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Quality of government and innovative performance in the regions of Europe

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Abstract

Although it has frequently been argued that the quality of institutions affects the innovative potential of a territory, the link between institutions and innovation remains a black box. This paper aims to shed light on how institutions shape innovative capacity, by focusing on how regional government quality affects innovative performance in the regions of Europe. By exploiting new data on quality of government (QoG), we assess how government quality and its components (control of corruption, rule of law, government effectiveness and government accountability) shape patenting capacity across the regions of the European Union (EU). The results of the analysis – which are robust to controlling for the endogeneity of institutions – provide strong evidence of a causal link between the quality of local governments and the capacity of territories to generate innovation. In particular, low quality of government becomes a fundamental barrier for the innovative capacity of the periphery of the EU, strongly undermining any potential effect of any other measures aimed at promoting greater innovation. The results have important implications for the definition of innovation strategies in EU regions.

Keywords: Institutions, Quality of government, Innovation, Regions, Europe

JEL classification: O3; O52; R11

1. Introduction

The promotion of innovation has become one of the key objectives of the European Union's (EU) Europe 2020 strategy. The aim is to foster high quality research, technological development, and innovation (RTDI) as one of the foundations of a smart, sustainable and inclusive economy across the whole of Europe (European Commission, 2012). Considerable resources have been earmarked in order to achieve this in an effort to complement existing national innovation policies. However, the returns of innovative policies in the periphery of Europe have been questioned in a number of studies (e.g. Rodríguez-Pose, 2001). It has often been the case that past regional development programmes have had limited success in improving the innovative potential and spurring growth in peripheral European regions. The arguments behind this apparent failure have included an excessive distance to the technological frontier (Greunz, 2003), human capital shortages (Rodríguez-Pose and Crescenzi, 2008; Sterlacchini, 2008), or geographical distance from the main innovative areas (Moreno et al., 2005a). Institutional factors, despite being often mentioned as important constraining factors for innovation (e.g. Iammarino, 2005), have tended to be overlooked from the large comparative analyses. Indeed, most economic growth theories dealing with innovation take institutions for granted (Huang and Xu, 1999) and do not explicitly consider them as drivers of technological change. Other strands, such as the endogenous growth theory (Romer, 1986; Lucas, 1988; Grossman and Helpman, 1991) and the systems of innovation approach (Lundvall, 1992; Nelson, 1993; Edquist, 2001) have acknowledged the role of public policy and institutional conditions in determining the position of a place with respect to the technological frontier, but few scholars have attempted to demonstrate empirically how government institutions affect innovative capacity. Knowledge is generally assumed to be simply the result of innovation investments promoted by the public and private sectors. Public policy and R&D investment thus determine changes in the innovation potential of places (Fagerberg, 1994), meaning that we know little about the role that institutions effectively play in the capacity of territories to innovate.

Another major problem has been data availability. There has been a dearth of reliable measures of institutional quality and, in particular, of information about the variation of institutional factors within countries. Traditional indicators relating to political institutions tend to be either the result of independent research by political scientists [e.g. Jaggers and

Marshall's (2000) Polity IV dataset] or are calculated on the basis of surveys of representative individuals [e.g. the Freedom House dataset or Kaufmann et al.'s (2009) World Bank Governance Indicators]. Either way, the data are normally collected and aggregated at the national level. Hence, most empirical studies adopting measures of sub-national institutional quality are conducted within specific national contexts (e.g. Putnam, 1993; 2000; Kemmerling and Stephan, 2008; De Blasio and Nuzzo, 2010). Whenever research has wandered into the analysis of how local institutional conditions shape growth and innovation across European countries, the analyses have generally focused on informal institutions, such as culture, trust and social capital (Akcomak and ter Weel, 2009; Tabellini, 2010).

In this paper we aim to fill these gaps in the literature and will argue – is the same vein as contributions from Huang and Xu, 1999 or Cooke et al., 2000 – that government institutions make an important difference for the innovative performance of the regions of Europe. We posit that investing in innovation in territories with relatively weak institutional settings, such as the majority of the peripheral regions of the EU, is likely to yield lower returns than in areas with healthy institutions. Local institutional quality will thus shape the set of constraints and incentives for local actors to perform technical innovation, affecting, in turn, the capacity to transform public R&D policies into innovation.

In order to achieve this aim, we develop an empirical knowledge production function model that directly connects local government institutions with the innovative performance of European regions. We argue that alongside traditional innovation inputs, cross-territorial knowledge spillovers, and socio-economic institutional features, local innovative performance is directly conditioned by the quality of regional institutions. We use the sub-national EU Quality of Government (QoG) index created by Charron et al. (2013) as our proxy for regional government institutions. The QoG index includes four basic 'pillars' – control of corruption, rule of Law, government effectiveness, and government accountability – which will also be considered in the analysis.

The results of the analysis stress that local quality of government plays a strong and significant role in determining the innovative potential of European regions. Regions with local governments which are capable of designing and implementing effective policies, while, at the same time, keeping corruption at bay are much more innovative than those where corruption is rife and governments ineffective. This result is robust to controlling for the endogeneity of institutions. When the analysis is conducted for ‘core’ and ‘peripheral’ regions separately some significant differences in the in the determinants of innovation are unveiled, providing solid empirical evidence in favour of the hypothesis that development strategies should account for the institutional specificities of each territory (Tödtling and Trippl, 2005; Barca, 2009; Barca et al., 2012). The analysis suggests that for the periphery of Europe ensuring that public intervention is efficiently targeted and adequately managed is crucial in order to develop the innovative potential of regions, making institution-building almost a precondition to develop the innovative potential of the periphery of Europe (Farole et al., 2009; Rodríguez-Pose, 2013).

The paper adopts the following structure. Section 2 introduces the relevant literature and examines in depth the mechanisms through which institutions and quality of government influence the innovation capacity across EU regions. Section 3 describes the indicator of government quality used in the analysis, outlines the modelling framework, and discusses variables and data issues. Section 4 presents the econometric results, starting with the fixed effects estimates for the full sample, followed by the analysis for ‘core’ and ‘peripheral’ regions and the instrumental variable (IV) estimation. Section 5 concludes and presents some preliminary policy implications.

2. Government institutions and innovation

Institutions are generally assumed to matter for growth, but they are seldom explicitly factored in growth equations. Even rarer is the connection between government institutions and innovative potential as an element which shapes growth trajectories. In endogenous growth and neo-Schumpeterian approaches institutions are normally taken as a given (Symeonidis, 1996; Huang and Xu, 1999) and not considered as independent components in models of technical change. Regional systems of innovation (RSI) (Cooke et al., 1997), innovative milieux (Camagni, 1995), and learning regions (Morgan, 1997) approaches have, by contrast, brought the role of institutions, in general, and government institutions, in particular, closer to the fore by underlining that institutions can play a key role in shaping the returns of investment in innovation. However, the focus of these approaches has been mainly on the association channels, organisational mechanisms and collaborative institutional structures, disregarding to a large extent the importance of the legal and political systems and of the quality of government for innovation.

The development of the 'New Institutional Economics' (NIE) has represented an additional steppingstone towards capturing the role of institutions. The NIE's concept of 'adaptive efficiency' (North, 1990: 80) – i.e. "the willingness of a society to acquire knowledge and learning, to induce innovation, to undertake risk and creative activity of all sorts, as well as to resolve problems and bottlenecks of the society through times" – is of particular importance for innovation. The capacity of local institutional conditions to adjust over time shapes local technological and economic change. Several attempts have been made in order to model 'adaptive capacity' and other institutional factors and to gauge their effect on economic performance. Most of these analyses, however, have been conducted at the national level (e.g. Hall and Jones, 1999; La Porta et al., 1999; Acemoglu et al., 2001; Rodrik et al., 2004). Research at the sub-national scale is limited (e.g. Acemoglu and Dell, 2010) and there is virtually none examining the link between government institutions and innovative capacity.

In this paper we develop an empirical model assessing how the quality of local government institutions affects innovation across European regions. Formal and informal government institutions contribute to define the degree of economic uncertainty in the society and the way in which collective decisions are made. They are responsible for regulating learning processes, supporting the formation of mutual trust and facilitating the transmission of knowledge between innovation players. The localised character of these innovation dynamics entails that the responsibility for promoting innovation-enhancing measures is increasingly borne by sub-national administrations (OECD, 2011). But the quality of government varies considerably within European countries. We argue that the success of innovation intervention is conditional on the capacity of regional government institutions to limit moral hazard and to provide local policy-makers with the right incentives to take decisions that maximise the technological capability of regional stakeholders.

