The effectiveness of regional, national and EU support for innovation in the UK and Spain

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ABSTRACT

Innovation policy aims to stimulate innovation and hence firm-level productivity and growth. Here, we use data from the national innovation panel surveys in the UK and Spain over the 2004 to 2012 period to explore the effectiveness of regional, national and EU innovation support in promoting the extent of innovation activity, its novelty, and market success. Allowing for potential selection effects, our results suggest that regionalised support is most influential in increasing the probability of undertaking both process and organisational innovations. For both the UK and Spain, national innovation support is associated with a higher probability of product or service innovation, and the degree of novelty of product or service innovations. In terms of innovation success (sales) we see a rather different pattern in the UK and Spain. In the UK only regionalised support is associated with increased innovative sales. In Spain, innovative sales are influenced by both regional, national and EU support measures. Our results suggest that moves towards more centralised innovation policy in the UK since 2012 may reinforce a focus on leading edge, novel product and service innovation while placing less emphasis on broadly based process and organizational innovation.

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Keywords: Innovation, policy, Spain, UK

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1. INTRODUCTION

Innovation policy typically aims to stimulate innovation and hence firm-level productivity and growth. Here, we use data from the national innovation panel surveys in the UK and Spain over the 2004 to 2012 period to explore the effectiveness of regional, national and EU innovation support in promoting the extent of innovation activity, its novelty, and market success. The comparison of the UK and Spain is particularly interesting given the very different levels of engagement of the public sector in the innovation system in the two countries, the greater regionalisation of innovation support in Spain (Mate-Sanchez-Val and Harris 2014), and other aspects of the business environment in the two countries such as regulation (Capelleras et al. 2008).

In both countries the most common type of policy interventions are grants or subsidies which reduce the cost and risk of undertaking innovation. Our study adds to the existing literature on the effectiveness of such supports with one recent review, which considered the results of 77 studies of the relationship between subsidies and R&D spend, concluding that 'approximately 60 per cent of the studies find that public subsidies are complementary and thus add to private R&D investment' (Zuniga-Vicente et al. 2014, p.38). This positive result in the evidence on R&D and innovation policy effects is reflected in other recent evidence reviews (What Works Centre for Local Growth, 2015). We extend the existing literature on the effectiveness of innovation policy measures in three main areas. First, using a two stage modelling approach we are able to examine simultaneously the effects of firms' receipt of policy support from different sources (i.e. region, nation and EU) and identify the relative effectiveness of each type of support. Second, by considering policy effects at both the extensive and intensive margin (i.e. the percentage of innovating firms and the percentage of innovative sales) we are able to identify which types of support impact most strongly on different innovation outcomes. And, finally, our comparative analysis provides insights into the effects of two very different innovation support regimes, and a robustness check on the effectiveness of each type of innovation support.

Our empirical analysis relates to the period 2004 to 2012, covering five waves of the UK Innovation Survey and Spanish PITEC. In England, this was a period during which the shape of innovation policy was largely determined nationally but implementation, particularly in terms of support for SMEs, was operated through the Regional Development Agencies. In other areas of the UK (Wales, Scotland and Northern Ireland) both policy and implementation were regional. Our results provide strong evidence of the differential effects of regional and national support and shed some light on the potential implications of the centralisation of UK innovation policy which has occurred since 2012 and the closure of the Regional Development Agencies (RDAs).

The study proceeds as follows. In Section 2 we provide an overview of the main justification for public support for R&D and innovation and for the contrasting impacts of regional and national support. This relates both to potential contrasts in the objectives of regional and national innovation policy, and inefficiencies introduced into the allocation of policy resources in a regional allocation system. Section 3 provides an overview of public support for innovation in the UK and Spain, emphasising the greater extent of public engagement in the innovation system in Spain, stronger Spanish regionalisation and the stronger barriers to innovation perceived by Spanish firms. Section 4 deals with data and estimation methods, and Section 5 presents our main empirical results. Section 6 concludes.

2. PUBLIC INTERVENTION TO SUPPORT R&D AND INNOVATION

R&D and innovation have well recognised social and private benefits (Mohnen 1996; Ceh 2009). Market failures related to firms' inability to appropriate the full value of these benefits have long been used to justify corrective public interventions to support firms' R&D and innovation investments (Arrow 1962; Rigby and Ramlogan 2013). For example, one market failure which has been much discussed in the research literature, and which is repeatedly emphasised in surveys of innovative activity, is a lack of finance for innovation. Classical finance theory suggests that in perfect capital markets with no asymmetric information, investment decisions will not be dependent on capital structure (Modigliani and Miller 1958). In practice, however, 'information problems, skewed and highly uncertain returns, and lack of collateral value likely make debt a poor substitute for equity finance' and make funding innovation difficult (Brown, Fazzari, and Petersen 2009, p. 152). Credit constraints for innovation may reduce the average level of innovative activity at firm level (Savignac 2008; Hottenrott and Peters 2012; Alvarez and Crespi 2015) but may also change the nature of the innovation firms undertake, away from more experimental, radical innovations to incremental and sustaining innovations (Nanda and Nicholas 2014). Financial barriers may also increase the likelihood of failure or the abandonment of innovative projects (Segarra, Garcıa-Quevedo, and Teruel 2013)[1]. Such effects seem likely to be stronger for newer or smaller firms (Alvarez and Crespi 2015).

The ability of public investments in innovation to correct this type of market failure depends crucially on the allocation of support across firms. Where innovation support is allocated through a competitive process or peer or technical review it is likely to be concentrated in the strongest companies, or at least those with the strongest innovation projects[2]. Indeed, previous studies have identified eight factors linked to the receipt of public support for innovation. First, some hysteresis is evident in firms' receipt of public innovation support, hence 'a firm whose R&D activity was subsidised in the past is *more likely* to be subsidised again' (Zuniga-Vicente et al. 2014, p. 54). This may reflect firms' awareness of the availability of public support, the commercial advantages of previous success in obtaining funding or a choice by public agencies to support firms with particular characteristics which remain the same through time and therefore lead to repeated support.

