Innovation across Europe: How important are institutional differences?

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Abstract

By changing the level of competition and/or affecting the allocation of resources, institutions can play a very important role on innovation activity. In this paper we investigate the relative importance of institutional variation across European countries in explaining differences in their innovation intensity at the industry level. We employ a novel indicator of innovation therefore circumventing the limitations of more traditional indicators. Our results are broadly consistent with previous empirical literature. They show that stringent product and labor market regulation affects innovation intensity negatively, and that more developed credit markets foster innovation. However, the empirical findings also raise doubts with respect to the strengthening of intellectual property rights as a means to stimulate innovation, a result that is in accordance with recent propositions in the literature.

JEL Classification: O31, O33, O38.

Keywords: Institutions, innovation, European Union, instrumental variables.

1. Introduction

There has been a recent growing interest on the importance of institutions as a means to explain various economic phenomena[1]. The role of institutions in determining technological change and cross-country differences in innovation activity has also become the focus of some recent literature.

Contributions from the innovation systems literature have repeatedly proposed that key technologies need supporting institutions that may be different over time. Accordingly, the countries that will succeed are those that already have in place the basis of these institutions when they are needed (Freeman, 1987; Dosi et al., 1988, Lundvall, 1992; Nelson, 1988). In these studies, institutions are mainly concrete entities related to the production or diffusion of innovation as universities, research institutes, prevailing patent law, public programs or technical societies (Nelson, 2008). More recently attention has focused on institutions related to political and educational aspects, product and labor markets regulation, and intellectual property rights (see the evidence in Menezes-Filho et al. (1998), Bassanini and Ernst (2002), Varsakelis (2006), Samaniego (2006), Griffith et al. (2006a), Kanwar (2007)).

Besides institutions, previous empirical evidence on the determinants of innovation intensity across countries has shown that differences in national innovation systems (e.g. public investment in R&D and education) as well as industry-specific characteristics largely explain differences in innovation across countries (Furman et al., 2002). Mathieu and Potterie (2008) explored this issue by investigating to what extent differences in innovation performance are more driven by structural factors, such as technological specialization, than by intrinsic national policies. Their results suggest that taking into account the technological specialization of countries drastically reduces the observed macroeconomic differences in relative R&D efforts.

Other works exploring the drivers of innovation activities corroborate the view that emphasizes the importance of industry-specific characteristics for the

[1] See, inter alia, Djankov et al. (2002) and Desai et al. (2003) on the impact of institutions on entrepreneurial activity and firm dynamics, Alesina et al. (2005) on investment, Griffith et al. (2007) on unemployment, and Matschke (2010) on trade.

development and diffusion of new technologies (e.g. Breschi et al., 2000; Fagerberg, 2002; Braguinsky et al., 2007; Dinlersoz and MacDonald, 2009, Samaniego, 2006)[2]. They found that much of the firm's innovative behavior depends on the response of firms to deeper industry parameters, such as the industries' technological opportunities, appropriation methods, the stages of the industry life-cycle, and the innovation itself.

In this paper we integrate these literatures, combining industry and country level perspectives, in order to understand cross-country differences in innovation at industry level and the role of institutional environment on innovation activities. In particular, we focus on three types of country-level market regulation, namely product, labor and financial markets regulation, as well as on the stringency of intellectual property rights and explore their relationship with industries' innovation intensity.

This study contributes to our understanding of the institutional context of technological change in the following ways. First, it provides new empirical evidence on the role institutions play on innovation by using a richer set of institutional indicators and an alternative indicator of innovation. Second, it focuses the analysis on European Union (EU) countries. Several recent studies have investigated the role of regulatory practices across EU countries, yet very few analyze their impact on innovation. The focus on EU countries is also motivated by the two landmarks of institutional reform in the EU, the Single Market Program and the Lisbon Strategy whose underlying belief is that more competition and less regulation should bolster innovation and thus productivity and growth.

Third, conversely to previous works, we address the issue of potential endogeneity in the relationship between institutions and innovation. As innovation leads to changes in both product and factor markets by changing its structure and shifting demand, we can expect that innovation may also determine institutions in particular those that are aimed to regulate those markets. By explicitly addressing

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[2] The literature on sectoral systems of innovation (Breschi et al., 2000) has shown that the sources and opportunities for progress are specific in individual industries. Consequently, innovation activity is characterized by different patterns that are driven by technological regimes, i.e., some essential features of the knowledge base and the prevailing learning conditions within an industry.

causality, our findings are a step ahead in assessing the relationship between institutions and innovation.

The remainder of the paper is organized as follows: Section 2 discusses the ways in which some institutions can affect innovation. Section 3 describes our data, the institutional context in the EU and presents the empirical model. Section 4 proposes the econometric approach and discusses the empirical results. Section 5 concludes our study.

2. Institutions and innovation

The term "institutions" has been used in the literature to represent different aspects of economic, legal, political, and social activity, making it difficult to arrive at a single definition. In the seminal contribution North (1990) defines institutions as the rules of the game in a society. This approach to institutions has been followed by other authors. Hwang and Powell (2005) view institutional change as the rule-making, or the creation of formal laws, that defines the playing field, enabling the efforts of certain groups and retarding the efforts of others. In turn, Nelson (2008) views institutions as a device to explain "prevalent methods of doing things in contexts where actions and interactions of several parties determine what is achieved" (p. 2).

In this paper we follow this perspective on institutions and focus our attention on administrative and economic practices and policies aimed at regulating the product, labor, and capital markets, as well the intellectual property systems. While these aspects of regulation do not completely cover all institutional dimensions, they include some of the most important structures and forces that shape and maintain the institutional environment affecting innovation activities.

Product market regulation and innovation

Existing theories of regulation present different predictions relating the impact of these costs on economic activity and who benefits from regulation. The public interest theory holds that regulation is needed to correct market failures and protect the public interest. On the other hand, the public choice theory sees regulation as a means by which large incumbent firms seek to maintain their rents (Stigler, 1971). As such, stronger regulation means less competition, and higher market power for incumbents, impeding the ability of new entrants to innovate.

Anti-trust policy is one of the dimensions of product market regulation commonly believed to exercise the most influence on innovation as it is aimed at reducing market power and market concentration. Although it has been widely recognized that the level of competition is one of the main determinants of innovation, economic theory presents conflicting perspectives. According to Schumpeter (1942) more competition reduces firms' incentives to innovate as the monopolistic rents resulting from innovation come to be eroded. Twenty years later, Arrow (1962) argued that firms in a more competitive market have greater incentives to innovate than those in a monopolistic one due to the profits replacement effect, i.e., the difference between post-innovation and pre-innovation profits.[3]

The possibility of an inverted-U relationship between competition and innovation was the first noted by Scherer (1967) and it has been explored more recently by some endogenous growth models (Aghion et al., 2005) and R&D race models (e.g. Boone, 2001; Dubey and Wu, 2002; Dinlersoz and MacDonald, 2009). These models predict that both effects are possible, i.e., that a non-monotone relation between intensity of competition and innovation is possible.

In particular, Aghion et al. (2005) argue that more competition may foster innovation in industries where incumbent firms are operating at similar technological levels. In this in case, R&D investments aim at "escaping competition". On the other hand, in industries where innovation is made by laggard firms with already low initial profits, an increase in competition may erode post-innovation profits, thus discouraging innovation. Other works (e.g. Boone, 2001; Dubey and Wu, 2002; Dinlersoz and MacDonald, 2009; D'Aspremont et al., 2010) suggest that the incentives to innovation will ultimately depend upon innovation- and industry-specific characteristics, namely technological level and technological regime of the industry.

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[3] Subsequent models of product differentiation and monopolistic competition (Salop, 1977; Dixit and Stiglitz, 1977) and some R&D or patent race models (e.g. Gilbert and Newbery, 1982) predict that more intense product market competition discourages innovation by reducing post entry rents, but some R&D or patent race models (e.g. Reiganum, 1983) provide opposite results.

Thus increasing competition as a means to stimulate innovation requires a detailed analysis of the industry at hand.

