Science and Public Policy, 36(6), July 2009, pages 457–467
DOI: 10.3152/030234209X460953; http://www.ingentaconnect.com/content/beech/spp

Public support to private innovation in multi-level governance systems: an empirical investigation

Andrea Fernández-Ribas

This paper explores the distinct distributive nature of innovation programs by government levels. The research setting is a European region actively involved in regional, national, and supra-national (EU)-level programs. The results suggest that sub-national programs lead to changes in firms' attitudes towards product and process innovation. The impacts of national and supra-national programs are different: nationally supported firms are more likely to accelerate their path towards product (but not to process) innovations; supra-national supported businesses gain in greater sales due to incremental innovative products. From a policy perspective, the results suggest that lower levels of government could alleviate entry barriers into technological activities while upper-level programs improve the economic performance of pre-existing innovators.

IN THE LAST DECADE the governance landscape of innovation policy has experienced deep changes in both Europe and the United States (Feldman and Link, 2001; Biegelbauer and Borrás, 2003; Shapira and Kuhlmann, 2003). A growing number of policy actors — from multiple policy levels and policy fields — are now involved in the design, development and implementation of science, technology and innovation policies. In Europe governance changes have been intensified by an increasing involvement of the European Union (EU) and a gradual expansion of regional level governments (Cooke *et al*, 2000; Borrás, 2003; Sanz-Menéndez and Cruz-Castro, 2005).[1] As a result of this process, the nature of public support to private innovation has also changed, becoming more diversified and consistent with a broader policy framework that encompasses regional, national, and international interests.

Following this trend, several scholars have studied the complex interactions that emerge between public-sector innovation programs (Schachtel and Feldman, 2000; Feldman *et al*, 2000; Bacaria *et al*, 2002; Ruegg and Feller, 2003; Kaiser, 2003; Van der Horst *et al*, 2006; Busom and Fernández-Ribas, 2007). Despite these advances, we still know little about whether programs of different levels of government offer an integrated range of public support to firms. Nor do we know enough about the impacts and distributive effects of programs: Are programs equally distributed across types of firms? Do they tend to narrow differences between advantaged and disadvantaged firms or is it more likely that they reinforce these differences? The goal of this paper is to explore these intriguing questions in the context of a European regional innovation system (RIS) involved in regional, national and supra-national (EU) innovation programs.

The empirical model is estimated using a large sample of manufacturing and service companies drawn from the Spanish version of the 4th Community

Andrea Fernández-Ribas is at the School of Public Policy, and also the Enterprise Innovation Institute, Georgia Institute of Technology, Atlanta GA 30332-0345, USA; E-mail: afribas@gatech.edu.

I gratefully acknowledge financial support from the Generalitat de Catalunya through grant FGENCAT2005/39702274. Thanks are also due to IDESCAT for providing the data. Valuable comments were received by participants in the International Workshop on New Directions for Innovation Measurement, Atlanta, May 2008: Stephen Roper, Wolfgang Sofka, Philip Shapira, Jan Youtie, Ken Voytek, Francisco Moris, Susana Borrás, and two anonymous referees.

 0302-3427/09/060457-11 US$12.00

Andrea Fernández-Ribas holds a teaching and research faculty position at the School of Public Policy and at the Enterprise Innovation Institute of the Georgia Institute of Technology. Her contributions are in the areas of organizational innovation, regional innovation, and globalization of science and technology. Her current research projects are about the role of emerging technologies in emerging markets, the global patent strategies of small and mid-size companies, and the decentralization of invention activities by multinational corporations.

Innovation Survey (2002–2004) in the region of Catalonia. Empirical findings show different selection mechanisms across programs. In accordance with theoretical predictions, participation in national and international pre-competitive programs is associated with scale economies and firms' capacity to generate codified knowledge. The determinants of participation in regional and locally supported programs are less clear, probably reflecting the broader scope of these programs.

Interestingly, when comparing supported firms with an adequate control group of non-supported firms, programs appear to have distinct distributive effects. Regionally supported programs increase the propensity that a firm becomes a product and process innovator; national programs lead to more product innovators. By contrast, supra-national programs do not show a change in a company's propensity to develop technological innovation. Participation in supra-national programs translates into a better commercialization performance, by increasing sales due to new-to-the-firm innovations.

The paper is organized as follows. The next section develops some hypotheses and the empirical framework. The third section reviews the data source and the characteristics of programs under study. The empirical results are presented in the fourth section. The paper concludes with some policy recommendations.

Analytical framework

Innovation governance structures have been continually evolving since the mid-1990s (Feldman and Link, 2001; Shapira and Kuhlmann, 2003). These changes can be attributed to several interconnected factors, including the influence of evolutionary and systemic approaches of innovation in the policy-making, the corresponding involvement of multiple policy actors in the innovation domain (Biegelbauer and Borrás, 2003), and the role of lower policy levels in fostering local linkages, learning across institutions, and knowledge diffusion (Morgan, 1997; Cooke *et al*, 2000). A key policy issue in this context concerns to the distribution of innovation policy competencies by levels of government. This paper addresses this question with respect to the allocation of public funding to the business sector.

Government support to private innovation in multi-level governance settings

Which level of government should support the conduct of private sector innovations? This question can be answered using the principles of fiscal federalism and the idea that each administration has 'different advantages' depending on the specific characteristics of the innovation process.[2] The following motives have been put forward to justify the involvement of upper-level administrations:[3]

Externalities Certain innovation activities generate significant cross-border externalities and spillovers. These include, for example, upstream technologies (such as genetic inventions or information and communication technologies), general purpose technologies, basic research and, in general, activities that generate many patents and publications. Since the outcomes of these activities produce broad-ranging economic benefits to a country or to the world, and are therefore not geographically constrained to a specific territory, local/regional administrations may act like private agents by providing sub-efficient levels of funding to firms.