[1] Mohnen, P., Palm, F. C., Van Der Loeff, S. S., & Tiwari, A .(2008). Financial constraints and other obstacles: Are they a threat to innovation activity? *De Economist*, 156, 201–214.
Segarra, A., Garcıa-Quevedo, J.,and Teruel, M. (2013). Financial constraints and the failure of innovation projects. Universitat Rovira i Virgili, wp 06-2013.
[2] This type of selection criteria may maximise scheme additionality (Hottenrott and Lopes-Bento 2014) but may also reinforce rather than reduce regional disparities.

Second, financially constrained firms are more likely to use public funding, often to fund riskier projects (Zuniga-Vicente et al. 2014, p. 56), with smaller or younger firms generally thought to face stronger liquidity or financial constraints (Ali-Yrkk¨o 2005; Mina, Lahr, and Hughes 2013), and some evidence suggesting that for small firms financing constraints are positively associated with the likelihood of receiving a subsidy (e.g. Busom, Corchuelo and Marti´nez, 2014). Third, firms which have a history of patenting are more likely to receive/seek public support (Aerts and Schmidt 2008; Czarnitzki and Lopes-Bento 2013).[3] And, fourth, firms which are exporters are also more likely to receive public support for R&D and innovation. The mechanism through which patenting and exporting influence the probability of receiving public support for innovation remains ambiguous, however. Both indicators may be acting as quality signals, increasing firms' ability to attract public support. Or, the resource cost of engaging in patenting and exporting may be encouraging firms to seek additional financial resources. Fifth, firm size also matters although the evidence on this is ambiguous reflecting both selection criteria (which might be biased towards smaller firms) and larger firms' greater propensity to undertake innovation (Aerts and Schmidt 2008; Czarnitzki and Lopes-Bento 2013)[4]. Sixth, foreign-owned firms are less likely to receive public support (Aerts and Schmidt 2008; Czarnitzki and Lopes-Bento 2013) but there is some evidence that firms which are part of a wider enterprise group are more likely to receive public support (Karhunen and Huovari 2015). Finally, there is some evidence that the presence of R&D staff within an enterprise is also linked positively to the receipt of subsidies in smaller Finnish firms (Karhunen and Huovari 2015).

Compounding these firm-level influences, broader structural factors linked to both sectors and geography may also influence the probability that firms will

[3] Conversely, there is some evidence that receipt of public support can increase the number of patent applications by subsidised firms, especially for smaller firms (Bronzini and Piselli, 2016).
[4] Tax incentives for R&D and innovation seem less sensitive to firm characteristics with take-up having less relationship to age or firm size (Radas et al. 2015).

seek and receive public innovation support[5]. For example, there is some evidence that R&D subsidies are more effective in low-tech industry sectors (Gonz´alez and Paz´o 2008; Becker and Hall 2013). R&D subsidies may also have a disproportionately large effect on the R&D spending of firms in industries facing significant capital market limitations (Hyytinen and Toivanen 2005). Other studies suggest the importance of distinguishing between the differential benefits of public intervention to support 'R' and 'D' with some studies indicating higher levels of additionality from subsidies for more basic R&D activities (Czarnitzki, Hottenrott, and Thorwarth 2011; Clausen 2007). Sectors' appropriability regime may also be important in terms of encouraging co-operative models of innovation with implications for the demand for innovative finance. Where, for example, the patent system is effective, and intellectual property regimes are transparent, co-operation is more likely reducing the financing cost to any individual enterprise (Becker 2015).

The structure of the mechanisms through which public innovation support is allocated may also influence the extent of additionality or social benefit achieved. Where strong firms or projects are uniformly distributed across regions, for example, national and regional schemes are likely to be available to the same pool of companies. However, where the distribution of stronger firms is uneven across regions, local eligibility criteria are likely to mean that competition for support is stronger in some regions than others, leading to a potential misallocation of support.[6] Equity consideration between regions may be another mechanism which leads to a misallocation of public support. To illustrate consider Figure 1 in which, following Haapanen, Lenihan, and Mariani (2014), we represent the marginal benefits of innovation and cost of

[5] Geographical factors may also be important in shaping how firms innovate, particularly in terms of their willingness to work with university partners and their ability to benefit from localised spillovers. See the review of evidence in Becker, B. 2015. "Public R&D Policies and Private R&D Investment: A Survey of the Empirical Evidence." *Journal of Economic Surveys*, 29(5), 917-42.

[6] Region-specific factors, in addition to firm-specific factors, may also increase the innovativeness of companies in a specific region, which may also mean stronger competition between firms for support (e.g. Romero-Martinez and Ortiz-de-Urbina-Criado, 2011).

capital of firms in regions with high (region A) and low (region B) social benefits. In each case firms' private optimum will be at point A where the marginal private benefit (MPB) and marginal cost of capital (MCC) of innovation are equal. In each region, as there are positive social benefits from innovation, the social optimum is to the right of this point at higher levels of innovation. A national policy-maker taking a combined view of the two regions might allocate grant spending to maximise national benefit by providing a higher grant (G^A) in region A than in region B (G^B) to reflect the higher level of social benefit from R&D in region A. Now assume that the same level of resource is first allocated to regions and then by regional authorities to firms. Here, equity considerations might mean that regional authorities are able to insist that firms in each region are offered the same average level of subsidy (G) such that $G^A>G>G^B$ and moving firms' optimum to point C. In region A the lower grant level G means that only a proportion of the potential social benefit of higher levels of R&D are captured while in region B deadweight occurs as the level of R&D activity is increased beyond the socially optimal level. Note, however, that in aggregate innovation levels may be the same, or even higher, than with national grant allocation although the aggregate social benefit derived will be lower.