Besides the direct impact on competition, stricter anti-trust laws can also lead to a smaller average firm size (Kumar et al., 1999). In this case, it could be argued that stricter anti-trust laws could have a negative impact on innovation because firm size is usually positively correlated with innovation. Yet, evidence shows that this may not be always the case since small firms tend to outperform large firms when using innovation counts as an indicator for innovation (Kleinknecht et al., 2002).

Another important aspect of product market regulation is entry regulation, of which start-up costs are a relevant component. High start-up costs can act as a barrier to entry making it difficult for entrepreneurs to start a new business, thereby hindering the introduction of innovations. Antunes and Cavalcanti (2007) argue that high start-up costs may also increase the size of the shadow economy, thus they would impact negatively on innovation as firms in the shadow economy have greater difficulty in securing credit and attracting highly skilled labor and investments in innovation.

Although several studies analyze the impact of product market regulation on productivity, only two studies (Griffith et al., 2006a; Amable et al., 2010) provide empirical evidence of the impact of product market regulation on innovation. The work by Griffith et al. (2006a) suggests that the reforms carried out under the EU Single Market Program (SMP) reduced the average level of profitability, and that this had a positive impact on innovative activity which in turn affected total factor productivity growth. Yet, they also reported a negative impact of deregulation on R&D and productivity in the high-tech public procurement market industries. On the other hand Amable et al. (2010) present evidence contradicting the belief in the innovation-boosting effect of product market deregulation, even in industries close to the frontier as predicted by Aghion et al. (2005).

Labor market regulation and innovation

Labor market regulation can assume various forms such as legislation regulating hiring and firing practices, wages, and unemployment insurance. Among labor market regulatory practices, employment protection legislation (EPL) has been identified as most influencing innovation. However opposite theoretical effects can be anticipated from employment rigidity and empirical evidence has thus far been inconclusive.

On the one hand, the rigid regulation of hiring and firing may increase the bargaining power of unions, making it more difficult for the firm to invest in R&D and to adjust wages after an innovation has occurred. The argument is based on the view that the union wage mark-up is financed from appropriating the quasi-rents earned on capital. This acts as a tax which will raise the sunk costs of investment and therefore reduce the amounts that firms are willing to invest. This is particularly a problem for intangible investments such as R&D because it is highly risky, has long gestation lags and is largely irreversible (Menezes-Filho et al, 1998). Unions and stringent dismissal laws can also make it more difficult for firms to adapt to new technologies that require the reallocation of staff or downsizing.

More stringent labor market regulation can also hinder innovation if wages are sufficiently high as they create incentives to develop and adopt labor saving capital intensive technologies at the low end of the skill distribution (Alesina and Zeira, 2006). Samaniego (2006, 2008) proposes that firing costs are particularly detrimental to profits in industries in which the rate of technical change is rapid, such as ICT, and countries with high firing costs specialize in industries in which technical change is sluggish. Gust and Marquez's (2004) results support the view that burdensome regulatory environments and, in particular, regulations affecting labor market practices have impeded the adoption of information technologies in a number of industrial countries.

On the other hand, others (Acharya et al., 2010) have argued that unions and/or stringent dismissal laws may encourage greater training, and incentive employers to invest in training and thereby increase employees' productivity and motivation to engage in more successful, and more significant, innovative pursuits. Acemoglu (1997) argues that stronger EPL decreases the need to maximize current wages, as an employee can look forward to job security and future higher wages.

Menezes-Filho et al. (1998) found that union density has at first a positive effect on a firm's relative R&D performance. The effects of union power were only negative when the union density was very high and/or the union bargained only over wages. Koeniger (2005) and Acharya et al. (2010) found that stronger dismissal laws lead to more investment in R&D and more innovation at industry level. Furthermore Acharya et al. (2010) found that stronger dismissal laws lead to relatively more innovation in the innovation-intensive industries than in the traditional industries.

In turn, Bassinini and Ernst (2002) found that the impact of employment protection policies on innovation depends on the state of industrial relations (e.g. bargaining arrangements, business associations, business codes of conduct, etc.) and on the industry's level of technology. Overall, their results suggest that strict employment protection policies are likely to negatively affect R&D intensity, especially in the high-tech industries of countries where industrial relation systems are relatively decentralized. These differences may reflect the way in which the innovation process across industries and the state of industrial relations affect firms' efforts to satisfy the need for skilled labor to cope with innovation.

Recently Griffith and Macartney (2010) found that multinational enterprises locate more innovative activity in countries with high EPL. However they locate more technologically advanced innovation in countries with low EPL. They interpret their results as corroborating evidence for both opposite effects as advanced in the theoretical literature.

Capital market regulation and innovation

Financial development may affect innovation activity either directly or through indirect mechanisms. To begin with, and starting by the latter, financial development may affect the innovation intensity in a given industry through two main mechanisms: the firm size distribution and the industry's dynamics and competition level. Various studies have found that financial development fosters entry of firms in the industry and leads to a more competitive environment (see, e.g., evidence in Rajan and Zingales (1998), Kumar et al., 1999; Guiso et al. (2004), and Macchiavello (in press)). We will come back to this topic further below since this result is particularly relevant in the case of technology-based start-ups.

Financial constraints have also been found as one of the major reasons that prevent new firms from attaining their optimal initial size (Cabral and Mata, 2003). As such, credit availability is an important determinant of firm growth and survival (e.g. Guiso et al., 2004; Clementi and Hopenhayn, 2006). We can expect that firms that have attained their optimal size are in better position to engage in innovation investment. This idea is corroborated by Davis and Henrekson (1997) who argue that regulations restricting capital access favor larger, established firms over smaller entrants.

Also financial development may reduce vertical integration of larger firms and lead smaller, non-integrated, firms to exit the industry (Macchiavello, in press). As a result, higher financial development reduces vertical integration in industries where a high share of output is produced by small firms. The positive effect of financial development on entry also reduces vertical integration by fostering the development of input markets. This evidence is consistent with the development of technology markets and the appearance of new technology-based firms that produce intermediate inputs for large established firms.

One important channel through which financial development may influence innovation intensity directly is by the financing of technology-based start-ups or high-tech investment. This is so because the returns from high-tech investment are highly uncertain and because information asymmetries are also likely to exist between firms and potential investors. Moreover high-tech investments often have very little collateral value because most R&D investment is devoted primarily to salary payments, which have little salvage value in the event of failure (Carpenter and Petersen, 2002).

Recent increasing empirical findings show a positive impact of credit availability on both the creation of technology-based firms and on firms' innovation effort (e.g. Bottazzi and Da Rin, 2002; Cassar, 2004; Audrestch and Elston, 2006). However, some studies did not find similar effect on the growth of these start-ups (e.g. Cressy, 1996; Bottazzi and Da Rin, 2002).

Overall empirical findings on the impact of financial credit on innovation suggest a positive and significant effect. In particular, evidence shows that venture capital favors the entry of new firms and/or small firms, particularly technology based start-ups. So, we can expect that financial development will have a positive and larger effect in industries with high innovation intensity where small firms can enter and compete (e.g. software, biotechnology).

On the other hand, some credit regulations may be more favorable to incumbent firms, enabling them to grow, and, possibly, increase concentration. In this case, the expected impact of financial credit on innovation intensity at industry level will depend whether innovation is mostly done by incumbents or new firms.

Intellectual property rights and innovation

It is widely recognized that the incentives to work, produce, invest or innovate depend crucially on the quality of institutions in general, and the degree of protection of property rights in particular. The underlying idea is that the less secure are the property rights, the weaker these incentives, which would impact negatively on economic outcomes (Angelopoulos et al., 2010).

Intellectual property rights (henceforth, IPRs), and patents in particular, have two aims to provide incentives to research and to disclose information, but at the social costs of reducing the invention's use during the patent life. The main argument in favor of patents is that they encourage *ex ante* innovation by creating *ex post* monopoly rents (e.g. Romer, 1990; Aghion and Howitt, 1992; Economides et al., 2007; Eicher and Garci-Peñalosa, 2008).

IPRs may also induce innovation through other mechanisms.[4] First, secure property rights facilitate international technology transfer and diffusion through foreign direct investment and trade (Helpman, 1993; Coe et al., 2008) [5]. Second, IPRs contribute to the functioning of technology markets (Arora et al., 2001). Third, IPRs may facilitate start-ups in some circumstances by giving an inventor the time to get established in the industry. Fourth, IPRs may also facilitate capital investment, since venture capitalists often look at IPRs portfolios in deciding whether to invest in a new company (Lemley, 2009).