Scale economies Often firms need a critical minimum amount of resources to make their research projects viable and efficient. To take advantage of scale economies and reduce the long-term average costs of their investments, firms need robust amounts of public money. Since it is likely that such investments encompass long time frames (either between discovery and development and/or between development and economic payoff), firms need to reduce associated uncertainties by employing a large number of scientists and inventors. Large administrations tend to have more financial resources, as well as more capacity to pool resources from different agencies.

Indivisibilities Sometimes there are parts of the research process that cannot be easily divided. This structural characteristic of innovation also leads to scale advantages and the need to use compact amounts of money, rather than atomistic funding structures. In this line of reasoning, some argue that a centralized provision of public funding can reduce the costs of collective decision-making, by reducing inefficiencies derived from excessive fragmentation of initiatives and duplicate policy efforts.

Intervention of lower levels of government responds to the following reasons.

Systemness Regional and local governments tend to have a better understanding of the formal and informal institutions that shape behavioral patterns and social interactions in the territory (Bacaria *et al*, 2002). As a result, these administrations have a greater capacity to correct systemic dysfunctions that may exist in an innovation system. Specifically, the advantage will be in supporting non-tradable innovation inputs that require geographical proximity (Coburn and Brown, 1998; Feldman and Kelley, 2002). Such inputs include, for example, inter-business linkages, local linkages between firms and universities, or linkages between firms and other innovation support institutions.[4] They may also refer to other forms of organizational capital such as channels that facilitate interdisciplinary research. Not surprisingly, many regional governments have been very active in launching technology transfer, commercialization and cluster initiatives.

Heterogeneity Sub-national governments have a greater capacity to tailor programs to local conditions. Their policy actions compensate for welfare losses that appear with the design and development of homogeneous national and international programs. Preferences for the type and amount of public funding can be substantial across regions. Demands may diverge due to the existence of marked structural cross-regional differences (e.g. industrial structure, or scientific and technological capabilities). They can also appear because of the different nature of political interests and preferences (e.g. governments and individuals in a region may prefer to devote public funding to environmental research, while in another region this may not be a policy priority).

Multiple formal mechanisms have been put into practice to achieve vertical policy coordination. In Europe, the Treaty of Maastrich (1992) established the ‘principle of subsidiarity’ as the common rule to distribute competencies across different levels of government. Accordingly, the highest government level should act only when action at the national and sub-national levels is insufficient. In science, technology and innovation, the action of upper-level governments is justified by the three factors explained above: cross-border externalities, indivisibilities and scale economies in the provision of public funding.

In 2000, in an effort to achieve more vertical coordination across innovation policies, the Lisbon Council adopted the ‘principle of reciprocal opening-up’ of national science and research programs, according to which governments agreed to share (with other member states and EU bodies) the progress of national innovation initiatives, as well as to participate in systematic evaluations of national innovation programs.

In science, technology and innovation, the action of upper-level governments is justified by cross-border externalities, indivisibilities and scale economies in the provision of public funding

Despite these efforts, there is a remarkable lack of empirical evidence about interdependencies and coordination between sub-national, national and supranational initiatives. The assessment of public support systems has focused on input and output additionality without generally distinguishing between types of programs (Feller, 2007).[5] Contradictory findings of these works suggest that in fact institutional differences across countries, regions, programs and industries should be taken into account when assessing the determinants and influence of public support. The *effectiveness* of public funding has been addressed indirectly (Schachtel and Feldman, 2000; Ruegg and Feller, 2003; Blanes and Busom, 2004; Van der Horst *et al*, 2006) and through in-depth case studies (Feldman *et al*, 2000; Bacaria *et al*, 2002; Kaiser, 2003).

Feldman and Kelley (2002), in an interesting case study about the role of US state programs in the development of technology pioneering firms, find that state support contributes to a great extent in complementing funds from the federally funded programs. Their results suggest that a major contribution of state support is on pooling multiple external funding sources (private and public) that firms need to innovate. State investments are found to be important determinants in the development of scientific and technological infrastructure of local universities. In a similar vein, Bozeman *et al* (in press) suggest that for the emerging field of nanotechnology, some states act as catalysts of venture capital to private firms.

Busom and Fernández-Ribas (2007), using a sample of Spanish firms, address the factors that shape participation in national and international R&D programs. Their results suggest that national R&D programs are oriented towards domestic firms with higher levels of human capital and greater capacity to patent abroad, while international research programs reach export-oriented firms. Drawing from these results, they conclude that no signs of program overlaps have occurred during the period under consideration. However, as they reckon, more empirical analysis is required to confirm whether or not such complementarities actually exist across programs.

Based on the above discussion one can formulate the general hypothesis that innovation programs implemented at different levels of government are likely to be heterogeneous with respect to targeted firms, selection mechanisms and intended/ unintended effects. Institutional differences between programs translate into distinct participants’ characteristics. The following hypotheses can be added:

- *Hypothesis 1* There is some degree of specialization across programs which is related to the relative advantages of each administration. National and supra-national programs are likely to target firms that engage in research activities that involve high technological and commercial risks as well as scale economies. Disadvantaged firms with limited access to higher government-level programs are more likely to receive support from regional and local-level programs.

- *Hypothesis 2* Innovation programs of different administrations are likely to have distinctive distributive effects across types of firms. Regional and local-level programs are more likely to narrow existing differences between technological and non-technological innovators. National and supra-national programs are likely to be less distributive than lower government-level programs. National and supra-national programs are more likely to improve the performance of firms which are already innovating.