Figure 1 depicts an extreme situation. In reality firms within each region will differ markedly in terms of the potential social benefits of their R&D. For example, in peripheral regions absorptive capacity, and therefore the ability to capture potential spillovers from R&D, is lower (Hewitt-Dundas and Roper 2011). Weaknesses in intermediaries or knowledge brokers may also limit knowledge diffusion (Cornett 2009). Lagging regions may also have a deficit in human capital endowments reducing their capacity for R&D (Becker 2015) and the absorptive capacity of local businesses (Roper and Love 2006). In terms of public support, this suggests what Oughton et al. (2002) call the regional innovation paradox, i.e. 'the comparatively greater need to spend on innovation in lagging regions and their relatively lower capacity to absorb public funds earmarked for the promotion of innovation' (Oughton, Landabaso, and Morgan 2002, p. 98). EU Structural Funds, for example, aim to develop productive capacity in lagging regions with around one Euro in six allocated to supporting innovation over the 1989-99 period (Musyck and Reid

2007). National initiatives may involve targeted support for business R&D and innovation in particular regions, investments in public or public-private R&D capacities or cluster-type interventions (Cornett 2009). In either case, if resources are allocated in proportion to the population of firms, this will mean that in regions with concentrations of stronger firms some strong projects will be unsupported. Conversely, in regions with concentrations of weaker firms some weaker projects will be supported.

Regionalised innovation support measures may also differ in their intent from national measures and have a more compensatory objective, seeking to support existing innovation capacities which are threatened by short-term crises or transition processes (Hall and Soskice 2001) or specific regional weaknesses. Compensatory interventions may also aim to equalise regional growth potential, with a focus on supporting innovation and knowledge diffusion in lagging regions (Cornett 2009). Both potential misallocation effects, and the compensatory tendency of regional support are likely to mean that regional schemes are likely to dominate national initiatives in terms of their impact on the probability of undertaking innovation, i.e. at the extensive margin. National measures may, however, be more effective in their allocation of support to the strongest firms or projects and therefore dominate at the intensive margin.

EU funding for innovation is of two main sorts: the Framework Programmes and Horizon 2020 support leading edge innovation regardless of location; EU Structural Funds, aim to develop productive capacity in lagging regions with around one Euro in six allocated to supporting innovation over the 1989-99 period (Musyck and Reid 2007). There is considerable evidence that Framework Programme and Horizon 2020 funding tends to be concentrated in stronger regions and firms, and works primarily at the intensive margin although the implications for growth are less clear. The regionalised nature of EU Structural Funds, however, is likely to lead to similar allocation biases to regional support measures, with an emphasis on the extensive margin. In combination, we might expect EU programmes to have more modest impacts on the extensive margin than regional support and more modest effects on the intensive margin than national support.

3. INNOVATION POLICY IN THE UK AND SPAIN

In the UK, the governance of innovation policy is predominantly national and since 2010, and the abolition of the Regional Development Agencies, innovation policy delivery has also been largely centralised. Resource allocation is determined predominantly by national innovation competitions run by Innovate UK[7]. In Spain, by contrast, federal and regional policies exist alongside each other. At the federal level the Centre for Industrial Technological Development provides support for innovation, while the autonomous regions are responsible for financing and managing public universities and operating their own R&D and innovation policies including specific calls for proposals[8]. This leads to more strongly regionalised priorities in Spain. For example, Nijhoff-Savvaki et al (2010) examined pork meat supply chains in the UK and Spain and identified developments focussed on traceability in the UK and geographically defined and protected designations of origin (PDO) in Spain. They conclude: '…in the UK niche pork netchains mainly strive for operational excellence and leadership, in … Spain niche pork netchains are working towards preserving tradition and culture through more localised supply-chain relationships' (Nijhoff-Savvaki et al, 2010, p. 1113)[9].

The comparison of the UK and Spain also provides an opportunity to assess the impact of the different rationales (i.e. creative, compensatory, and corrective) for innovation policy. In the Varieties of Capitalism literature the UK is usually identified as a liberal market economy in which factor allocation

[7] See https://www.gov.uk/government/organisations/innovate-uk/about. It is worth noting however that in the devolved territories of the UK - Scotland, Wales and Northern Ireland – the range of support measures differs from that in England. Here, UK wide initiatives run by InnovateUK sit alongside regional innovation support measures.

[8] http://www.euraxess.es/eng/services/foreign-researchers-in-spain/guide-for-the-management-of-the-mobility-of-the-foreign-researcher-in-spain-2014/2.researching-in-spain/2.1.-the-spanish-science-technology-and-innovation-system.

[9] In a broader econometric study of manufacturing innovation, Roper et al (2007) find no significant innovation effects from regional public support in the UK but do find a significant effect from regional support on process innovation in Catalonia.

and co-ordination is driven primarily by market mechanisms, and where 'collective actors, as well as other forms of non-market coordination through chambers or cross-shareholdings, play a minor role' (Hassel 2014, p. 6). Here, public innovation policy is either corrective – designed to address market failures in R&D and innovation – or creative, intended to enable leading edge innovation[10]. Spain, by contrast, is characterised as a Mixed Market Economy (or MME) (Molina and Rhodes, 2007), or having a 'Mediterranean' mode of capitalism (Hall and Soskice 2001), in which clientalism is more pronounced, and the state plays a compensatory role, intervening to offset competitive or financial shocks rather than facilitating firms' competitive strategies. Here too, however, corrective action might also be taken by government to address either market or innovation system failures with the aim of maximising the social benefits of innovative activity (Klette, Moen, and Griliches 2000; Martin and Scott 2000).

