizable differences between lagging regions in North America and those in Europe. More specifically, it becomes apparent that Europe's lagging regions are more disadvantaged in terms of R&D expenditure and investment in business R&D functions, in particular, than their North American counterparts. Moreover, Europe's less developed regions also lag behind North America's in patent production, suggesting that the innovative capacity of North America's lagging regions is greater than that of those in Europe. The geography of patenting activity across both North America and Europe is summarized in Figure A1 in the Appendix.

4. Model and variables

4.1. The model

The econometric model assumes a 'modified regional knowledge production function' form (Ó hUallacháin and Leslie, 2007) within which regional innovative capacity is a function of regional investment in knowledge generation; the innovative activities occurring in neighboring regions; and a vector of socioeconomic factors.

The basic model is specified as follows:[7]

$$y_{i,t} = \beta R\&D_{i,t} + \theta WR\&D_{i,t} + \delta X_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where:

y	represents regional innovative performance proxied by patent intensity;
$R\&D$	depicts regional investment in R&D activities;
$WR\&D$	represents average R&D expenditure in neighboring regions;
X	is a vector of socioeconomic factors;
i,t	depict region and time, respectively

4.2. The variables[8]

4.2.1. Dependent variable

The dependent variable is patent applications per million inhabitants. Patents applications reflect the introduction of commercially viable, applied innovations (Furman et al., 2002) and as a result, are an oft-employed barometer of a territory's innovative capacity. Despite their shortcomings, patent applications statistics are the most suitable option for cross-country comparative econometric analyses. We opt to use Patent Cooperation Treaty ('PCT') patent applications. This decision is motivated by the comparative nature of the research. Crescenzi et al. (2012:1062) highlight, citing the OECD (2009:66), that PCT patent applications function as "'worldwide patent application[s]' [that are] much less biased than national applications".[9]

Prior to proceeding, it must be stressed that there is considerable debate surrounding the suitability of patent applications as a proxy for innovative capacity. Detractors assert that many innovations are not patented either because they are not legally patentable or because the inventor has opted not to patent it (Desrochers, 1998:57-58). Patent applications offer a reasonably good measure of specifically commercially viable, more tangible innovation – especially that which is generated by/ in sectors and industries with higher propensities to patent (e.g. Mäkinen, 2007; Fontana et al., 2013) – but, as noted by Capello and Lenzi (2014:189), they do not reflect "innovative efforts that can be developed either in the form of process, marketing, and organizational innovations or in the form of product innovation not [necessarily] obtained via research and patenting activities". We are therefore only able to observe certain types of innovations and certain dimensions of a region's overall innovative capacity. Hence, while patents are a generally accepted proxy for innovation, they do not capture *all* types of innovative activity. Similarly, the validity of patent statistics as a measure of innovativeness is adversely affected by biases in the types of innovations that are patented (i.e. product versus process) and by variability in the propensity of firms in different industries and of different sizes to patent (Desrochers, 1998:58). In spite of these well-documented limitations, patent application statistics remain the most frequently used proxy for innovation, often as a product of necessity, and they do not impede the formulation of exploratory and indicative comparative insights into innovation in the types of environments with which this research is concerned. As Trajtenberg (1990: 183) observes, they are "the only observable manifestation of inventive activity with a well-grounded claim for universality".

4.2.2. Independent variables

Processes of regional innovation are subject to influence by any number of factors. This research is most immediately concerned with those of a structural and socioeconomic nature.[10] The theoretical and empirical literature has identified a host of variables that reflect a series of socioeconomic and structural influences that are among the preeminent shapers of processes of knowledge creation and application and, ultimately, innovation. We incorporate these variables into the empirical model. They are the following.

R&D expenditure

The first of our independent variables are measures of regional R&D expenditure, expressed, including the spatially-lagged ones, as percentages of GDP.

R&D activities are intrinsically linked to processes of innovation (e.g. Grilliches, 1979). Regional investment in R&D is a central determinant of a region's capacity to generate new, economically useful knowledge as well as to absorb externally generated knowledge and innovations (Cohen and Levinthal, 1990; Griffith et al., 2003; 2004; Vogel, 2015).

We disaggregate regional R&D expenditure into three sub-categories: a) business enterprise; b) higher education; and c) government sector R&D. The motivation for doing so is twofold. First, from a more theoretical perspective, certain types of R&D expenditure are more readily associated with the generation of innovation than others (Malecki, 1991, Rodríguez-Pose, 1999). Business R&D, on the one hand, is, as Guellec and Van Pottelsberghe de la Potterie (2004: 355) note, more readily linked to the generation of "new goods and services, [with] higher quality of output and new production processes". Higher education and government sector R&D expenditure, on the other hand, are more commonly associated with advances in "scientific, basic knowledge and [public missions]" and the maintenance and expansion of the "stock of knowledge available for the society" (Guellec and Van Pottelsberghe de la Potterie, 2004: 356).

Second, as illustrated in *Section 3*, there are marked differences in the allocation of R&D resources across public and private functions between North America and Europe, and again between their more developed and less developed regions. The consideration of the three subclasses of R&D expenditure is therefore necessary to develop nuanced insights into the returns to R&D in the lagging regions of both North America and Europe.

R&D knowledge flows

Returns to R&D investment are often realized beyond the borders of the region undertaking it (Audretsch and Feldman, 2004:2718; Feldman and Kogler, 2010). Exposure to interregional knowledge flows and externally generated knowledge and innovation is a non-negligible influence on the innovativeness of a territory (e.g. Fritsch and Franke, 2004; Bathelt et al., 2004; Moreno et al., 2005; Cabrer-Borrás and Serrano-Domingo, 2007; Sonn and Storper, 2008; Rodríguez-Pose and Crescenzi, 2008; Fitjar and Rodríguez-Pose, 2011a; b; Rodríguez, 2014; Grillitsch and Nilsson, 2015).

We have therefore developed two types of spatially-lagged R&D expenditure variables to explore the relationship between exposure to interregional knowledge spillovers and regional innovative capacity. The spatially-lagged R&D variables reflect the average R&D expenditure of neighboring regions and are constructed for all three subcategories of R&D expenditure. The first type of spatially-lagged variable uses first-order contiguity spatial weights and is included to estimate the influence of exposure to shorter distance knowledge flows on regional innovativeness. The second type uses inverse-distance spatial weights to capture longer distance flows.

Skills in the labor force

As indicated in the theoretical section, human capital and the availability of suitably skilled labor are key for regional innovation. Accordingly, higher education attainment assesses the relationship between regional innovativeness and the skills available in a region. Similarly, the efficient mobilization of local human resources is linked to a region's innovativeness (Rodríguez-Pose, 1999). Regional unemployment is therefore included to explore the link between the "productive employment of human resources" (Crescenzi et al., 2007:684) and regional innovation.

Industrial composition

Certain industrial compositions or 'mixes' are more conducive to innovation than others (e.g. Capello et al., 2012). Employment in industry – the International Standard Industrial

Classification (ISIC) rev. 3 and rev. 4 “employment, industry, including energy”, with data expressed as a percentage of total regional employment – is used to assess the relevance of a region’s industrial composition to its innovative capacity.

Agglomeration

The link between agglomeration and innovation is explored, as customary in the literature, using regional population density (e.g. Moreno et al., 2005; Crescenzi et al., 2007, 2012; Usai, 2011; Paci et al., 2014). Density represents a proxy for the co-location of economic actors and the agglomeration of economic activity.

Demographics and development

The percentage of the population aged 15-24 is included to control for regional demographic composition, the relevance of which to innovation has been verified by empirical examination (e.g. Frosch and Tivig, 2007; Poot, 2008). GDP per capita is considered to control for a region’s relative wealth and overall level of socioeconomic development.

5. Results of the empirical analysis

5.1. Introduction to results and econometric details

The model is estimated using time and geographical[11] fixed- and random-effects at the regional level, and with robust standard errors. The analysis considers TL2 regions of Canada, the United States, and a large selection of European countries for the eleven-year period between 2000 and 2010. A complete list of the countries and regions included is provided in *Appendices 2-5*.[12]

The decision to employ the TL2 regions as the unit of analysis is not an arbitrary one and is based on three factors. First, the comparative nature of the research requires the use of comparable spatial units. TL2 regions have been uniformly defined for by the OECD, making them comparable across the countries considered in the empirical analysis. Second, the TL2 level is the regional level for which the data necessary to conduct the type of comparative econometric analysis performed here are available and as complete as possible. Third, and perhaps, most importantly, the TL2 level is the level for which many regional policies, including those geared towards the promotion of innovation, are designed and at which they implemented. Many of the European TL2 regions examined are classified by the European Commission's nomenclature system as 'NUTS2' regions. This NUTS2 level is defined by the Commission as the spatial level at which regional policies are applied.[13] In those cases where the TL2 classification differs from the NUTS2 level, the TL2 classification includes territories with a considerable degree of regional autonomy. That is, for example, the case of the German *Länder* and the Belgian regions. Similarly, in North America, many of the programs and strategies pursued to catalyze innovation and promote regional innovation potential are undertaken by states in the US and provinces in Canada.[14]

The section is structured as follows: *Sections 5.2* and *5.3* present the estimation results for both the lagging and the more economically advanced regions of North America and Europe respectively.[15] In both of these sections, results for the more developed, non-lagging, regions are discussed with reference lagging ones. *Section 5.4* provides a brief discussion of a test that was performed to ensure the results are robust to the employment of a marginally different dependent variable. *Section 5.5* compares the estimation results for North America's economically disadvantaged regions to those for their European counterparts.[16]

5.2. North America

Less developed regions

Table 1 presents the estimation results for the economically disadvantaged, lagging regions of North America.