Empirical model of interactions between programs

To test the proposed hypothesis empirically, I posit an econometric model that explains inter-firm differences in program participation determinants and their impacts. The model relates a series of *ex-ante* characteristics of participants and non-participants to the receipt (yes/no) of public financial support. The following equation is specified accordingly: $P_{ji}^* = X_{ji}b_{xj} + u_{ji,}$ where P_{ji}^* is the propensity that a sample firm *i* applies (and is awarded) in a particular innovation program *j*, and X_s is a vector of firm-related characteristics (these are explained in more detail in the next section). u_{ji} is a vector of potentially correlated error terms.

Three binary indicators are observed for the dependent variables of the model:

- $P_{1i} = 1$ if a firm participates in national-level innovation programs ($X_{1i}b_{xj} + u_{1i} > 0$);
- $P_{2i} = 1$ if a firm participates in sub-national innovation programs ($X_{2i}b_{xj} + u_{2i} > 0$);
- $P_{3i} = 1$ if a firm participates in supra-national level programs ($X_{3i}b_{xj} + u_{3i} > 0$).

Due to the different nature of supra-national programs as well as the possibility of distinguishing across programs with the dataset, two sub-types of supra-national programs are considered:

- $P_{31i} = 1$ if a firm participates in supra-national pre-competitive research programs;
- $P_{32i} = 1$ if a firm participates in other international programs, including programs focused on commercially viable innovations and restructuring actions.

Since multiple-program participation is possible, error terms are allowed to follow a three-variate normal distribution (ϕ_3) with mean vector 0 and covariance matrix with diagonal components equal to 1, and off-diagonal elements correlations to be estimated: $(u_{1i},u_{2i},u_{3i}) \sim\phi_3(0,1,\rho_{12},\rho_{13},\rho_{23})$ where $\rho_{\varphi\kappa}$ is the correlation coefficient between error terms u_j and u_k.

Impact differences across participants and non-participants are computed using nearest neighbor matching.[6] The average treatment effect on the treated (ATT) is computed as: $\tau_{ATT} = \Pr(Y_{ki} = 1|P_{ji} = 1) - \Pr(Y_{ki} = 0|P_{ji} = 1)$, where Y_{ki} is a set of innovation indicators that are assumed to be influenced — directly or indirectly — by public support programs. These include:

- Technological innovation: includes two discrete choice variables (yes/no) for the introduction of new goods and services in the market or in the company PDINNO, and the development of new methods for the production or supply of goods and services, PRINNO;
- Non-technological innovation: includes ORGINNO equaling 1 if a firm introduces new or significant changes in organizational innovation; MKINNO equaling 1 if a firm introduces marketing innovations;
- Innovation novelty: NOVMAR computed as the percentage of sales due to new-to-the-market products and services; NOVFIRM measured as the percentage of sales due to new-to-the-firm products and services. NOVMAR is related to more radical innovations and NOVFIRM to incremental innovations.[7]

Additionally, a series of measures is used to capture the impact of national and regional programs on businesses' connectivity:

- UDCOOP equals 1 if a firm cooperates in innovation with national universities;
- UINTCOOP equals 1 if a firm cooperates in innovation with international universities;
- DHOR equals 1 if a firm cooperates in innovation with domestic costumers and suppliers;
- INTHOR equals 1 if a firm cooperates with international costumers and suppliers;
- DVER equals 1 if a firm cooperates with domestic competitors;
- INTVER equals 1 if a firm cooperates with international competitors.[8]

Data source and programs overview

Data come from the fourth wave of the Spanish Community Innovation Survey (CIS). Overall the sample consists of 2,607 industrial and service firms with more than 10 employees, located in Catalonia, engaged in some sort of innovative activity (either product, process, organizational and/or marketing innovation) during 2002–2004.

Catalonia represents an excellent research setting to study existing interactions between national, regional and supra-national innovation programs.

Because of its long industrial tradition, the increasing number of export-oriented firms, and also the expanding foreign direct investment within the region, Catalan companies face increasing domestic and international competition. In such an economic environment, companies are (in principle) more likely to engage in some sort of innovation activity. In fact, there is evidence that Catalan firms have good success ratios in applying and receiving public support from national and international programs (Fernández-Ribas, 2003). Furthermore, Catalonia has the institutional and governance conditions to be considered a regional innovation system (Bacaria *et al*, 2004). Thus, in future, results and methodology can be extended to other RIS. Its semi-federal structure represents an interesting case study of interdependencies between national and regional governments.[9]

Program context

During the period under study (2002–2004), firms could apply to EU pre-competitive research programs such as the 5th (1998–2002) and the 6th (2003–2006) Framework Programs (FP). These programs funded research, technologies and processes that had not yet yielded any introduction of new innovations to the market. Firms could also receive support from other EU programs aimed at helping market-oriented and commercially viable innovations. These included, for example, multilateral public research and technology schemes (e.g. Eureka, Cost), as well as programs financed by the European Regional Development Funds (ERDF). Except for the programs that were explicitly designed to help less favored regions,[10] eligibility rules were similar for all EU-based firms, irrespective of where they originated.

The main distinctive trait of European programs referred to the establishment of partnerships with partners from at least two other European countries.[11] Some geographic bias could exist, however, in the application for EU funding and in the actual distribution of innovation funding across regions. This is due to cross-regional differences (e.g. different S&T capabilities), and to geographic location issues. Peripheral regions (such as Catalonia), and regions not very well integrated into international research networks, could be at a disadvantage for getting funding from these programs.