We look not only at overall government quality but also at four of its components: government effectiveness, rule of law, government accountability and control of corruption. The reason for this is that these different quality of government categories affect technological development in different ways. First, an effective government is more credible in designing long-term innovation strategies, as well as better able to target the right areas of investment and to implement the adequate measures that would make these strategies effective. In Europe, strategic interventions and innovation policies are today more and more defined through a complex process of multilevel agreements, involving negotiations at the local, national and supranational levels. Through the principle of subsidiarity, many of the EU interventions targeting the development of innovation are implemented by local governments who, furthermore, have a significant say in the design of the intervention. This trend has been reinforced by progress towards political and fiscal decentralisation, which has substantially increased the number of innovation policy domains in which regions have an important say (OECD, 2011; European Commission, 2012). In Federal or decentralised systems, such as Germany, Italy and Spain, not only do regions enact the legislative framework regulating higher education and define cooperative arrangements between business, universities and other social stakeholders, but they also play an important role in the promotion of R&D policy. However, as Farole et al. (2011) have noted, it is often the case that EU regions face implementation weaknesses, due to inadequate institutional capability. The degree of decentralisation affects the capacity to design and implement innovation strategies. The absence of regional administrative structures in Lithuania, for example, has been identified as a major constraint to the realisation of an effective regional innovation policy (European Commission, 2010). However, rather than with levels of decentralisation, the weak returns of some innovation policies are more often associated with the low capacity of local decision-makers and governments to implement efficient policies, either because of a lack of adequate resources to finance innovation strategies or because interventions are not accompanied by coherent frameworks of practice, monitoring, and programme evaluation.

Rule of law affects the investment propensity of the business sector in a region. Institutional conditions guaranteeing a high level of appropriability for new inventions, techniques and products introduced in the market are crucial for firm-level innovation. "Weak protection of intellectual property rights undermines incentives to invest in innovation, facilitates counterfeiting and piracy, reduces the potential for technology transfer and limits the formation of markets for knowledge" (OECD, 2010: 18). Moreover, the effectiveness and impartiality of local courts has been identified as an essential element for innovation (e.g. Baumol, 1990; Caselli and Coleman, 2001; Rose-Ackerman, 2001). Before the unification of the EU patent system in early 2013, the different capacities of national legal structures to enforce contracts and rules and to punish infringements affected the innovative potential of regions even more than today. To our knowledge, no research has ever attempted to verify the presence of a direct link between legal institutions and innovation with sub-national data.

The degree of self-government of the region can also have an influence on whether rule of law conditions affect innovation. Across a number of countries in Europe the powers over innovation policies have been enhanced and regional parliaments have broaden their legislative reach in order to encompass certain aspects linked to research and development and innovation. Regions often share these responsibilities with national and supranational institutions. As a consequence, it has been argued that in the progressive emergence of a European model of governance for innovation policy entails an increasing integration of the regional dimension in national innovation systems, although nations still remain the main guarantor of the rule of law (Kuhlmann, 2001). This leads to a system where national government organisations oversee legislation and the implementation of intellectual property rights, whereas other governance factors depend on a number of phenomena which have a more localised territorial dimension, such as trust in the capacity of local administrators and the *de facto* control of some regions by local economic and political elites (Acemoglu and Dell, 2010).

Trust can also be considered an increasingly local phenomenon. The building of trust is a complex process that goes beyond the legal architecture or the effectiveness of the regional executive and also involves broader mechanisms of legitimation of the actions of politics deriving from the morality of members of governments and their use of the power delegated to them by the population. Decentralised institutional set-ups involve a delicate balance between increased accountability and higher risks of rent-seeking. On the one hand, the reduced distance between local politicians and civil society in sub-national political systems can enhance the generation of trust between those in government and those governed (Putnam, 1993; Azfar et al., 1999). On the other hand, it may be easier to develop strong links between decision-makers and interest groups at the local level (Tanzi, 1995; Prud'homme, 1995; Blanchard and Schleifer, 2000). Innovation policy cannot escape this type of risk. As it often involves systems of incentives designed to support the innovative activities of firms, it may end up as "a mechanism of rent transfer to unscrupulous businessmen and self-interested bureaucrats" (Rodrik, 2004: 17). Avoiding this risk requires developing a set of checks and balances at the local level. This often implies a democratic, unbiased and accountable system, with public decision-making and policies embedded in the local context and responsive to the real needs of any given territory, but at the same time independent from external pressures. The development of public-private and private-private collaborative networks should occur in a transparent environment, in order to provide the right incentives for new-coming investors to contribute to the evolution of the regional innovation system, and to prevent institutional lock-in (Boschma, 2005). The regional innovation system must thus find the right balance between the interaction among its components and the independence of the local government from the pressure of other local actors. The minimisation of corruption also involves an effective system of control and sanctioning inefficient and unauthorised government behaviours.

Limited empirical research has tried to establish the link between corruption and innovative activities. The few existing studies point to a strong and negative association between corruption practices and R&D investments, technological progress, and the generation of patents (Anokhin and Schulze, 2009; Sivak et al., 2011). Once again, the focus of these analyses is on country-level data and the intra-national variation in institutional quality is not taken into account.

3. Model and data

Empirical model and estimation methodology

In order to examine whether government institutions affect the innovative capacity of regions in Europe, we use an extended knowledge production function (KPF) in which we not only include the traditional elements of a KPF, such as the private sector's efforts in innovative activities (Griliches, 1979) and local externalities (Jaffe, 1989; Audretsch and Feldman, 1996), but also an index of the characteristics of the regional labour pool and the local socio-economic structure – the 'social filter' (Rodríguez-Pose, 1999; Rodríguez-Pose and Crescenzi, 2008). The key innovation of the paper, however, is – following the theoretical section – to insert quality of government and its components, as a means to assess how differences in the local institutional environment affect the capacity of regions in the EU to innovate.

Our KPF relies on a simplified version of Romer's (1990) endogenous growth model without physical capital. Romer's (1990) model adopts the following form:

(1) $$\dot{A}_t = \kappa\,(A_t)^{\theta}\,(a_L L_t)^{\delta}$$

Where $\dot{A}_t$, the variation of technological progress over time t, is a function of the current stock of knowledge (or current innovation capacity) A_t and the proportion of the labour force employed in the production of new knowledge $a_L L_t$. We add to this framework a parameter accounting for the quality of government institutions in their multiple forms. Model (1) becomes:

(2) $$\dot{A}_t = \kappa\,(A_t)^{\theta}\,(a_L L_t)^{\gamma}(q(G_t))^{\delta}$$

Where $q(G_t)$ is one of the dimensions of regional governance affecting the rate of accumulation of new technology. Dividing by A_t and taking logs on both sides yields:

(3) $$\ln g_{At} = (\theta - 1)\ln A_t + \gamma\ln(a_L L_t) + \delta\ln q(G_t)$$

Where $g_{At} \equiv \frac{\dot{A}_t}{A_t}$ is to the growth rate of A_t.

In Romer's (1990) model the parameter θ is associated to the effect of the existing stock of knowledge on the success of R&D investments. Our interpretation of θ is somewhat broader and refers to past innovative capacity and to the efforts put into acquiring new technical knowledge, both through the intensity of local R&D expenditure and through the connection with partners outside regional borders (spillover effect). $a_L L_t$ represents the 'social filter' index describing the mix of local social conditions which "determine the rhythm at which any society adopts innovation and transforms it into real economic activity" (Rodríguez-Pose, 1999: 81-82).

The 'extended'-KPF takes the form:

(4)
$$\ln patents_{r,t} = \theta_1 \ln patents_{r,t-1} + \theta_2 \ln busR\&D_{r,t} + \theta_3 \mathrm{W} \ln busR\&D_{r,t} + \gamma\, SFindex_{r,t} + \delta\, QoGindex_{r,t} + \epsilon_{r,t}$$

Our dependent variable ($\ln patents_{r,t-1}$) is subtracted on both sides, as customary for dynamic panel models (Bond et al., 2001). The model also controls for national characteristics (change in national patenting capacity). Two types of unobservable factors are taken into consideration: permanent and time-varying elements, assuming that $\epsilon_{r,t}$ has two orthogonal components, the fixed effects μ_r, and the white noise term $\eta_{r,t}$.

Taking this into consideration, the final model adopts the following form:

(5)
$$\Delta \ln patents_{r,t} = (\theta_1 - 1) \ln patents_{r,t-1} + \theta_2 \ln busR\&D_{r,t} + \theta_3 \mathrm{W} \ln busR\&D_{r,t} + \gamma\, SFindex_{r,t} + \delta\, QoGindex_{r,t} + \varphi\, \Delta\, Nat\ patents + \mu_r + \eta_{r,t}$$

Where $\Delta \ln patents_{r,t} = \ln patents_{r,t} - \ln patents_{r,t-1}$, the dependent variable, is the annual change in the logarithmic transformation of patent applications to the European Patent Office (EPO) per million of inhabitants in region *r*. Regional patents in t-1 reflect the initial distance of a region from the technological frontier. We are aware that patents is a highly imperfect proxy for innovation output (Griliches, 1990). Not only do different industries have different propensities to patent, but also not all new inventions are patented. However, the lack comparable statistics on innovation counts at a regional level for the whole of the EU leaves no viable alternative. Moreover, in those cases where innovation counts have been used in other geographical contexts, they have been shown to provide very similar results to analysis utilising patents (Acs et al., 2002).