Table 1. *North America's less developed regions*

	North America, less developed regions					
	(I)	(II)	(III)	(IV)	(V)	(VI)
GDP per capita (ln)	0.791	0.918*	0.893	0.861	0.744	0.694
	(0.531)	(0.542)	(0.643)	(0.647)	(0.633)	(0.640)
Business enterprise R&D	0.012	0.025				
(BERD) (ln)	(0.059)	(0.062)				
Higher education R&D			0.132***	0.132***		
(HERD) (ln)			(0.050)	(0.049)		
Government sector R&D					-0.042	-0.044
(GOVERD) (ln)					(0.032)	(0.032)
Spatially-lagged BERD	0.315**					
(contiguity) (ln)	(0.132)					
Spatially-lagged BERD		1.343**				
(inverse) (ln)		(0.661)				
Spatially-lagged HERD			0.067			
(contiguity) (ln)			(0.127)			
Spatially-lagged HERD				0.547		
(inverse) (ln)				(0.401)		
Spatially-lagged GOVERD					-0.030	
(contiguity) (ln)					(0.0508)	
Spatially-lagged GOVERD						-0.164
(inverse) (ln)						(0.133)
Tertiary educational	0.047***	0.043**	0.034*	0.033*	0.038**	0.037*
attainment	(0.017)	(0.018)	(0.018)	(0.018)	(0.019)	(0.019)
Unemployment rate	-0.015	-0.019	-0.017	-0.015	-0.011	-0.011
	(0.024)	(0.025)	(0.026)	(0.026)	(0.026)	(0.026)
Employment in industry	-0.025	-0.021	-0.016	-0.017	-0.023	-0.024
	(0.018)	(0.019)	(0.020)	(0.021)	(0.020)	(0.020)
Population density (ln)	0.203**	0.182*	0.205*	0.198*	0.193*	0.204
	(0.092)	(0.102)	(0.111)	(0.116)	(0.117)	(0.125)
Percentage of the	0.057**	0.075**	0.052	0.036	0.051*	0.047*
population aged 15-24	(0.024)	(0.030)	(0.032)	(0.028)	(0.031)	(0.028)
Constant	-5.745	-7.743	-6.675	-5.764	-5.351	-4.964
	(5.330)	(5.314)	(6.320)	(6.432)	(6.280)	(6.309)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	297	297	297	297	297	297
Overall R2	0.783	0.750	0.687	0.675	0.664	0.656

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

We begin the analysis with an examination of the links between the three types of R&D expenditure and regional innovative capacity. Regional investment in higher education R&D is positively and statistically significantly associated with regional patent generation across all specifications of the model for which it is included (*Specifications III, IV*). Business enterprise and government sector R&D expenditure are not, however, statistically significantly linked to regional innovative output (*Specifications I, II, V, VI*).

A positive relationship also emerges between skilled human capital and innovation. The percentage of the labor force with higher education is positively and statistically significantly related to regional patent intensity in the majority of model specifications (*Specifications I – VI*). The agglomeration of economic activity and the youthfulness of a region's demographic composition are associated with regional innovativeness as well. The coefficients of population density (*Specifications I – V*) and the percentage of the population aged 15-24 (*Specifications I, II, V, VI*) are positive and statistically significant across most specifications of the model. Conversely, neither the unemployment rate – as a proxy for a region's capacity to mobilize its human capital – nor employment in industry – as a proxy for the industrial structure of a region's economy – is linked to regional innovative output (*Specifications I – VI*).

In North America's less developed regions, exposure to interregional knowledge flows matters for regional innovative capacity. A positive and statistically significant relationship exists between a region's innovative output and its exposure to both short- and long-distance business enterprise R&D flows (*Specifications I, II*). The coefficients for the spatially-lagged higher education and government sector R&D variables, by comparison, are not statistically significant in any specifications (*Specifications III – VI*).

More developed regions

While there are numerous similarities between the innovation processes transpiring in North America's lagging regions and in their more economically advanced counterparts, there are also noticeable differences. The estimation results for the more developed regions of North America are presented in *Table 2*.

Table 2. *North America's more developed regions*

	North America, more developed regions					
	(I)	(II)	(III)	(IV)	(V)	(VI)
GDP per capita (ln)	-0.147	-0.124	0.293	0.329	-0.028	0.002
	(0.215)	(0.209)	(0.213)	(0.216)	(0.229)	(0.231)
Business enterprise R&D	0.088*	0.081				
(BERD) (ln)	(0.052)	(0.054)				
Higher education R&D			0.367**	0.367**		
(HERD) (ln)			(0.182)	(0.183)		
Government sector R&D					0.024	0.025
(GOVERD) (ln)					(0.028)	(0.028)
Spatially-lagged BERD	-0.015					
(contiguity) (ln)	(0.085)					
Spatially-lagged BERD		-0.306				
(inverse) (ln)		(0.258)				
Spatially-lagged HERD			-0.008			
(contiguity) (ln)			(0.091)			
Spatially-lagged HERD				-0.172		
(inverse) (ln)				(0.326)		
Spatially-lagged GOVERD					0.018	
(contiguity) (ln)					(0.036)	
Spatially-lagged GOVERD						0.161*
(inverse) (ln)						(0.088)
Tertiary educational	0.043***	0.043***	0.034**	0.034**	0.038***	0.038***
attainment	(0.015)	(0.015)	(0.015)	(0.016)	(0.014)	(0.014)
Unemployment rate	-0.032	-0.030	-0.030	-0.030	-0.036	-0.036*
	(0.022)	(0.022)	(0.019)	(0.019)	(0.022)	(0.021)
Employment in industry	0.027	0.026	0.023	0.020	0.022	0.019
	(0.023)	(0.023)	(0.024)	(0.023)	(0.024)	(0.023)
Population density (ln)	0.211**	0.214**	0.193*	0.189*	0.208**	0.191*
	(0.091)	(0.095)	(0.113)	(0.113)	(0.102)	(0.107)
Percentage of the	-0.094	-0.099	-0.093	-0.087	-0.097	-0.095
population aged 15-24	(0.065)	(0.066)	(0.071)	(0.072)	(0.074)	(0.071)
Constant	5.421**	5.358**	1.217	0.693	4.434*	4.390*
	(2.261)	(2.237)	(2.191)	(2.378)	(2.551)	(2.602)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	374	374	374	374	374	374
Overall R2	0.681	0.674	0.552	0.548	0.594	0.575

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

Three prominent similarities between the set of factors that govern processes of innovation in the less and more developed regions of North America emerge. First, both higher education R&D expenditure (*Specifications III, IV*) and tertiary educational attainment (*Specifications I – VI*) play an important role for innovation in both areas. A positive and statistically significant relationship between the agglomeration of economic activity and regional patent intensity is also evident in both contexts (*Specifications I – VI*).

Moreover, as is true for its lagging regions, innovative capacity is not consistently and robustly linked to regional unemployment (*Specifications I – V*);[17] employment in industry (*Specifications I – VI*); or investment in government sector R&D in North America's more economically advanced regions (*Specifications V – VI*).

In spite of these similarities, two critical differences come to light between the two types of regions. First, business enterprise R&D expenditure, which is not significantly linked with innovative output in the continent's less developed regions, is positively and statistically significantly connected with regional innovative capacity in the more developed ones (*Specification I*). Second, the positive, significant relationship between exposure to business enterprise R&D knowledge flows and patent intensity observed in North America's lagging areas disappears in richer regions (*Specifications I, II*).

There is some cursory evidence to suggest that the innovative capacity of North America's more economically developed areas may be negatively and significantly linked to exposure to long-distance business enterprise R&D knowledge flows. One interpretation for this negative relationship is, following Crescenzi et al. (2012:1075), that the concentration of innovative activity in certain regions may "promote the outflow of knowledge from neighboring regions". The analysis also reveals a positive and significant relationship between exposure to long-distance government sector R&D knowledge flows in these regions that is not seen in their lagging neighbors (*Specification VI*). The two aforementioned relationships, however, only hold in model specifications that *do not* include regional business R&D expenditure.

No relationship exists between regional innovative output and exposure to any type of shorter-distance R&D knowledge flows nor longer-distance higher education R&D knowledge flows in North America's lagging regions (*Specifications I, III, IV, V*).

A final point of divergence between the two types of regions in North America relates to the relevance of regional demographic compositions. The innovativeness of North America's more developed regions is not connected to the youthfulness of their respective populations like it was in the continent's lagging regions. (*Specifications I – VI*).

5.3. Europe

Less developed regions

Table 3 presents the estimation results for the Europe's lagging regions.

