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Agustí Segarra-Blasco, Jose Garcia-Quevedo,

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BARRIERS TO INNOVATION AND PUBLIC POLICY IN CATALONIA*

Agustí Segarra-Blasco, Mercedes Teruel-Carrizosa†

Jose Garcia-Quevedo ‡

Abstract:

The present paper analyses the link between firms' decisions to innovate and the barriers that prevent them from being innovative. The aim is twofold. First, it analyses three groups of barriers to innovation: the cost of innovation projects, lack of knowledge and market conditions. Second, it presents the main steps taken by Catalan Government to promote the creation of new firms and to reduce barriers to innovation. The data set used is based on the 2004 official innovation survey of Catalonia which was taken from the Spanish CIS-4 sample. This sample includes individual information on 2,954 Catalan firms in manufacturing industries and knowledge-intensive services (KIS). The empirical analysis reveals pronounced differences regarding a firm's propensity to innovate and its perception of barriers. Moreover, the results show that cost and knowledge barriers seem to be the most important and that there are substantial sectoral differences in the way that firms react to barriers. The results of this paper have important implications for the design of future public policy to promote entrepreneurship and innovation together.

Keywords: obstacles to innovation, industrial policy, innovation system

JEL Classification: O31, O38, D21

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† Contact: agusti.segarra@urv.net , mercedes.teruel@urv.net, Industry and Territory Research Group & Rovira i Virgili University, Department of Economics – Av. Universitat, 1 (43204 Reus – Spain).

‡ Contact: jgarciaq@ub.edu, Economic Institute of Barcelona (IEB), Dpt. of Econometrics, Statistics and Spanish Economy, University of Barcelona – Av. Diagonal 690; 08034 Barcelona.

1. Introduction

Innovation is crucial for the competitiveness and economic growth. Nowadays, an important dimension of the market economy is the role of innovation, rather than price, as a driving force in competition and rivalry between firms in the marketplace. In this scenario large firms play a crucial role in the innovation process, but small and medium firms are also important in applying new knowledge in the marketplace. Of course, the debate about the best market structure and firm size to promote innovation is not a dichotomic question between monopolistic or competitive markets or between larger and smaller firms. In addition, the relation between market competition and innovation is not linear and simple. Intense competition promotes innovation but excessive rivalry discourages change and innovation.

In this new context governmental institutions must ensure incentives for entrepreneurs and small and large firms in the innovation race. One crucial difference in the evolution of productivity between the United States and European countries is the involvement of the entrepreneurial system in the creation of new firms and, in particular, the capacity to survive and grow in the marketplace. The European Lisbon agenda tries to diminish the productivity gap between the United States and Europe by promoting an economic and institutional environment which provides incentives to create new firms and to start R&D and innovation projects.

At present there is a wide range of literature on firms' decisions to innovate, which includes important recent empirical estimations using firm level data. However, these empirical works usually focuses on manufacturing industries from a particular country (see a survey in Smith, 2005) or different countries (Mohnen, Mairesse, Dagenais, 2006; Peters, 2005). Despite the increasing prominence of services in European economies and the diversity of innovation systems at regional level, few works deal with both manufacturing and service industries in particular regions[1]. In addition, although the number of innovative firms has increased during recent years in European countries, nowadays there are many barriers preventing participation in innovative projects, especially among small and medium firms.

The aim of this paper is twofold. First, it analyses the relationship between firms' decisions to innovate and the barriers that both innovative and non-innovative firms find to their innovation projects. Ten different obstacles to innovation can be dealt with using the data contained in this paper, and these obstacles have been grouped in three partial indices: factors related to the cost

[1] The innovation patterns at firm level are dealt with in Cainelli, Evangelista and Savona, 2006; Tether, 2002; Lööf, 2004; and Miles, 2005.

of projects; factors related to access to information and skilled labour; and factors related to market characteristics. In addition, during the empirical work the barriers to innovation will be treated from two different perspectives, one extensive, that is, the number of firms that present barriers, and another intensive, that is, the intensity level of the barriers to innovation. Second, it presents the main steps taken by the Catalan Government to promote the creation of new firms and to reduce barriers to innovation.

Community Innovation Survey data (CIS4) offers information about the barriers to innovation faced by Catalan firms in manufacturing and knowledge intensive services. In the line with the analytical framework described by Crépon, Duguet and Mairesse (1998) and revised in successive re-examinations (Mairesse and Mohen, 2004), we use an econometric approach based on a logit binomial model. The data provides information about the presence and the intensity of obstacles to innovation over 2,954 firms, during the period 2002-2004.

Catalonia is an interesting case to study for various reasons. Firstly, in this region firms show a high vitality in R&D activities compared to the rest of Spain. Secondly, there is an urban system dominated by the metropolitan area of Barcelona, but with a network of medium-size cities with great economic and social vitality. Thirdly, the region has an industrial tradition based on medium and low technological industries. Finally, new sectors are emerging, such as biotechnology, information technologies, logistical services, etc., where knowledge plays an increasing role as a driving force of market competition.

The interaction between firms and agents that make up the regional innovation system (universities, research and transfer centres, firms carrying out R&D activities, etc.) generate external economies of knowledge that benefit firms. Most research on knowledge spillover suggests that the territorial effects are local or regional. The Catalan innovation system, for example, can be seen as a hierarchy of a series of regional innovation systems, starting with the central nucleus formed by the metropolitan area of Barcelona. It could be argued, therefore, that the Catalan innovation system consists, on the one hand, of the Catalan system of science and technology (including universities, public research centres and in-house R&D departments) and, on the other hand, innovating firms located in Catalonia.

Regional governments are interested in designing their own innovation policies mainly due to the considerable importance of innovation in the economic transformation and stimulation of regional development (Fritsch and Stephan, 2005). The configuration of the Catalan innovation system, which consists of the flows and relationships among industry, government and

academia, is an important challenge to the new policy applied by the regional government since 2004.

This paper is organized as follows. The second section presents the theoretical framework concerning the barriers to innovation. The third section analyses the CIS database for Catalan manufacturers and knowledge-intensive services (KIS). The fourth section shows the relation between barriers to innovation and the innovative activity, as well as the relation between the determinants of the barriers to innovation. The fifth section shows the effect of policies on innovation projects in SME. The final section summarizes the main results.