$busR\&D_{r,t}$ represents the amount of R&D expenditures from the private sector as a percentage of regional GDP, for region r at time t. This is a standard proxy for innovation inputs, widely employed in the KPF literature (e.g. Feldman and Florida, 1994; Anselin et al., 1997; Acs et al., 2002; Crescenzi et al., 2007). The variable also helps to capture the capacity of local firms to 'absorb' and adopt innovation generated elsewhere (Cohen and Levinthal, 1990). To control for between-region knowledge externalities produced by high-order technological activities, we include the spatial lag of the $busR\&D_{r,t}$ variable, which is calculated using the k-4 neighbours as a spatial weighting method. This method has been commonly used for cross-country studies of European regions The spatial matrix *W(r,j)* is operationalised as follows:

$$W\ busR\&D_{r,t} = \sum_{j=1}^{n} R\&D_j w_{rj} \qquad \text{with } r \neq j$$

$$W(r,j) = \begin{cases} 1/k & \text{if } j \text{ is one of the 4 k-nearest neighbours to region } r \\ 0 & \text{otherwise} \end{cases}$$

$SFindex_{r,t}$ accounts for the characteristics of the local socio-economic structure influencing the production of new knowledge. The index is calculated as a composite index, following Crescenzi et al. (2007), but including a number of variables inspired by the OECD's classification of regions by level of innovativeness (Ajmone and Maguire, 2011). In this classification regions are sub-divided into three categories: knowledge hubs, industrial and production zones and non-S&T-driven regions.

Our version of the social filter index includes a measure of educational attainment, another of labour market rigidity, and two on the sectoral composition of the regional industry. Educational attainment is proxied by the natural logarithm of graduates as a percentage of those in employment. Long-term unemployment over the total unemployment rate is used in order to reflect labour market rigidity. Finally, the regional sectoral structure is captured by the percentage of total employment in agriculture and the proportion of high-tech manufacturing employment as a percentage of the total labour force. A significant share of the economy in the primary sector is common in many Non-S&T-driven regions (Ajmone and Maguire, 2011). We therefore assume a negative correlation with regional innovativeness. High-technology manufacturing employment, instead, is expected to be positively correlated with innovative capacity: a specialisation in manufacturing high-tech is typical of many European regional knowledge hubs.

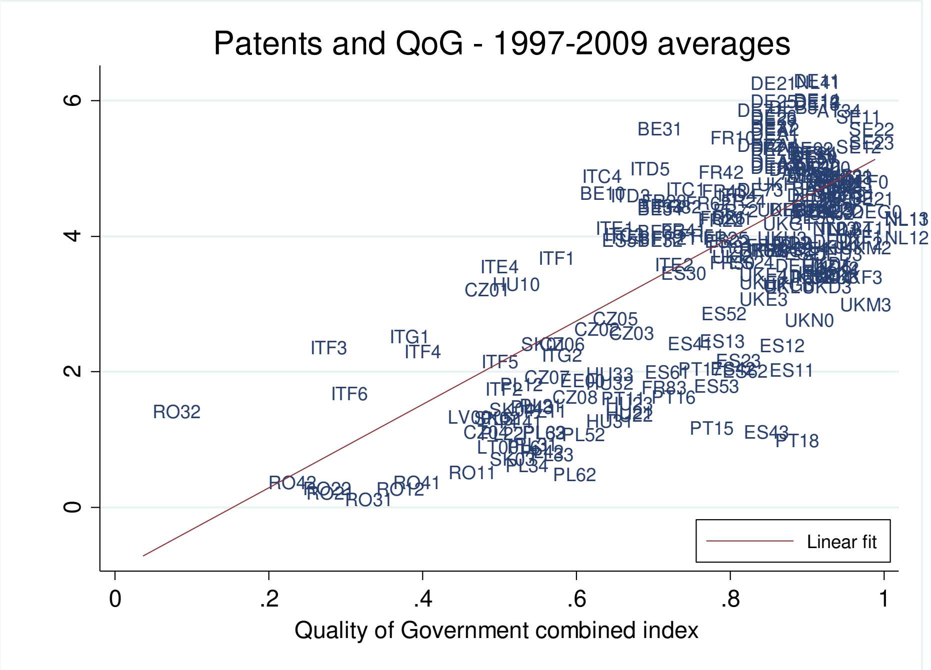
In order to generate the composite social filter index PCA is used, following Crescenzi et al. (2007). PCA necessarily entails some loss of some information. In our case the first principal component accounts for 46% of the cumulative variance of the variables (see tables in the appendix). All variables are assigned large weights in the first principal components, with agricultural employment and the proportion of employed graduates having the highest weights. Given that the signs of the variables are contrary to expectations (graduate employment and high-tech manufacturing employment are assumed to be positive, unemployment rate and agricultural employment to be negative), the final social filter index is computed by multiplying the predicted first principal components by -1.

The empirical model is completed with the QoG index and its four different 'pillars'. The QoG index has been compiled by the Quality of Government Institute at the University of Gothenburg. It is the first homogeneous survey-based index of quality of government at the regional level for the EU-27 (Charron et al., 2011). The questions on which the index is based are centred around three main pillars: quality of education, public health care and law enforcement; impartiality in education, public health and legal protection; level of corruption in education, health care and the legal system. Charron et al. (2013) have extended their index over time by integrating it with the country-level World Bank Governance Indicators (WBGI) (Kaufmann et al., 2009). The authors adapt the answers to the QoG surveys to the four 'pillars' of the WBGI, namely (1) effectiveness of regional government and bureaucracy, (2) rule of law, (3) accountability of the local administration and strength of democracy, (4) level of corruption. In order to facilitate the interpretation of results, we have normalised the institutional variables to make them range from 0 to 1.

We expect that a favourable institutional setting will support the research activity of firms, facilitate the connection between organisations, higher education institutions and businesses, improve the effectiveness of place-based policy, and generate the right environment for the development of mutual trust. Figure 1 displays the scatter plot between the natural log of patents applications, dependent variable, and the QoG combined index, our independent variable of interest, both averaged for the period of analysis (1997-2009). A positive relationship between regional governance and the level of innovative capacity is evident in the Figure. The simple correlation coefficient between patents and government quality is 0.66, significant at the 1% level.

Figure 1

Scatter plot association: Patens application and Quality of Government – full sample



source: own elaboration with Eurostat and QoG Institute data

The main parameter of interest of the empirical model is δ, the coefficient describing the relationship between regional government institutions and changes in patenting.

Data availability and estimation issues

The hypotheses derived from the empirical model are tested on a panel of European Nuts2 regions including all EU countries for which a sufficiently long time variation in patents' production and in the main variables of interest is available. The model is estimated for the 1997-2009 period. Serious data constraints lead to the exclusion of Bulgarian, Cypriot, Danish, Greek, Maltese, and Slovenian regions. For those EU countries with only one Nuts2 region (Estonia, Latvia, Lithuania, Luxembourg), national data are used. Most data stem from the Regio database, compiled by the EU statistical office, while the institutional variables of interest have been compiled by the Quality of Government Institute at the University of Gothenburg.[1] In total, the analysis covers 225 regions from 19 countries.[2]

4. Regression results

Fixed Effects Estimates

We estimate equation (5), in the first instance, using a least squares dummy variable (LSDV) analysis, checking for the existence of a correlation between independent variables and individual effects by means of the usual Hausman test. Time dummies are included in all specifications in order to control for time-related shocks. All variables except for the two indexes (social filter and QoG) have been log-linearised to reflect the estimable version of the model in equation (3) and to facilitate the interpretation of coefficients.

Tables 1 and 2 summarise the results obtained with heteroscedasticity-robust FE, as suggested by the Hausman test. Table 1 includes the combined QoG variable, whereas Table 2 comprises its four constituent components: control of corruption, rule of law, government effectiveness, and government accountability.

Overall, the estimation displays a decent goodness-of-fit (R^2 always above 50%). The coefficients for all the control variables are as expected. First, the coefficient for $\ln patents_{r,t-1}$ is highly significant, negative and lower than one, suggesting a process of convergence in patenting activity (Tables 1 and 2). Less innovative regions have, during the period of analysis, been able to reduce the technological gap with more advanced regions, as suggested by Moreno et al. (2005b) and Crescenzi et al. (2007).

[1] Data on quality of government are available for all countries at Nuts2 regional level, with the exception of Belgium, the Czech Republic, Germany, Hungary, the Netherlands, and the United Kingdom, for which the original data were collected at Nuts1 level. For these six countries, we assign the same institutional values and variation to all Nuts2 regions nested within the bigger Nuts1. Finally, we exclude Ireland and Finland from the sample because their QoG score does not vary across their Nuts2 regions.

[2] Additional details on the variables considered in the analysis are in the appendix.

R&D expenditures also display a positive and significant coefficient. A higher effort in R&D by the industrial sector in any given European region is robustly correlated with a stronger innovative capacity. The elasticity of the estimates of patents production to business R&D expenditures ranges from 0.090 to 0.108 (Tables 1 and 2), slightly lower than previous studies with similar samples but different time-spans (e.g. Bottazzi and Peri, 2003; Akcomak and ter Weel, 2009). Extra-regional innovative activities seem to contribute positively to the patenting capacity of neighbouring regions, as indicated by the positive and significant coefficient of the spatial weight of business R&D expenditures. This suggests that European regions benefit from cross-border knowledge spillovers (Greunz, 2003), possibly as a consequence of the geographical proximity between European innovative centres which favours the formation of inter-regional relational networks (Crescenzi et al., 2007).