At the national level, several programs were specifically designed for helping firms to innovate, including the Program for the Promotion of Technical Research (PROFIT) (2000–2003).[12] CDTI implemented different kinds of projects within this context:[13]

1. Pre-competitive projects involving high technical and commercialization risks;
2. Projects aimed at introducing new or significantly new product or process in the market; and
3. Technological innovation projects aimed at introducing or improving emergent technologies in companies.

Except for pre-competitive projects which had to be developed in cooperation with universities and/or public research organizations, applied projects could or could not be done in collaboration with other organizations. Otherwise, calls for program participation were competitive across firms.

Regional initiatives focused on promoting a local market of technology, where users (companies) could subcontract technologies from producers (mostly universities).[14] Several programs were developed accordingly, including programs to improve technological transfer between industry and universities; programs to boost local links in microclusters; and programs to promote new technological infrastructures. In parallel, the regional administration continued to develop and execute initiatives to leverage national and international research funding, entrepreneurship, and the internationalization of the regional economy.

Determinants of participation innovation programs

Drawing on extant research, the following firm-related characteristics are selected as control variables in the structural model. To capture the influence of firm size, there are three binary variables:

- *Small* takes the value 1 if a firm has 0–49 employees;
- *Medium* equals 1 if a firm has 50–249 employees;
- *Large* equals 1 if a firm has more than 250 employees.

To control for differences between domestic and foreign-owned companies, the variable *Foreign* is included, taking the value 1 if foreign share in ownership is at least 50%.

Two variables are considered to capture the effect of codified knowledge:

- *Patents* equals 1 if a sample firm applied for national and/or international patents;
- *Other protection* equals 1 if a firm registered an industrial model, brand or copyright and did not apply for patents.

To capture the influence of tacit knowledge factors on the decision to apply and be selected for receipt of public support, two variables are considered:

- *In-house RD* is an indicator for whether or not a firm does creative work internally, on a continuous basis, to increase the stock of knowledge and its use to devise new and improved products and processes;
- *Training* is an indicator for whether or not a firm provides training on innovation to employees.

There is one variable designed to explore the impact of the perceived barriers to innovation: *major constraint* equals 1 if a sample firm reports that lack of funding, excessive costs and demand uncertainties for innovative goods or services are major barriers to innovation.

Finally, there are six specific dummies to capture differences across industries:

- *High tech* equals 1 if a firm operates in manufacturing sectors with high technological content;
- *Medium-high tech* includes manufacturing sectors with medium-high technological content;
- *Medium-low tech* includes manufacturing sectors with medium-low technological content;
- *Low tech* includes manufacturing sectors with low technological content;
- *High-know* includes services with high knowledge-intense content;
- *Low-know* includes services with low knowledge-intense content;
- *Science-based* includes science-based services (education and health sectors).

A detailed description of the industrial activities contained in each category is provided in Appendix 1.

Empirical findings

Table 1 shows the distribution of firms by types of programs. The national government is the most frequent source of public funding (20%) followed by the local and regional (13%) and the EU (5%). Receiving support from one single source is the most common practice among firms. Only 2% of firms combine regional, national and EU sources. Interestingly, participation in national and regional programs appears to be a precondition to have success at the EU level. About 63% of firms that benefit from EU programs participate in national programs, but only 17% of nationally supported firms participate in EU programs. Similarly, there are more participants in EU programs (42%) taking part in regional programs, than the other way around (18%). When crossing regional and national sources, there are more regionally supported firms accessing national programs (48%) than nationally supported firms receiving regional support (30%). Descriptive statistics are reported in Table 2. No apparent significant differences seem to emerge across firms participating in different programs.

Table 1. Mix of public support for innovation, 2002–2004

Type of support	Number of firms
Any support ($P_{ij} = 1$)	748 (29)
National support ($P_{1i} = 1$)	531 (20)
Regional support ($P_{2i} = 1$)	333 (13)
EU support ($P_{3i} = 1$)	142 (5)
National support only ($P_{1i} = 1$, $P_{2i} = 0$, $P_{3i} = 0$)	332 (13)
Regional support only ($P_{1i} = 0$, $P_{2i} = 1$, $P_{3i} = 0$)	165 (6)
EU support only ($P_{1i} = 0$, $P_{2i} = 0$, $P_{3i} = 1$)	43 (2)
National and regional support ($P_{1i} = 1$, $P_{2i} = 1$)	159 (6)
National and EU support ($P_{1i} = 1$, $P_{3i} = 1$)	90 (3)
Regional and EU support ($P_{1i} = 1$, $P_{2i} = 1$)	59 (2)
National, regional and EU ($P_{1i} = 1$, $P_{2i} = 1$, $P_{3i} = 1$)	50 (2)

Notes: Percentage in parenthesis, relative to total number of firms in the sample: 2,607
Regional also includes local support

Table 3 reports the estimated marginal effects of the multivariate probit model. The effect of firm size on the likelihood of participation is different across programs. Small and medium-sized firms are less likely to receive support from national and supra-national programs. Thus, in accordance with theory, evidence confirms that higher levels of government give financial support to businesses with greater capacity to develop large research and innovation projects that exhibit economies of scale. One would expect that regional programs were specifically targeting the smallest firms. However, firm size does not play a significant role in regional programs. A potential explanation here is that regional programs are broader in scope and therefore it is more difficult to find a homogenous participation pattern within the sampled firms. Participation in any program is more likely to be observed among non-foreign-owned companies. This might be because foreign companies are less likely to apply for funding, or because these firms prefer to apply for funding from their home country. However, another factor may be related to the participation rules of programs and the fact that domestic companies are favored.

A key characteristic of participants is firms' tacit knowledge in innovation practices. Firms with innovation experience, and firms that train employees to develop or introduce innovators, are more likely to apply for and be awarded financial assistance from any source. This result confirms the need of having internal capabilities to identify, apply, and use public funding.