2. Barriers to innovation

It is well known that innovation is a complex and collective phenomenon. For that reason it is not easy to determine either when a firm makes a certain innovation or the intensity of the innovative activity. Innovation means change, and change is often intangible and difficult to measure. Firms' innovations differ in their nature and their social return. For that reason, neither innovation nor the proportion of innovators can be measured, although the effect within innovative firms differs, as do the externalities of the location (Tether et al., 2002).

Innovation activities differ from knowledge generation. A firm's innovation is based on new combinations of knowledge which is not strictly new itself. When a firm decides to generate new knowledge through R&D projects, it must spend cash, invest in sunk costs and face to high risks. Usually, only large firms generate new knowledge through their research and development projects, but, as Arrow (1962) pointed out, there are different sources accumulating knowledge such as practice, experience and research. In general, small and medium firms apply new knowledge through practice and experience by means of a learning-by-doing process. In addition, knowledge is a non-rival and indivisible good which generates either increasing returns or market failures and whose production is uncertain and risky. As Marshall (1890) argued, new knowledge is the magical something that flows in the air and produces externalities that benefit local actors.

The economic background shows that innovation is related to the nature of market competition and the size of the market. Adam Smith's framework that firms innovate because the size of the market determines the division of labour and the level of specialization and the market process promotes the interrelation between suppliers and customers. The first effect is related to market power, while technological change is related to the division of labour in a world of decreasing

returns. The second effect is related to the appearance of collateral activities and the externalities of the market related to its size in a world of increasing returns. The problem is that both fundamentals theorems of Adam Smith run in contradictory directions. The first economist to point out this contradictory view was Georges Stigler (1951), who stated they cannot both be true. Later, Paul Romer's (1986) seminal paper developed a technical approach which explains the externalities of knowledge over rising productivity and integrates both metaphors in a new set of endogenous growth models.

Recently, William J. Baumol (2002) shows that in many contemporary economies innovation, rather than prices, is the primary instrument of competition. He argues that the competitive model that is most helpful in understanding competition in markets driven by innovation is the perfectly contestable market, where entry and exit are instantaneous and cost free. The contestability models nevertheless can help us better understand how markets perform. For this reason, we are interested in studying if an individual firm finds barriers when accessing external knowledge and undertaking innovation projects.

During recent years, access to data sources designed specifically for empirical research into the innovation process at firm level has opened up a wide range of possibilities to deal with the subject from a new angle. Since the early nineties, two main initiatives undertaken by international bodies have led to projects that will have a favourable bearing on later research. On the one hand, a collective project by statisticians under the auspices of the OECD on the nature and measurement of innovation activities resulted in the so-called *Oslo Manual* (1992). Subsequent versions of the *Oslo Manual* (1996, 2005) provide new views on the innovation process in firms. In particular, the most recent version of the *Oslo Manual*, together with product and process innovation, notes the role of organizational and marketing innovation. On the other hand, following the guidelines set out in the *Oslo Manual*, a number of countries have designed a common core questionnaire on firms' innovation activities. Since then, many European countries have launched different versions of the Community Innovation Survey[2].

The access of CIS databases allows different topics related to firms' innovation in manufacturing and service industries to be studied. In European countries the information provided by innovation surveys implies an important quantitative and qualitative improvement. The common design of the questionnaire, the comparative studies and the application of suitable econometric techniques allow significant advances in empirical research. In addition, since the

[2] There are four editions of the CIS: CIS1 covering the period 1990-1992, CIS2 covering the period 1994-1996, CIS3 covering the period 1998-2000, and CIS4 covering the period 2002-2004.

nineties questionnaires have looked in greater depth at the internal factors influencing a firm's innovation and how this affects its position in the market. Consequently, the focus of empirical researchers has changed in favour of output-oriented innovation indicators.

The increased availability of micro-level data in the EU in recent years has led to a growing number of studies on the links between R&D, innovation and productivity at firm level. A survey on business innovation in many European countries has allowed light to be shed on the "black box" that represents the innovation process undertaken by firms. Nowadays we know more about the nature of innovation and its sources, however, few researches have focused on barriers to innovation. But what are barriers to innovation? This is not an easy question to answer.

The CIS questionnaire addresses some of the questions concerning obstacles to innovation. The question is, "*During the three-year period 2002-2004, how important were the following factors as constraints to your innovation activities or influencing a decision not to innovate?*" The questionnaire presents ten factors related to the obstacles to innovation with four options in terms of the presence and the intensity of the barriers (high, medium, low and not experienced).

This information provides an alternative point of view in relation to the usual theoretical contributions on the determinants of a firm's innovation. The nature of the technology and the R&D process, the market structure and the rivalry between firms, the scale economies of R&D and innovation, the size and organizational profile of the firms, among others, usually determine innovation activities (Cayseele, 1998). However, our data shows the barriers to innovation from a firm approach. This question differs between innovative and non-innovative firms. In the first case, when innovative firms identify a specific obstacle, we can say that they have found a barrier to increasing their innovating activities. However, in the second case, when non-innovative firms answer the question, we can say that they have found barriers to carrying out their innovating activities.

Obstacles to innovation are usually thought of by managers and owners of firms as external and internal factors that make it difficult to be innovative. External barriers appear when the firm has difficulties accessing technological information, or when it lacks external finance, or skilled personal, or when there are factors related the market conditions. A firm finds internal barriers when it lacks internal funds and when the firm's staff feels that the risks and costs of innovation are too high.

Despite the interest in improving knowledge about barriers to innovation, until now there has been little research in the field. The pioneering research on barriers to innovation carried out for the Commission of European Communities includes contributions from several researchers in eight European countries (Piatier, 1984). This research identifies some major barriers to innovation in European firms related to the education system and skilled labour, the effect of venture-capital and the banks on financing innovation and the effect of norms, legislation and public bureaucracy. For SMEs in Cyprus, Hadjimamolis (1999) presents a barriers approach to innovation in the context of small less developed countries and finds the reduction of bureaucracy and the reorganization of technical education are very important for reducing obstacles to innovation. In Canada, Mohnen and Rosa (2002) analyse the obstacles to innovation in a sample of service firms and Baldwin and Lin (2001) study the obstacles to advanced technology adoption in a sample of manufacturing firms. Mohnen and Röller (2005) study the complementarities between barriers to innovation with a sample of the CIS1 from Ireland, Denmark, Germany and Italy. Galia and Legros (2004) investigate the complementarities between obstacles to innovation using CIS2 data for a sample of French manufacturing firms. At regional level, Freel (2003) observed the barriers to product innovation in a sample of small manufacturing firms in the West Midlands area, and Mark et al (2002) analysed empirically the barriers to innovation in a small sample of SMEs located in the Valencia region of Spain.