Table 3. *Europe's less developed regions*

	Europe, less developed regions					
	(I)	(II)	(III)	(IV)	(V)	(VI)
GDP per capita (ln)	0.759**	0.687**	0.543	0.527	0.647*	0.670*
	(0.317)	(0.338)	(0.383)	(0.412)	(0.360)	(0.364)
Business enterprise R&D	0.226***	0.228***				
(BERD) (ln)	(0.067)	(0.065)				
Higher education R&D			0.093	0.104		
(HERD) (ln)			(0.059)	(0.064)		
Government sector R&D					0.029	0.026
(GOVERD) (ln)					(0.028)	(0.029)
Spatially-lagged BERD	0.110					
(contiguity) (ln)	(0.069)					
Spatially-lagged BERD		1.128**				
(inverse) (ln)		(0.570)				
Spatially-lagged HERD			0.207**			
(contiguity) (ln)			(0.092)			
Spatially-lagged HERD				1.096		
(inverse) (ln)				(0.693)		
Spatially-lagged GOVERD					-0.075	
(contiguity) (ln)					(0.083)	
Spatially-lagged GOVERD						0.385*
(inverse) (ln)						(0.234)
Tertiary educational	0.019*	0.017	0.021*	0.020*	0.021*	0.021**
attainment	(0.011)	(0.0111)	(0.011)	(0.011)	(0.011)	(0.010)
Unemployment rate	0.004	0.002	0.010	0.009	0.010	0.009
	(0.006)	(0.006)	(0.007)	(0.007)	(0.006)	(0.006)
Employment in industry	0.003	0.003	0.009*	0.010*	0.008*	0.009*
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Population density (ln)	0.263***	0.260***	0.288***	0.304***	0.278***	0.306***
	(0.082)	(0.080)	(0.099)	(0.103)	(0.100)	(0.100)
Percentage of the	-0.140***	-0.137***	-0.164***	-0.170***	-0.172***	-0.162***
population aged 15-24	(0.031)	(0.030)	(0.033)	(0.035)	(0.036)	(0.034)
Constant	-3.685	-2.974	-1.161	-0.133	-2.379	-2.162
	(3.398)	(3.583)	(4.097)	(4.713)	(3.821)	(3.951)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	768	768	757	757	768	768
Overall R2	0.865	0.865	0.843	0.845	0.848	0.848

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

Of the three types of R&D expenditure, only investment in business enterprise R&D – which is rather limited in Europe's less developed regions – is consistently significantly linked to innovative output. The coefficient for business enterprise R&D expenditure is positive and significant in all specifications of the model for which it is included (*Specification I, II*). By contrast, there is no significant association between regional higher education (*Specification III, IV*) and government sector R&D expenditure (*Specification V, VI*), which represent half of the R&D effort in Europe's lagging regions, and regional innovation.

Human capital endowments are linked to innovative capacity. A positive and statistically significant relationship is found between educational attainment and regional patent intensity (*Specification I, III, IV, V, VI*). The agglomeration of economic activity is also positively and significantly related to regional innovativeness (*Specification I – VI*) as is employment in industry in the majority of model specifications (*Specifications III – VI)*. Interestingly, the statistical significance of the latter relationship only holds in specifications of the model that *do not* control for business enterprise R&D expenditure, suggesting that industrial structure is not immediately relevant to the generation of innovative output in regions with sufficiently high levels of business R&D investment (*Specifications I, II*).

The association between the youthfulness of a region's population and its innovativeness is significant but negative (*Specifications I – VI)*. The regional unemployment rate is not robustly linked to patent generation (*Specifications I – VI).*

The coefficients of the spatially-lagged variables suggest that exposure to interregional knowledge flows *is* of relevance to processes of innovation in the less developed regions of Europe. More specifically, there is a positive and statistically significant relationship between regional innovative capacity and exposure to long-distance business enterprise; short- and long-distance higher education; and long-distance government sector R&D knowledge flows, respectively (*Specifications II, III, VI*).

The coefficient for tertiary educational attainment is, however, not significant in *Specification II* which includes the spatially-weighted variable for long-distance business enterprise R&D knowledge flows. This hints at the importance of long-distance business R&D knowledge flows to the innovativeness of Europe's lagging regions. Exposure to short-distance business enterprise and short-distance government sector R&D spillovers is not robustly linked to regional innovativeness (*Specifications I, V*).

More developed regions

As is very much the case in the North American context, there are a number of similarities between the set of factors that governs processes of innovation in Europe's more developed regions and that which explains the innovative capacity of their more economically disadvantaged neighbours. Once again, however, these similarities are matched by several significant differences. *Table 4* presents the estimation results for Europe's more developed regions.

Table 4. *Europe's more developed regions*

	Europe, more developed regions					
	(I)	(II)	(III)	(IV)	(V)	(VI)
GDP per capita (ln)	0.161	0.171	-0.099	-0.091	-0.091	-0.067
	(0.195)	(0.196)	(0.240)	(0.233)	(0.245)	(0.241)
Business enterprise R&D	0.266***	0.269***				
(BERD) (ln)	(0.073)	(0.075)				
Higher education R&D			-0.058	-0.059		
(HERD) (ln)			(0.060)	(0.060)		
Government sector R&D					0.018	0.038
(GOVERD) (ln)					(0.038)	(0.031)
Spatially-lagged BERD	0.024					
(contiguity) (ln)	(0.057)					
Spatially-lagged BERD		0.510**				
(inverse) (ln)		(0.222)				
Spatially-lagged HERD			-0.077*			
(contiguity) (ln)			(0.045)			
Spatially-lagged HERD				-0.703		
(inverse) (ln)				(0.475)		
Spatially-lagged					0.094	
GOVERD (contiguity) (ln)					(0.085)	
Spatially-lagged						0.810*
GOVERD (inverse) (ln)						(0.483)
Tertiary educational	0.017***	0.017***	0.020***	0.020***	0.016**	0.017**
attainment	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Unemployment rate	-0.016*	-0.015*	-0.014*	-0.014*	-0.016*	-0.017**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)
Employment in industry	0.008	0.008	0.008	0.008	0.008	0.009
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Population density (ln)	0.105*	0.110**	0.163***	0.165***	0.172***	0.152**
	(0.054)	(0.053)	(0.056)	(0.055)	(0.060)	(0.061)
Percentage of the	-0.073***	-0.064***	-0.100***	-0.100***	-0.100***	-0.095***
population aged 15-24	(0.017)	(0.017)	(0.021)	(0.020)	(0.021)	(0.020)
Constant	2.904	2.674	5.493**	4.749**	5.850**	6.722***
	(1.871)	(1.896)	(2.323)	(2.258)	(2.395)	(2.480)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	888	888	884	888	888	888
Overall R2	0.841	0.841	0.756	0.764	0.759	0.748

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

In terms of similarities, business R&D expenditure is the only type of R&D expenditure that is consistently significantly linked to patent intensity in both contexts (*Specifications I, II*). Regional innovativeness in lagging and non-lagging regions alike is also found to be positively and significantly associated with the percentage of adults with a tertiary education and with regional population density (*Specifications I-VI*). Similarly, the negative relationship between the youthfulness of a region's population and its innovativeness observed in the continent's less developed regions is visible in its more developed ones as well (*Specifications I-VI*).

Exposure to longer-distance business enterprise and longer-distance government sector R&D knowledge flows is also positively and significantly linked to regional innovation in both environments (*Specifications II, VI*). Short-distance business enterprise and short-government sector R&D knowledge flows are not robustly linked to the generation of patents in either type of region (*Specifications I, V*).

A number of important differences, however, emerge between Europe's lagging and non-lagging regions. First, the coefficient for short-distance higher education R&D knowledge flows is negative and statistically significant in more developed areas (*Specification III*). This suggests that Europe's more economically developed regions may be drawing knowledge resources away from neighboring areas. Relatedly, there is no indication of a statistically significant relationship between exposure to longer-distance higher education R&D knowledge flows and regional innovative output in the more economically advanced regions (*Specification IV*).

Second, the mobilization of human capital – proxied by the unemployment rate – is significantly linked to regional innovative capacity in Europe's more developed regions but not in lagging ones (*Specifications I – VI*). Finally, the significant and positive relationship between industrial employment and patenting observed in the Europe's lagging regions does not hold in richer areas (*Specifications I – VI*).

5.4. Changing the dependent variable and lagging the independent variables

One important potential caveat of these results relates to the fact that, although patents per capita is the most widely used innovation indicator in comparative analysis, analyses based on this indicator may reflect the population structure of a region to the same or greater extent than its innovativeness. Regions with a higher dependency ratio or with an abundance of less skilled workers will have an inflated denominator and therefore emerge as disadvantaged simply because of the choice of dependent variable (Wojan et al., 2015). Using patents per capita is particularly problematic in less developed regions where the young and highly qualified are very mobile, as has been mainly the case of North America. Highly skilled graduates may leave these regions for areas with greater job opportunities, either in other less developed or in more developed regions. Hence, the use of patenting per capita as the dependent variables may tell us relatively little about the patenting productivity of a region and is likely to further bias the perception that innovation is fundamentally a rich and agglomerated area phenomenon (Wojan et al., 2015).

In order to assess the extent to which this choice of innovation proxy may affect the results, we repeat the estimations using patent applications per 100,000 labor force participants.

The results of this sensitivity analysis – in which the estimations for the two different dependent variables are reproduced side-by-side to facilitate interpretation – are presented in Tables A7, A8, A9, and A10 in the appendix. The results are broadly consistent with those that employ patent applications per million inhabitants as the dependent variable. The only exception is that related to higher education attainment, which displayed positive coefficients in the patent per capita regressions across North America and Europe, but becomes not significant for North American and negative and significant for Europe, when patents per the level of education of the workforce is considered. This change is to be expected, as the level of education of the population is now considered in the dependent variables. All other coefficients remain stable, suggesting that the results are robust to changes in dependent variable and do not necessarily reflect a bias derived from different population and skill structures across North America and Europe.