The view that strong IPRs, and patents in particular, are necessary to stimulate innovation has been challenged by the literature on the optimal design of patents that is rooted in the idea of cumulative or sequential innovation, whereby new innovations produce the ideas for future innovations (Horwitz and Lai, 1996; Hopenhayn et al., 2006). In contrast, these studies predict that the relationship between patents and innovation may be nonmonotonic, depending on the relative effects of innovators being both leaders and followers and on the ease with which they can transfer their technologies (Gallini, 1992).

Empirical evidence seems to support the view of new theoretical models and raises doubts with respect to the efficacy of patents to stimulate innovation. Hall (2007) reviews recent studies and observes two empirical regularities. First, the strengthening

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[4] See Besley and Batak (2010) for a detailed discussion of some of these mechanisms.

[5] IPRs may also affect international technology diffusion between developed and developing countries. Since our focus is on the EU countries we do not review this literature here.

of a patent system[6] unambiguously results in an increase in patenting and also in the use of patents as a tool in most firms' business strategies. Second, an increase in innovation due to patents is likely to be concentrated in specific industries, namely pharmaceutical, biotechnology, medical instrument industries, and possibly specialty chemicals (see, e.g, Hall (2007), Qian (2007), Arora et al. (2008)).

Also Boldrin and Levine (2008) argue and provide extensive data and facts in order to build a case against IPRs and to what they call an "intellectual monopoly". Their point is that the monopoly effect brings more harm than benefit to the collective well-being and that the strengthening of the intellectual property system does not bring more innovation.

Indeed, these results just confirm those obtained by Levin et al. (1987) and Cohen et al. (2000) that patents are highly industry-specific and they are not the firm's preferred method of protection against imitation (trade secrets and first-mover advantages rank first in firms' preferences). Patents efficacy as a protection method depends on the type of knowledge (tacit or codified) and the innovation type (product or process). This will partly determine appropriability, i.e., the ability of the creator to capture rents sufficient to pay back the fixed cost investment of creation.

An important conclusion from these studies is that IPRs work differently in different industries. Whereas innovators in the information and technology industries tend to use patents defensively, to protect themselves against suit, rather than relying on exclusivity and affirmative enforcement of IP rights. By contrast, the pharmaceutical, biotechnology, and medical devices industries depend critically on the enforcement of patents to obtain at least partial market exclusivity (see, e.g., Boldrin and Levine, 2008; Lemley, 2009).

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[6] That is, lengthening the patent term, broadening subject matter coverage or available scope, and improving enforcement.

3. Data, empirical model and variables

Data

Our data is derived from different sources. Our main data source is the Fourth Community Innovation Survey (CIS4) which covers the years from 2002 to 2004 and includes most EU countries. The Community Innovation Survey takes place every 4 years in European countries and it aims at collecting information on firms' innovation activities. The fourth CIS wave took place in 2005 and it follows the recommendations of the OSLO Manual on conducting innovation surveys (see OECD and EUROSTAT, 1997). Each country implements the survey under the auspices of EUROSTAT.

There are at least three key advantages in using data from the CIS surveys. First, they provide different measures of innovation from those previously used in the literature. Second, the data are internationally comparable given that the definitions of variables and the methodology employed in collecting the data are consistent across countries. Third, much of CIS surveys' innovative indicators are based on subjective perceptions of respondents, which means that they are less affected by measurement errors (Mairesse and Mohnen, 2010).

Our sample is restricted to manufacturing industry and, on account of data availability, includes the following countries: Belgium, Denmark, Germany, Greece, France, Italy, Portugal, The Netherlands, Spain, and Sweden. Since our main interest is analyzing the relationship between institutional context and innovation intensity at industry level, from the CIS4 we collected data on employment, R&D expenses, and the number of firms that *actually* introduced innovations, either product or process innovation, in 2004 and for 2-digit level NACE classification of industries. Detailed information on the survey questions used in the analysis can be found in the Appendix.

This data was then combined with data on countries' institutional environment, which were collected from various sources, namely the Doing Business Database from the World Bank, the OECD Indicators of Product Market Regulation Database and the Park (2008) indicator for IPRs.

Both the World Bank and the OECD have produced several indicators designed to measure the institutional and regulatory environments of countries that in some cases are equivalent. The choice of each indicator was determined by both its content and data availability, thus whenever possible we selected indicators which did not overlap in terms of content. In particular, we employed synthetic indicators of regulatory stringency in the product and labor markets, of patent rights protection strength, and an indicator of the level of development of capital markets.

We supplemented our data with patent and R&D data from EUROSTAT and gross domestic production (GDP) and population data from OECD Statistics.

Empirical model and variables

In order to investigate the effect of country-level variation in institutions on innovation intensity in Europe we rely on a cross-section of twenty-two 2-digit manufacturing industries in ten countries of the EU. In this way we control for industrial heterogeneity in a context where technologies are relatively homogenous while there is still variation among institutional regimes at the country level. Our reduced form model of industry innovation intensity is thus specified by:

$$Innov_{ij} = g\left(\mathbf{INST}_j \beta + \boldsymbol{\mu}_{ij} \alpha + \boldsymbol{\eta}_j \gamma\right) + e_{ij} \qquad (1)$$

where $Innov_{ij}$ is the proportion of innovating firms in industry i of country j, $\mathbf{INST}_j$ is a vector of indicators of country-level institutions that vary across countries, $\boldsymbol{\mu}_{ij}$ is a vector of industry-specific variables that vary across industries and countries, $\boldsymbol{\eta}_j$ is a vector of country-specific characteristics and e_{ij} is a disturbance term capturing unobservable variables affecting innovation activities. β, α, and γ are the conformable vectors of unknown parameters. The parameters of interest are the β coefficients on the institutional indicators.

Dependent variable. We measure innovation intensity as the share of firms that reported having actually introduced an innovation in the market, over the last three previous years, in the total number of firms in a given industry. We focus on innovation *intensity* at the industry level. As such, we do not make a distinction between innovation and imitation. In fact, imitation is an economic activity much the same as innovation, since it requires resources and it responds to economic incentives (Helpman, 1993).

Our measure of innovation is based on innovative output. It has the limitation of treating a firm as non-innovative in the case it answered negatively the question about the introduction of an innovation in the market, even though it had pursued R&D.

That is, the dependent variable is the ratio of firms introduced an innovation in the market over the total number of firms in the industry, independently of pursuing R&D activity. Thus, we focus on firm's innovative output rather than its R&D effort.

Similarly, more traditional indicators of innovation activity, such as R&D expenses or patents, have also well-known limitations. R&D measures only an input in the innovation process, although it is a major one, and only captures formal R&D activities. Thus, they may not capture small firms' innovation activity where innovation often occurs without the performance of formal R&D, therefore incurring the risk of underestimating their innovation effort. In fact, it has been documented that in some European countries small firms' non-formal R&D activities account for an important share in the total of innovative activities (Griffith et al. 2006b; Hall et al., 2008).

Likewise patents only cover innovations that are sufficiently new and deemed worth to be patented by the patent applicant, and that may never be introduced on the market. Furthermore, small firms may also find it especially difficult to commercialize their intellectual property, either because they are unaware of the IPR system or because of the disproportionately high costs for such firms (Siegel and Wright, 2007). Finally, patenting propensity is highly specific to the industry (Hall, 2007; Mairesse and Mohen, 2010).

Institutional variables. Institutions may shape the dynamics of innovation through various channels. One way in which the quality of prevailing economic, political and legal institutions leads to higher rates of innovation is by promoting entrepreneurial effort into productive activities and competition.

As indicator of product market regulation we include *PMR,* a summary index of economic and administrative regulation that captures aspects of inward and outward-oriented economic regulation and administrative barriers to start-ups, features of the licensing and permit system, and the communication and simplification of rules and procedures. This indicator summarizes a large set of formal rules and regulations that have the potential to reduce intensity of competition on a scale from 0 to 6 (from least to most restrictive).