3. Database and some statistics

The data set used is based on the 2004 official innovation survey of Catalonia which has been a part of the Spanish sample of CIS4. To analyse innovative behaviour in Catalan firms we have a data source at firm level developed by the Spanish National Statistics Institute (Instituto Nacional de Estadística) in the Technological Innovation Survey. This database contains much information about firms' strategies and performance when innovating during the period 2002 to 2004. The Spanish CIS4 covered private sector firms with at least 10 employees.

Our data base includes the CIS questionnaires made by 2,954 Catalan firms. The industrial classification based on technology and knowledge intensity in manufacturing and services follows the OECD criteria. To begin, the OECD defined technology intensity in manufacturing sectors on the basis of the ratio of R&D expenditure to added value. This classification provides four groups according to their technology intensity –high, medium-high, medium-low and low- in the manufacturing sector and a group of knowledge-intensity services (OECD, 2006). Our database includes 2,356 firms in manufacturing industries, including codes 15 to 36 but

excluding sectors 16 and 23, and 598 firms in knowledge-intensive services (KIS), including codes 64 to 67 and 72 to 74. Energy industries, recycling, trade, restoration, education, health and cultural activities have been excluded from our sample.

Table 1 summarises the characteristics of firms in 2004 according to the technological intensity. The high-tech manufacturers include industries with an intense level of innovative activities and technological externalities. The low-tech manufactures include industries which are natural resource intensive sectors, labour intensive sectors and sectors with large economies of scale. KIS include industries which are knowledge intensive sectors and, therefore, with knowledge externalities. Our database contains 1,024 high-technological firms that account for 34.66% of firms, 1,332 low-tech firms that account for 45.09%, and finally 598 KIS firms that account for the remaining 20.24%.

Table 1.
Characteristics of firms depending on the technological intensiveness

	High-tech manuf.	Low-tech manuf.	KIS services
Innovative firms			
Employment	198	183	329
Sales (thousands of euros)	57,018	44,427	78,952
Export by sales (%)	41.69	26.30	1.27
R&D and innovation expenditure per employee (euros)	15,553	6,019	10,671
Expenditure on R&D per employee (%)	31.15	36.38	43.05
Expenditure on other sources of innovation per employee (%)	68.85	63.62	56.95
Innovation output in sales (%)	26.06	22.50	38.74
Number of firms	502	344	177
Non-Innovative firms			
Employment	93	92	274
Sales (thousands of euros)	22,136	21,302	31,182
Export in sales (%)	29.52	16.91	1.50
R&D and innovation expenditure per employee (euros)	4,420	1,116	946
Expenditure on R&D per employee (%)	10.27	3.44	3.06
Expenditure on other sources of innovation per employee (%)	89.73	96.56	96.94
Innovation output in sales (%)	9.63	6.97	5.64
Number of firms	522	988	421

Source: own elaboration from Catalan CIS database

A large number of firms operate in markets every year. One important question that must be addressed before entering the market or once they have started production is their innovative activity. Innovation leads firms to increase their efficiency and their chances of survival in order to be more competitive in the market. Here, we consider that a firm innovates when it states that it innovates in products or processes and invests in R&D projects. Table 1 shows that 1,023 firms say they were innovative in 2004, which accounts for 34.63%.

Innovative activity implies a large number of steps; from the basic research to analysis of market application, innovation is a complex activity. Our data shows that innovative firms are heterogeneously distributed among industries. On the one hand, nearly half the firms in high-tech manufacturing are permanent innovators. On the other hand, around 30% of firms in low-technological manufacturing and KIS services are innovative firms.

Regarding firm size and sales, both variables differ between sectors. Specifically, service industries are larger and have more sales than manufacturing industries, regardless of the innovative activity. As we expected, high-tech manufacturing has a larger percentage of exports than its counterparts. However, the percentage of sales which are exported diminishes considerably when observing non- innovative firms. The capacity to innovate differs among firms and among industries. While large firms have more capacity to innovate, small firms tend to make profit from innovative networks and get ideas from suppliers and customers. Furthermore, firms in high-technological manufacturing will have more incentive to innovate, while service industries will be able to invest in innovation when they increase their size.

Regarding R&D and innovation expenditure per employee, first, we should differentiate between innovative and non-innovative firms. If we look at innovative firms, high-tech manufacturers and knowledge-intensive services invest more in R&D and innovation with 15,553 euros per employee and 10,671 euros per employee respectively. Second, regarding the distribution of expenditure, the percentage of expenditure related to other sources different from research is higher in manufacturing industries (around 65%) than in knowledge-intensive services. If we look at non-innovative firms, the amount of expenditure per employee falls to 4,420 euros in high-tech manufacturing, 1,116 euros in low-tech manufacturing and 946 euros in knowledge-intensive services. Finally, the innovation output on sales is larger in knowledge-intensive services than in manufacturing industries.

4. Barriers to innovation and the effect on innovation

4.1. Barriers to Innovation Index

Firms find different obstacles during their innovation activities, but there are few sources of data that allow us to go deeper into this subject. However, in the CIS4 questionnaire we get interesting information on the obstacles to innovation. Firstly, for each of the 10 items in the questionnaire we know if a firm thinks there is a barrier to innovation or not. Secondly, when a firm perceives a barrier in one particular factor, the questionnaire also shows the intensity: low, medium or high.

In line with other literature and in order to make the first analysis of the data, we group barriers to innovation into three partial indices related to the cost of innovation, lack of knowledge and market characteristics (Smallbone and North, 1999)[3]. Cost barriers explain a firm's difficulties in financing its innovation projects. Knowledge barriers concern access to information on technology and skilled labour. Finally, market barriers explain the market structure and pull-technology derived from demand.