The local socioeconomic conditions also make a difference for regional innovation. Regression (vi) in Table 1 presents the estimation of model including the social filter index. The coefficients for the individual components of the social filter index are shown in regressions (ii)-(v). In all cases, the four elements of the social filter display the expected sign. Agricultural employment is negatively associated with regional innovation and is significant at the 5% level. The coefficient for the ratio of employed people with higher education is positive and significant, confirming that regions endowed with a highly-educated labour force can rely on a skills-base that contributes to their innovative potential. Long-term unemployment is, by contrast, negatively and significantly connected to innovation. This indicates that structural rigidities in the local labour market are a major obstacle for the development of regional innovation systems. Finally, the presence of a high-tech labour pool is an indicator of a healthy local innovative capacity (Riddel and Schwer, 2003). Taken together, the composite social filter index displays a positive and significant coefficient in Table 1, regression (vi) and Table 2, regressions (vi)-(x). This finding highlights that the socioeconomic structural characteristics of a region represent a crucial element for its capacity to translate innovative efforts into the production of new knowledge.

However, the generation of innovation does not uniquely depend on traditional knowledge inputs – R&D expenditures or extra-regional R&D spillovers – or on the socioeconomic characteristics of a region represented by its social filter. The results of the analysis also indicate in an unambiguous way that our main variable of interest, government institutions, plays a fundamental role for unleashing the local innovative potential. Table 1 provides clear evidence of a substantial impact of government quality on patenting capacity in European regions. In all the specifications of Table 1, the coefficient of the QoG index is positive and significantly different from zero. As the index was standardised between 0 and 1,[3] the observed coefficients – which range from 0.54 and 0.85 – imply that an increase of 0.1 in the value of government quality leads to an improvement in regional patenting capacity of between 5.4% and 8.5%. The magnitude of the point estimates is not negligible, given that the index reports a fairly notable degree of inter-temporal variation. As an example, the Portuguese region of Norte (PT11) improved its overall QoG index score from 0.55 in 2006 to 0.60 in 2009. In this short period of time, according to our estimates, its patenting capacity should have potentially improved from 2.5% to 4%. Similarly, the Southern Italian region of Calabria suffered an important loss in innovative capacity between 2001, when its QoG score was 0.30, and 2009, when the index was 0.17. Deteriorating institutional conditions in Calabria have thus lead to a decline in the local innovative capability of more than 1% per year. It must be noted that the changes in government institutions reported in our data are the result of changes in public opinion about the capacity of local government structures. The real institutional variation may be less pronounced than that reported in the data. However, even if we assume a slower institutional change, the estimated coefficients remain high as a consequence of the large gap in institutional quality among the regions of Europe. Overall, the estimates predict considerable potential gains in innovative potential for all regions at the bottom of the QoG index, provided the institutional gap with the core of Europe is reduced.

The de-composition of the QoG index into its four basic components in Table 2 uncovers significant differences in the link between specific institutional factors and regional innovation. Control of corruption and government effectiveness exhibit a significant and positive correlation with innovation. A 0.1 improvement in corruption control would result in

[3] The lowest value of the QoG index refers to the region of of Bucuresti-Ilfov (RO32) in Romania. It equals $6.38*10^{-9}$ in the year 1998. The highest value is found in Groningen (NL11), Friesland (NL12) and Drenthe (NL13), the Netherlands, with a value of 1 in 1998.

a boost of regional innovativeness of more than 10%. This result is in line with previous research suggesting a detrimental effect of corruption on innovation (Anokhin and Schulze, 2009; Sivak et al., 2011). Moreover, it provides compelling evidence of the harmful impact of rent-seeking behaviours in regionalised institutional contexts (Prud'homme, 1994) and of the dramatic importance of promoting transparent relationships between agents involved in the process of knowledge production. The capacity of local administrators to design and implement effective development policies also appears to affect the definition of successful innovation processes, as shown by the highly significant coefficient of government effectiveness in Table 2, Regression (x). In contrast, rule of law and government accountability appear to have limited impact on regional patenting in Europe.

Table 1

Robust fixed Effects estimation - Innovation and governance quality, 1997-2009

Dependent variable: Δ Patents application	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Patents application (t-1)	-0.517***	-0.495***	-0.491***	-0.493***	-0.497***	-0.516***
	(0.0470)	(0.0473)	(0.0466)	(0.0468)	(0.0468)	(0.0464)
Quality of Government Combined Index (QoG)	0.757**	0.706**	0.614**	0.539*	0.537*	0.849***
	(0.292)	(0.296)	(0.291)	(0.276)	(0.280)	(0.289)
Business R&D expenditure as percentage of GDP	0.101***	0.108***	0.0967***	0.0946***	0.0955***	0.101***
	(0.0282)	(0.0276)	(0.0288)	(0.0280)	(0.0289)	(0.0283)
Spatial weight of business R&D expenditure	0.141**	0.177***	0.180***	0.167**	0.154**	0.144**
	(0.0604)	(0.0641)	(0.0661)	(0.0653)	(0.0603)	(0.0613)
Social Filter Index[a]						0.124***
						(0.0221)
Employed people with tertiary education	0.102**	0.120***				
	(0.0408)	(0.0411)				
Long-term unemployment	-0.0947**		-0.0904**			
	(0.0397)		(0.0410)			
Agricultural Employment	-0.0784			-0.143**		
	(0.0545)			(0.0555)		
Employment in high tech industry	0.223***				0.224***	
	(0.0478)				(0.0476)	
National patents' growth	0.615***	0.619***	0.626***	0.626***	0.618***	0.617***
	(0.0792)	(0.0807)	(0.0807)	(0.0808)	(0.0812)	(0.0787)
time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,605	2,605	2,621	2,621	2,621	2,605
Nuts regions	225	225	225	225	225	225
R^2 within	0.540	0.530	0.526	0.526	0.531	0.539
Hausman FE/RE ($p>\chi^2$)	582.67 (0.00)	538.67 (0.00)	520.52 (0.00)	542.44 (0.00)	524.32 (0.00)	592.26 (0.00)

Note: Robust standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms except for the QoG Index and the Social Filter Index. a/ the Social Filter is obtained as the first principal component of: employed people with tertiary education, long-term unemployment rate, employment in high tech industry, agricultural employment.

Table 2

Robust fixed Effects estimation - Innovation and QoG components, 1997-2009

Dep. variable: Δ Patents application	(vi)	(viii)	(ix)	(x)
Patents application (t-1)	-0.525***	-0.514***	-0.516***	-0.516***
	(0.0465)	(0.0459)	(0.0461)	(0.0458)
Business R&D in percentage of GDP	0.0968***	0.0936***	0.0982***	0.0898***
	(0.0280)	(0.0285)	(0.0282)	(0.0281)
Spatial weight of busR&D expenditure	0.133**	0.130**	0.147**	0.124**
	(0.0583)	(0.0610)	(0.0627)	(0.0607)
Social Filter Index[a]	0.112***	0.112***	0.123***	0.107***
	(0.0202)	(0.0230)	(0.0220)	(0.0214)
Control of Corruption	1.124***			
	(0.281)			
Rule of Law		0.0440		
		(0.261)		
Government Effectiveness			0.559***	
			(0.169)	
Government Accountability				-0.209
				(0.150)
National patents' growth	0.616***	0.631***	0.618***	0.633***
	(0.0785)	(0.0800)	(0.0785)	(0.0800)
time effects	Yes	Yes	Yes	Yes
Observations	2,605	2,605	2,605	2,605
Nuts regions	225	225	225	225
R^2 within	0.542	0.536	0.539	0.536

Note: Robust standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms except for the QoG Index and the Social Filter Index. a/ the Social Filter is obtained as the first principal component of: employed people with tertiary education, long-term unemployment rate, employment in high tech industry, agricultural employment.

Core vs. periphery

Economic, social and institutional conditions between the core and the periphery of Europe vary substantially. This may affect the connection between government quality and innovation in very different ways depending on how peripheral a region is. In order to check whether this is the case, we divide the sample into two categories: 'periphery' (regions eligible for Objective 1 or 'convergence' support in the European regional policy during the period 2000-2006)[4] and 'core' (all remaining regions). Of the 225 regions included in the full sample, 78 are classified as 'periphery' and 147 as 'core' (Figure 2). Table 3 presents the descriptive quality of government statistics for the 'core' and the 'periphery'. The mean value

[4] Romania was not a member of the EU during the period 2000-2006. All its regions have been included in the 'periphery'.

of the QoG index and all of its individual components is significantly lower in peripheral regions.