Labor market regulation is measured by the indicator *Employment*, an employment rigidity index that represents the difficulty which firms encounter in adapting to the labor force. This index deals with three broad areas of labor regulation - employment laws, collective relations laws, and social security laws. The index measures the strength of protective measures against alternative employment contracts, the cost of increasing working hours, the economic cost of dismissing workers, and restrictions on employers for dismissing workers, either individually or collectively. Higher values correspond to greater legal protection of workers.

With respect to the efficiency of the legal and judicial system in resolving legal disputes there are indicators that measure the extent to which agents trust in the rule of law and, in particular, the quality of contract enforcement, the protection of property rights, the police, and the courts. They are, nonetheless, generic indicators for legal protection. A more specific indicator of legal protection of innovation is the index of patent protection proposed by Ginarte and Park (1997) and updated by Park (2008), which measures the strength of patent laws and patent rights protection. We use this indicator to proxy the institutional context related with intellectual property rights – *IPRs*.

Our indicator of capital markets' regulation is *Credit*, which is an index of the development of capital markets. The credit index includes rules affecting the scope, accessibility, and quality of credit information available through either public or private credit registries. The index ranges from 0 to 6, with higher values indicating the greater availability of credit (from either a public registry or a private bureau) to facilitate lending decisions.

Control Variables. We also include control variables in the regression. At the country-level, the variable *GDP* measures gross domestic product per capita. We expect a positive impact of this variable on innovation by providing firms with a larger market and better infrastructure. At the industry-level, we include *Size*, measured by the industry (log) total turnover in 2002. Industry-specific capabilities in terms of innovation may also depend on the level of investment in R&D and the intensity of patenting. The variable *R&D* in the industry i of country j is the total expenditure in R&D, while the variable *Patent* in the industry i of country j is the ratio of number of patents in industry i to total number of patens in the manufacturing industry of country j. Finally, we include industry dummies in order to control for differences in technological regimes. We use Pavitt's (1984) taxonomy[7] to classify industries. According to this taxonomy, four types of industries are identified: scale-intensive, science-based, specialized suppliers and supplier dominated. The main limitation of this taxonomy, as with any other taxonomy, is the fact that these boundaries are not always straightforward. Nevertheless, it still is a valuable yardstick in helping us to describe the differences in technological regimes across industries.

Table 1 lists the definition of each variable used in the empirical analysis, the exact source and time period, and the expected impact on innovation intensity at industry level according to the prior discussion in Section 2.

Insert Table 1 here

Some descriptive statistics of the dependent variable, institutional variables and control variables are reported in Table 2. Part I of the table reports some summary statistics, whereas Part II reports correlation coefficients among selected variables. Overall, European industries are quite intensive in innovation, as measured by the proportion of innovative firms, having a mean of 51% innovating firms. The data also show that differences in innovation intensity are quite significant with the proportion of innovating firms varying between 0.18 and 1. Another interesting feature is that European countries exhibit greater variation in their R&D expenditures than in their GDP per capita.

Insert Table 2 here

The data also shows that, although over the last two decades there has been some convergence in the EU's regulatory environment as a result of the Single Market Program and the Lisbon Agenda, there still is some variation with respect to institutions across EU countries. In particular, EU countries seem to differ most in the credit regulation, followed by the intellectual property regulation and then the product market regulation. This evidence is in line with Nicolleti and Scarpeta (2003), who provide evidence that large differences in regulatory patterns within Europe still subsist.

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[7] This taxonomy classified firms, according to their principal activity, based on the sources of technology, the nature of users' needs, and means of appropriation, which then allows for a industry-level classification.

The correlation coefficients show that GDP per capita has a negative correlation with heavier regulatory environments, namely in the product market (*PMR*) and labor markets (*Employment*), and has a positive correlation with patent protection strength (*IPRs*) and capital market development (*Credit*) indicators. Also, this correlation is stronger in former than in the latter. More interestingly, the correlation coefficients among institutional variables are sufficiently low to not raise concerns about potential multicolinearity problems.

4. Econometric model and results

Econometric model

The nature of the dependent variable, the proportion of innovating firms in industry *i* of country *j*, suggests the use of the econometric method proposed by Papke and Wooldridge (1996). Their main assumption applied to (1) will be that, for all *i* and *j*

$$E\left(Innov_{ij} \mid \mathbf{INST}_j, \boldsymbol{\mu}_{ij}, \boldsymbol{\eta}_j\right) = G\left(\mathbf{INST}_j\beta + \boldsymbol{\mu}_{ij}\alpha + \boldsymbol{\eta}_j\gamma\right) \quad (2)$$

where G(.) is a known cumulative distribution satisfying $0<G(z)<1$ for all $z \in R$. This ensures that the predicted values of the proportion of innovating firms in industry *i* of country *j* lay in the interval (0,1). The two most common choices for G(.) are the logistic distribution and the standard normal cumulative function.

Based on Gourieroux *et al.* (1984) and McCullagh and Nelder (1989), Papke and Wooldridge (1996) propose to estimate the unknown parameters by a quasi-likelihood method, which only requires the validity of the mean function, see equation (2), and the choice of a cumulative distribution that is a member of the linear exponential family, irrespective of whether it is or not the true distribution. If these two conditions hold, then the quasi-maximum likelihood estimator (QMLE) of β, α, and γ provide consistent estimates of the unknown parameters, given that the QMLE provides robust estimators of the conditional mean parameters with satisfactory efficiency properties (Papke and Wooldridge, 1996).

However, the dependent variable, $Innov_{ij}$, can be considered a special case as it is a proportion of a count variable – the number of innovating firms - in a group of a known size – the total number of observed firms. The Papke-Wooldrigde method does not take directly into account the information on group size. Although they have argued that, under the imposed assumptions, "the method … need not be less efficient than methods that used information on group size" (p. 621), we can use an alternative estimator that takes into account the nature of the dependent variable and allows us to control for group size.

One alternative would be to apply the QMLE Poisson estimator, using group size as the exposure control. Similarly to the Papke-Wooldridge estimator, the QMLE Poisson estimator only requires the validity of the conditional mean function to provide robust estimates of parameters with satisfactory efficiency properties. The advantage of this alternative approach is that it incorporates information on group size, which allows us to discriminate between equal values of the proportion of innovating firms. It maintains the computational simplicity of the Papke-Wooldridge method and their estimates can be interpreted in a similar fashion.

However, the Poisson estimator is mostly used to model rare events, in which the response variable is often small integers including zero. In cases where the response variable attains large means, as it is the case of the number of innovating firms, the Poisson distribution may fail to correctly predict large counts. In this case, it may well be approximated by the normal distribution, which implies that the conditional mean of the number of innovating firms could be estimated through a linear function of regressors.

A similar approximation is suitable for dependent variables that are a proportion. However, when the dependent variable comes from binary data summarized as proportions, the specification of G(.) –see equation (2) - as a normal distribution violates the homogeneity of the variance assumption across industries required for the validity of statistical tests. One way to cope with this violation is to transform the dependent variable. For an analysis of binary data summarized as proportions, the arcsine-root transformation is used commonly based on a variance-stabilizing argument for binary data. Therefore, the conditional mean can be estimated by weighted least squares (WLS) applied to the transformed variable, using group size - the total number of observed firms - as a weight in order to make proportions closer to normal distribution with equal variance.

In the next section these alternative econometric approaches are considered to ascertain the estimates' sensibility and to perform an empirically-oriented model selection.

Results

To begin the empirical analysis, we carry out a sensitivity analysis in order to evaluate whether the magnitude and sign of estimates significantly change across alternative econometric approaches. We compare estimates among the four alternative econometric models discussed above: (i) a model of the ratio of innovating firms as a linear function of regressors; (ii) a model of the arcsine transformation of the ratio of innovating firms as a linear function of regressors, weighted by group size; (iii) a QMLE Poisson estimator applied to the number of innovating firms, using group size as the exposure control; and (iv) a QMLE Fractional Logit applied to the ratio of innovating firms. Table 3 shows the estimates for those alternative econometric approaches along with specification tests and goodness-of-fit in order to choose the best alternative.