Aside from the contrasting objectives and governance of innovation policy in the UK and Spain there are also significant differences in the extent of public involvement in the innovation system. Spain has an innovation system which is more strongly shaped by the public sector than the market influences which shape the innovation system in the UK. This is evident in any consideration of the profile of R&D spending and financing: the public sector is more important in both dimensions in Spain, although relative levels of R&D spend have changed markedly in recent years (Table 1). In particular, while levels of total R&D investment in the UK have remained broadly stable over the last decade a more cyclical pattern is evident in Spain. Prior to the great recession R&D investment in Spain increased rapidly rising from around half to two-thirds of the UK level. Since 2008, however, R&D spend in Spain has fallen sharply both in aggregate and in the business sector. The composition of R&D spend and funding has remained more stable, however, with businesses accounting for a larger proportion of R&D spend in the UK than in Spain, and government spend proportionately less important in the

[10] For example, creative activity, with a more strategic intent, might be taken in order to reshape the innovation system or support R&D and innovation activity in particular sectors or localities (Asheim et al. 2007; Hewitt-Dundas and Roper 2011).

UK. Higher education accounts for around a quarter of all R&D spend in both countries (Table 1, part a). As with total R&D spend, levels of business R&D spend in Spain rose prior to the recession, converging on UK levels. Since 2008, however, levels of R&D spend in both countries have declined as private innovation investment has fallen and the volume of venture capital investments declined (EU 2015).

In terms of the funding of R&D, government is a more significant funder of R&D in Spain both in terms of total R&D and R&D undertaken by firms. Government funding for business R&D in Spain rose particularly rapidly during the 2000-08 period rising from 7.2 per cent of business spend to 17.9 per cent by 2008. Subsequently, government support for business R&D fell rapidly reaching 10.7 per cent in 2013, around its 2002 level. International funding for R&D is conversely more important in the UK. The relative importance of public R&D support and international funding is reflected in the findings of Mate-Sanchez-Val and Harris (2014) whose empirical analysis suggests that 'in Spain, public support is more important in promoting innovation activities; whereas linkages with international markets are more important for companies in the UK' (p. 452)[11].

Another contrast between the business environments of the UK and Spain noted in earlier studies is that the burden of regulation and legislation is greater for Spanish companies, a factor which has often been seen as having a potentially negative effect on innovative activity (Blind 2012; Epstein 2013; Ford, Steen, and Verreynne 2014; Kneller and Manderson 2012; Mazon et al. 2012; Michie and Sheehan 2003)[12]. The World Bank's 'Doing Business' index, for example, ranks the UK 8th globally in terms of the regulatory and legislative environment for commercial activity, with the UK

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[11] Public sector support (from national or regional authorities) was also more common in Spain. Over the 2002-2004 period public support for innovation was received by 22 per cent of manufacturing firms in Spain compared to 13.1 per cent of such firms in the UK (Mate-Sanchez-Val and Harris 2014), Table 5, p. 456.

[12] Regulation can be defined as: 'the legal and administrative rules created, applied and enforced by state institutions – at local, national and supra-national level – that both mandate and prohibit actions by individuals and organisations, with infringements subject to criminal, civil and administrative penalties' (Kitching 2006).

recognised as having a particularly strong legal framework to protect minority investors, something which is seen as important in facilitating business angel and venture capital investment (World Bank Group 2015). Spain ranks 33rd on the same measure, performing relatively strongly in terms of legislative aspects of bankruptcy and minority investment but more poorly on more operational aspects of business life such as property registration and access to utilities (World Bank Group 2015). More direct evidence on the impact of regulation on existing firms comes from a comparative investigation of manufacturing innovation in the UK and Spain during the 2002-2004 period in which Mate-Sanchez-Val and Harris (2014) found that all eight 'factors hampering innovation' were more commonly cited by Spanish firms than in the UK[13]. In a related study, Roper et al (2016) find that where firms' innovation objectives include the need to meet regulatory requirements, Spanish firms seek out non-interactive strategies to acquire external knowledge for innovation, such as imitation or copying (Glückler, 2013, Borgatti and Halgin, 2011) – rather than more innovation-ambitious interactive direct collaboration (Hewitt-Dundas and Roper, 2011, Mueller, Rosenbusch and Bausch, 2013). There is no effect on UK firms' acquisition strategies. This indicates that the stronger regulatory burden faced by Spanish firms may dampen innovative ambition and suggests a corrective role for government policy.

4. DATA AND EMPIRICAL APPROACH

Our analysis is based on the UK and Spanish contributions to the EU Community Innovation Survey covering the period 2004 to 2012. In the UK, the UK Innovation Survey (UKIS) is conducted every two years, with each survey conducted by post using as a sampling frame the Interdepartmental

[13] The eight factors and the proportions citing them in Spain (the UK) were (Mate-Sanchez-Val and Harris, 2014, Table 5): direct innovation costs too high, 47.5 per cent (29.9 per cent); costs of finance 53.3 per cent (29.9 per cent); availability of finance 44.2 per cent (22.4 per cent); lack of qualified personnel 35.9 per cent (24.4 per cent); lack of information on technology 32.1 per cent (13.7 per cent); lack of information on markets 29.6 per cent (13.9 per cent); market dominated by established enterprises 42.1 per cent (22.2 per cent); uncertain demand 22.0 per cent (13.1 per cent).

Business Register, with structuring by sizeband, region and sector. Surveys are non-compulsory and achieved response rates ranging from 51.1 per cent in UKIS 7 (2010) to 58 per cent in UKIS 4 (2004)[14]. For Spain our analysis makes use of data from the "Panel of Technological Innovation" (PITEC). The PITEC comprises data collected annually by the Innovation in Companies Survey and is Spain's input to the Community Innovation Survey[15]. The PITEC is based on four samples targeting different firms' populations: a sample of larger firms listed on the Spanish Central Company Directory (DIRCE); firms with intra-mural R&D drawing on the Research Business Directory (DIRID) (Vega-Jurado *et al.* 2009); and two samples of smaller firms (with less than 200 employees) that report external R&D, but no intramural R&D expenditures, and that report no innovation expenditure. Both the UK Innovation Survey and the PITEC apply the definitions and type of questions defined in the OECD Oslo Manual (2005) providing the basis for a direct comparison. For innovating firms – i.e. those that undertook innovation in products or services, or processes - both surveys provide detailed information on firms' knowledge acquisition activities. In addition both surveys provide information on a range of other workplace level characteristics which we use as control variables.