Figure 2

Classification of core and peripheral regions in our analysis

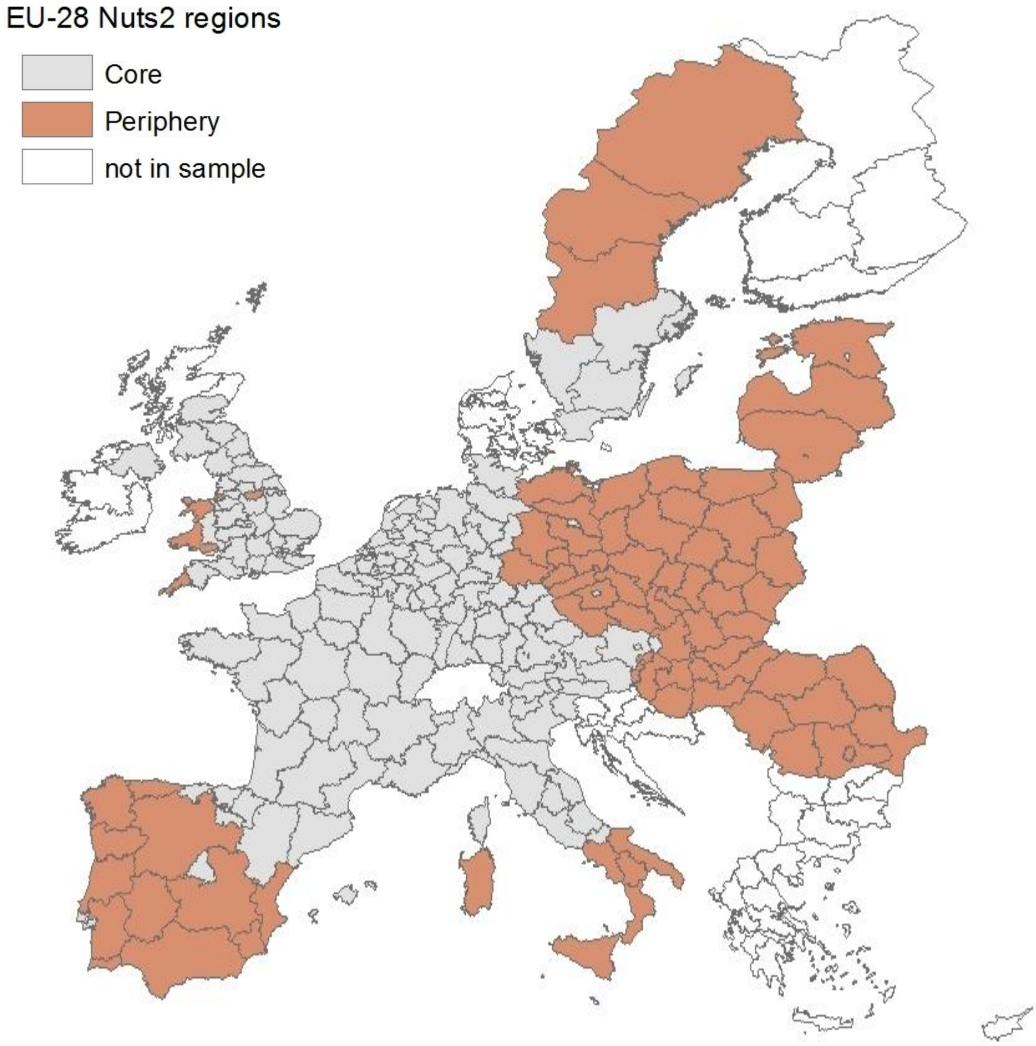


Table 3
Quality of government in the core and the periphery

Periphery

Component	Observations	Mean	Std. Dev	Min	Max
QoG combined index	1014	.5918372	.211943	6.38e-09	.9684653
Control of Corruption	1014	.5967667	.1909336	1.78e-07	.9691926
Rule of Law	1014	.5907354	.2146147	1.72e-07	.9907007
Govt Effectiveness	1014	.5381444	.2225347	1.89e-07	1.0000
Govt Accountability	1014	.5654771	.2010523	1.61e-07	1.0000

Core

Component	Observations	Mean	Std. Dev	Min	Max
QoG combined index	1911	0.807274	0.111008	0.370425	1.000
Control of Corruption	1911	0.818242	0.120417	0.311911	1.000
Rule of Law	1911	0.800939	0.125236	0.337537	1.000
Govt Effectiveness	1911	0.738525	0.120101	0.252225	0.950698
Govt Accountability	1911	0.750599	0.105591	0.289416	0.945737

The regression results for these two separate categories of regions are presented in Tables 4 and 5. The estimates confirm the presence of significant differences in the factors that affect innovation in the core and the periphery of Europe. In the periphery, innovative performance is primarily explained by a combination of institutional quality and the socio-economic conditions in place. As in the case of the full sample model, corruption is the main institutional factor affecting innovation (Table 3, Regression 3). R&D business expenditures, by contrast, display an insignificant coefficient, reflecting the frequent absence of an industrial sector capable of developing advanced scientific and technological strategies in peripheral regions (Bilbao-Osorio and Rodríguez-Pose, 2004). These results point to the existence of technological thresholds “under which the benefits of investments in high order technologies do not accrue” (Farole et al., 2011: 1103). Innovation systems in peripheral areas of Europe may be incapable of attaining the critical mass of R&D necessary to trigger returns from technological investments (Charlot et al., 2012). The insignificant coefficient of the R&D spatial weight also indicates that knowledge spillovers are rare in the periphery. Hence, instead of being dependent on traditional innovation inputs, technological advances in the periphery of Europe are fundamentally associated to institutional progress, to improvements in human capital, and to a better matching between labour supply and demand. These factors become more important for innovation the greater the distance from the technological frontier and the farther away a region is located with respect to the main innovation generating centres.

By contrast, core regions, which already enjoy better institutional environments, benefit little in terms of innovation from further increases in quality of government. Of the four variables relating to the QoG index, only control of corruption remains positive and significant (Table 5). The combined QoG indicator displays a very low and insignificant coefficient in Table 7 (Regressions 7 and 8). This result reinforce the view that the positive impact of government institutions observed in the full sample is basically as a consequence of the dynamics taking place in lagging regions. This implies that the institutions-innovation nexus appears to be subject to a threshold effect. Small changes in quality of government have important consequences for regional patenting up to a certain threshold level of institutional quality. When the quality of the local government reaches a sufficient degree of efficiency, the relevance of institutions wanes significantly until ultimately disappearing. In the core of Europe, R&D investments and local socioeconomic and labour market conditions remain the key determinants of patenting capacity (Table 5, Regressions 8-12).

Table 4

Robust FE estimation - Innovation and QoG components in peripheral regions, 1997-2009

Dep. variable: Δ Patents application	Periphery					
	(1)	(2)	(3)	(4)	(5)	(6)
Patents application (t-1)	-0.528***	-0.527***	-0.533***	-0.522***	-0.530***	-0.523***
	(0.0514)	(0.0522)	(0.0517)	(0.0504)	(0.0527)	(0.0500)
Business R&D expenditure as % of GDP	0.0520	0.0494	0.0447	0.0414	0.0470	0.0355
	(0.0348)	(0.0349)	(0.0343)	(0.0344)	(0.0343)	(0.0341)
Spatial weight of R&D expenditures	0.0466	0.0551	0.0364	0.0289	0.0624	0.0146
	(0.191)	(0.195)	(0.188)	(0.188)	(0.198)	(0.182)
Social Filter Index		0.112***	0.0972***	0.111***	0.116***	0.106***
		(0.0380)	(0.0359)	(0.0399)	(0.0383)	(0.0390)
Employed people with tertiary education	0.195**					
	(0.0794)					
Long-term unemployment	-0.0353					
	(0.0723)					
Agricultural Employment	-0.0761					
	(0.144)					
Employment in high tech industry	0.148					
	(0.110)					
QoG Index	1.119**	1.053**				
	(0.498)	(0.482)				
Control of Corruption			1.202**			
			(0.528)			
Rule of Law				0.264		
				(0.403)		
Government Effectiveness					0.886***	
					(0.300)	
Government Accountability						-0.102
						(0.304)
National patents' growth	0.646***	0.650***	0.653***	0.664***	0.647***	0.670***
	(0.0901)	(0.0893)	(0.0893)	(0.0899)	(0.0888)	(0.0904)
time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	857	857	857	857	857	857
Nuts regions	78	78	78	78	78	78
R^2 within	0.472	0.471	0.471	0.466	0.474	0.466

Note: Robust standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms except for the QoG Index and the Social Filter Index. a/ the Social Filter is obtained as the first principal component of: employed people with tertiary education, long-term unemployment rate, employment in high tech industry, agricultural employment.