Insert Table 3 here

The model estimated by OLS (see estimates in the first column of Table 3) can be considered a benchmark model, in which the standard normal cumulative function is assumed for G(.) in equation 2. Interestingly, it passes the robust RESET test[8], leading to the no rejection of the null hypothesis under which the mean of the ratio of innovating firms is a linear function of the regressors. This may well be explained by the descriptive statistics of the dependent variable, which resemble quite well a normal distribution in terms of skewness and kurtosis. The OLS procedure, however, does not guarantee that the predicted values will be in the unit interval. Moreover, given the fact that the dependent variable comes from binary data summarized as proportions, it violates the homogeneity of the variance assumption across industries required for the validity of statistical tests.

The robust RESET test applied to the other econometric specifications also indicates no misspecification problem in none of them. This suggest that the choice for G(.) – see equation 2 – is quite flexible given the statistical characteristics of the dependent variable. Moreover, as in Table 3 all choice of G(.) are members of the linear

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[8] The robust RESET test is based on the regression of the OLS residuals on the defined set of regressors and polynomials of the OLS fitted values. The test statistics is $NR^2 \sim\chi^2(p)$, where p is the number of polynomials of the OLS fitted values.

exponential family, the coefficients estimates are consistent, irrespective of whether it is or not the true distribution, provided that the correct specification of the conditional mean.

Looking at coefficient estimates[9], all the alternative approaches yield qualitatively similar results. In particular, the effects of institutional variables on the ratio of innovative firms are roughly unchanged in terms of size, sign, and statistical significance. It appears that they provide an accurate representation of the effects of institutional environment on the ratio of innovative firms throughout the entire distribution of each institutional variable.

Based on the gathered evidence, all alternative approaches could be considered valid econometric strategies in estimating the effects of institutional environment on the conditional mean of the fractional response. Despite of that they exhibit unequal goodness-of-fit based on the predicted mean of the fractional response and on the R^2 statistic.

The Poisson specification largely fails to correctly predict the mean of the dependent variable. The long right tail of the number of innovating firms appears to affect negatively the Poisson goodness-of-fit. In fact, the underestimate of the mean of the ratio of innovative firms suggests that the Poisson specification fails to correctly predict large counts and, hence, the fractional variable. Conversely, the QMLE Fractional Logit model and the WLS-Arcsine model seem to perform better than the QMLE Poisson.

It is interestingly to note that the OLS and QMLE Fractional Logit specification are similar in terms of goodness-of-fit, reinforcing the finding that statistical proprieties of the dependent variable allow a quite flexible choice of the cumulative distribution. However, using the R^2 - a measure of the predictive power of the models - the econometric approaches that take into account information on group size (the QMLE Poisson and the WLS-Arcsine) show better performance than the other approaches.

[9] The coefficient estimates from the nonlinear QMLE Poisson and QMLE Fractional Logit models are not directly compared with the OLS and WLS-Arcsine estimates, as the first are nonlinear functions of the coefficient estimates and the levels of regressors. The comparison needs to be done with the marginal effects estimates, which measures changes in the ratio of innovative firms associated with changes in the regressors.

Based on these results and in order to benefit from a number of state-of-the-art techniques for the estimation and testing of regression models with endogenous variables, we choose the WLS-Arcsine econometric specification to go on with empirical analysis.

In all regressions the institutional indicators are lagged one year to reflect the premise that institutions are predetermined. Given the cross-sectional nature of the model and, hence, of the estimates we can argue that institutions are, at least, partially predetermined as they tend to be much more erratically and slowly changing than firms' innovative behavior (Nelson, 2008). At the firm level, innovation is driven by individual preferences and the endowment of resources, which may change with each period that firms operate in the market. On the other hand, the dynamics of institutional change are strongly dependent on the assessment of existing institutions, which is a difficult task because of the uncertainty concerning their effectiveness. Therefore, in terms of institutional choices, "mistakes can be made, and can last a long time" (Nelson, 2008: p. 10).

However, the validity of such premise needs to be empirically evaluated. In fact, there may be underlying variables driving innovative activity in an industry/country and, simultaneously, determining the institutional environment in that country. If so, the relationship between innovation and institutional environment may be the result of these omitted variables and it would be not possible to identify a causal relationship.

Moreover, the institutional environment itself (and regulation in particular) may respond to industry specific technological opportunities, generating an endogeneity problem for institutional variables in models that do not control for such shocks. For example, Alesina et al. (2005) have addressed this in the context of technological change associated with cellular phones and wireless technology, showing that a new market structure in the telecommunications industry may have given impetus to deregulation. We tackle this problem by using instrumental variables (IV) techniques in order to test for the presence of endogenous variables, to evaluate the validity and strength of instruments and to estimate a causal relationship between institutional environment and innovation.

The instruments need to be correlated with the institutional variables but uncorrelated with firms' innovation behavior at industry/country level. Our instruments for institutions' quality reflect differences in historical circumstances with respect to the legal environment and human capital, as well as differences in political institutions and regulatory framework. In particular, we use countries' legal origins, literacy level, degree of judicial review, and intensity of transposition of European directives as instruments (see Table 4 for exact definition of instruments and source).

Insert Table 4 here

Following La Porta's et al. (1998, 1999), several papers have shown that current regulatory environments correlate with each country's legal tradition (see La Porta et al. (2008) for a literature review). For example, the laws of common law countries (originating in English law) tend to be more protective of outside investors than the laws of civil law countries (originating in Roman law), especially French civil law countries. Countries' legal origins have been used as an instrument for contemporary institutional quality because since it occurred centuries ago is unlikely to be correlated with nowadays firms' and individuals' behavior, and in our case with firms' innovative behavior. Other historical variables that have been proposed as instruments for institutional quality today relate political institutions and human capital (Rodrik et al. 2002; Acemoglu et al., 2002).

The validity of political institutions as measures, however, has been criticized by Glaeser et al. (2004): these measures represent outcomes that are neither permanent nor durable characteristics of the political environment and political constraints on the executive. As such, we use the measures proposed by Glaeser et al. (2004) for political constraint, namely the rigidity of constitution and the degree of judicial review.

On the other hand, Glaeser et al. (2004) found evidence that initial levels of human capital continue to be strong predictors of institutions' quality. Thus, we use the literacy level in 1880 as an instrument for institutions' quality. Finally, we use the intensity of transposition of European directives as an instrument for product market regulation, an approach that was also used by Griffith et al. (2007).

Table 5 display some test statistics that allows us to discuss empirically the validity of the premise of predetermined institutions. In particular, we use these tests as pretests in order to choose between estimates. If the tests reject exogeneity of institutional variables, and hence do not validate the premise of predetermined institutions, then inference about the parameter of interest will be based on estimates obtained from an estimator that is consistent under endogeneity. Otherwise, estimates can be computed from an estimator that is consistent under exogeneity.

Insert Table 5 here

Inspection of the results displayed in Table 5 suggests that the premise of predetermined institutions is not valid for all variables that proxy institutions. When all institutional variables are jointly tested for exogeneity, the results suggest the presence of endogeneity. Moreover, the other diagnostic tests reject the null hypothesis of weak instruments, suggesting that the instruments are adequate to identify the first-stage equation.

Looking at each institutional variable, the diagnostic tests suggest that the presence of endogeneity is only empirically confirmed to the *IPRs* variable. In this case, the Hansen J statistic suggests that we cannot reject the over-identifying restrictions that the instruments can be excluded from the regression and, hence, it provides evidence on the validity of the instruments. Moreover, the other tests reinforce the evidence of strong instruments. Overall, the diagnostic tests suggest that the instruments we use affect the *IPRs* variable in a sensible way and confirm their power to circumvent the endogeneity problem.

This finding is consistent with previous empirical evidence. In fact, the view that *IPRs* evolve over time and are driven by economic and political forces has been previously documented (North, 1990; Acemoglu, 2003; Kanwar, 2007; Eicher and Penalosa, 2008).

Nonetheless, the failure to reject exogeneity should not be strictly interpreted as that the variable in question is exogenous. The test is important in its own right as may provides empirical confirmation for a-priori concerns about potential endogeneity. Given the theoretical concerns about endogeneity, we implement an estimation procedure that accounts for this and the diagnostic tests provide ex-post empirical evidence of these concerns not having been justified for three of the institutional variables. Accordingly, the model was re-estimated with the *IPRs* variable being instrumented with the selected instruments. Table 6 display coefficients estimates along with standard errors.