We also exploited the panel nature of our data to further test the robustness of the results using temporally-lagged independent variables. We were initially, and to an extent still are, weary of lagging our explanatory variables due to concerns relating to further limiting an already, somewhat, temporally limited dataset. We did, in the end, estimate our model with independent variables lagged by one year. The results, specifically with respect to our variables of primary interest – i.e. R&D variables – of the lagged estimations are *broadly* consistent with the unlagged ones. The only point of significant divergence (and concern) relates to the relationship between higher-education R&D expenditure and patenting in the less developed regions of North America. While significant in the original estimations, it is not found to be significant in the lagged specifications.

One possible explanation for this relates to the notion that public R&D expenditure (higher education R&D included) tends not to feed directly into patenting activity to the same extent as R&D activities undertaken by the private sector; it contributes to the maintenance of "the stock of knowledge available for society" (Guellec and Van Pottelsberghe de la Potterie, 2004:356). The impact of public (i.e. higher education) R&D expenditure on patent generation could conceivably be more immediate as this type of investment funds the continued, ongoing pursuit of the sorts of activities and the generation of basic knowledge that assume a fundamentally important, but supportive role as a facilitator in the genesis of innovation. Stable and perpetual investment in public R&D activities can therefore be assumed to be prerequisite to the cultivation of an environment within which innovation can occur. The impacts of investments of this nature (or the absence of them) may, in turn, be visible in the more immediate term.

5.5. Comparing the lagging regions of North America and Europe

Are the drivers of innovation in North America's lagging regions the same as those at play in their European counterparts? The following section compares the factors that govern processes of innovation in the economically disadvantaged regions of North America and Europe. Overall, the empirical analysis confirms the second hypothesis forwarded in *Section 2*:

innovation processes in North America's and Europe's lagging regions are far from identical and are governed by distinct combinations of factors.

In the economically disadvantaged regions of North America, processes of innovation are governed by five factors. First, lagging regions in North America display some ability to transform their relatively high levels of investment in higher education R&D activities (*Section 3*, Figure *1B*) into innovative output – a process that is indicative of the continent's mature system of university-industry linkages (e.g. Rothaermel et al., 2007). These regions are less able to capitalize on local investment in business enterprise R&D functions but are reasonably adept at translating knowledge generated by firms in both neighboring *and* more distant regions into measureable innovative dynamism. The capacity to do so is attributable, at least in part, to the relatively high levels of public R&D investment documented in *Section 3* (*Figure 1B* and *1C*) that contribute to the enhancement of the 'absorptive capacity' of these regions (Cohen and Levinthal, 1990; Griffith et al., 2003; 2004; Vogel, 2015).

Socioeconomic contextual conditions in North America's lagging regions also influence their innovative capacities. Provinces and states with a young and highly skilled population are more innovative. The innovativeness of the North America's economically disadvantaged regions is enhanced by the co-location of individuals and economic actors – and the knowledge-related externalities associated with agglomeration – as well.

In short, innovation in the lagging regions of North America is a product, most immediately, of the application of basic knowledge generated via local higher education R&D

investment *and* the more commercially applicable knowledge from elsewhere by economic actors operating in close physical proximity. These actors benefit from access to a skilled labor force that is continuously invigorated by the entry of younger and perhaps also more creative and dynamic individuals. The result is a set of less developed regions that are decidedly more innovative than their European counterparts.

Table 5. *Summary table of results*

	N.A. Less Developed	**N.A. More Developed**	**EU Less Developed**	**EU More Developed**
Business enterprise R&D expenditure		✓	✓	✓
Higher education R&D expenditure	✓	✓		
Government sector R&D expenditure				
Spatially-lagged BERD (Contiguity)	✓			
Spatially-lagged BERD (Inverse)	✓	✓(-)	✓	✓
Spatially-lagged HERD (Contiguity)			✓	✓(-)
Spatially-lagged HERD (Inverse)			✓	
Spatially-lagged GOVERD (Contiguity)				
Spatially-lagged GOVERD (Inverse)		✓	✓	✓
Tertiary educational attainment	✓	✓	✓	✓
Unemployment rate				✓
Employment in industry			✓	
Population density	✓	✓	✓	✓
% of population aged 15-24	✓		✓(-)	✓(-)

Note: Check-marks indicate the existence of a positive relationship. Checkmarks followed by a minus sign in parenthesis (-) indicate the existence of a negative relationship.

Innovation in the lagging regions of Europe is a product of a distinctly different set of influences. Most immediately, economically disadvantaged regions in Europe are capable of translating business enterprise R&D investment into measurable innovation. The challenge for these regions as it relates to R&D expenditure is therefore not necessarily one of exploitation, but rather one of underinvestment. That is, levels of business enterprise R&D investment in the less developed regions of Europe lag significantly behind not only those of the Europe's and North America's more developed regions, but also those of their North American lagging counterparts (*Section 3*, *Figure 1A*). This implies that whatever facility Europe's lagging regions have for the mobilization of business R&D activities is largely wasted – or certainly under exploited – due to chronic underinvestment in these functions. The relative absence of dynamic firms capable of investing in R&D in the economically disadvantaged regions of Europe should therefore be seen as a serious handicap for generation of innovation in these territories. This problem is compounded by a relative inability to mobilize their comparatively weak commitments to public R&D functions (*Section 3*, *Figure 1B* and *1C*).

Underinvestment in R&D is, however, by no means the only factor curtailing innovation in Europe's lagging regions. In Europe, as in North America, access to a well-developed pool of human capital is conducive to innovation, as are the externalities associated with the co-location of individuals, firms and other actors. But, in contrast to the North America's economically disadvantaged regions, lagging regions in Europe are less able to mobilize the skills of their young – the best educated age group. Persistently high levels of youth unemployment – youth unemployment in, for example, Greece, Spain and Italy stood at 45%, 39% and 31.6%, respectively, in 2014[18] – limit the 'absorptive capacity' of the Europe's lagging regions in ways which are not evident in North America. Certain industrial compositions may also serve as barriers to innovation in these regions. The influence of industrial composition on their innovativeness is, however, negligible when levels of business R&D are sufficiently high.

Europe's lagging regions have, against the odds, developed some capacity to exploit externally generated knowledge. They are capable of drawing upon the knowledge generated via the higher education R&D activities in their immediate neighbours and the public *and* private R&D activities occurring in more distant regions. The capacity to mobilize knowledge flowing from distant higher-education R&D activities is, however, contingent on levels of local business enterprise R&D investment and the 'absorptive capacity' they foster. It would seem, at least in some respects, that the less developed regions in Europe draw more heavily upon their more distant neighbours – at least in terms of the scope of the knowledge they source – than their North American counterparts. That is to say, processes of innovation in Europe's lagging region are shaped, to some extent, not only by exposure to business enterprise R&D knowledge flows emanating from more distant regions, but also by exposure to longer-distance government sector R&D knowledge flows, and perhaps also longer distance higher education R&D knowledge flows, though the empirical evidence is less robust for the latter.

That Europe's lagging regions seem to benefit primarily from the R&D activities of firms and economic actors *in more distant locations* is likely a product not only of chronically low levels of all types of R&D investment in these regions (*Section 3*, *Figure 1*) that gives rise to a need for externally generated knowledge, but also of the spatial distribution of lagging regions in Europe. That is, patterns of economic disadvantage in Europe are generally consistent with patterns of geographic peripherality, meaning that a lagging region in Europe is most immediately geographically proximate to other lagging regions. This stifles the extent to which they can rely on their closest neighbours as sources of knowledge. Pools of skilled, creative and knowledgeable workers and a sufficient degree of physical proximity between economic actors do, however, seemingly permit many of Europe's lagging regions to absorb and mobilize knowledge that is being generated in their more geographically distant neighbours (e.g. Griffith et al., 2004). This extra-local knowledge may be acting as a substitute for locally sourced knowledge in contexts that struggle to generate it endogenously and may ultimately be the key to the cultivation of innovation in these types of regions (e.g. Tödtling et al., 2012; Fitjar and Rodríguez-Pose, 2011a; b; Grillitsch and Nilsson, 2015; Fitjar and Rodríguez-Pose, 2017).

Finally, the analysis reveals that lagging regions in North America and Europe behave, from an innovation perspective, more like their respective more developed counterparts than one another. Innovation in North America's less- and more developed regions is fueled by the presence of research universities and by skilled human capital and agglomeration. In Europe, skills and agglomeration are also central for innovation in both types of regions, as is investment in business R&D expenditure and exposure to long distance business enterprise R&D knowledge flows. Moreover, and in contrast to North America, a young population represents more of a barrier than an asset for innovation. In this respect, it would seem that there is greater continuity between the dynamics of innovation at play in the differentially developed regions that make up a broader economy, than there is between those shaping processes of regional innovation in similarly developed areas spread across different geographic contexts.

6. Conclusion

This research has compared and contrasted the socioeconomic factors that govern processes of innovation in the less developed regions of North America and Europe in an effort to provide systematic, macroeconomic insights that the literature thus far has yet to offer. An econometric investigation of a large sample of North American and European regions has been conducted to formulate inferences relating to the factors that govern innovation in the contexts considered.

The analysis has shown that the generation of innovative output in North America's lagging regions is most directly linked to regional investment in higher education R&D, the quality of local human capital, the co-location of economic actors and activities, and the youthfulness of the local population. Economically disadvantaged regions in North America also benefit from business enterprise R&D activities occurring in both their immediate and more distant neighbours. In Europe's lagging regions, on the other hand, regional innovative capacity is robustly associated with regional business enterprise R&D expenditure, the availability of sufficiently skilled human capital, an industrially biased economic structure, and the agglomeration of economic activity. Exposure to interregional knowledge flows is, again, positively linked to regional patent intensity – these regions seem to benefit from long-distance business enterprise and public sector R&D knowledge flows, and from short-distance higher education R&D knowledge flows.