Our dependent variables are chosen to reflect the outputs from the innovation process. In doing so, we add to the relatively few micro-econometric studies to date that examine the effect of public support on innovation output (e.g. Branstetter and Sakakibara, 2002; Bérubé and Mohnen, 2009; Moretti and Wilson, 2014; Bronzini and Piselli, 2016), compared with the much more researched effect on innovation input. First, we consider a series of binary variables indicating whether firms have undertaken product/service, process, strategic, marketing, managerial or organizational innovation over the last three years. Firms' innovation profiles vary somewhat across the two countries with UK firms more likely to engage in organizational innovation and Spanish firms more likely to be involved in

[14] See: https://www.gov.uk/government/collections/community-innovation-survey
[15] This dataset is freely available from the National Statistics Institute, INE, on request at: http://icono.fecyt.es/PITEC/Paginas/descarga_bbdd.aspx

product/service, strategic, managerial or marketing innovation (Table 2). Second, for product/service and process innovation, we consider the novelty of firms' innovation by considering whether firms have introduced any new-to-the-market innovation over the previous three years. This was the case with 25 per cent of UK firms and 28 per cent of Spanish firms (Table 2). Finally, we consider the market success of firms' innovation activity as represented by the proportion of current sales derived from innovative products. On average UK firms derived 5.6 per cent of revenues from sales of new products or services compared to 8.0 per cent of sales by Spanish firms (Table 2).

In terms of public support, PITEC and the UKIS do not identify the specific support schemes from which firms benefitted, and the UKIS does not identify the amount of support they received. Instead, we have three binary indicators relating to whether firms received innovation support from local or regional agencies, national bodies or EU (for Spain) or EU and international (for the UK) organisations. The balance between regional, national and EU support differs significantly between the UK and Spain reflecting more intensive public involvement in the innovation system in Spain. In the UK, 5.9 per cent of firms received regional innovation support compared to 19.4 per cent in Spain, while 5.0 per cent of firms received national innovation support in the UK compared to 18.3 per cent in Spain. The proportion of firms in each country attracting EU or international support was 1.7 per cent in the UK and 5.1 per cent (EU support only) in Spain.

We also include in our analysis a set of control variables which previous studies have linked to dimensions of innovation activity. First, we include a binary indicator of whether or not a firm reported in-house R&D expenditure (Love and Roper, 2001, Love and Roper, 2005, Griffith et al., 2003) which we anticipate will be positively associated with innovation outputs. In our sample of firms, 32.7 per cent of UK firms reported in-house R&D spend compared to 49.7 per cent in Spain. Second, we include a number of other variables reflecting firms' innovation related investments in design, market intelligence, machinery etc. In each case we anticipate these having a positive association with innovation outputs. Thirdly, we include variables reflecting the strength of firms' human resources (Leiponen, 2005, Freel, 2005, Hewitt-Dundas, 2006). On average in the UK 14.2 per cent of firms' workforce are graduates. In Spain we have a slightly different labour quality measure with 26.3 per cent of employees being 'superior education' graduates (Table 2). Third, we include (log) employment in the estimated models to reflect the scale of plants' resources. Finally, to capture any market scale effects we include a binary variable indicating whether or not a firm was selling in export markets. Previous studies have linked exporting and innovative activity through both competition and learning effects (Love and Roper 2013). On average the proportion of firms which were exporting was 34.2 per cent in the UK and 58.3 per cent in Spain, a contrast which was rather unexpected given earlier arguments that international market conditions were potentially a stronger influence on innovation in the UK than in Spain (Mate-Sanchez-Val and Harris, 2014). Finally, we include a measure of the extent or breadth of firms' innovation co-operation to measure the extent of firms' interactive knowledge search. Specifically, following (Laursen and Salter 2006) and (Moon 2011), we construct a count indicator which takes values between 0, where firms had no innovation partners, and a maximum of 7 where firms were collaborating with all partner types identified. Firms in the UK had an average of 0.80 interactive partnerships compared to 0.94 in Spain (Table 2).

Our estimation strategy is shaped by the binary or truncated nature of our dependent variables and the need to be able to deal with multiple (binary) treatments which may be subject to selection bias. We adopt a two-stage approach. First, following other studies such as (Aerts and Schmidt 2008; Czarnitzki and Lopes-Bento 2014) we estimate models for the probability that firms received regional, national or EU support for innovation S_{ki}, where k denotes the source of innovation support:

$$S_{ki} = \propto_0 + \propto_1 FC_i + \propto_2 BARR_i + \propto_2 TARG_{ki} + \varepsilon_1$$

Where FC_i is a group of variables designed to reflect firms' identifiable characteristics, $BARR_i$ are variables to reflect firms' demand for public support and $TARG_{ki}$ are variables to reflect the availability of public support in each industry and sizeband. In terms of firms' identifiable characteristics we include measures of firm size, workforce quality and whether or not a firm is an exporter. Each of these variables has previously been linked to an increased probability of receiving public innovation support (Zuniga-Vicente et al. 2014, p. 54). The demand for support we reflect in a series of variables reflecting the finance and market barriers to firms' innovation activity. The core idea here is that firms are more likely to seek public support for innovation when they perceive stronger resource constraints[16]. Finally, to reflect policy targeting – i.e. public willingness to offer support to specific groups of firms - we include a variable reflecting the proportion of firms in each sector, region and sizeband receiving public support.