Insert Table 6 here

Comparing the WLS and IV estimates, we can see that the IV estimates of interest are larger than the non-IV (WLS) estimates, suggesting that if there are unobserved variables driving innovative activity in an industry/country, they cause the non-IV estimates to understate the true effect of *IPRs* in innovation intensity. It is interesting to note, however, that all IV estimates maintain the sign of non-IV estimates, indicating that the direction of institutional environment effects is not affected by an endogeneity problem.

From Table 6 we can see that those institutions that have the largest effect on the intensity of innovative firms are intellectual property protection, *IPRs*, and labor market regulation, *Employment*, followed by product market regulation, *PMR*, and credit market development, *Credit*.

The size and significance of the coefficient estimate of the variable *IPRs* illustrate the importance of property rights protection as an element of the institutional structure of an economy and in shaping innovation intensity (e.g. North, 1990; Acemoglu, 2003). Interestingly, whereas the negative sign of the associated coefficient is at odds with some previous evidence (e.g. Kanwar, 2007) it provides evidence supporting the arguments against the use of patents (e.g. Horwitz and Lai, 1996; Boldrin and Levine, 2008; Hopenhayn et al., 2006).

As such, this result seems to suggest the underlying following effects. First, patents are acting as barrier to the flow of knowledge and creation of new ideas across firms and industries. Second, the level of strength in the protection of property rights has attained the desired threshold beyond which increases in the strength of protection of *IPRs* does not lead to increases in innovation (Ginarte and Park, 1997; Qian, 2007; Eicher and Penalosa, 2008). Third, patenting costs are too costly. These costs relate the costs of obtaining the patent as well as enforcement costs (e.g. litigation expenses, monitoring for possible infringement, and the costs of establishing new case law to ensure legal protection for new innovations), which can be substantial (see Lanjouw and Schankerman, 2003) and particularly detrimental to small firms (Siegel and Wright, 2007).

The interdependence between innovation and *IPRs* that is shown in the data can be the result of private decisions. Eicher and Penalosa (2008) show that a lower degree of protection reduces the returns from research and hence the incentives to do R&D; similarly, a low level of R&D will reduce the return to investment in IPR protection. Though this argument predicts a positive relationship between investments in R&D and strengthening of IPR, it also indicates that the private cost of strengthening IPR protection is an important determinant of the returns to innovation.

The second most important institution that seems influencing innovation intensity in European industries is labor market regulation. Specifically, the magnitude of the coefficient of the variable *Employment*, a proxy for labor markets' rigidity implies that, ceteris paribus, the intensity of innovation at the industry level decreases around 0.54 for a unit increase in the indicator of employment rigidity. This finding is consistent with the view that rigidities in the labor market regulation hinder innovation (e.g. Menezes-Filho et al., 1998; Gust and Marquez, 2004; Koeninger, 2005; Samaniego, 2006, 2008; Alesina and Zeira, 2006).

Furthermore, if one assumes that the mechanisms by which regulation influences innovation are related to productivity growth, investment and trade then this result is also consistent with the evidence that finds a negative impact of employment protection rigidity on productivity (Forteza and Rama, 2006; Kılıçaslan and Taymaz, 2008, Bassanini et al., 2009; Poschke, 2009), on investment (Cingano et al., 2010) and on trade (Kambourov, 2009) in EU countries.

In turn, the estimates of the variable *PMR*, a proxy for product market regulation, indicate that heavier regulation has a negative effect on innovation, specifically innovation intensity decreases by 0.16 for a unit increase in the indicator *PMR*. This result is overall consistent with the evidence of Griffith et al. (2006a) regarding the EU market but at odds with the findings of Amable et al. (2010) regarding a set of OECD countries. As in the case of *Employment*, if one assumes that the mechanisms by which regulation influences innovation are related to productivity growth then the evidence emerging from our data is consistent with a growing number of studies that found a negative impact of heavy product market regulation on productivity (Conway et al., 2005; Aghion et al., 2005; Bourlès et al., 2010).

A study related to ours is that by Amable et al. (2010). Although a direct comparison of our findings with theirs is not straightforward, given the differences in the sample, model and dependent variable, it is useful to establish a link between their results and ours. Whereas our results suggest an overall negative association across industries, particularly in the more R&D intensive industries and in line with most studies (e.g. Aghion et al., 2005), Amable et al. (2010) found a positive association between regulation and innovation in industries close to the technological frontier and a *negative* association between regulation and innovation in industries distant to the frontier.

The difference between results may to some extent be explained by differences in the dependent variable as Amable et al. (2010) use patents as indicator of innovation. A similar explanation could be underlying the differences between this study and others (Amable et al., 2010; Griffith and Macartney, 2010) regarding the relationship between employment protection regulation and innovation. Though the differences in the sample and methodology between studies do not allow us to draw a conclusion, at least it suggests the relevance of employing different indicators of innovation when assessing its drivers.

The coefficient estimates associated with the variable *Credit* illustrate that financial development, namely through increases in information sharing and credit access, are fostering innovation thereby confirming previous evidence (Carpenter and Petersen, 2002; Botazzi and Rin, 2002). Specifically, results suggest that innovation intensity increases around 0.04 for a unit increase in the indicator *Credit* across European industries.

Few studies have investigated the impact of credit market regulation on innovation. In this sense our results can be directly compared to those by Griffith and Macartney (2010) who also found a positive correlation between the indicator of credit market regulation and innovation. Our results are also related to the literature that found evidence showing a positive impact of financial development on firm survival and economic success (Clementi and Hopenhayn, 2006; Guiso et al., 2004).

Regarding the control variables their estimates reveal that the most important drivers of differences in innovation intensity across European industries are the country's wealth, measured by the *GDP per capita* variable, and differences in technological regimes and opportunities across industries, as proxied by the Pavitt's taxonomy variables. These results are in line with the view that emphasizes the importance of industry-specific characteristics for the development and diffusion of new technologies (e.g. Breschi et al., 2000; Fagerberg, 2002; Samaniego, 2006; Ngai and Samaniego, 2010).

Moreover, these results raise the question whether the effects of institutions on innovation may vary across different types of industries. To test for it, we interact the country-level institutional factors with the industry dummies and let the data tell us how the institutions' interaction with industry characteristics influences innovation.

Table 7 shows the estimates, along with standard errors, of the interplay between institutions and type of industries.

Insert Table 7 here

The estimates indicate there are differences on the size of the impact of regulation across industries. Specifically the size of the negative impact is larger on the *Science based industries* than in the other industries indicating that these industries are being negatively affected by the lack of competition. The *Science based industries* are technology-intensive industries and, according to Aghion et al. (2005), one should expect a negative impact of a decrease in competition on innovation activity in these industries. In fact, Aghion et al. (2005) have proposed that less competition could possibly boost innovation in laggard industries, but would hinder it in leading industries, i.e., close to the technological frontier. The possibility of both effects has been proposed by other contributions (e.g. Boone, 2001; Dubey and Wu, 2002; Dinlersoz and MacDonald, 2009) while others have argued that firms' incentives to innovation depend not only on the competitive environment in which they operate but also on the underlying technology and technological regime of the industry (Breschi et al., 2000; Fagerberg, 2002; Samaniego, 2006; Ngai and Samaniego, 2010).

Furthermore, it should be noted that estimates of Table 7 reveal a consistent negative association (though not always statistically significant), across industries with different technological regimes, between the interactive term and innovation intensity. Thus the evidence seems to favor the argument of innovation-boosting effect of competition. Yet we should be cautious and not to interpret this result as evidence against the Schumpeterian effects argument. First and foremost, the *PMR* indicator comprehends other dimensions than the level of competition in the markets, namely the level of bureaucracy, which acts as important barriers to the easy of doing business.

It has been argued that the impact of employment protection regulation may have different effects on innovation across industries (Bassanini and Ernst, 2002). We find that labor market regulation – *Employment* – impact differently across industries, with the *Specialized suppliers industries* being those where the effects of strict employment regulation on innovation intensity are negative and statistically dissimilar from the other types of industries.