Table 5

Robust FE estimation - Innovation and QoG components in core regions, 1997-2009

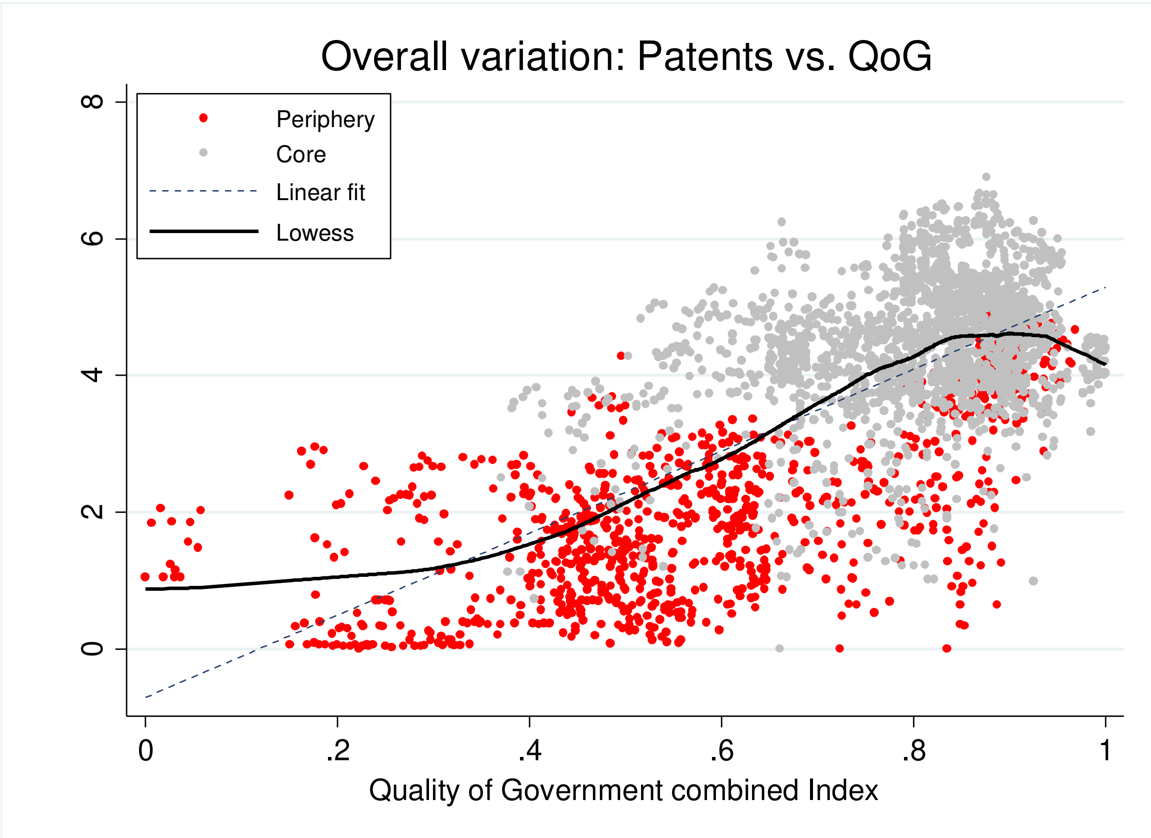
Dep. variable: Δ Patents application	Core					
	(7)	(8)	(9)	(10)	(11)	(12)
Patents application (t-1)	-0.624*** (0.0812)	-0.624*** (0.0805)	-0.631*** (0.0815)	-0.628*** (0.0786)	-0.625*** (0.0801)	-0.625*** (0.0798)
Business R&D expenditure as % of GDP	0.138*** (0.0449)	0.138*** (0.0442)	0.137*** (0.0448)	0.132*** (0.0446)	0.136*** (0.0443)	0.136*** (0.0442)
Spatial weight of R&D exp.	0.172*** (0.0625)	0.175*** (0.0656)	0.172*** (0.0627)	0.168** (0.0659)	0.171** (0.0661)	0.170** (0.0657)
Social Filter Index		0.0624** (0.0251)	0.0648*** (0.0244)	0.0414 (0.0254)	0.0563** (0.0236)	0.0569** (0.0234)
Empl. people with tertiary education	-0.0180 (0.0297)					
Long-term unemployment	-0.0644 (0.0500)					
Agricultural Employment	0.0200 (0.0530)					
Employment in high tech industry	0.187*** (0.0529)					
Quality of Government Index	0.0345 (0.345)	0.153 (0.341)				
Control of Corruption			0.772** (0.320)			
Rule of Law				-0.502* (0.278)		
Government Effectiveness					-0.0884 (0.173)	
Government Accountability						-0.144 (0.163)
National patents' growth	0.567*** (0.125)	0.576*** (0.124)	0.558*** (0.132)	0.610*** (0.118)	0.585*** (0.120)	0.575*** (0.123)
time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,748	1,748	1,748	1,748	1,748	1,748
Nuts regions	147	147	147	147	147	147
R^2 within	0.637	0.633	0.636	0.634	0.633	0.633

Note: Robust standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms except for the QoG Index and the Social Filter Index. a/ the Social Filter is obtained as the first principal component of: employed people with tertiary education, long-term unemployment rate, employment in high tech industry, agricultural employment.

The non-linearity of the relationship between innovation and government quality can be further appreciated by looking at the non-parametric association between patents' applications and QoG (Lowess curve) (Figure 3). Peripheral regions are reported in a darker shade. Figure 3 confirms the presence of a marked difference in the average level of both government quality and patenting capacity between the core and the periphery of Europe. Better institutional conditions are incrementally associated with stronger regional innovative performance up to a certain threshold of institutional quality (around 0.8 in our index), after which the evidence of a positive relationship disappears.

Figure 3

Locally weighted smoothing: Patents application and Quality of Government



source: own elaboration with Eurostat and QoG Institute data

Addressing endogeneity: GMM and instrumental variable estimates

A common concern when dealing with institutional variables and economic outcomes is the endogeneity of institutions. All works including institutions as explanatory variables in growth-accounting models need to take the risk of reverse causality into account (e.g. Acemoglu et al., 2001; Rodrik et al., 2004; Tabellini, 2010). Innovation may be determined by government quality, but government quality may, in turn, be affected by the innovative capacity of a region. In order to assess the direction of causality and to control for the endogeneity of institutions and of other explanatory variables, we exploit the predetermined past values of our variables as an instrument for their current levels, estimating the model by means of system Generalised Methods of Moments (GMM) for dynamic panel (Arellano and Bover 1995; Blundell and Bond 1998). We opt for a GMM-system rather than a GMM-difference because it better accounts for a high degree of persistence in our data (Roodman, 2009). In order to avoid instrument proliferation, all the variables are instrumented with their fourth to sixth-order time lags only. We choose t-4, t-5 and t-6 because the serial correlation test (Arellano and Bond, 1991) on residuals leads to a rejection of the null hypothesis of no autocorrelation on the second and third order lags, but not in the case of the fourth to sixth order lags at the 1% level. We also include country-specific dummies in place of our variable on national innovative capacity, as a means to further reduce the number of instruments. The results of estimating model (5) by means of GMM-sys (Table 6) are very similar to those obtained with fixed effects (Tables 1 and 2). The main difference is that the coefficient for the R&D spillovers variable is no longer significant. Another difference worth mentioning is that rule of law has a positive and significant impact on innovation. All other quality of government factors – control of corruption, government effectiveness and the combined QoG index – remain key determinants of innovative performance. The only exception is government accountability.

Table 6

Robust GMM-system estimation (fourth to sixth order lags as instruments)

Innovation and quality of government, 1997-2009

Dependent variable: Δ Patents application	(i)	(ii)	(iii)	(iv)	(v)
Patents application (t-1)	-0.358*** (0.0676)	-0.371*** (0.0656)	-0.313*** (0.0659)	-0.344*** (0.0659)	-0.326*** (0.0694)
Business R&D expenditure as percentage of GDP	0.105** (0.0515)	0.119** (0.0495)	0.0941* (0.0495)	0.102** (0.0462)	0.0944* (0.0504)
Spatial weight of R&D expenditure	-0.0322 (0.0640)	-0.0197 (0.0561)	-0.0102 (0.0603)	-0.0226 (0.0654)	0.00299 (0.0575)
Social Filter Index	0.256*** (0.0515)	0.222*** (0.0507)	0.266*** (0.0502)	0.264*** (0.0524)	0.225*** (0.0565)
Quality of Government Index	1.037*** (0.381)				
Control of Corruption		0.847*** (0.313)			
Rule of Law			0.878*** (0.317)		
Government Effectiveness				0.685*** (0.227)	
Government Accountability					0.0101 (0.195)
National dummies	Yes	Yes	Yes	Yes	Yes
time effects	Yes	Yes	Yes	Yes	Yes
Observations	2,605	2,605	2,605	2,605	2,605
Nuts regions	225	225	225	225	225
p-value of AR(4) test	0.192	0.171	0.193	0.219	0.172
p-value of AR(5) test	0.868	0.834	0.827	0.920	0.849
p-value of AR(6) test	0.945	0.920	0.992	0.982	0.970
Instruments	188	188	188	188	188
p-value of Hansen test	0.283	0.221	0.342	0.243	0.208

Note: Robust standard errors in parenthesis; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. All variables are in natural logarithms except for the QoG Index and the Social Filter Index. a/ the Social Filter is obtained as the first principal component of: employed people with tertiary education, long-term unemployment rate, employment in high tech industry, agricultural employment.

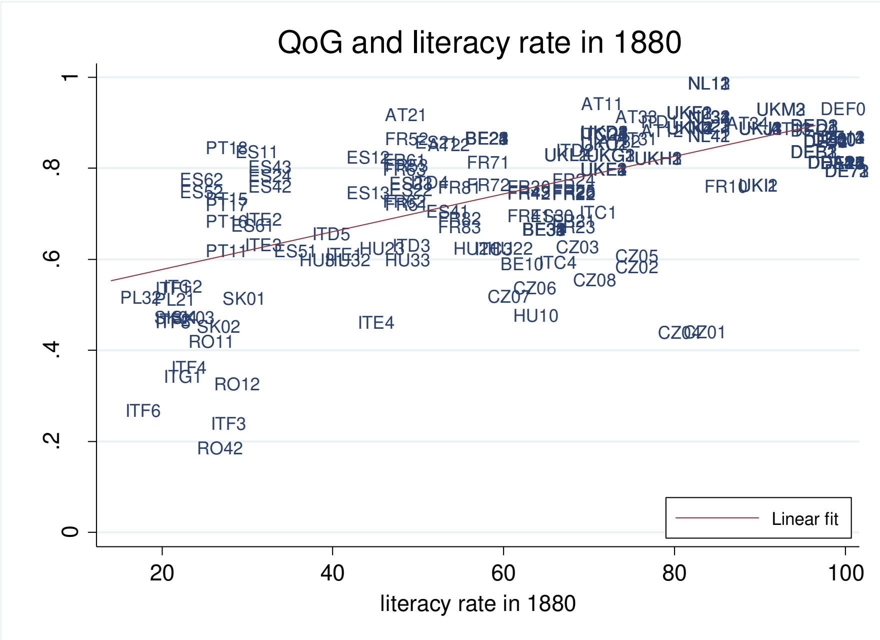
The GMM method, however, accounts only partially for the endogeneity of government quality. The high degree of persistence of institutions (La Porta et al., 1999; Acemoglu et al., 2001; Rodríguez-Pose, 2013) may limit the validity of the fourth or the sixth time lags as instruments. As variations in institutional conditions as measured by the QoG indicators may reflect short-term changes in the population's perception of government structures rather than permanent modifications of the way in which the political framework operates and functions, there is a need to search for external factors capable of isolating the exogenous impact of government institutions on regional innovation (Akcomak and ter Weel, 2009; Laursen et al., 2012; Crescenzi et al., 2013; Tebaldi and Elmslie, 2013).