In sum, while there are some not inconsequential similarities between the structural and socioeconomic factors that shape processes of innovation in the economically disadvantaged regions of North America and Europe, there are, as hypothesized in *Section 2*, several points of divergence. Most notably, they differ in their respective capacities to transform different types of R&D activities into innovative output and, although they both benefit to a degree from non-local innovative activities, there is variation in both the types of knowledge flows they can capitalize upon.

The analysis points in the direction of several related policy implications all of which must be read and interpreted with an appropriate degree of caution in view of the limitations imposed by, among other factors, the availability of suitable data and the spatial units employed in the analysis. Most generally, the analysis provides evidence in support of contextually-tailored innovation policies (e.g. Tödtling and Trippl, 2005; Navarro et al, 2009).

The analysis did expose a number of similarities between North America's and Europe's lagging regions that would justify commonalities between the contextually-tailored policies that should be implemented in them. Lagging regions – be they in North America, Europe, or possibly elsewhere – that are characterized by larger endowments of skilled human capital and feature the operation of economic actors in close physical proximity are more capable of generating new knowledge and are decidedly more innovative than those that lag behind in terms of their human capital development and within which economic actors and activity are more dispersed and thus less likely to interact. The analysis also offers evidence to suggest that economically disadvantaged regions on either side of the Atlantic have at least some facility for the absorption and exploitation of extra-local knowledge and that this type of knowledge can catalyze innovative activity. It would therefore be reasonable to assert that the innovation policies for lagging areas, irrespective of location, should priorities labor up-skilling and human capital development more broadly and should incorporate the development of interregional connections and relationships – so-called "pipelines" (Bathelt et al., 2004) – as a means to import new knowledge to supplement local innovative activities, or perhaps more accurately, to compensate for a lack of them.

Policy-makers must, however, be aware that there will inevitably be certain policy 'levers' available in some economically disadvantaged contexts – or for that matter, more economically advanced ones as well – that are not available in others. There is, for example, considerable cross-regional variation in the capacity to transform and capitalize upon different types of R&D. Similarly, not all interregional knowledge flows and non-local connections operate in the same way or offer the same benefit for different lagging regions in different geographic contexts. Policy-makers need to recognize this latter phenomenon and should attempt, through the engagement of, and consultations and dialogue with, local actors – a cornerstone, in fact, of bottom-up, territorial specific policy-making – to identify the types of extra-local connections, partnerships and relationships – be they with actors in academia or the private, public, or third sectors – from which local innovators garner the greatest benefit and should channel resources accordingly.

Notes

1. The use of patent statistics is, nevertheless, problematic not least because patents statistics do not capture all, or all types of innovations generated in or by an economy. A great deal of innovation, especially process and incremental innovation remains unpatented. Moreover, some sectors have a much greater propensity to patent than others. That said, there is no better proxy for innovation at the time of writing that is available for regions in North America and Europe. Patent statistics, despite their problems, remain the only reliable and comparable quantification of innovative activity occurring at a regional level in these two contexts. The rationale behind the use of patents as a proxy for innovation is further elaborated on the section dealing with the dependent variable.

2. While other researchers have conducted analyses of innovation from comparative perspectives comparable to the one employed here (e.g. Crescenzi et al., 2007, 2012; Usai, 2011; Fagerberg et al., 2014), none, however, have to our knowledge focused explicitly on the dynamics and drivers of innovation in less socioeconomically developed, lagging regions.

3. Japan is the third.

4. Capital and labor cannot move freely across the US-Canada border, although NAFTA facilitates a high degree of economic integration between the two countries. Similarly, non-Eurozone EU countries and Norway are considered in the analysis. The degree of economic integration between them and the rest of the EU is, however, high.

5. Regions that are not classified as lagging are referred to, throughout the paper, as 'more-developed regions.

6. 90% of the average GDP per head of the EU is also the threshold to distinguish between more developed and less developed and transition *regions*.

7. Our estimation strategy is addressed in more detail in the results section. The basic form of the model is presented here to provide the reader with a cursory sense of the relationships with which we are concerned and how we conceptualize them.

8. Data sources are summarized in *Appendix A6*.

9. The PCT Patent Statistics data upon which the analysis relies were compiled using the 'fraction counts'. The fractional counting approach entails dividing the applications amongst the applicants and, by extension, their regions of residence (paraphrasing European Commission, 2007). OECD (2009:64) notes that "fractional counts can be used

if multiple inventors are provided in the patent data to credit each unit of analysis with its correct population and avoid double counting".

10. Influences on innovative processes are by no means confined to those considered here. We have, however, because of the aims of the study and the documented relevance of these factors, as well as the availability of data for comparative analysis, elected to focus on socioeconomic and structural influences. This is not to discount the relevance of other regional factors or assets including, for example, formal and informal institutional conditions and arrangements, or other intangible assets or competencies. Issues related to, in the first instance, data availability and, in the second, the less tangible and thus quantifiable nature of certain influences and factors explain the exclusion of such factors from the econometric analysis that follows.

11. Country fixed-effects are employed for the European estimations. In the North American case they are replaced by macro-region (Canada, Southern United States, North-Eastern United States, Mid-Western United States, and Western United States) fixed-effects to enhance the comparability of the empirical analysis.

12. The analysis considers all of the North American and European TL2 regions for which suitable data are available. Data are available for all US States and Canadian provinces. Unfortunately, there are several regions in Europe – mainly in Finland, Italy and Poland – for which suitable data do not yet exist. Consequently, these regions are not, in spite of a concerted effort, captured by the analysis.

13. NUTS Overview (Eurostat): http://ec.europa.eu/eurostat/web/nuts/overview

14. In 2015, the Canadian province of Ontario, for example, released a multifaceted innovation agenda entitled "Seizing Global Opportunities: Ontario's Innovation Agenda" (Ontario Ministry of Research and Innovation, 2015). The overarching aim of the strategy is to deliver "a high and sustainable level of prosperity, and healthy communities, that provide high-quality jobs and better lives for people in Ontario" (p. 1).

15. The tables provided to summarize the results of the empirical analysis include only a small selection of the model specifications employed in the analysis. While a concerted effort has been made not to do so, Sections 5.2 and 5.3 do reference, albeit infrequently, model specifications not included in the four tables provided.

16. The objective of this analysis is to provide insights of a more indicative and exploratory nature. Consequently, the focus of the analysis remains on the 'direction' and significance of coefficients and, importantly, on the extent to which the direction and significance of relationships hold across the many specifications of the model. It should

also be highlighted, as noted by the reviewers, that, because fixed-effects are employed, our results are reflective not of ‘levels’ but of ‘changes’. This should be borne in mind when reading the proceeding section. We have opted, in the interest if maintaining the simplicity of language and syntax (and consistently with the aforementioned intention to in identifying simple associations between patenting and a multitude of factors) to discuss the relationships that emerge from the analysis in a more general manner.

17. *Specification VI* is one of *only* two model specifications run in which regional unemployment is significantly linked to regional innovativeness. This minimal frequency with which this significant relationship is insufficient cause to assert that regional unemployment is robustly associated with innovation.