The role of codified knowledge is somehow different across programs. Firms with experience in patenting are more likely to benefit from national and European pre-competitive programs. Firms using other forms of intellectual protection (copyrights, industrial brands, etc.) are more prone to participate in national programs. Intellectual property methods are not significant determinants of regional and other supra-national programs. A possible interpretation here is that physical proximity between regional agencies and firms mitigates the role of codified knowledge as informal signals. Another explanation is that sub-national programs are more sensitive to innovation while national and supra-national programs have a stronger focus in R&D. Finally, results can respond to the existing institutional differences in terms of intellectual property protection rules. Full sharing of R&D results (including patents) is a feature that is likely to influence a firm's decision to participate in national and European pre-competitive programs.

Table 2. Summary characteristics by types of program

Variable	National participants N = 531		Regional participants N = 333		EU participants N = 142		FP participants N = 89	
	Mean	**Std dev.**	**Mean**	**Std dev.**	**Mean**	**Std dev.**	**Mean**	**Std dev.**
Small	0.40	0.49	0.47	0.50	0.39	0.49	0.40	0.49
Medium	0.36	0.48	0.32	0.47	0.29	0.45	0.29	0.46
Large	0.24	0.43	0.20	0.40	0.32	0.47	0.30	0.46
Foreign	0.13	0.34	0.11	0.32	0.11	0.31	0.12	0.33
In-house RD	0.76	0.42	0.67	0.47	0.81	0.39	0.89	0.32
Training	0.63	0.48	0.59	0.49	0.71	0.45	0.73	0.45
Patents	0.35	0.48	0.32	0.47	0.37	0.49	0.40	0.49
Other protection	0.27	0.44	0.25	0.43	0.25	0.43	0.26	0.44
Major constraint	0.55	0.50	0.58	0.49	0.56	0.50	0.58	0.50
High-tech	0.23	0.42	0.18	0.38	0.14	0.35	0.15	0.36
Medium-high-tech	0.16	0.37	0.15	0.35	0.11	0.31	0.11	0.32
Medium-low-tech	0.11	0.32	0.11	0.31	0.03	0.17	0.04	0.21
Low tech	0.19	0.39	0.23	0.42	0.16	0.37	0.09	0.29
High know	0.23	0.42	0.24	0.43	0.44	0.50	0.54	0.50
Low know	0.05	0.21	0.06	0.24	0.07	0.26	0.06	0.23
Science-based	0.02	0.13	0.03	0.17	0.04	0.18	0.01	0.11

The finding for European non-pre-competitive programs could be explained by the less formal nature of innovation of applicants. Interestingly, firms with major limitations to innovate are more likely to participate in regional and local programs. By contrast, estimates for national and EU programs do not show a significant effect.

Sector dummies point to differences across programs. National and international (pre-competitive) programs appear to be attractive to firms in high-knowledge content services (e.g. IT, R&D, and telecommunications). In contrast, regional programs do not appear to be targeted to this sector. This is a puzzling result as regional development often

Table 3. Propensity to participate in national, regional and EU programs, multivariate probit, marginal effects

	National level $Pr(P_{1i})$			Regional/local level $Pr(P_{2i})$			EU level $Pr(P_{3i})$			EU pre-competitive level $Pr(P_{31i})$			EU pre-commerical level $Pr(P_{32i})$		
	Marg. eff.	**Std. error**		**Marg. eff.**	**Std. error**		**Marg. eff.**	**Std. error**		**Marg. eff.**	**Std. error**		**Marg. eff.**	**Std. error**	
Small	–0.09	0.02	***	–0.01	0.02		–0.03	–0.03	***	–0.01	0.01	**	–0.01	0.01	**
Medium	–0.04	0.02	***	–0.01	0.02		–0.02	–0.02	***	–0.01	0.004	**	–0.01	0.01	**
Foreign	–0.07	0.02	***	–0.03	0.02	**	–0.02	–0.021	***	–0.01	0.004		–0.01	0.01	**
Patents	0.07	0.04	***	0.03	0.03		0.04	0.043	**	0.02	0.01	**	0.01	0.01	
Other protection	0.07	0.04	**	0.06	0.04		–0.01	–0.008		0.004	0.01		0.001	0.01	
In-house R&D	0.16	0.02	***	0.07	0.01	***	0.04	0.041	***	0.03	0.01	***	0.01	0.01	**
Training	0.06	0.02	***	0.03	0.01	**	0.02	0.021	***	0.01	0.004	***	0.01	0.01	**
Major constrain	0.02	0.02		0.02	0.01	*	0.003	0.003		0.002	0.004		0.001	0.01	
High tech	0.04	0.03		–0.03	0.02	*	–0.01	–0.011		0.01	0.01		–0.01	0.01	**
Medium-high tech	–0.01	0.02		–0.04	0.02	**	–0.01	–0.014	*	0.004	0.01		–0.01	0.01	**
Medium-low tech	0.01	0.03		–0.03	0.02	*	–0.03	–0.029	***	–0.001	0.01		0.002	0.01	
High know	0.07	0.03	***	0.02	0.02		0.06	0.057	***	0.07	0.02	***	–0.01	0.01	
Low know	–0.07	0.03	***	–0.05	0.02	***	0.003	0.003		0.01	0.01		0.01	0.02	
Science-based	–0.04	0.05		0.02	0.05		0.02	0.019		0	0.02		0.001	0.01	
Y=1	531			333			142			89			53		
Log likelihood function	–2,479									–2,351			–2,288		
Wald chi^2 (42)	428.7		***							418.6	***			360.7	***
Correlation terms															
Rho (1,2)	0.38	0.04	***							0.38	0.04	***	0.23	0.04	***
Rho (1,3) [(1,4) (1,5)]	0.43	0.05	***							0.46	0.06	***	0.18	0.07	***
Rho (2,3) [(2,4) (2,5)]	0.38	0.05	***							0.28	0.06	***	0.42	0.07	***
LR chi2 (3) of rho12=rho13=rho23 =0	185.79		***							135.12		***	108.5		***