One way of achieving this is through long-term factors which act as robust determinants of institutional conditions (Hall and Jones, 1999; Acemoglu et al., 2001; 2005). Historical educational endowments represent a good predictor of current institutional differences across the regions of Europe. As Glaeser et al. (2004) demonstrate, historical levels of schooling are robustly correlated with changes in political institutions and economic development. And this is the case not only at the nation-level but also within countries. Tabellini (2010) has shown that literacy in 1880 provides a significant source of variation for the cultural traits and level of social capital of today's European regions. We adopt the same instrumental variable to show that initial human capital acts as an exogenous determinant of current government quality. Our dependent variable is the annual change in patents' applications, which depends on present conditions rather than on historical factors. This means that the chosen instrument is not correlated with the error term in equation (5).

We complement Tabellini's (2010) indicator for Western European regions with information on literacy rates in 1880 in the Austro-Hungarian Empire (see appendix). This implies that we have a valid instrument on the stock of human capital in 1880 for 186 of the 225 regions of the original sample. Figure 4 reports the scatter plot showing the positive linear association between the standardised QoG index (averaged between 1997 and 2009) and our instrumental variable.

Figure 4

Scatter plot association: Quality of Government and long-term literacy rate



source: own elaboration with QoG Institute data

To perform the IV estimation, we need to adopt a procedure that accounts for the possibility that the regressors in equation (5) are correlated with region-specific effects μ_r . Given that 'literacy rate in 1880' is a time-invariant variable, we cannot perform an IV regression by means of fixed effects. The best way to circumvent the problem without losing information is to estimate the impact of long-term human capital on institutions with a Hausman and Taylor (1981) model, assuming that only some regressors are correlated with the individual effects. This technique uses the within transformations and the individual means of both time-varying and time-invariant exogenous variables in order to identify the endogenous variables of the model, while the strictly exogenous variables are used to identify themselves (Baltagi, 2001; Baltagi et al., 2003).

The Hausman-Taylor (HT) estimator allows for the inclusion of time-invariant variables in the model, which enables the inclusion of a new time-invariant control in regression (5). The new control is the regional degree of 'accessibility', calculated as the distance from European centres of production based on physical geography and transport connections. With this variable we can determine whether the generation of new knowledge and innovation is conditioned by the physical position of a region and the opportunities to develop medium/long-distance networks. Our proxy for accessibility is the total number of flights within 90 minutes travel time from region *r*. The full model to be estimated in two steps becomes:

(6)
$$\Delta \ln patents_{r,t} = (\theta_1 - 1) \ln patents_{r,t-1} + \theta_2 \ln busR\&D_{r,t} + \theta_3 \mathrm{W} \ln busR\&D_{r,t} + \gamma\, SFindex_{r,t} + \delta\, \widehat{QoGindex}_{r,t} + \rho \ln accessibility + \varphi\, \Delta\, Nat\, patents + \mu_r + \eta_{r,t}$$

Where $\widehat{QoGindex}_{r,t}$ is the predicted value obtained from a first regression in which we isolate the source of variation of institutional quality explained by 'literacy rate in 1880'. The instrument enters as an exogenous regressor in a model including all other controls of equation (6), with the QoG index as dependent variable treated as endogenous. The second stage consists of another HT estimation with the 'predicted QoG term' in place of the original QoG index.

The 'first stage' regressions are illustrated in Columns 1-5 of Table 7. In all cases the coefficient of the instrument is positive and significant at the 1% level. These results validate the instrument, as they suggest a strong correlation between regional literacy rates in the late XIX century and present government quality. This finding also unveils a double channel through which human capital investments influence local innovative performance: a direct and immediate impact, via the stock of skilled people in employment, as well as an indirect and long-term impact, through its influence on changes in the institutional infrastructure of the region.

The 'second stage' estimates are presented in columns 6-10 of Table 7. They, by and large, confirm the results reported in Tables 1 and 2. The quality of government is an important determinant of the innovative capacity of a region and the direction of causality goes from quality of government to innovation, and not vice versa. Once again the control of corruption and government effectiveness are the two components of overall government quality which have the greatest impact on regional innovation. The coefficients are slightly lower with respect to the FE estimates, probably because the sample now excludes several regions in Romania and Poland, as well as the Baltic countries.

The accessibility variable is positively and significantly connected to innovation. Regions with a higher number of medium/long distance transport linkages with other territories are more likely to innovate. This is important for regions located in the core of the EU, but matters even more for remote and isolated areas which have fewer possibilities to develop effective and long-lasting links with neighbouring industries. All other coefficients are virtually unchanged with respect to the FE model in Tables 1 and 2. R&D spending, neighbouring innovative efforts and socio-economic characteristics all significantly contribute to improve the patenting propensity of European regions.

Table 7

Hausman-Taylor estimation - Innovation and governance quality, 1997-2009

Dependent variable:	QoG index	Control of Corruption	Rule of Law	Govt Effectiv.	Govt Account.	Δ Patents application				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Literacy rate in 1880	0.237*** (0.0250)	0.198*** (0.0229)	0.274*** (0.0278)	0.240*** (0.0280)	0.161*** (0.0245)					
QoG index (error term 1st stage)						0.797*** (0.240)				
Contr. Corruption (error term 1st stage)							1.104*** (0.213)			
Rule of Law (error term 1st stage)								-0.126 (0.211)		
Govt Effectiveness (error term 1st stage)									0.522*** (0.148)	
Govt Accountability (error term 1st stage)										-0.133 (0.161)
Patents application (t-1)	0.00134 (0.00206)	0.0103*** (0.00229)	-0.00585** (0.00235)	0.00109 (0.00329)	-0.00348 (0.00302)	-0.450*** (0.0196)	-0.451*** (0.0195)	-0.451*** (0.0196)	-0.449*** (0.0196)	-0.452*** (0.0197)
Business R&D expenditure as percentage of GDP	-0.0146*** (0.00191)	-0.0069*** (0.00214)	-0.0203*** (0.00218)	-0.0138*** (0.00308)	-0.0210*** (0.00283)	0.149*** (0.0205)	0.149*** (0.0204)	0.148*** (0.0205)	0.149*** (0.0204)	0.148*** (0.0205)
Spatial weight of R&D expenditure	-0.0127*** (0.00438)	0.00352 (0.00489)	-0.0104** (0.00500)	-0.0254*** (0.00699)	-0.0282*** (0.00641)	0.274*** (0.0472)	0.274*** (0.0470)	0.272*** (0.0473)	0.274*** (0.0472)	0.274*** (0.0472)
Social Filter Index	-0.0186*** (0.00163)	-0.00416** (0.00183)	-0.0310*** (0.00187)	-0.0246*** (0.00264)	-0.0123*** (0.00242)	0.0858*** (0.0174)	0.0881*** (0.0174)	0.0841*** (0.0175)	0.0856*** (0.0174)	0.0869*** (0.0176)
Access to markets (90 mins distance flights)	0.0208** (0.00963)	0.0143 (0.00880)	0.0243** (0.0107)	0.0187* (0.0107)	0.0455*** (0.00937)	0.134*** (0.0317)	0.134*** (0.0316)	0.136*** (0.0317)	0.134*** (0.0316)	0.135*** (0.0318)
National patents' growth	0.0153** (0.00681)	0.00883 (0.00766)	0.0247*** (0.00778)	0.0159 (0.0111)	0.0238** (0.0102)	0.622*** (0.0729)	0.621*** (0.0727)	0.622*** (0.0731)	0.625*** (0.0729)	0.621*** (0.0731)
time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Observations	2,196	2,196	2,196	2,196	2,196	2,196	2,196	2,196	2,196	2,196
Nuts regions	186	186	186	186	186	186	186	186	186	186
Wald test on instrument	89.87	75.01	97.12	73.59	43.23					
($p>\chi^2$)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)					

Note: Robust standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms except for the QoG Index and the Social Filter Index. a/ the Social Filter is obtained as the first principal component of: employed people with tertiary education, long-term unemployment rate, employment in high tech industry, agricultural employment.

5. Conclusions and policy implications

This paper set out to examine the role of sub-national government institutions for the production of technical innovation in European regions, a topic which has attracted considerable interest but for which there is a dearth of evidence. Our analysis has unveiled a clear and positive impact of government quality on changes in regional innovation, proxied by the growth rate of patents' applications. After fully controlling for the traditional innovation inputs, such as R&D investments, cross-territorial R&D externalities, human capital endowment, and other socioeconomic conditions – as well as for national characteristics and region and time-specific fixed effects – quality of government has a considerable impact on local processes of knowledge production. High levels of corruption and low policy-making capacity emerge as the two main quality of government factors constraining the dynamics of knowledge generation and the effectiveness of innovation policies in the regions of Europe.