This could be due to the lack of skills required to implement innovations within the firm, which makes the adjustment cost imposed by hiring and firing restrictions to be high (Bassanini and Ernst, 2002). Another reason why the negative effect of strict employment regulation is more pronounced in these industries is that these adjustment costs may be exacerbated due to negative externalities coming from adjustments in the labor markets of their downstream industries (e.g. textiles, apparel, specialized components).

Our results highlight a negative effect of employment protection stringency on innovation. Nonetheless, the fact that the impact of employment rigidity on innovation intensity is more pronounced in these industries indicates that there are inter-industry differences to the same labor laws.

Although well-developed credit markets are expected to favor innovation overall, there might be differences of its impact across industries. Specifically, access to credit can be more critical in high-technology industries, which typically have higher external financing needs (Dabla-Norris et al., 2010). As shown in Table 7 credit market regulation has always a positive impact on innovation intensity across industries, being its effect more pronounced in the *Scale intensive industries*, which are among the most technology-intensive.

Also the protection of property rights is expected to be more important in industries in which the main appropriation strategy is through patents (e.g. pharmaceuticals, instruments) versus an appropriation strategy based on secrecy, more common in process innovations. Yet the estimates of the interaction terms between *IPRs* and industries do not reveal differences of their impact on innovation intensity at industry level.

5. Conclusions

In this paper we empirically investigated the role of institutional variation in explaining differences in innovation intensity across European industries. Our focus was on a set of regulatory practices and policies that are aimed at regulating product, labor and capital markets, as well as the strength of intellectual property rights.

As theoretical contributions do not provide a clear cut prediction on the relationship between these institutions and innovation, ultimately the answer has to come from the data. Yet existing empirical evidence is still relatively scarce and inconclusive. Therefore this paper contributes to the literature by supplementing previous evidence using the proportion of innovating firms in EU manufacturing industries as a proxy for innovation.

Our results highlight the importance of institutions in explaining differences in the intensity of innovation in manufacturing industries of EU countries and are largely consistent with most theoretical and empirical contributions.

Regarding product and labor market regulation we found an unambiguous negative association between regulation and innovation, which validates the propositions of the Lisbon Agenda towards deregulation of these markets as a means to promote innovation and growth. However, one should note that in some cases product market regulation may be instrumental in pushing firms to efficiency and innovation, such as regulation on quality standards and on energy efficiency and development. The product market regulation indicator employed in this paper measures a set of both administrative and economic policies and practices that are detrimental to the ease of doing business, so in this case regulation is expected to be a barrier and not a driver of innovation. As such, first and foremost our findings should be interpreted as corroborating this view.

A particularly interesting finding of this paper with policy implications is the negative association between intellectual property protection and innovation intensity at industry level. It appears that intellectual property protection is hindering innovation across EU industries. As such one key message that stands out is how one should be cautious in thinking about property rights extension in a monolithic way.

The empirical findings also point out the relevance of industry-specific effects and their interactions with institutions in order to deeper understand how institutions influence innovation. As such, one interesting extension of this research would be to investigate the mechanisms through which institutions shape innovation in specific type of industries. This would require a longitudinal study of a specific type of industries and a focus on one institution. Ideally the selected institution would be gone through a truly exogenous shift or a natural experiment could be found and exploited in order to eliminate any potential endogeneity problem. Another potentially fruitful extension would be to improve our understanding on the way exogenous changes in institutions may foster innovation activity at firm-level. While our study is set at the industry level, it would be interesting to complement it with studies at other levels, notably the firm level. We plan to address these issues in future research.

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Table 1 Variables acronym, description and expected impact on innovation

Variable	Description	Expected Impact
Innov	Dependent variable: proportion of innovative enterprises in industry *i*, of country *j*. 2-digit level of NACE classification, 2004. Source: CIS4, EUROSTAT.	
PMR	Product market regulation index, measuring economic and administrative formal rules and regulations that have potential to block competition; values vary between 0 and 6 from least to most restrictive competition, 2003. Source: Product Market Regulation Indicators Database, OECD.[10]	+/-
Employment	Rigidity of employment index, measuring the difficulty of employers to hiring and firing. Higher values of the index mean more protection, 2003. Source: Doing Business Database, The World Bank Group.[11]	+/-
Credit	Credit information index measures rules affecting the scope, accessibility and quality of credit information available through either public or private credit registries. The index ranges from 0 to 6, with higher values indicating the availability of more credit information, 2003. Source: Doing Business Database, The World Bank Group.	+
IPRs	Indicator of the strength of patent protection. Source: Park(2008)	+/-
GDP	Logarithm of gross domestic product per capita, constant prices average 2001-2003. Source: National Accounts Database, OECD.	+
Patent	The ratio of number of patents in industry *i* of country *j* to total number of patents in manufacturing industry of country *j*. Source: EUROSTAT	+
R&D	Logarithm of total expenditure in R&D on industry *i*, country *j*, 2004. Source: CIS4, EUROSTAT.	+
Size	Logarithm of total turnover in industry *i*, 2002. Source: CIS4, EUROSTAT.	+

[10] See Conway et al. (2005) for detailed description on the construction of the *PMR* indicator.

[11] See Botero et al. (2004) for detailed description on the construction of the *Employment* indicator.

Table 2 Descriptive statistics of dependent and explanatory variables

Variable	Min.	Max.	Mean	Std. Dev.
Part I Summary statistics				
Innov	0.182	1	0.513	0.180
PMR	1.1	1.9	1.557	0.203
Employment	0.1	0.56	0.464	0.101
Credit	3	6	4.634	1.076
IPRs	3.97	4.67	4.425	0.271
GDP per capita	2.407	3.406	2.943	0.295
Patent	0.0004	6.531	0.171	0.759
R&D	2.959	7.398	5.313	0.779
Size	1.607	3.509	0.180	0.257
Scale intensive	0	1	0.379	0.487
Science based	0	1	0.124	0.331
Specialized suppliers	0	1	0.199	0.400

Part II Correlation coefficients among selected variables

	GDP	*PMR*	*Employment*	*Credit*	*IPRs*
GDP	1.000				
PMR	-0.552	1.000			
Employment	-0.588	0.530	1.000		
Credit	0.125	-0.052	-0.059	1.000	
IPRs	0.859	-0.322	-0.569	0.355	1.000

Table 3 Alternative estimates for the relationship between innovation and institutions along with standard deviations

	OLS	WLS-Arcsine	QMLE-Poisson		QMLE-Fractional Logit	
Variables	Estimates	Estimates	Estimates	Marginal effects	Estimates	Marginal effects
PMR	-0.159**	-0.196*	-0.354*	-0.160*	-0.675***	-0.168***
	(0.062)	(0.097)	(0.195)	(0.090)	(0.261)	(0.065)
Employment	-0.361*	-0.506**	-1.025***	-0.463***	-1.530**	-0.382**
	(0.184)	(0.181)	(0.361)	(0.167)	(0.761)	(0.190)
Credit	0.025	0.042**	0.082**	0.037**	0.108	0.027
	(0.024)	(0.018)	(0.037)	(0.017)	(0.100)	(0.025)
IPRs	-0.504**	-0.672***	-1.204***	-0.544**	-2.149***	-0.537 ***
	(0.170)	(0.149)	(0.279)	(0.129)	(0.747)	(0.186)
GDP per capita	0.352**	0.547**	0.971***	0.439***	1.496***	0.373***
	(0.132)	(0.182)	(0.352)	(0.161)	(0.571)	(0.142)
Patents	-0.028***	-0.032***	-0.042***	-0.018**	-0.125***	-0.031***
	(0.009)	(0.009)	(0.015)	(0.007)	(0.044)	(0.011)
Size	0.198**	-0.003	0.037	0.017	0.827***	0.207***
	(0.069)	(0.048)	(0.097)	(0.044)	(0.286)	(0.071)
R&D	0.026	0.082*	0.127*	0.057*	0.121	0.030
	(0.035)	(0.042)	(0.069)	(0.030)	(0.151)	(0.038)
Industry dummies	Yes	Yes	Yes		Yes	
Observations	161	161	161		161	
(Pseudo) R^2	0.491	0.785	0.709		0.490	
Robust RESET	0.08 [0.96]	3.27 [0.195]	0.782 [0.676]		0.528 [0.767]	
Predicted mean of *innov*	0.513	0.545	0.452		0.516	
Observed mean of *innov*			0.513			