18. Eurostat Employment and Unemployment (Labor Force Survey) Database.

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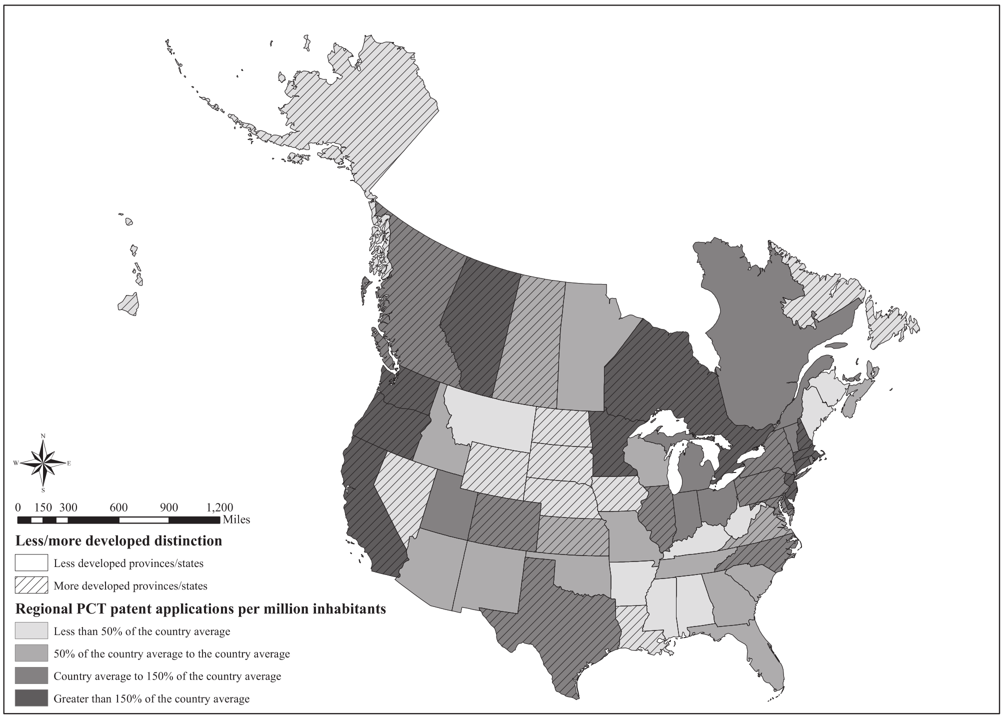
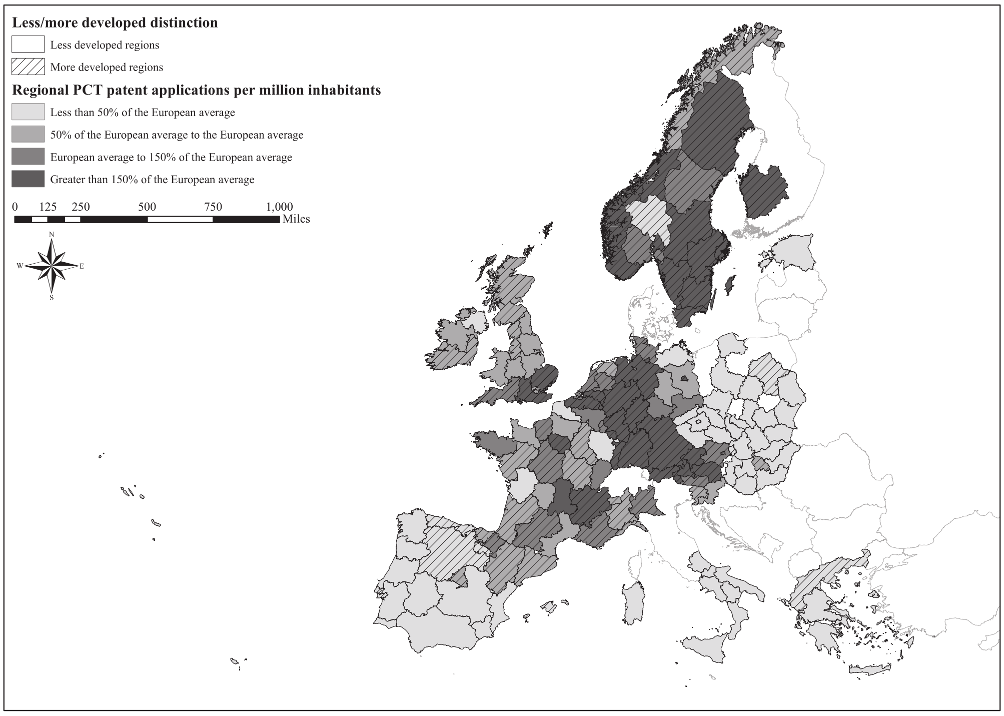
Appendix

A1. *Innovation in the less and more regions of North America and Europe (2000-2010)*





A2. *Europe's less developed regions*

BE3: Wallonia	GR1: Northern Greece	SI01: Eastern Slovenia
CZ02: Central Bohemian Region	GR2: Central Greece	SK02: West Slovakia
CZ03: Southwest	GR4: Aegean Islands and Crete	SK03: Central Slovakia
CZ04: Northwest	HU21: Central Transdanubia	SK04: East Slovakia
CZ05: Northeast	HU22: Western Transdanubia	UKC: North East England
CZ06: Southeast	HU23: Southern Transdanubia	UKE: Yorkshire and The Humber
CZ07: Central Moravia	HU31: Northern Hungary	UKF: East Midlands
CZ08: Moravia-Silesia	HU32: Northern Great Plain	UKG: West Midlands
DE4: Brandenburg	HU33: Southern Great Plain	UKL: Wales
DE8: Mecklenburg-Vorpommern	IE01: Border, Midland and Western	UKN: Northern Ireland
DED: Saxony	ITF1: Abruzzo	
DEE: Saxony-Anhalt	ITF2: Molise	
DEG: Thuringia	ITF3: Campania	
EE00: Estonia	ITF4: Apulia	
ES11: Galicia	ITF5: Basilicata	
ES42: Castile-La Mancha	ITF6: Calabria	
ES43: Extremadura	ITG1: Sicily	
ES52: Valencia	ITG2: Sardinia	
ES61: Andalusia	PL11: Lodzkie	
ES62: Murcia	PL21: Lesser Poland	
FR22: Picardy	PL22: Silesia	
FR25: Lower Normandy	PL31: Lublin Province	
FR30: Nord-Pas-de-Calais	PL32: Podkarpacia	
FR41: Lorraine	PL41: Greater Poland	
FR43: Franche-Comté	PL51: Lower Silesia	
FR52: Brittany	PL63: Pomerania	
FR53: Poitou-Charentes	PT11: North	
FR63: Limousin	PT15: Algarve	
FR72: Auvergne	PT16: Central Portugal	
FR81: Languedoc-Roussillon	PT18: Alentejo	
	PT20: Azores	

__A3.__ Europe's more developed regions

AT12: Lower Austria	FI19: Western Finland	PL12: Mazovia
AT13: Vienna	FR10: Ile de France	PT17: Lisbon
AT21: Carinthia	FR21: Champagne-Ardenne	PT30: Madeira
AT22: Styria	FR23: Upper Normandy	SE11: Stockholm
AT31: Upper Austria	FR24: Centre (FR)	SE12: East Middle Sweden
AT32: Salzburg	FR26: Burgundy	SE21: Småland with Islands
AT33: Tyrol	FR42: Alsace	SE22: South Sweden
BE1: Brussels Capital Region	FR51: Pays de la Loire	SE23: West Sweden
BE2: Flemish Region	FR61: Aquitaine	SE31: North Middle Sweden
CZ01: Prague	FR62: Midi-Pyrénées	SE32: Central Norrland
DE1: Baden-Württemberg	FR71: Rhône-Alpes	SE33: Upper Norrland
DE2: Bavaria	FR82: Provence-Alpes-Côte d'Azur	SI02: Western Slovenia
DE3: Berlin	GR3: Athens	SK01: Bratislava Region
DE5: Bremen	HU10: Central Hungary	UKD: North West England
DE6: Hamburg	IE02: Southern and Eastern	UKH: East of England
DE7: Hesse	ITC1: Piedmont	UKI: Greater London
DE9: Lower Saxony	ITC2: Aosta Valley	UKJ: South East England
DEA: North Rhine-Westphalia	ITC3: Liguria	UKK: South West England
DEB: Rhineland-Palatinate	ITC4: Lombardy	UKM: Scotland
DEC: Saarland	LU00: Luxembourg	
DEF: Schleswig-Holstein	NL1: North Netherlands	
ES12: Asturias	NL2: East Netherlands	
ES13: Cantabria	NL3: West Netherlands	
ES21: Basque Country	NL4: South Netherlands	
ES22: Navarra	NO01: Oslo and Akershus	
ES23: La Rioja	NO02: Hedmark and Oppland	
ES24: Aragon	NO03: South-Eastern Norway	
ES30: Madrid	NO04: Agder and Rogaland	
ES41: Castile and León	NO05: Western Norway	
ES51: Catalonia	NO06: Trøndelag	
ES53: Balearic Islands	NO07: Northern Norway	

A4. *North America's less developed regions*

CA11: Prince Edward Island	US13: Georgia	US35: New Mexico
CA12: Nova Scotia	US16: Idaho	US39: Ohio
CA13: New Brunswick	US18: Indiana	US40: Oklahoma
CA24: Quebec	US21: Kentucky	US45: South Carolina
CA46: Manitoba	US23: Maine	US47: Tennessee
US01: Alabama	US26: Michigan	US49: Utah
US04: Arizona	US28: Mississippi	US50: Vermont
US05: Arkansas	US29: Missouri	US54: West Virginia
US12: Florida	US30: Montana	US55: Wisconsin

A5. *North America's more developed regions*

CA10: Newfoundland and Labrador	US17: Illinois	US37: North Carolina
CA35: Ontario	US19: Iowa	US38: North Dakota
CA47: Saskatchewan	US20: Kansas	US41: Oregon
CA48: Alberta	US22: Louisiana	US42: Pennsylvania
CA59: British Columbia	US24: Maryland	US44: Rhode Island
US02: Alaska	US25: Massachusetts	US46: South Dakota
US06: California	US27: Minnesota	US48: Texas
US08: Colorado	US31: Nebraska	US51: Virginia
US09: Connecticut	US32: Nevada	US53: Washington
US10: Delaware	US33: New Hampshire	US56: Wyoming
US11: District of Columbia	US34: New Jersey	
US15: Hawaii	US36: New York	

A6. *Variables used in the analysis*

Variables (Europe)		**Source**
Innovative output	PCT patent applications per million inhabitants	*OECD Regional Database*
Regional R&D expenditure	Business enterprise R&D expenditure as % of GDP	*OECD Regional Database*
	Higher education R&D expenditure as % of GDP	*OECD Regional Database*
	Government sector R&D expenditure as % of GDP	*OECD Regional Database*
Availability and use of human capital	% of population aged 25-64 with a tertiary education	*Eurostat Regional Education Statistics*
	Unemployment rate	*OECD Regional Database*
Industrial composition	Employment in "industry, including energy" as % of regional employment	*OECD Regional Database*
Agglomeration of economic activity	Population density	*OECD Regional Database*
Demographics and development	% of population aged 15-24	*OECD Regional Database*
	GDP per capita	*OECD Regional Database*

Note: Missing values for independent variables were interpolated linearly where possible. In the case of regional R&D expenditure, a regional R&D expenditure dataset prepared by Tobias Ketterer was used to replace missing values when reasonable linear interpolation was not possible. Missing values for the dependent variable (PCT patent applications) were not interpolated. Due to data availability constraints necessitated the use of statistics that correspond to the ISIC rev. 3 classification 'industry, including energy' for the years 2008-2008 and the use of statistics that correspond to the ISIC rev. 4 classification for 'industry, including energy' for the years 2009 and 2010.