Notes: *** denotes significance at 1% level; ** at 5% level; * at 10% level
Conditional probabilities are available upon request

Table 4. Average treatment effects on participants

	National level Pr(P_{1i})			Regional/local level Pr(P_{2i})			EU level Pr(P_{3i})			EU level pre-competitive Pr(P_{31i})			EU level pre-commercial Pr(P_{32i})		
	ATT	Std error		ATT	Std error		ATT	Std error		ATT	Std error		ATT	Std error	
PDINNO	0.05	0.02	**	0.08	0.03	***	0.06	0.04		0.04	0.05		0.08	0.06	
PRINNO	0.02	0.03		0.05	0.03	**	–0.01	0.04		–0.05	0.06		0.06	0.06	
ORGINNO	0.01	0.03		0.001	0.03		0.02	0.04		0.00	0.06		0.05	0.07	
MKINNO	0.01	0.03		0.001	0.03		–0.07	0.05		–0.05	0.06		–0.11	0.08	
NOVMAR	0.02	0.01		0.02	0.01		0.04	0.03		0.04	0.04		0.04	0.04	
NOVFIRM	0.004	0.02		0.01	0.02		0.08	0.03	***	0.05	0.04		0.13	0.05	***
UDCOOP	0.16	0.02	***	0.15	0.03	***									
UINTCOOP	0.16	0.02	***	0.15	0.03	***									
DHOR	0.05	0.02	***	0.05	0.02	***									
INTHOR	0.04	0.01	***	0.06	0.02	***									
DVER	0.05	0.01	***	0.05	0.01	***									
INTVER	0.07	0.02	***	0.034	0.021										
Observations Y = 1	531			333			142			89			53		

Note: *** denotes significance at 1% level; ** at 5% level

depends on the existence of specialized knowledge and technology-intense services.

Table 4 reports the average treatment effect of each program on the selected set of impact measures. Results indicate that participants in national and regional programs are more likely to become product innovators. Regional public support is also positively associated with process innovation. The influence of supra-national programs on the conduct of technological innovation is statistically insignificant. The impact on soft forms of innovation — adoption of organizational structures and marketing strategic innovation — is not found to be significantly affected by any program. Results on novelty measures show that participants in supra-national pre-commercial programs have larger sales due to new-to-the-firm innovations. However, no significant positive effects are found in other programs and in regards to new-to-the-market innovations.[15]

Another interesting finding refers to connectivity measures. Participation in national and regional programs increases the probability that firms collaborate in innovation with universities by 15–16 points. Other asymmetric forms of collaboration, such as partnerships with national and international customers and suppliers, also increase because of public support. Symmetrical partnerships with domestic competitors are positively affected by national and regional programs. Unfortunately with the current database it is not possible to know whether domestic partners are located in the same region. Consequently, it is not possible to know whether regional and local governments have an advantage in fostering local linkages. However, results do suggest that national and regional governments are well positioned to encourage organizational and systemic distributive changes in the development of cooperation agreements with national and international partnership.

Concluding remarks

Few empirical attempts have been made to understand the rationale and effects of innovation programs by policy levels (Vonortas *et al*, 2007; Laranja *et al*, 2008). This paper extends previous qualitative and quantitative work by investigating and testing the distinct distributive impacts of innovation programs on firms' behavior. Drawing on CIS data, the paper focuses on three questions:

- How firm characteristics influence the propensity to participate in innovation support programs at different levels;
- How different programs affect firms' choices to become innovators and collaborators in innovation; and
- How sales of innovative products change because of participation in each program.

The findings are the following. First, firms that train employees and engage in creative work internally on a continuous basis are more likely to receive support from any program. Participation in regional programs is more likely to be observed among domestic-owned firms facing major obstacles to innovate. Participants in national and pre-competitive international programs are more likely to be found within domestic firms with patenting experience, as well as in firms operating in high-knowledge content industries; in contrast, small and medium-sized firms are less likely to participate in these programs. Firms that protect their proprietary knowledge and technologies with other methods (e.g. industrial brands, copyrights) are more likely to participate in national-level programs; but this factor does not seem to affect the propensity to receive support from European programs. These results may suggest that tacit knowledge in innovation is a necessary, but not sufficient condition, to receive financial assistance from upper-level agencies. Some kind of codified knowledge is needed to access national and European pre-competitive support. Intangible assets in the form of patents appear to be stronger informational signals than other intellectual property methods.

Second, receiving public support from domestic sources increases the likelihood that firms cooperate in innovation with both national and international partners. The probability that firms collaborate with domestic and international academic organizations increases by 16 points when the assistance comes from national sources and 15 points when it is regional. Horizontal and vertical cooperation also increase because of government intervention, but to a lesser extent. These results demonstrate the corrective and integrative nature of domestic programs in fostering links among agents that have difficulties in collaborating by themselves. They are in line with recent work on behavioral additionality (Busom and Fernández-Ribas, 2008).

Third, national and regional programs increase the probability that firms develop product innovations. Regional programs additionally leverage changes in process innovation. By contrast, international programs don't appear to trigger a change in the probability that private businesses do technological innovations. Pre-competitive supra-national participants have more sales due to incremental innovations.