Notes: Dependent variable*: innov* - ratio of innovative firms to total number of firms of industry *i*, country *j*, 2004. Manufacturing industries are identified at 2-digit level of NACE classification. All regressions include intercept. Clustered by country standard errors are in parentheses. Based on them ***, **, * mean coefficients statistically significant at 1%, 5%, and 10% level, respectively. *p-values* are in square brackets. In the case of QMLE Fractional-logit model, the R^2 is a summary measure of the predictive power of the model. It is the square of the correlation between the dependent variable and its predicted values. See Table 2 for the exact definition of the variables

Table 4 Instrument acronyms, description and statistical source

Variable	Description	Source
Legor_fr	Dummy variable that identifies the legal origin of each country, equals 1 if French and 0 otherwise.	La Porta et al. (1999)
Jud_rev	Judicial review measures the extent to which judges (either supreme court or constitutional court) have the power to review the constitutionality of laws in a given country. The variable takes three values: 2 if there is full review of the constitutionality of laws, 1 if there is limited review of the constitutionality of laws, and 0 if there is no review of the constitutionality of laws.	Glaeser et al. (2004)
Liter_1880pc	Literacy in 1880 is the percentage of enrollment of primary-school students of ages 5-14.	Lindert (2009) available at http://www.econ.ucdavis.edu/faculty/fzlinder/
EU-trans	Transposition deficit is the percentage of internal market directives not yet communicated as having been transposed, average value 1997-2003.	Internal market scoreboard available at http://europa.eu.int/comm/internal_market/score/index_en.htm.

Table 5 Test for endogeneity of each institutional variable and strength of instruments (IV)

Variable	**Endogeneity test** [H0: the variable is exogenous]	**Hansen J test** [H0: instruments are valid]	**Anderson canonical correlations LR test** [H0: first-stage equation is underidentified]	**First-stage F-statistic** [H0: weak instruments]
All *(PMR, Employment, Credit, IPRs)*	27.368 (0.000)	0.000 (equation exactly identified)	51.888 (0.000)	-
PMR	0.791 (0.374)	33.025 (0.000)	426.567 (0.000)	73.92 (0.000)
Employment	0.411 (0.522)	27.988 (0.000)	380.727 (0.000)	64.01 (0.000)
Credit	0.838 (0.360)	33.452 (0.000)	201.183 (0.000)	28.38 (0.000)
IPRs	16.729 (0.000)	6.394 (0.094)	305.256 (0.000)	138.23 (0.000)

Notes: For all test the *p-values* are in parenthesis. See Table 2 for the exact definition of the variables and Table 4 for the exact definition of the instruments.

Table 6 Instrumental variables estimates for the relationship between institutions and innovation

	Arcsine transformation	
Variables	WLS	IV
PMR	-0.196* (0.097)	-0.159* (0.071)
Employment	-0.506** (0.181)	-0.536** (0.117)
IPRs	-0.672*** (0.149)	-0.708*** (0.128)
Credit	0.042** (0.018)	0.042**** (0.014)
GDP per capita	0.547** (0.182)	0.571*** (0.130)
Patents	-0.032*** (0.009)	-0.029 (0.007)
Size	-0.003 (0.048)	0.004 (0.057)
R&D	0.082* (0.042)	0.079 (0.029)
Scale intensive industries	-0.015 (0.019)	-0.014 (0.022)
Science based industries	0.202*** (0.038)	0.201*** (0.052)
Specialized suppliers industries	0.107*** (0.032)	0.108*** (0.027)
Observations	161	161
R^2	0.785	0.784

Notes: Dependent variable*: innov* - ratio of innovative firms to total number of firms of industry *i*, country *j*, 2004. Manufacturing industries are identified at 2-digit level of NACE classification. All regressions include intercept but estimates of the intercept are not reported. Robust standard errors are in parentheses. Based on them ***, **, * mean coefficients statistically significant at 1%, 5%, and 10% level, respectively. See Table 2 for the exact definition of the variables and Table 4 for the exact definition of the instruments.

Table 7 Estimates of the interplay between institutions and type of industries

	Baseline coefficients	Interactions coefficients		
		Scale intensive industries	*Science based industries*	*Specialized suppliers industries*
PMR	0.358 (0.247)	-0.166 (0.182)	-0.446* (0.233)	-0.117 (0.179)
Employment	0.140 (0.339)	-0.587 (0.398)	-0.508 (0.380)	-0.620* (0.375)
Credit	0.011 (0.035)	0.067* (0.035)	0.022 (0.039)	0.036 (0.036)
IPRs	-1.287*** (0.306)	-0.053 (0.171)	0.070 (0.222)	-0.015 (0.180)

Notes: Dependent variable*: innov* - ratio of innovative firms to total number of firms of industry *i*, country *j*, 2004. Manufacturing industries are identified at 2-digit level of NACE classification. All regressions include intercept and control variables but estimates are not reported for clarity purposes. Robust standard errors are in parentheses. Based on them ***, **, * mean coefficients statistically significant at 1%, 5%, and 10% level, respectively. See Table 2 for the exact definition of the variables and Table 4 for the exact definition of the instruments.

Appendix

The Community Innovation Survey (CIS) is a survey conducted by EU member states under the auspices of EUROSTAT that allows the monitoring of Europe’s progress in the area of innovation. The survey was originally conducted every four years, but since 2005 has been conducted every two. The survey includes sections on factors that hamper innovation, the impact of innovation on the business and the sources of information used. It also touches on aspects of the wider innovation process, such as the introduction of new management techniques. The CIS follows the OECD recommendations published in the Oslo Manual (OECD/Eurostat, 2005). Nowadays the CIS data has been widely used and the validity of its innovative indicators recognized by researchers (see, e.g., Kleinknecht et al., 2002; Mairesse and Mohnen, 2010).

The CIS data were collected from http://epp.EUROSTAT.ec.europa.eu/. Although the CIS data are at the firm-level, EUROSTAT only makes it available at 2-digit level of NACE classification. Our dependent variable, i.e., the number of enterprises that introduced a product and/or process innovation refers to two questions in the survey. The questions include a definition of product innovation and process innovation: “A product innovation is the market introduction of a new good or service or a significantly improved good or service with respect to its capabilities, such as quality, user friendliness, software or subsystems. The innovation must be new to your enterprise, but it does not need to be new to your market. It does not matter if the innovation was originally developed by your enterprise or by other enterprises. During the three-year period 2002-2004, did your enterprise introduce: (1) new or significantly improved goods. (Exclude the simple resale of new goods purchased from other enterprises and changes of a purely cosmetic nature); (2) new or significantly improved services. Process innovation is the use of new or significantly improved methods for the production or supply of goods and services. The innovation must be new to your enterprise, but it does not need to be new to your industry. It does not matter if the innovation was originally developed by your enterprise or by other enterprises. Purely organizational or managerial changes should not be included. During the three-year period 2002-2004, did your enterprise introduce any new or significantly improved processes for producing or supplying products (goods or services) which were new to your enterprise?". Although the questionnaire has two different questions, EUROSTAT aggregates both.

The R&D expenditures refer to the total expenditure made by the enterprise in 2004: "Please estimate the amount of expenditure in each innovation activity in 2004, either from management accounting information or using informed estimates". Table A.1 reports the specific EUROSTAT tables from which the data were collected.

Table A.1 CIS4 data collected from EUROSTAT

Variable	Description	Source
Innoact	Enterprises with innovation activities 2004	INN_CIS4_PROD = Product and process innovation
REXP04	Total innovation expenditure in 2004	INN_CIS4_EXP = Innovation activity and expenditure
Emp04	Total number of employees in 2004	INN_CIS4_BAS = Basic economic information on the enterprises
Ent_popu04	Total number of enterprises in the population in 2004	INN_CIS4_BAS = Basic economic information on the enterprises