Variables (North America)		Source
Innovative output	PCT patent applications per million inhabitants	*OECD Regional Database*
Regional R&D expenditure	Business enterprise R&D expenditure as % of GDP	*OECD Regional Database*
	Higher education R&D expenditure as % of GDP	*OECD Regional Database*
	Government sector R&D expenditure as % of GDP	*OECD Regional Database*
Availability and use of human capital	% of labour force with a tertiary education	*OECD Regional Database*
	Unemployment rate	*OECD Regional Database*
Industrial composition	Employment in "industry, including energy" as % of regional employment	*OECD Regional Database*
Agglomeration of economic activity	Population density	*OECD Regional Database*
Demographics and development	% of population aged 15-24	*OECD Regional Database*
	GDP per capita	*OECD Regional Database*

The research relies on the "OECD Regional Database" which may be accessed via the OECD's interactive statistics portal (*OECD. Stat*: http://stats.oecd.org/). The "EuroStat Regional Education Statistics" are available for download via the European Commission's data portal (*EuroStat*: http://ec.europa.eu/eurostat/data/database). All of the data were downloaded from these publically-available resources. The data were consolidated and the dataset built using *Microsoft Excel* and *Stata*.

A7. *Summary Statistics*

	Europe				North America			
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
PCT patent applications per million inhabitants	75.04	91.44	0.09	743.45	111.26	93.04	6.27	497.49
Business enterprise R&D expenditure as % of GDP	0.85	0.79	0.00	5.33	1.30	1.11	0.04	5.87
Higher education R&D expenditure as % of GDP	0.37	0.26	0.00	1.76	0.42	0.25	0.13	3.95
Government sector R&D expenditure as % of GDP	0.19	0.19	0.00	1.15	0.36	0.91	0.00	8.16
Tertiary educational attainment	22.00	8.42	3.70	48.30	23.38	5.26	12.67	46.43
Unemployment rate	8.59	4.68	1.80	27.97	5.99	2.44	2.22	16.58
Employment in industry, % of regional employment	19.12	7.16	3.97	38.90	10.23	3.48	0.06	19.76
Population density	330.96	814.23	3.31	6809.61	120.59	462.46	0.42	3805.82
% of population aged 15-24	12.79	1.72	7.54	17.60	14.30	1.03	11.89	19.79

Table A8. *North American 'less developed' regions, higher education based dependent variable*

	North America, less developed regions											
	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members
GDP per capita (ln)	0.791	0.798	0.918*	0.948*	0.893	0.912	0.861	0.875	0.744	0.763	0.694	0.711
	(0.531)	(0.536)	(0.542)	(0.544)	(0.643)	(0.655)	(0.647)	(0.662)	(0.633)	(0.640)	(0.640)	(0.651)
Business enterprise R&D (ln)	0.0115	0.0193	0.0245	0.0342								
	(0.0585)	(0.0606)	(0.0615)	(0.0636)								
Higher education R&D (ln)					0.132***	0.129***	0.132***	0.130**				
					(0.0496)	(0.0499)	(0.0493)	(0.0521)				
Government sector R&D (ln)									-0.0424	-0.0424	-0.0440	-0.0443
									(0.0322)	(0.0324)	(0.0329)	(0.0334)
Spatially-lagged business enterprise R&D (1st-order contiguity) (ln)	0.315**	0.331***										
	(0.132)	(0.123)										
Spatially-lagged business enterprise R&D (inverse distance) (ln)			1.343**	1.478**								
			(0.661)	(0.635)								
Spatially-lagged higher education R&D (1st-order contiguity) (ln)					0.0667	0.0931						
					(0.127)	(0.139)						
Spatially-lagged higher education R&D (inverse distance) (ln)							0.547	0.591				
							(0.401)	(0.439)				
Spatially-lagged government sector R&D (1st-order contiguity) (ln)									-0.0299	-0.0285		
									(0.0508)	(0.0531)		
Spatially-lagged government sector R&D (inverse distance) (ln)											-0.164	-0.172
											(0.133)	(0.144)
Tertiary educational attainment	0.0468***	-0.00819	0.0429**	-0.0126	0.0343*	-0.0209	0.0326*	-0.0231	0.0381**	-0.0173	0.0374*	-0.0182
	(0.0171)	(0.0164)	(0.0179)	(0.0172)	(0.0179)	(0.0173)	(0.0180)	(0.0172)	(0.0187)	(0.0183)	(0.0191)	(0.0185)
Unemployment rate	-0.0150	-0.00546	-0.0194	-0.0103	-0.0167	-0.00662	-0.0147	-0.00467	-0.0108	-0.00103	-0.0110	-0.00107

	(0.0238)	(0.0241)	(0.0248)	(0.0250)	(0.0261)	(0.0263)	(0.0255)	(0.0259)	(0.0261)	(0.0264)	(0.0257)	(0.0261)
Employment in industry	-0.0248	-0.0249	-0.0213	-0.0215	-0.0160	-0.0164	-0.0168	-0.0184	-0.0233	-0.0239	-0.0235	-0.0245
	(0.0177)	(0.0180)	(0.0191)	(0.0193)	(0.0200)	(0.0208)	(0.0206)	(0.0217)	(0.0198)	(0.0204)	(0.0200)	(0.0208)
Population density (ln)	0.203**	0.198**	0.182*	0.173*	0.205*	0.193	0.198*	0.185	0.193*	0.184	0.204	0.195
	(0.0919)	(0.0920)	(0.102)	(0.104)	(0.111)	(0.118)	(0.116)	(0.124)	(0.117)	(0.122)	(0.125)	(0.131)
Percentage of the population aged 16-24	0.0568**	0.0526**	0.0747**	0.0711**	0.0523	0.0431	0.0375	0.0290	0.0511*	0.0457	0.0467*	0.0400
	(0.0242)	(0.0246)	(0.0295)	(0.0292)	(0.0321)	(0.0332)	(0.0282)	(0.0289)	(0.0305)	(0.0312)	(0.0279)	(0.0283)
Constant	-5.745	-4.741	-7.743	-7.005	-6.675	-5.712	-5.764	-4.701	-5.351	-4.444	-4.964	-4.023
	(5.330)	(5.384)	(5.314)	(5.326)	(6.320)	(6.415)	(6.432)	(6.542)	(6.280)	(6.336)	(6.309)	(6.409)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	297	297	297	297	297	297	297	297	297	297	297	297

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

Table A9. *North American 'more developed' regions, higher education based dependent variable*

	North America, more developed regions											
	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members
GDP per capita (ln)	-0.147	-0.201	-0.124	-0.174	0.293	0.189	0.329	0.228	-0.0277	-0.119	0.00245	-0.0890
	(0.215)	(0.200)	(0.209)	(0.195)	(0.213)	(0.204)	(0.216)	(0.205)	(0.229)	(0.213)	(0.231)	(0.216)
Business enterprise R&D (ln)	0.0883*	0.0827	0.0811	0.0746								
	(0.0519)	(0.0506)	(0.0542)	(0.0529)								
Higher education R&D (ln)					0.367**	0.363**	0.367**	0.363**				
					(0.182)	(0.177)	(0.183)	(0.178)				
Government sector R&D (ln)									0.0235	0.0253	0.0250	0.0267
									(0.0280)	(0.0286)	(0.0283)	(0.0290)
Spatially-lagged business enterprise R&D (1st-order contiguity) (ln)	-0.0153	-0.0245										
	(0.0849)	(0.0838)										
Spatially-lagged business enterprise R&D (inverse distance) (ln)			-0.306	-0.358								
			(0.258)	(0.279)								
Spatially-lagged higher education R&D (1st-order contiguity) (ln)					-0.00778	0.000168						
					(0.0909)	(0.0957)						
Spatially-lagged higher education R&D (inverse distance) (ln)							-0.172	-0.185				
							(0.326)	(0.363)				
Spatially-lagged government sector R&D (1st-order contiguity) (ln)									0.0178	0.0149		
									(0.0356)	(0.0377)		
Spatially-lagged government sector R&D (inverse distance) (ln)											0.161*	0.167*
											(0.0878)	(0.0944)
Tertiary educational attainment	0.0427***	-0.00265	0.0431***	-0.00215	0.0343**	-0.0108	0.0343**	-0.0109	0.0376***	-0.00773	0.0367***	-0.00860
	(0.0146)	(0.0155)	(0.0145)	(0.0153)	(0.0152)	(0.0161)	(0.0156)	(0.0165)	(0.0139)	(0.0150)	(0.0137)	(0.0145)
Unemployment rate	-0.0321	-0.0252	-0.0303	-0.0233	-0.0299	-0.0243	-0.0299	-0.0243	-0.0356	-0.0296	-0.0360*	-0.0304
	(0.0223)	(0.0222)	(0.0218)	(0.0216)	(0.0191)	(0.0188)	(0.0190)	(0.0188)	(0.0223)	(0.0221)	(0.0213)	(0.0211)