Policy implications are multiple. First, given the wide variety of firms that generally co-exist in a territory (highly innovative, less innovative, imitators, non-innovative …) it becomes fundamental to set up an integrative public support system that includes (and does not exclude) less advantaged businesses. Second, understanding what programs exist at multiple levels and how they can interact in a complementary way, in the sense that inefficient overlaps are reduced and synergies across programs increased, is necessary to achieve a well-articulated and more-equitable support scheme.

Despite the fact that innovation is now recognized as a complex, social and non-lineal process, and despite the multiple efforts made in the EU (and elsewhere) to increase policy coherence and coordination across levels of government, the evaluation of public-sector research programs has not yet been analyzed with a systemic lens (Feller, 2007). There are several important challenges in this regard. One is to change our attitude on how we approach public support in multiple-level governance settings. Another is to develop a next-generation of concepts and metrics to better understand, intended and unintended, direct and indirect, effects of multiple-level programs on the multiple stages of the innovation process.

Appendix 1. Classification of economic activities by technology and knowledge content

	NACE
High tech	
Chemicals	24
Office and computing machinery	30
Radio, TV and communication	32
Precision instruments	33
Medium-high tech	
Electrical machinery	31
Automobiles	34
Other transport equipment	35
Machinery and equipment	29
Medium-low tech	
Rubber and plastic	25
Other non-metallic mineral products	26
Basic metals	27
Metal products	28
Low-tech tech	
Food, beverages and tobacco products	15+16
Textiles, wearing apparel, leather and footwear	17+18+19
Wood, pulp, paper, printing and publishing	20+21+22
Furniture and recycling	36+37
High knowledge content	
Post and telecommunications	64
Financing	65
Insurances	66
Activities auxiliary to financing	67
IT activities	72
Research and development	73
Other business activities	74
Low knowledge content	
Sale, repair motor vehicles	50
Gross sale	51
Retail trade	52
Hotels and restaurants	55
Land, water, air transport	60+61+62
Travel agencies	63
Science-based services	
Education	80
Health and social work	85

Source: Author's elaboration, based on OECD (2003)

Notes

1. In the USA, the expansion of regional policies has also been documented (Shapira, 2005). Despite the majority of US states have limited financial resources, a growing number of states are taking leading roles in some research areas and emerging technologies. See, for example, Bozeman *et al* (in press), and Levine (2006) for an interesting work on state funding of stem-cell research.
2. A review of these principles can be found in Oates (1998).
3. These arguments are rather similar to those used in the literature to explain the insufficient engagement of the private sector in research and technology activities (Laranja *et al*, 2008).
4. The effect of domestic programs on firms' collaborative behavior can be particularly significant when partnerships are characterized by substantial market failures (e.g. public–private partnerships) (Busom and Fernández-Ribas, 2008). National and regional programs can induce (directly or indirectly) a significant change in the internationalization and cooperative patterns of companies (Fernández-Ribas and Shapira, 2009).

5. See, for example, analyses on impacts in private R&D spending (Lerner, 1999; Wallsten, 2000; Feldman and Kelley, 2003), patent capacity (Zucker and Darby, 2003), and labor productivity (Jarmin, 1999).
6. This method has become standard in the evaluation literature. Recent examples include: Duguet (2004), Busom and Fernández-Ribas (2008), González and Pazó (2008) and Fernández-Ribas and Shapira (2008). The idea is to construct a comparable counterfactual of non-supported firms, controlling for a set of observable characteristics that affect participation and non-participation, without assuming an structural specification. By comparing supported firms with an adequate group of non-supported firms, one can obtain an estimate of the average program effect on the supported firms.
7. The Spanish version of the Community Innovation Survey (CIS) defines product innovation as the market introduction of a new (or significantly improved) good or service. The definition of process innovation is the use of new or significantly improved methods for the production or supply of goods and services. In both cases, the innovation must be new to the firm, but it does not need to be new to the company's market. Organizational innovation is defined as new or significant changes in firm structure, and knowledge management methods. Marketing innovation is defined as new or significant changes in design, packaging, or distribution methods.
8. As supranational programs typically require the establishment of partnerships, cooperation metrics are not considered for international programs. In the Spanish CIS, cooperation in innovation implies active participation in joint innovation projects (including R&D) with other organizations. Contracting-out of research activities is not regarded as active cooperation.
9. Despite the fact that both the Spanish Constitution and the Science Law (1986) foresee that the state has exclusive policy competencies in the domain of S&T promotion, regional governments have increasingly gained legal competencies in innovation promotion through laws and regional innovation plans (Olazaran and Gómez Uranga, 2001). Innovation competencies have become 'concurrent competencies'. Each administrative level has its own policy and programs, which it funds with its own resources, and then coordinates with other administrations.
10. This includes e.g. Objective 1 regions under the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund. Firms located in Catalonia were not eligible under the Objective 1 Program but could benefit from an Objective 2 Program.
11. One exception to this rule was ERDF programs.
12. These programs were developed within the framework of the 4th National R&D Plan (2000–2003) and the 5th Plan for R&D and Technological Innovation (2004–2007).
13. CDTI is the national agency in charge of granting research and innovation funding to firms.
14. These initiatives were developed under the second regional innovation plan (2001–2004), and were managed by CIDEM, the regional agency responsible for executing business-oriented programs.
15. Due to the cross-sectional nature of the data, some caution is needed in interpreting this result.

References

Bacaria, J, S Borrás and A Fernández-Ribas 2002. Public action and innovation-support institutions in new technological agglomerations: the case of the Vallès Occidental County. *European Urban and Regional Studies*, **9**(4), 283–296.