Table 2
Index of barriers to innovation

1. Cost barriers (4)	Lack of internal funds Lack of external funds Direct innovation costs too high
2. Knowledge barriers (4)	Lack of qualified personnel Lack of information on technology Lack of information on markets Barriers to finding partners for innovation
3. Market barriers (4)	Market dominated by established enterprises Uncertain demand for innovative goods or services Lack of demand for innovation
Total index of barriers to innovation (12)	
Maximum global index score (12), maximum partial index score (4) All barriers are weighted by degree: high (3), medium (2) and low (1)	

To begin, we are interested in giving the average level of the total and the partial indices of the cost of innovation between high-tech manufacturing, low-tech manufacturing and KIS. The results are shown in Table 3. The level of the partial index differs according to sector. In high-

[3] Applying CIS1 data in a sample of firms from Ireland, Denmark, Germany and Italy, Mohnen and Röller (2005) found the probability of becoming an innovator and the intensity of innovation are subject to different constraints.

tech industries cost barriers are very important and the Global Barrier Index is higher than for their counterparts. In low-tech industries and KIS the partial and global indices are rather similar. Finally, the cost barriers index is higher than both the knowledge barriers index and the market barriers index. March et al (2002) found in the results from the Valencian regions that most obstacles to innovation in all the sectors arise from the excessive cost of maintaining innovation projects.

Table 3
Barriers to innovation per industry

Index	All firms	High technology	Low technology	Services
Global Index barriers	4.821	5.206	4.605	4.641
	(2.915)	(2.767)	(3.001)	(2.908)
Cost Index barriers	1.986	2.198	1.884	1.852
	(1.069)	(1.023)	(1.400)	(1.471)
Knowledge Index barriers	1.323	1.438	1.268	1.248
	(1.069)	(1.023)	(1.095)	(1.072)
Market Index barriers	1.569	1.569	1.453	1.539
	(0.984)	(0.984)	(1.045)	(0.924)
Number of firms	2,954	1,024	1,332	598

Note: Maximum value of the indices is: cost barrier = 4; knowledge barrier = 4; market barriers = 4; and global barriers to innovation = 12.
Source: IDESCAT

Our first index suggests there is heterogeneity across items and industries, especially between high-tech industries and the remaining industries. If we look at the highest barriers to innovation, these are related to cost factors. At industrial group level, high-tech manufacturing shows a higher global index of barriers to innovation, especially in the items related to cost factors, than low-tech manufacturing and KIS.

In addition, the heterogeneity in the intensity of the barriers to innovation is very important between firms. Here we are interested in a preliminary analysis of firms' heterogeneity in the barriers to innovation. We pay special attention to the firm's innovation performance and its size in relation to the barriers to innovation. We run the following OLS regression:

$$B_{ikj} = \alpha + \beta_1 INNO_{ij} + \beta_1 SMALL_{ij} + \sum_j IND_j + \varepsilon_{ij}$$

where B_{ikj} refers to the 'k' different barriers to innovation following the CIS-questionnaire of firm 'i' in industry 'j'; *INNO* is a dummy equal to 1 if an individual firm was innovative during the period 2002-2004; *SMALL* is a dummy equal to 1 if firms had 20 or fewer employees in

20o4; *IND* is a dummy control at two digits of sectoral distribution; and ε is the usual error term.

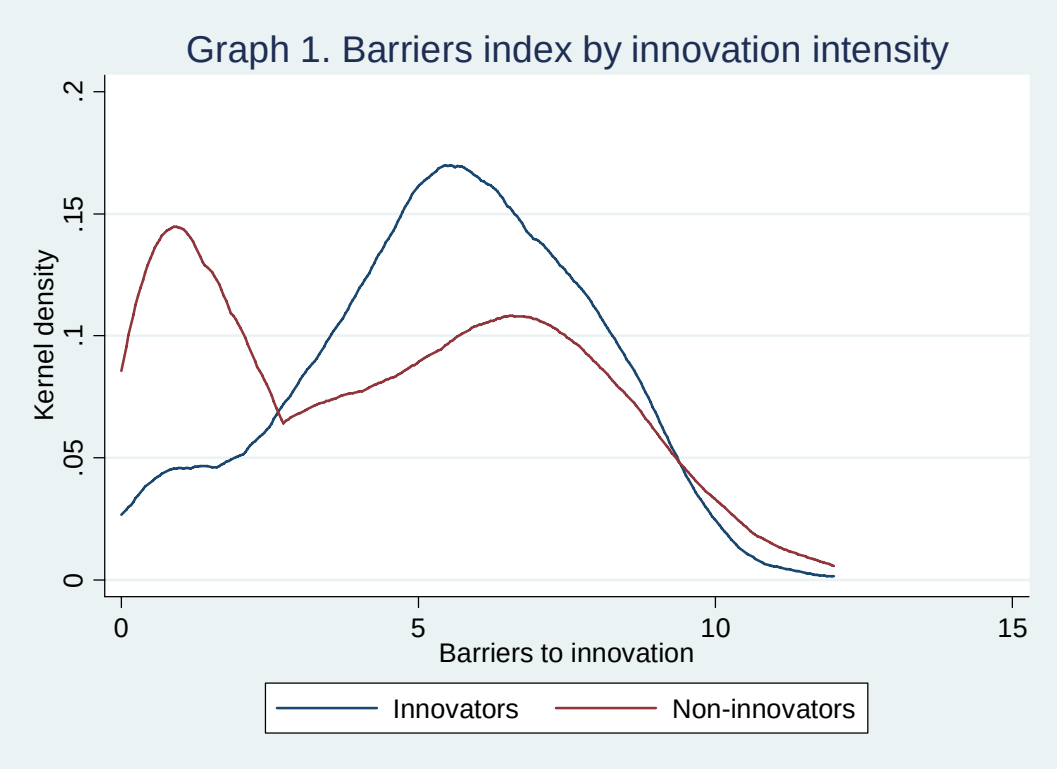
Table 4
Barriers to innovation depending on innovative activity and firm size. OLS regression

Barriers to innovation	β_1	β_2	R^2
Global Index barriers innovation	0.932	0.729	4.9
Index Cost barriers	0.515	0.383	7.2
Lack of internal funds	0.387	0.294	6.1
Lack of external funds	0.443	0.186	6.4
High cost of innovation	0.328	0.382	5.7
Index Knowledge barriers	0.327	0.141	3.3
Lack of qualified personnel	0.202	0.092*	2.4
Lack of information on technology	0.214	0.083*	2.4
Lack of information on markets	0.294	0.101	3.4
Barriers to finding partners	0.271	0.146	4.0
Index Market factors barriers	0.088*	0.204	2.3
Market dominated by incumbents	0.349	0.200	6.2
Uncertain demand	0.403	0.168	5.7
Lack of demand for innovation	-0.553	0.091*	13.6

Note: All coefficients are significant at 1% except * that are significant at 5%. Maximum value of index cost barriers is 4, index knowledge barriers is 4, index market barriers is 2, and global index of barriers to innovation is 10. Maximum value individual items 3.
Source: IDESCAT

The results are interesting. Innovative firms find higher barriers to innovation than non-innovative firms, especially in the cost and knowledge fields. Innovative firms perceive important barriers to innovation, while non-innovative firms tend to underestimate the problems associated with innovation. In addition, small firms present higher barriers to innovation than their counterparts, especially in two items related to cost barriers, lack of internal funds and high cost of innovation. Furthermore, the barriers related to the market are more important in small firms than innovative firms. In conclusion, small and innovative firms present the highest barriers to innovation overall.