The second stage of our estimation approach is the standard innovation production function which relates innovation outputs (I_i) to inputs such as R&D, skills and the results of external knowledge search (Leiponen and Byma 2009; Leiponen 2012). We can write:

$$I_i = \beta_0 + \beta_1 FC_i + \beta_2 RD_i + \beta_3 XS_i + \beta_4 HC_i + \beta_5 S_{ri} + \beta_6 S_{ni} + \beta_7 S_{si} + \varepsilon_2$$

Where FC_i is a set of firm level control variables (e.g. internal versus external R&D, design, training, external knowledge acquisition, market intelligence and machinery spend), RD_i is an indicator of R&D spending, XS_i external knowledge search and HC_i an indicator of the quality of firms' human capital. We also include three binary treatment terms indicating whether firms received local or regional (S_{ri}), national (S_{ni}) or EU/international (S_{si}) innovation support. We estimate these models using the conditional mixed process or CMP approach developed by Roodman (2011). This technique allows us to instrument the three binary treatment innovation support terms using simplified versions of the selection models described earlier. Our estimation sample is based on pooled data from five waves of the UKIS and PITEC innovation surveys, an approach we adopt to allow robust sub-sample estimates. To allow for sectoral and temporal heterogeneity we also

[16] In the PITEC and UKIS data sets firms are asked to identify whether these factors are a major, medium, minor or no constraint on their innovation activity. We translate these into dummy variables which take value 1 when each factor is a major or medium constraint.

include sector dummies at the 2-digit level and wave dummies in each model.[17]

5. EMPIRICAL RESULTS

We initially investigate the determinants of the probability of receiving public support for innovation with the expectation that as a result of competitive or peer review-based allocation mechanisms the receipt of regional, national and EU level support will be associated with stronger internal resources (Aerts and Schmidt 2008; Czarnitzki and Lopes-Bento 2013; Karhunen and Huovari 2015). Probit models for the probability of receiving support in the UK and Spain are reported in Tables 3 and 4. All models include industry and time dummy variables intended to control for sectoral differences in innovation propensity and appropriability regimes (Becker 2015). Workforce quality, an indicator of scale (employment), and exporting are positively associated with the receipt of innovation support in both the UK (Table 3) and Spain (Table 4) (Aerts and Schmidt 2008; Czarnitzki and Lopes-Bento 2013). Firms experiencing finance constraints for innovation and uncertain demand are also more likely to receive each type of public support although these effects are more sizable in terms of regional and national rather than EU support (Tables 3 and 4) (Hyytinen and Toivanen 2005). Targeting effects also prove important with penetration rates for each type of public support positively associated with individual firms' receipt of such support. In both Spain and the UK these penetration rate effects are strongest for regional innovation support (Tables 3 and 4). Here, our results are largely consistent with those of previous studies which have considered the correlates of the receipt of public innovation support.

In terms of the impact of public support on the extensive margin, i.e. the probability of innovating, our expectation is that this will be most strongly linked to regional support due to potential misallocation effects and the

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[17] Our samples include all firms – innovators and non-innovators – so as to take account of the fact that a sizeable share of firms do not innovate, or may become innovators over the sample period due to receipt of public support.

compensatory tendency of regional support measures. This is the focus of Tables 5 (UK) and 6 (Spain). We find that regional or local support initiatives are positively associated with the probability of undertaking process, organisational, strategy, management and marketing innovation in the UK (Table 5) and product, organisational, management and marketing innovation in Spain (Table 6). In each case, effect sizes are larger in Spain perhaps due to the greater influence of public sector support in the Spanish innovation system (Mate-Sanchez-Val and Harris 2014). For example, regional support in Spain is associated with a 33 per cent increase in the probability of undertaking organisational innovation compared to 11 per cent in the UK (Tables 5 and 6). The consistently positive and significant effects associated with regional support also contrast with much weaker links between national and EU policy support and the probability of innovating in both countries (Tables 5 and 6). Notably, however, in both the UK and Spain we do find a positive association between the receipt of national innovation support and the probability of product or service innovation. One possibility is that this is linked to the competitive nature of much national innovation support which may favour product or service changes over more organisational changes. Again, however, the scale of this effect (21 per cent) is notably larger in Spain than in the UK (8 per cent) again reflecting the greater influence of public sector support in the Spanish innovation system (Mate-Sanchez-Val and Harris 2014). In terms of EU support we find a contrasting picture with weak negative associations with the probability of process and marketing innovation in the UK (Table 5) and sizable positive associations with strategic and marketing innovation in Spain (Table 6).

Our results suggest the differential effects of regional, national and EU support at the extensive margin: regional initiatives support broadly-based innovation, while national initiatives impact only on the probability of product or service innovation. Other control variables impact largely as anticipated. The probability of innovation – of all types – is positively linked to scale, design spend (Filipetti 2010), exporting (Love and Roper 2015), external partnerships (Moon 2011), in house R&D (Love and S 2001; Love and Roper 2005) and innovation related investment in external knowledge, market intelligence and equipment in both the UK and Spain.

While the extent of innovation activity in a population of firms may be important in generating potential market advantages and externalities it is arguably more important to be generating new-to-the-market innovations and increased innovative sales. New-to-the-market innovations provide the basis for creative destruction, while innovative sales provide an indication of the market success of an innovation and have been linked in previous studies to future productivity and sales growth. Both are examined in Table 7. Again, we anticipate that public support of all types will have a positive effect on both the novelty and market success of innovation, however, due to the combination of competitive allocation and a lack of any regionalised bias we anticipate stronger national policy effects. In both the UK and Spain – as anticipated - we find a strong positive association between national innovation support and new-to-the-market innovation and a weaker (or negative) regional policy link (Table 7). Again the effect size of national innovation support is larger in Spain (26 per cent) than in the UK (8 per cent). EU support has little effect in the UK but has a strong positive association with new-to-the-market innovation in Spain. In terms of the impact of public support on innovative sales we see some contrasts between the UK and Spanish results. In the UK, national support influences the novelty of innovation – again perhaps linked to the competitive allocation mechanisms – but only regionalised support influences the market success of innovation. In Spain both national and regional support influence both novelty and innovation success with stronger national policy effects. Again, control variables impact largely as anticipated (Table 7). EU support again has little effect on innovative sales in the UK but has a large and significant influence in Spain.