Employment in industry	0.0273	0.0240	0.0264	0.0229	0.0227	0.0215	0.0199	0.0184	0.0224	0.0209	0.0185	0.0170
	(0.0227)	(0.0229)	(0.0227)	(0.0228)	(0.0237)	(0.0236)	(0.0228)	(0.0225)	(0.0240)	(0.0241)	(0.0230)	(0.0228)
Population density (ln)	0.211**	0.233***	0.214**	0.236**	0.193*	0.220**	0.189*	0.215**	0.208**	0.233**	0.191*	0.215**
	(0.0913)	(0.0889)	(0.0948)	(0.0927)	(0.113)	(0.108)	(0.113)	(0.108)	(0.102)	(0.0985)	(0.107)	(0.103)
Percentage of the population aged 16-24	-0.0936	-0.0997	-0.0992	-0.106	-0.0926	-0.0994	-0.0870	-0.0927	-0.0969	-0.103	-0.0950	-0.101
	(0.0652)	(0.0644)	(0.0655)	(0.0645)	(0.0706)	(0.0694)	(0.0718)	(0.0705)	(0.0737)	(0.0722)	(0.0711)	(0.0695)
Constant	5.421**	6.928***	5.358**	6.850***	1.217	3.232	0.693	2.639	4.434*	6.303***	4.390*	6.279***
	(2.261)	(2.066)	(2.237)	(2.048)	(2.191)	(2.081)	(2.378)	(2.286)	(2.551)	(2.386)	(2.602)	(2.435)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	374	374	374	374	374	374	374	374	374	374	374	374

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

Table A10. *European 'less developed', higher education based dependent variable*

	Europe, less developed regions											
	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members
GDP per capita (ln)	0.759**	0.628*	0.687**	0.572	0.543	0.395	0.527	0.396	0.647*	0.520	0.670*	0.535
	(0.317)	(0.363)	(0.338)	(0.382)	(0.383)	(0.433)	(0.412)	(0.465)	(0.360)	(0.407)	(0.364)	(0.411)
Business enterprise R&D (ln)	0.226***	0.222***	0.228***	0.223***								
	(0.0667)	(0.0650)	(0.0651)	(0.0642)								
Higher education R&D (ln)					0.0927	0.0679	0.104	0.0807				
					(0.0594)	(0.0501)	(0.0637)	(0.0557)				
Government sector R&D (ln)									0.0293	0.0362	0.0263	0.0331
									(0.0284)	(0.0249)	(0.0286)	(0.0251)
Spatially-lagged business enterprise R&D (1st-order contiguity) (ln)	0.110	0.0962										
	(0.0690)	(0.0669)										
Spatially-lagged business enterprise R&D (inverse distance) (ln)			1.128**	0.880*								
			(0.570)	(0.524)								
Spatially-lagged higher education R&D (1st-order contiguity) (ln)					0.207**	0.255**						
					(0.0917)	(0.102)						
Spatially-lagged higher education R&D (inverse distance) (ln)							1.096	1.164				
							(0.693)	(0.800)				
Spatially-lagged government sector R&D (1st-order contiguity) (ln)									-0.0748	-0.0598		
									(0.0829)	(0.0837)		
Spatially-lagged government sector R&D (inverse distance) (ln)											0.385*	0.459**
											(0.234)	(0.233)
Tertiary educational attainment	0.0189*	-0.0323***	0.0166	-0.0340***	0.0207*	-0.0301**	0.0201*	-0.0309**	0.0205*	-0.0315***	0.0211**	-0.0307***
	(0.0106)	(0.0117)	(0.0111)	(0.0123)	(0.0109)	(0.0118)	(0.0111)	(0.0122)	(0.0105)	(0.0117)	(0.0103)	(0.0115)
Unemployment rate	0.00448	0.00632	0.00237	0.00485	0.0104	0.0120*	0.00906	0.0107	0.00970	0.0113*	0.00939	0.0109*
	(0.00573)	(0.00599)	(0.00609)	(0.00646)	(0.00654)	(0.00665)	(0.00656)	(0.00685)	(0.00648)	(0.00654)	(0.00646)	(0.00652)

Employment in industry	0.00271	0.00306	0.00272	0.00313	0.00901*	0.00911*	0.00972*	0.00978*	0.00797*	0.00835*	0.00857*	0.00894*
	(0.00455)	(0.00488)	(0.00472)	(0.00507)	(0.00490)	(0.00496)	(0.00509)	(0.00517)	(0.00481)	(0.00501)	(0.00494)	(0.00510)
Population density (ln)	0.263***	0.259***	0.260***	0.257***	0.288***	0.295***	0.304***	0.310***	0.278***	0.280***	0.306***	0.307***
	(0.0817)	(0.0830)	(0.0799)	(0.0829)	(0.0992)	(0.102)	(0.103)	(0.107)	(0.0999)	(0.101)	(0.0956)	(0.0974)
Percentage of the population aged 16-24	-0.140***	-0.126***	-0.137***	-0.125***	-0.164***	-0.150***	-0.170***	-0.156***	-0.172***	-0.154***	-0.162***	-0.145***
	(0.0310)	(0.0314)	(0.0297)	(0.0300)	(0.0329)	(0.0328)	(0.0350)	(0.0351)	(0.0355)	(0.0351)	(0.0343)	(0.0338)
Constant	-3.685	-1.382	-2.974	-0.810	-1.161	1.289	-0.134	2.175	-2.379	-0.116	-2.162	0.263
	(3.398)	(3.860)	(3.583)	(4.032)	(4.097)	(4.613)	(4.713)	(5.301)	(3.821)	(4.289)	(3.951)	(4.422)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	768	767	768	767	757	756	757	756	768	767	768	767

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

Table A11. *European 'more developed' regions, higher education based dependent variable*

	Europe, more developed regions											
	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members	Per mil. inhabitants	Per 100k ter. ed. LF members
GDP per capita (ln)	0.161	0.149	0.171	0.155	-0.0990	-0.131	-0.0905	-0.117	-0.0908	-0.115	-0.0666	-0.0864
	(0.195)	(0.212)	(0.196)	(0.215)	(0.240)	(0.246)	(0.233)	(0.241)	(0.245)	(0.252)	(0.241)	(0.249)
Business enterprise R&D (ln)	0.266***	0.268***	0.269***	0.270***								
	(0.0733)	(0.0727)	(0.0754)	(0.0771)								
Higher education R&D (ln)					-0.0577	-0.0523	-0.0594	-0.0531				
					(0.0597)	(0.0720)	(0.0597)	(0.0717)				
Government sector R&D (ln)									0.0184	0.0125	0.0379	0.0423
									(0.0382)	(0.0418)	(0.0306)	(0.0327)
Spatially-lagged business enterprise R&D (1st-order contiguity) (ln)	0.0237	-0.00258										
	(0.0565)	(0.0799)										
Spatially-lagged business enterprise R&D (inverse distance) (ln)			0.510**	0.480**								
			(0.222)	(0.239)								
Spatially-lagged higher education R&D (1st-order contiguity) (ln)					-0.0767*	-0.0583						
					(0.0448)	(0.0463)						
Spatially-lagged higher education R&D (inverse distance) (ln)							-0.703	-0.477				
							(0.475)	(0.529)				
Spatially-lagged government sector R&D (1st-order contiguity) (ln)									0.0941	0.135		
									(0.0850)	(0.106)		
Spatially-lagged government sector R&D (inverse distance) (ln)											0.810*	0.935*
											(0.483)	(0.543)
Tertiary educational attainment	0.0167***	-0.0194***	0.0166***	-0.0192***	0.0201***	-0.0158*	0.0197***	-0.0161*	0.0162**	-0.0198***	0.0167**	-0.0192***
	(0.00568)	(0.00618)	(0.00572)	(0.00616)	(0.00741)	(0.00839)	(0.00746)	(0.00847)	(0.00674)	(0.00746)	(0.00666)	(0.00744)
Unemployment rate	-0.0157*	-0.0130	-0.0152*	-0.0127	-0.0138*	-0.0112	-0.0137*	-0.0112	-0.0159*	-0.0136	-0.0166**	-0.0144
	(0.00816)	(0.00962)	(0.00813)	(0.00977)	(0.00827)	(0.00994)	(0.00833)	(0.00999)	(0.00854)	(0.0101)	(0.00837)	(0.00994)

Employment in industry	0.00760	0.00819	0.00801	0.00826	0.00792	0.00860	0.00845	0.00927	0.00818	0.00911	0.00880	0.00993
	(0.00596)	(0.00631)	(0.00574)	(0.00606)	(0.00638)	(0.00671)	(0.00633)	(0.00666)	(0.00649)	(0.00685)	(0.00646)	(0.00677)
Population density (ln)	0.105*	0.0936	0.110**	0.0972*	0.163***	0.156***	0.165***	0.159***	0.172***	0.165**	0.152**	0.140**
	(0.0539)	(0.0615)	(0.0526)	(0.0590)	(0.0561)	(0.0593)	(0.0552)	(0.0590)	(0.0599)	(0.0656)	(0.0611)	(0.0668)
Percentage of the population aged 16-24	-0.0725***	-0.0678***	-0.0641***	-0.0578***	-0.0998***	-0.0930***	-0.0996***	-0.0933***	-0.100***	-0.0930***	-0.0947***	-0.0874***
	(0.0172)	(0.0201)	(0.0168)	(0.0187)	(0.0207)	(0.0234)	(0.0202)	(0.0229)	(0.0206)	(0.0232)	(0.0199)	(0.0220)
Constant	2.904	3.818*	2.674	3.615*	5.493**	6.580***	4.749**	5.992**	5.850**	6.899***	6.722***	7.873***
	(1.871)	(2.042)	(1.896)	(2.063)	(2.323)	(2.405)	(2.258)	(2.378)	(2.395)	(2.473)	(2.480)	(2.566)
Macro-region F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	888	887	888	887	884	883	888	887	888	887	888	887

Robust standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**