These results are very important for establishing the barriers to firms' innovation projects. Furthermore, it is important to highlight the nature of those barriers to innovation found by small firms. The main reason is that when new firms overcome barriers to innovation, they usually increase their chances of survival and growth potential (Cefis and Marsili, 2006).



Graph 1 shows significant differences in the distribution of the values of Global Barrier Index among innovative and non-innovative firms. On the one hand, the former presents a unimodal distribution characterised by a high number of firms with values between 4 and 8 on the global innovation barriers index. On the other hand, non-innovative firms present a bimodal distribution which shows the existence of two different levels of the Global Barrier Index. One group of firms perceives low barriers to innovation whereas another group perceive high barriers to innovation. Surprisingly, the group of non-innovative firms in the second hump of the distribution perceives higher values on the Global Barrier Index than innovative firms. The main reason may be the fact that when a non-innovative firm does not face up to an innovation project, managers or owners, in general, do not perceive any obstacles, whereas when a non-innovative firm tries to innovate it is conscious of the high obstacles to innovation.

The differences between both distributions of the Global Barrier Index together with the results from Table 4 show that the heterogeneous perception of barriers to innovation depend not on the sectoral specialisation but on the innovative activity. Indeed, innovative firms usually present more barriers to innovation, and non-innovative firms perceive less frequently barriers to innovation but they see them more intense, especially regarding obstacles related to knowledge and market factors. Our results are in line with previous results from other countries. Using CIS2 data on French manufacturing firms, Galia and Legros (2004) remark that the frequency of meeting at least one obstacle to innovation is higher in innovating firms. For Canadian firms

Mohnen and Rosa (2002) and Baldwin and Lin (2002) indicated that the obstacles increase with the innovative activity of the firms. But in a sample of SMEs from Cyprus, Hadjimanolis found the importance of barriers to innovation perceived by the firms' owners or managers did not correlate to innovativeness.

In order to appreciate these differences in the perception of the obstacles to innovation, we also analyze separately the information from the CIS questionnaire. On the one hand, we present the percentage of firms that perceive the existence of barriers to innovation and, on the other hand, we present the intensity of the barriers to innovation of those firms which perceive the existence of obstacles to innovation.

Table 5
Barriers to innovation depending on the innovative activity

	Innovative firms		Non-innovative firms	
	Firms with barriers (%)	**Intensity barriers**	**Firms with barriers (%)**	**Intensity barriers**
Cost barriers				
Lack of internal funds	86.02	2.05	63.18	2.13
Lack of external funds	80.55	2.12	58.52	2.10
High cost of the innovation	85.34	2.12	64.73	2.27
Knowledge barriers				
Lack of qualified personnel	78.98	1.59	59.87	1.78
Lack of information on technology	78.89	1.45	57.38	1.64
Lack of information on markets	78.40	1.52	55.46	1.60
Barriers to finding partners	61.39	1.67	39.51	1.84
Market barriers				
Market dominated by incumbents	80.06	1.85	55.57	1.93
Uncertain demand	83.09	1.91	58.62	1.98
Lack of demand for innovation	33.82	1.33	57.02	1.94

Firms with barriers refer to the dichotomic variable of 1 if the firm found a barrier and 0 if it did not. Intensity of the barriers refers to the level of the obstacles only for the firms with barriers. This categorical variable is 1 if the intensity is Low, 2 if the intensity is Medium, and 3 if the intensity is High.
Source: own elaboration from CIS database.

As we have seen previously, there is a large percentage of firms which innovate. However, innovative activity is not an easy process. A wide number of factors acting as barriers to innovation challenges firms. Table 5 shows firms' perceptions regarding the level of barriers to innovation. We classify the responses depending on their innovation activity. This difference is substantial since the perception of barriers will be different depending on whether firms are innovating or not. First, there is a higher percentage of innovative firms perceiving a barrier than non-innovative firms regardless of the type of barrier to innovation. These results agree

with those obtained by Baldwin and Lin (2001) in Canadian manufacturing industries and other research.

Second, one of the main hypotheses to explain the low level of innovation is the lack of economic sources to do so. That is to say, financial access will be one of the major determinants when innovating. Our results show that firms find cost to be a higher barrier (their values are closer to 3). Furthermore, this perception is higher among non-innovators. If we look at the item among the cost factors which act as the highest barrier, all groups of firms consider the cost of innovating as a large barrier.

Third, knowledge barriers seem to be slightly lower compared to cost barriers; however the difficulty in finding a partner seems to be another barrier for both, innovative and non-innovative firms. In this sense, knowledge flows and knowledge integration capabilities of members can be considered as crucial for innovation processes to be successfully implemented. However, the percentage of firms perceiving the barrier who find a partner is higher in innovators than in non-innovators.

Finally, market factors and, in particular, market uncertainty seem to be a barrier for firms. If we look at non-innovative firms, the absence of demand for innovation seems to also be an important barrier to innovation.

4.2. Barriers to innovation and firm decision

After analyzing the barriers to innovation from different perspectives, in this section we investigate the effect of three partial indexes (cost, knowledge and market factors) on firm' innovation decisions.

We adapt the analytical frame described by Crépon, Duguet and Mairesse (1998) to the role played by barriers to innovation in Catalan firms. Crépon, Duguet and Mairesse (CDM) propose a structural model which establishes a relationship among innovative input, innovative output and productivity. The CDM approach can be interpreted as a three-step model. In the first step, the firm decides the amount to invest in innovation. The second step defines the knowledge production function following Pakes and Griliches (1984), where innovation output is a function of innovation input and other factors. Finally, in the third step, an augmented Cobb-Douglas production function establishes the effect of innovative output on productivity. We only apply one specification of the model related to the determinants of firms' decisions to innovate and we

are interested in observing the barriers to firms' innovation decisions. We can estimate a logit binomial model explaining the intensity subject in the selection group.