6. CONCLUSIONS

Table 8 provides a symbolic summary of our estimation results focussing on the effects of regional, national and EU support on innovation outcomes. Our analysis suggests four key findings. First, at the extensive margin, regional support seems most influential in both the UK and Spain for process and organisational innovation. This may reflect both the regionalised allocation of support which means that in some cases weaker firms – and potentially non-innovators – are supported as well as the potential compensatory objectives of regional policies. Second, for both the UK and Spain - and by contrast with other types of innovation – national innovation support is associated with a higher probability of product or service innovation. This may reflect the orientation of national competitions for innovation support towards product/service innovations rather than organisational innovation. Third, only national (and in Spain EU support) prove important in positively shaping the novelty of product or service innovations. Finally, in terms of innovation sales we find a different pattern in the UK and Spain: in the UK only regional support is associated with increased innovative sales; while, in Spain, innovative sales are influenced by both regional, national and EU support measures.

For Spain our results confirm the importance of regional support measures on both the extent and success of innovation, as noted elsewhere (Mate-Sanchez-Val and Harris 2014). Interestingly, however, national support proves more influential in terms of both the novelty of innovation and the sales derived from new products. This may reflect the focus of the Centre for Industrial Technological Development on leading edge technologies, while regional strategies have broader objectives linked to local growth and productivity. In the UK, our results emphasise the role of regional initiatives in supporting broadly-based innovation and the commercialization of innovation and national support measures in encouraging novel product and service innovation. Two aspects of these results are important in terms of policy changes in the UK since 2012 which have centralised the support for innovation. First, our evidence suggests that national initiatives can be important in supporting novel product and service innovation, an aspect of policy support which recent policy trends seem likely to strengthen. Second, increased centralisation has reduced the availability of regional support and perhaps weakened the support for broadly based innovation in process and organisations. The differential impacts of national and regional support measures which our results suggest emphasize the importance of earlier calls for caution in the over-centralisation or over-decentralisation of innovation support measures (What Works Centre for Local Growth 2015).

Our analysis provides some new insights into the effectiveness of public support on different innovation outcomes. Regional support it seems impacts different aspects of innovation to that of national and EU funding. This undoubtedly reflects both the contrasting objectives of regional, national and EU support initiatives as well as rigidities in the allocation processes of regional and EU funding. Both commonalities and differences emerge between the UK and Spain, particularly the strength of regional initiatives in supporting broadly-based innovation. Limitations are legion, but perhaps the most profound is that the UKIS and PITEC provide no consistent information on the timing of support received, and the UKIS provides no information on the value or intensity of support received. We are therefore limited to modelling the policy effects as a simple treatment which takes no account of the intensity of support. In addition, our analysis while based on pooled panel data remains primarily non-causal. True, albeit relatively narrow, panels of longitudinal data do exist within PITEC and the UKIS and future studies might usefully explore the longer-term effects of regional, national and EU support. Finally, our analysis to date has focussed only on innovation outputs and the link to business performance in each country – productivity or growth - has yet to be established.

Table 1: Composition of R&D investment and funding: Spain and the UK

	2000	2005	2008	2009	2011	2013
(a) Sectors undertaking R&D						
Spain						
Business	53.7	53.8	54.9	51.9	52.1	53.1
Higher Education	29.6	29.0	26.7	27.8	28.2	28.0
Government	15.8	17.0	18.2	20.1	19.5	18.7
Charity Sector	0.9	0.1	0.2	0.2	0.2	0.2
UK						
Business	65.0	61.4	62.0	60.4	63.6	64.5
Higher Education	20.6	25.7	26.5	27.9	26.0	26.3
Government	12.6	10.6	9.2	9.2	8.6	7.3
Charity Sector	1.8	2.3	2.4	2.5	1.8	1.9
(b) Funding of R&D						
Spain						
Industry	49.7	46.3	45.0	43.4	44.3	46.3
Government	38.6	43.0	45.6	47.1	44.5	41.6
Other national	6.8	5.0	3.8	4.1	4.5	4.7
External sources	4.9	5.7	5.7	5.5	6.7	7.4
UK						
Industry	48.3	42.1	45.4	44.5	45.9	46.5
Government	30.2	32.7	30.7	32.6	30.5	27.0
Other national	5.5	5.9	6.2	6.3	5.9	5.8
External sources	16.0	19.3	17.7	16.6	17.8	20.6

Source: OECD Science and Technology Indicators database.

Table 2: Sample descriptives: UK and Spain

	UK (N>36,706)		Spain (N>41,072)	
	Mean	Std. Dev.	Mean	Std. Dev.
Innovation indicators				
Product or service innovation (0/1)	0.308	0.462	0.482	0.500
Process innovation (0/1)	0.196	0.397	0.382	0.486
Organisational innovation (0/1)	0.214	0.410	0.154	0.361
Strategic innovation (0/1)	0.210	0.407	0.350	0.477
Management innovation (0/1)	0.201	0.401	0.341	0.474
Marketing innovation (0/1)	0.227	0.419	0.255	0.436
New to market product innovation (0/1)	0.250	0.433	0.580	0.494
% of innovative sales - new products	5.615	15.946	8.045	20.876
% of innovative sales - new and improved products	9.641	22.695	19.259	32.908
Policy support measures				
Regional or local support (0/1)	0.059	0.235	0.194	0.395
National innovation support (0/1)	0.050	0.218	0.183	0.387
EU innovation support (0/1)	0.017	0.128	0.051	0.221
Controls				
Log (employment)	3.788	1.798	4.140	1.711
Design spend (0/1)	0.207	0.405	0.096	0.294
Science and engineering graduates (%)	6.129	15.635		
Other graduates (%)	8.166	17.143		
Superior education graduates (%)			26.284	28.995
Exporting firm (0/1)	0.342	0.474	0.583	0.493
Number of innovation partners (0-7)	0.799	1.669	0.935	1.587
In house R&D (0/1)	0.327	0.469	0.497	0.500
External R&D (0/1)	0.127	0.333	0.246	0.431
Training spend (0/1)	0.334	0.472	0.162	0.369
Acquisition of external knowledge (0/1)	0.129	0.336	0.040	0.197
Acquisition of market intelligence (0/1)	0.323	0.468	0.187	0.390
Machinery spend (0/1)	0.473	0.499	0.191	0.393