Bacaria, J, S Borrás and A Fernández-Ribas 2004. The changing institutional structure and performance of the Catalan Innovation System. In *Regional Innovation Systems: the Role of Governances in a Globalized World*, 2nd edn, eds. H-J Braczyk, P Cooke and M. Heidenreich, pp. 63–90. London: Taylor & Francis.

Biegelbauer, P S and S Borrás eds. 2003. *Innovation Policies in Europe and the US: the New Agenda*. Burlington, VT: Ashgate.

Blanes, J V and I Busom 2004. Who participates in R&D subsidy programs? The case of Spanish manufacturing firms. *Research Policy*, **33**(10), pp. 1459–1476.

Borrás, S 2003. *The Innovation Policy of the EU: From Government to Governance*. Cheltenham: Edward Elgar.

Bozeman, B, J Hardin and A N Link (in press). *Barriers to the Diffusion of Nanotechnology. Economics of Innovation and New Technology*.

Busom, I and A Fernández-Ribas 2007. Do R&D programs of different government levels overlap in the European Union? Working paper series, Instituto de Estudios Fiscales, Ministerio de Economía y Hacienda, Nb. 29.

Busom, I and A Fernández-Ribas 2008. The impact of participation in R&D programs on R&D partnerships. *Research Policy*, **37**(2), 240–257.

Coburn, C M and D M Brown 1998. State governments: partners in innovation. In *Investing in Innovation*, eds. L M Branscomb and J H Keller. Cambridge: MIT Press.

Cooke, P, P Boekholt and F Tödtling 2000. *The Governance of Innovation in Europe*. London/New York: Pinter.

Duguet, E 2004. Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non-experimental data. *Revue d'Economie Politique*, **114**(2), 263–292.

Feldman, M and A Link eds. 2001. *Innovation Policy in the Knowledge Based Economy*. Norwell, Massachusetts, USA: Kluwer Academy Press.

Feldman, M P and M R Kelley 2002. How states augment the capabilities of technology-pioneering firms. *Growth and Change*, **33**(2), 173–195.

Feldman, M P and M R Kelley 2003. Leveraging research and development: assessing the impact of the U.S. Advanced Technology Program. *Small Business Economics*, **20**(2), 153–165.

Feldman, M P, M R Kelley, J Schaff and G Farkas 2000. *Reinforcing Interactions between the Advanced Technology Program and State Technology Programs*, vol. 2. National Institute of Standards and Technology. NISTIR 6523.

Feller, I 2007. Mapping the frontiers of evaluation of public-sector R&D programs. *Science & Public Policy*, **34**(10), December, 681–690.

Fernández-Ribas, A 2003. El model d'innovació català. In *Documents de Reflexió Estratègica, Pla Governamental CAT21*, Departament de la Presidència, Generalitat de Catalunya, núm. 6-1.

Fernández-Ribas, A and P Shapira 2009. The role of national innovation programs in stimulating international cooperation in innovation. *International Journal of Technology Management*, **48**(4), 473–498.

González, X and C Pazó 2008. Do public subsidies stimulate private R&D spending? *Research Policy*, **37**(3), 371–389.

Jarmin, R S 1999. Evaluating the impact of manufacturing extension on productivity growth. *Journal of Policy Analysis and Management*, **18**(1), 99–119.

Kaiser, R 2003. Multi-level science policy and regional innovation: the case of the Munich cluster for pharmaceutical biotechnology. *European Planning Studies*, **11**(7), 841–857.

Laranja, M, E Uyarra and K Flanagan 2008. Policies for science, technology and innovation: translating rationales into regional policies in a multi-level setting. *Research Policy*, *37*, 823–835.

Lerner, J 1999. The government as venture capitalist: the long-run impact of the SBIR program. *Journal of Business*, **72**(3), 285–318.

Levine, A 2006. *States and Stem Cells: The Policy and Economic Implications of State-Funded Stem Cell Research*. Princeton University, NJ: Policy Research Institute for the Region.

Morgan, K 1997. The learning region: institutions, innovation and regional renewal. *Regional Studies*, 1360-0591, **3**(5), 491–503.

Oates, W E ed. 1998. The Economics of Fiscal Federalism and Local Finance. Cheltenham, UK: Edward Elgar.

Olazaran, M and M Gómez Uranga eds. 2001. Sistemas regionales de innovación. Editorial. Universidad del País Vasco.

Ruegg, R and I Feller 2003. A toolkit for evaluating public R&D investment models, methods, and findings from ATP's first decade. National Institute of Standards and Technology.

Sanz-Menéndez, L and L Cruz-Castro 2005. Explaining the science and technology policies of regional governments. *Regional Studies*, **39**(7), 939–954.

Schachtel, M R B and M P Feldman 2000. *Reinforcing Interactions between the Advanced Technology Program and State Technology Programs*, vol. 1. National Institute of Standards and Technology. NIST GCR 00-788.

Shapira, P 2005. Innovation challenges and strategies in catch-up regions. In *Rethinking Regional Innovation and Change*, eds. G Fuchs and P Shapira. New York, USA: Springer.

Shapira, P and S Kuhlman eds. 2003. *Learning from Science and Technology Policy Evaluation: Experiences in the United States and Europe*. Cheltenham, UK: Edward Elgar.

Van der Horst, A, A Lejour and B Straathof 2006. Innovation policy: Europe or the member states? CPB Document N. 132.

Vonortas, N S, M Stampfer and K Zinöcker 2007. Evidence never lies. Introduction to a special issue on New Frontiers in Evaluation. *Science and Public Policy*, **34**(10), December, 679–680.

Wallsten, S 2000. The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research program. *RAND Journal of Economics*, **31**, 82–100.

Zucker, L G and M R Darby 2003. Measuring success of advanced technology program participation using archival data. NBER Working Paper.