If the innovative status is adopted for the period 2002-2004 when the firm produces or starts the innovation process and the in-house R&D, the binary logit model can be written as:

$$Y_i^* = B_i \quad X_i + C_i \quad Z_i + u_i > 0, \qquad i = 1...N$$

where the innovation decision of the firm "*i*" is a function of a set of explanatory variables *X* affecting the innovation decision, such as the firm size measured in the log of the firm's employees; the firm's in-house R&D investment per employee in the log; a dummy that adopts the value 1 when the firm belongs to a group; a dummy that indicates whether the firm receives public funding for R&D in the EU, Spain or Catalonia; and the firm's market share in the log. Furthermore, we include a set of variables *Z* that explain the barriers to innovation that firms perceive; *B* and *C* are the corresponding coefficient vectors, and u_i is the usual error term, which we assume to be iid $N(0, \sigma^2)$, and $\sigma^2 = 1$. In all estimations industry dummies corresponding to SIC 2-digit industries are included.

However, the latent variable, the propensity to innovate Y_i*, is not observed. What is observed is the realization of Y_i, which depends simply on whether a firm is innovative or not, so that:

$$Y_i = \begin{cases} 1 \quad if \quad Y_i^* > 0 \\ 0 \quad if \quad Y_i^* \le 0 \end{cases}$$

The variable Y_i adopts the value 1 when the firm is innovative, that is, when the firm carried out product or process innovation during 2002-2004 and in-house R&D activities. The value 0 is for when the firm does not do this.

The results obtained using a logit binomial model show the probability of innovation increases with firm size, with the access to public grants and with the intensity of R&D expenditure per employee[4]. But these results offer some differences between manufactures and services. In services, firm size plays an ambiguous role, mainly due to the fact that there are many small

[4] In a representative panel of Spanish manufacturing firms, González, Jaumandreu and Pazó (2005) find that public subsidies stimulate R&D activities, and even show that some firms would stop these activities in their absence, but also reveal that most actual subsidies go to firms that would have done R&D otherwise. In these firms, however, subsidies are found to enlarge expenses with no crowding out of private funds.

firms with high intensity in innovation projects. In addition, firms in KIS seem to be more sensitive to access to public funding than manufactures.

A firm's innovation decision is closely linked to belonging to a group of firms. At a given time, the support to develop innovations from a group of firms may have an ambiguous impact. On the one hand, it may exert a positive impact if it gives support to the firm but, on the other hand, it may reduce incentives or even limit the firm's capacity to innovate. Our results show differences at sectoral level. Firstly, there is a negative impact on manufacturers but not a significant impact on services. Secondly, there is a positive impact on KIS industries but this is not significant. It is likely that the complexity of developing innovations in service industries can only be applied under the umbrella of a group of firms.

TABLE 6.
Logit binomial estimation of the decision to innovate

	High-tech manufactures	**Low-tech manufactures**	**KIS**
Determinants to innovation			
Size (log.)	1.329 (0.204)*	1.846 (0.215)*	0.005 (0.198)
R&D per employee (log.)	0.334 (0.032)*	0.804 (0.068)*	0.072 (0.016)*
Group (dummy)	-0.681 (0.198)*	-0.119 (0.199)	0.327 (0.259)
Public support (dummy)	0.539 (0.208)*	0.530 (0.206)*	1.643 (0.275)*
Market Share (log.)	0.040 (2.167)	-6.304 (3.375)**	4.661 (2.472)***
Barriers to innovation			
Cost barriers	0.489 (0.188)*	3.327 (0.199)***	1.001 (0.294)*
Knowledge barriers	0.191 (0.178)	0.563 (0.199)*	0.128 (0.279)
Market barriers	-0.170 (0.178)	-0.476 (0.195)**	-0.476 (0.276)***
Constant	-3.355 (0.361)*	-4.669 (0.655)*	-3.367 (0.730)*
Sectorial dummies	YES	YES	YES
Number observations	1024	1.332	598
R^2	0.259	0.347	0.319

*Note: * statistical significant at one per cent, ** at five per cent, and *** at ten per cent.*
Note: Cost, knowledge and market barriers are dummies equal to 1 when the firm perceives barriers in all the items from each barrier.

Furthermore, the regressions underline the role of market determinants in the decision to innovate. Our results highlight important differences depending on the technological and knowledge intensity. KIS and low-tech manufacturers are rather sensitive to market share. Therefore, firm market share appears as a crucial determinant in decisions to innovate. However, the features of technological and knowledge regimes mean that the impact of both variables will be different. The impact of market share on low-tech manufacturers is negative whilst the impact on services is positive. Related to the positive impact on KIS, two arguments can be given. First, firms can develop innovation projects by using their higher market power. Second, the fact that firms are in a better market position gives them access to privileged market information, and as a consequence they are able to take advantage of this. Related to the negative impact on low-tech manufactures, the intrinsic sectoral characteristics may expel a negative impact and oblige to the firm to choose between capturing market economies of scale and investing in innovation.

Furthermore, the results show important differences at sectoral level related to the effect of innovation barriers, after controlling for firm size, R&D intensity, firm market share, belonging to a group and receiving public support. In general, cost barriers and knowledge barriers make the decision to innovate difficult, whilst market barriers adopt an ambiguous relationship. However, the sensitivity of firms to these barriers differs among sectors. In high-tech manufacturing industries main barriers are related to the cost of innovation projects and knowledge factors such as the difficulties in finding specialized workers establishing cooperative partners and getting access to innovation flows. Furthermore, firms in low-tech industries and services have a larger coefficient when measuring the impact of barriers on innovation.

In addition, market barriers have a positive impact engaging in the innovation process, especially in low-tech industries and services. Thus, this effect shows that market incentives are the most important barriers perceived by non-innovative firms. This agrees with the results in Table 5, given that non-innovative firms find large barriers in the market.

These results suggest that, in general, barriers to innovation related to cost, knowledge and market factors limit a firm's decision to innovate, and affect through different ways the firm's capacity to carry out systematic innovations. Finally, non-innovative firms perceive as obstacles to innovation those barriers related to market factors, such as a market dominated by incumbents, the uncertain evolution of demand and the low value of innovative effort in the market.