Our results also stress that government institutions do not influence all European innovation systems in the same way. Knowledge production structures in lagging regions are massively affected by quality of government. Relatively small improvements in government effectiveness or the control of corruption may yield substantial benefits for the creation of sound regional innovation systems and for new knowledge generation in the periphery of Europe. Conversely, improvements in local government quality have only a small effect on the patenting capacity of core regions. The analysis also provides strong evidence of the existence of a quality of government threshold effect for innovation. Below a certain level of quality of government, policies aimed at increasing R&D expenditure in peripheral regions of Europe are likely to work only if the local quality of government is improved. Similarly, R&D investments generate cross-border technological benefits only in areas with a sufficient level of economic development and absorptive capacity. Poor and inadequate governments limit the efficiency of knowledge spillovers. These results are robust to controlling for the endogeneity of institutions, indicating that it is the quality of government that influences the capacity of regions to generate knowledge, and not the other way round.

The results of the analysis have important policy implications, especially at a time when there is increasing concern in policy and scholarly circles about what are the most appropriate instruments to create a knowledge-based economy. First, the results indicate that there is no one-size-fits-all approach to innovation policy (Farole et al., 2009; Barca, 2009; Barca et al., 2012). Different regions across Europe require diverse types of knowledge generating-intervention. The innovation dynamics at the regional level in Europe depend on region-specific institutional conditions, which by definition are not easily transferable from one place to another. Second, it has become clear that the degree of technological and economic development of a region determines the types and returns of innovation strategies. The same innovation strategy may produce different effects depending on the quality of government of the region. Government institutions may either propel or hinder the formation of efficient regional innovation systems, making the need to consider local institutional conditions a must in order to maximise the returns of policies aimed at improving innovation. Third, limiting corruption and improving government transparency can be as effective in promoting innovation as spending additional resources in R&D or improving the socioeconomic environment. Institutional reforms aimed at making the diffusion of public information more transparent, at minimising rent-seeking and clientelism, or at fighting corruption are *de facto* innovation policies for regions in the periphery of Europe. Finally, improving government effectiveness in the design, implementation, and monitoring of policies is essential as a means to realise a region's innovation potential. Only when the adequate political conditions and instruments are in place, do other measures aimed at improving knowledge generation and assimilation increase their effectiveness as producers of new innovation.

As a whole, our research has come to address some of the problems related to the dearth of analyses of the institutional factors behind innovation. It has provided novel insights about the complex relationship between government quality and innovative capacity at the local level. But it also raises a number of new and virtually unexplored questions about which institutional mechanisms are needed in order to promote greater innovation in parts of Europe – and of the world – with considerable institutional weaknesses and how do they work in a variety of contexts. There is a need to conduct much greater research on what works and what does not work for innovation in peripheral areas and about which mechanisms can help maximise the returns of either direct intervention in innovation or of efforts aimed at promoting the collaboration between regional and national authorities and local stakeholders involved in the generation of new knowledge.

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Appendix

A1 Description of the variables

Variable	Definition
Innovation	
Patents application	Number of applications filled for patents of all types per million of inhabitants, 1997-2009.
Business R&D as % of GDP	Expenditures in Research and Development (R&D) from the business sector as percentage of regional GDP, 1997-2009. Linear interpolation techniques adopted to complete the dataset.
Social Filter	
Employed people with tertiary education	Percentage of employed people (aged 25-64) with completed higher education (ISCED-97 levels 5 and 6).
Long-term unemployment	Long-term unemployment in percent of total unemployment.
Agricultural Employment	Share of employment in NACE categories A (Agriculture, forestry and fishing) and B (Mining and quarrying).
Employment in high tech industry	Employment in high-tech manufacturing in percent of total employment.
Quality of Government	
QoG combined index	EU Quality of Government (QoG) Index elaborated by the University of Gothenburg, a survey-based index constructed around three main pillars: quality of education, public health care and law enforcement; impartiality in education, public health and legal protection; level of corruption in education, health care and the legal system. This index has been extended to the 1997-2009 period adopting the World Bank Governance Indicators developed by Kauffmann *et al.* (2009). See Charron et al. (2013) for a detailed explanation on how the index was constructed.
Control of Corruption	Section of the QoG combined index based on the calculated score from the answers of its inhabitants to the following questions: 'Corruption is prevalent in my area's local public school system.' (0-10); 'Corruption is prevalent in the public healthcare system in my area.' (0-10); 'In the past 12 months have you or anyone living in your household paid a bribe in any form to: health or medical services?' (y/n); 'In your opinion, how often do you think other citizens in your area use bribery to obtain public services?' (0-10)
Rule of Law	Section of the QoG combined index based on the calculated score from the answers of its inhabitants to the following questions: 'how would you rate the quality of the police force in your area?' (0-10); 'The police force gives special advantages to certain people in my area.' (0-10); 'All citizens are treated equally by the police force in my area' (1-4); 'Corruption is prevalent in the police force in my area' (0-10).
Government Effectiveness	Section of the QoG combined index based on the calculated score from the answers of its inhabitants to the following questions: 'how would you rate the quality of public education in your area?' (0-10); 'how would you rate the quality of the public healthcare system in your area?' (0-10); 'Certain people are given special advantages in the public education system in my area' (0-10); 'Certain people are given special advantages in the public healthcare system in my area.' (0-10); 'All citizens are treated equally in the public education system in my area.' (1-4); 'All citizens are treated equally in the public healthcare system in my area.' (1-4).
Government Accountability	Section of the QoG combined index based on the calculated score from the answers of its inhabitants to the following questions: 'In your opinion, if corruption by a public employee or politician were to occur in your area, how likely is it that such corruption would be exposed by the local mass media?' (0-10); 'Please respond to

	the following: Elections in my area are honest and clean from corruption.' (0-10).
Other variables	
National patents' growth	First-difference of the annual number of application filled for patents of all types per million of inhabitants at the national level (same values for all regions of the same country), 1997-2009.
Access to markets (90 mins distance flights)	Total number of flights within 90 minutes travel time from the region.
Literacy rate in 1880	Percentage of literate people in the region in 1880. Calculated using data from Tabellini (2010) for Western European regions and a map on the Austro-Hungarian Empire produced by Ignaz Hatsek in 1884 (see A4).

A2 Principal Component Analysis

Table A2.1 Eigenanalysis of the correlation matrix

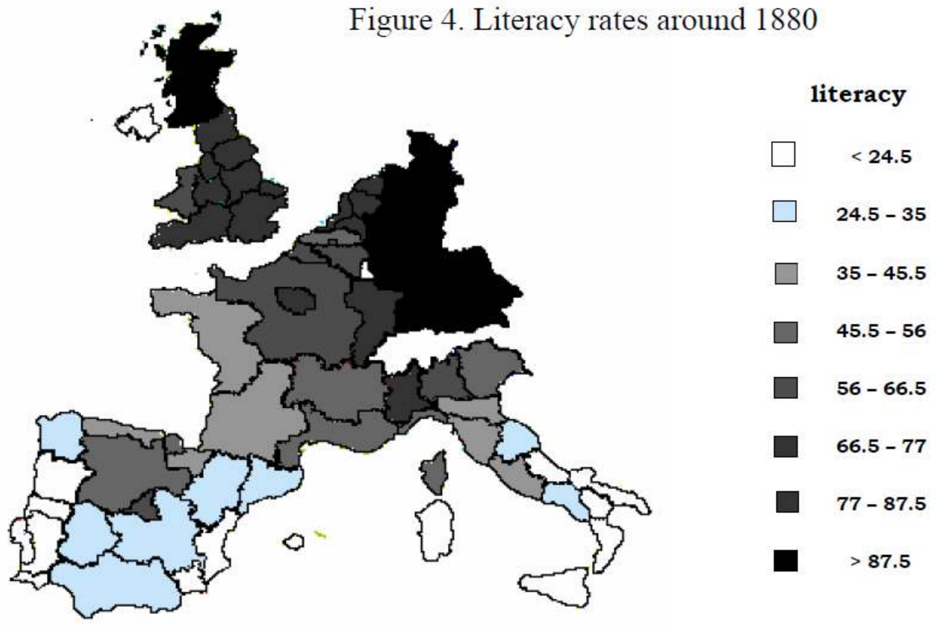
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.84293	.899792	0.4607	0.4607
Comp2	.943142	.103211	0.2358	0.6965
Comp3	.839932	.465941	0.2100	0.9065
Comp4	.373991	.	0.0935	1.0000

Table A2.2 Principal components' coefficients

Variable (in natural logs)	Comp1	Comp2
Employed people with tertiary education	-0.5449	-0.3250
Long-term unemployment	0.3656	0.5210
Agricultural employment	0.6423	-0.0886
High-tech manuf. employment	-0.3961	0.7843

A3 Sources of the variable ‘Literacy rate in 1880’

Figure A3.1 Literacy rate in 1880 in Western European regions



Source: Tabellini (2010)

Figure A3.2 Literacy rate in 1880 in the Austro-Hungarian Empire