5. Barriers and innovation policies in SME

Regional governments are increasingly designing their own innovation policies. As Fritsch and Stephan (2005) state, the regionalization of innovation policies may have substantial advantages. The main reasons are, firstly, that innovative processes have a regional dimension, as underlined by the analyses of the geography of innovation (Audretsch, 1998). Secondly, innovation is a key element in growth and, therefore, it may be very important for fostering regional development. Finally, regional systems of innovation may behave very differently and innovation policy should be in relation to specific regional characteristics because there is no a single “best practice” for all territories (Tödtling and Trippi, 2005).

Although innovation policy should relate to regional characteristics, there are some criteria that should prevail in all public interventions promoting innovation. Today, policy makers increasingly recognize the relevance of solid economic arguments to design a stable framework for public intervention to promote innovative activity in the economy overall. However, policy makers need two essential elements to design a stable framework to promote innovative activity. Firstly, it is necessary to identify the reasons why the market does not provide agents with suitable incentives for the optimal amount of R&D and innovation. Secondly, having determined the existence of market failures, public intervention to stimulate firm investments in R&D and innovation is necessary, therefore, policy makers must analyze how government intervention corrects these market failures, what the expected effects are and also what the expected costs of public intervention are.

In the market failures associated with innovation activities we can distinguish three dimensions: first, those failures related to the difficulties that innovative firms find when appropriating all the returns related to their innovations, i.e. 'spillover failures'; second, those failures generated by the difficulties of innovative firms when finding the partners (collaborating companies, research public centers, technological transfers centers, universities, etc.),who can carry out their innovations (coordination and systemic failures); and finally, those failures related to the lack of information on the evolution of the market or prospective technological 'information failures'.

The CIS questionnaire provides information about obstacles to innovation and market failures. In this sense, the cost factors plow relates to ‘spillover failures', since the high cost of innovation projects and the difficulties in accessing external finances for innovation activities reflect the innovators’ limitations when taking control of the return derived from their

innovations. In addition knowledge factor plows are associated with two important limitations for innovators; on the one hand, the lack of qualified workers for the innovation programs and, on the other hand, the difficulties in finding partners for cooperative projects (coordination failures). Finally, the CIS questionnaire offers information about the market evolution and the innovators' lack of information; in this sense, the market factor plows relate to the gap produced by 'information failures'.

If public policies are to promote innovation activities, it is very important to know which barriers affect the majority of firms. Also it should be taken into account that barriers to innovation are not the same for each firm. Barriers may differ depending, for example, on the degree of innovativeness, the location or the size of the firm. As Mohnen and Röller (2005) state, the probability of becoming an innovator and the intensity of innovation are subject to different constraints and different innovation policies are needed. In a large sample of CIS they found that some obstacles in the propensity to innovate may act as substitutes, whereas obstacles in the intensity of innovation are complementary. For example, the lack of finance and the lack of opportunities to cooperate are complementary for the intensity to innovate but they may act as substitutes for the propensity to become an innovator. This situation demands an innovation policy designed according to which stage of innovation a company finds itself at. In other words, the innovation policy should consider if the firm begins to be an innovative company or starts to raise the intensity of innovative effort. An innovation policy to overcome these barriers may help firms to increase not only their innovative performance but also their absorption capacity, both of which are generally strongly related to each other.

Furthermore, barriers may be interdependent or reinforce each other (Galia and Legros, 2004). The design of public policies to promote firms' innovation activities should also consider both the importance of the barriers depending on the number of firms affected and whether obstacles to innovation are complementary or substitutive. The estimates have shown the influence of barriers in innovative performance, distinguishing between high-tech and low-tech industries and KIS. Also, other analyses (Mohnen and Rosa, 2002; Galia and Legros, 2004), show that innovators seem to face higher obstacles than non innovators.

A high percentage of firms say they face obstacles to innovation, therefore, to increase the efficiency of public policy it seems sensible to concentrate efforts on those barriers that are perceived as being highly important by firms and to concentrate on whether they are complementary or not. In this sense table 7 shows the importance of each barrier, defined as high by the firms, depending on the percentage of firms affected by it, and provides a simple discrete combination with the three factors considered here: cost, knowledge and market. If we

have three obstacles to innovation eight different combinations are possible, for example, 000, 100, 101,…, 001. Firstly, there are a large number of firms that do not consider barriers to innovation to be very high, particularly in the case of non-innovators. Secondly, the obstacles associated with the high costs of the development of innovations usually present a large degree of complementarity. Thirdly, there is a large number of innovative firms that consider the lack of their own resources, the lack of external funds to innovate and the cost of innovation as the main obstacles to increasing their innovating intensity.

In addition, the combination of cost factors and knowledge factors is very important. However, market factors appear as small obstacles in comparison to barriers related to the cost of innovation and the lack of qualified personnel and information on technology and markets.

Table 7
Complementarities of barriers to innovation (in percentage)

	000	**100**	**101**	**110**	**111**	**010**	**011**	**001**
All firms	40.52	24.41	1.46	21.12	5.59	5.62	0.51	0.78
Innovative firms	29.33	32.65	0.98	25.90	3.42	7.14	0.39	0.29
Non innovative firms	46.45	20.04	1.71	18.59	6.73	4.82	0.57	1.04
Source: IDESCAT and own elaboration								

The results are very important for designing policies to promote innovation. Promoting innovative activities by means of public grants for R&D activities or credits reduces private sector underinvestment in R&D and innovation. However, it is important to accompany these measures with others supporting the incorporation of qualified personnel, informational fluxes and the cooperation between firms and public institutions. In particular, direct actions to facilitate the incorporation of human capital in companies have multiple effects on the organizations, because they equip companies with their own resources to undertake innovation activities in technological areas (product and process innovation) as well as in those closely related to internal management and those related to surroundings (organizational and marketing innovation).

If we interpret the barriers in the CIS questionnaire depending on the market failures related to spillover, coordination and information failures, we can directly analyze the innovation policy in Catalonia. Since 2004 the regional government has had an active industrial policy to promote firms' R&D investment and innovation and to move towards a knowledge economy. This policy is being applied within the framework of the Research and Innovation Plan 2005-2008, which takes into account, for the first time in Catalonia, innovation and research and scientific policy

together. Innovation policy provides a range of specific interventions at regional government level, and these measures are integrated in a framework where the Spanish government and European Union play an important role. Both the Catalan regional government and also the Spanish government want to give more public resources to improve what have been poor results in R&D private investment and innovation up to now. The low effort of firms in R&D continues to be one of the main weak points of the Spanish and the Catalan systems of innovation. Although Catalonia is in a better position than Spain, the expenditures on R&D, 1.35% of gross domestic product (GDP) in 2005, are much lower than the 2.25% of the OECD countries.

The specific targets for innovation policy, as presented in the Research and Innovation Plan, are to foster entrepreneurial spirit and the creation of technology based enterprises, to promote the entry of researchers and qualified human capital into the private enterprise sector, to consolidate research, technology transfer and innovation systems and to augment the innovative capabilities of firms established in Catalonia. To achieve these objectives the measures that have been implemented are devoted to supporting firms' R&D spending and to promoting technology transfer between the agents of the Catalan research and innovation system. In particular, there are seven main actions, three designed to reduce the cost of innovation, two to promote technological transfer with a network of technological centers and increase the relationships between firms and universities, one to foster the creation of technology based on enterprises and finally one to help young researchers and technical workers find employment with the firms.

The effects of these actions on barriers to innovation are presented in Table 8. In accordance with the most significant barriers for Catalan firms, these actions are mainly oriented towards removing or at least reducing costs and knowledge barriers. Furthermore, some of these measures act simultaneously on cost and knowledge factors which, as has been shown, are frequently complementary.

Table 8.
Innovation programs and effect on barriers to innovation

	Cost factors	Knowledge Factors	Market factors	Orientation intervention
Grants for R&D	Yes	No	No	Manufacturing All firms
Credit support for R&D	Yes	No	No	Multisectorial All firms
Grants for cooperative R&D projects	Yes	Yes	No	Manufacturing All firms
Technological Support Centers	Yes	Yes	Yes	Manufacturing SME firms
Improved University-Firm relations (grants to subcontract R&D to universities)	Yes	Yes	No	Manufacturing SME firms
Seed fund and concept capital fund	Yes	No	No	Entrepreneurs, new technology based firms
Grant for incorporating researchers and technical employees	Yes	Yes	No	Manufacturing All firms

The Lisbon Agenda means that a modernization program must be designed to facilitate knowledge transfer between public institutions, especially universities and research centers, and firms. As a consequence, it is essential that Catalan firms and also Spanish firms see innovation as a driving force for competition in their markets. The innovation policy's objectives are to increase R&D expenditure and to ensure that, from the total amount invested in R&D activities, a third comes from public funds and the rest comes from the private sector. In Spain, Catalonia is currently the only region where firms reach this level. Nevertheless, to reach the average firm R&D expenditure level of the European Union will require a sustained effort. For this reason, it is essential to guarantee that Catalan innovation policy continues and that this policy is governed by such criteria as transparency, stability and getting a good social return when investing public funds. However, there are important gaps that should be reduced. For example, the access of service firms, especially knowledge-intensive services, to public funds is low. In order to increase the specialization of services in industry it is essential to design specific programs.

On the other hand, coordination between public interventions is limited. This situation is especially serious if we consider the complementarities that exist between the obstacles to innovation. In particular, cost barriers to innovation are related to knowledge barriers. For that reason the most important current steps designed to reduce spillover failures (grants for R&D, lowering of fiscal duties, fiscal credits) have to be complemented with steps designed to

improve firms' knowledge before starting innovation programs and to increase the number of new innovators.

6. Concluding remarks

The innovation process and in particular, the incentives and the effects of innovation have been widely analyzed. As a consequence, there is a wide range of literature addressing the relation between innovation and its impact. However, few contributions have focused on the barriers that innovative firms find. Based on empirical evidence from the Catalan CIS questionnaire, the present study has attempted to shed some light on the complex relationship between innovation and barriers to innovation found by Catalan manufacturing and service firms.

Our empirical analyses reveal a number of pronounced differences regarding the propensity to innovate and the perception of barriers. One main result of the empirical analysis is that a large percentage of innovative firms find barriers to starting innovation projects. In general, there tend to be more innovators than non-innovators who claim that there are barriers to innovation. Interestingly, among those non-innovators who say they find barriers to innovation, there are two different groups. On the one hand, there is a group of non-innovators which perceive lower barriers than innovators and, on the other hand, a group of non-innovators which perceive higher barriers than innovators.

Our analysis also shows that the barriers to innovation which seem to most affect the innovation process are cost and knowledge. The high cost, together with the difficulty in finding qualified workers and partners, seem to be the most important factors affecting innovation.

Moreover, there are very interesting sectoral differences in the way that firms react to barriers. Low-tech manufacturers and KIS seem to be more sensitive to changes in the perception of barriers. The decision to innovate is strongly and negatively associated with cost and knowledge barriers. Furthermore, a firm's market share shows a negative impact on low-tech manufacturers' innovation. One possible explanation is that in these sectors there is a trade-off between exploiting economies of scale and R&D and innovation projects. Conversely, the effect of market share on the decision to innovate in KIS is positive. This implies that market power and market information have an important role in favouring innovation.

Innovation is considered to be the key tool for increasing economic growth and, as a consequence, it is a government target. With the purpose of promoting innovation according to

regional characteristics, Catalonia has designed its own regional innovation policy. The main aim of Catalan innovation policy is to promote firms' innovation and knowledge transfer. However, the innovation process implies the existence of barriers which challenge the innovation process. For this reason, Catalan innovation policy also has to take into account barriers to innovation.

Moreover, these barriers may be interdependent or reinforce each other. The findings of this paper suggest that in Catalonia the most important obstacles are cost and knowledge while market factors seem to be less important. The evidence also is consistent with the complementarity effect. Specifically, cost and knowledge factors are highly complementary. Therefore, public policies should try to reduce spillover failures, systemic failures and lack of coordination. The measures implemented in Catalonia are designed to fulfill these objectives.

To increase innovation capacity it is necessary to work both on the demand and supply side in order to increase both private and public sector investment in innovation. Nevertheless, Catalan firms' efforts in R&D and innovation continue to be very weak. A sustained effort is needed to reach European Union levels. While our results show the need to improve coordination between the different steps (at different levels of government and in Catalan innovation and research policy), it is worth remembering that well-intended but badly designed policies can do more harm than good. As a consequence, the Catalan government should bear in mind that innovation policy is important, but it must also increase public policy efficiency.

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xreap@pcb.ub.es