Notes and sources: UK: UKIS accessed in the Secure Data Service. Pooled data from UKIS waves 4-8. Spain: PITEC for matching years. UK observations are weighted to give representative results. No weights are available in the PITEC database.

Table 3: The probability of receiving regional, national and EU innovation support: UK

	Full models			Reduced models		
	Regional Support	National Support	EU Support	Regional Support	National Support	EU Support
Log (employment)	0.000	0.002***	0.000		0.002***	
	(-0.001)	(-0.001)	(0.000)		(-0.001)	
Science and engineering graduates (%)	0.000***	0.001***	0.000***	0.000***	0.001***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Other graduates (%)	0.000	0.000*	0.000		0.000*	
	(0.000)	(0.000)	(0.000)		(0.000)	
Exporting firm (0/1)	0.012***	0.023***	0.006***	0.012***	0.024***	0.006***
	(-0.003)	(-0.003)	(-0.001)	(-0.003)	(-0.003)	(-0.001)
Economic risk barrier	0.010**	0.003	0.001	0.011***		
	(-0.004)	(-0.003)	(-0.002)	(-0.004)		
Innovation cost barrier	0.012***	0.009**	0.002	0.013***	0.009***	
	(-0.004)	(-0.004)	(-0.002)	(-0.004)	(-0.003)	
Cost of finance barrier	0.002	-0.003	-0.002			
	(-0.004)	(-0.003)	(-0.002)			
Availability of finance barrier	0.012***	0.009**	0.004	0.015***	0.007***	0.003**
	(-0.004)	(-0.003)	(-0.002)	(-0.004)	(-0.003)	(-0.001)
Uncertain demand barrier	0.005*	0.007***	0.003*		0.008***	0.003**
	(-0.003)	(-0.003)	(-0.002)		(-0.003)	(-0.001)
Penetration rate – regional support	0.374***	0.000	0.000	0.375***		
	(-0.022)	(0.000)		(-0.021)		
Penetration rate – national support		0.223***			0.222***	
		(-0.013)			(-0.013)	
Penetration rate – EU support			0.152***			0.151***
			(-0.015)			(-0.015)
N	35230	35227	35141	35545	35408	35459
chi2	653.1	1316.52	446.886	645.254	1321.906	411.924
r2_p	0.071	0.192	0.106	0.069	0.191	0.105
bic	11857.43	9276.55	3964.898	12008.82	9308.902	3983.934

Notes and sources: UK: UKIS accessed in the Secure Data Service. Pooled data from UKIS waves 4-8. UK observations are weighted to give representative results. No weights are available in the PITEC database. All models include sectoral and wave dummies. Marginal effects at variable means are reported.

Table 4: The probability of receiving regional, national and EU innovation support: Spain

	Full models			Reduced models		
	Regional Support	National Support	EU Support	Regional Support	National Support	EU Support
Log (employment)	0.008***	0.020***	0.006***	0.008***	0.020***	0.006***
	(-0.001)	(-0.001)	(0.000)	(-0.001)	(-0.001)	(0.000)
Superior education graduates (%)	0.001***	0.002***	0.001***	0.001***	0.002***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Exporting firm (0/1)	0.054***	0.086***	0.014***	0.054***	0.086***	0.014***
	(-0.003)	(-0.003)	(-0.002)	(-0.003)	(-0.003)	(-0.002)
Innovation cost barrier	0.019***	0.003	-0.003	0.019***		
	(-0.004)	(-0.004)	(-0.002)	(-0.004)		
Cost of finance barrier	0.044***	0.060***	0.017***	0.044***	0.061***	0.016***
	(-0.005)	(-0.005)	(-0.002)	(-0.005)	(-0.004)	(-0.002)
Availability of finance barrier	0.027***	0.013***	0.006**	0.027***	0.013***	0.005**
	(-0.005)	(-0.005)	(-0.002)	(-0.005)	(-0.005)	(-0.002)
Uncertain demand barrier	0.027***	0.029***	0.006***	0.027***	0.030***	0.006***
	(-0.004)	(-0.003)	(-0.002)	(-0.004)	(-0.003)	(-0.002)
Penetration rate – regional support	0.801***			0.801***		
	(-0.014)			(-0.014)		
Penetration rate – national support		0.661***			0.661***	
		(-0.013)			(-0.013)	
Penetration rate – EU support			0.290***			0.290***
			(-0.009)			(-0.009)
N	52576	52576	52576	52576	52576	52576
chi2	7356.916	8493.614	4097.964	7356.916	8492.988	4095.409
r2_p	0.142	0.169	0.193	0.142	0.169	0.193
bic	44547.385	41714.870	17221.370	44547.385	41704.626	17213.055

Notes and sources: PITEC. Pooled data from 2004, 2006, 2008, 2010 and 2012 waves to match UK waves 4-8. UK observations are weighted to give representative results. No weights are available in the PITEC database. All models include sectoral and wave dummies. Marginal effects at variable means are reported.

Table 5: The probability of innovating: UK

	Product/service	Process	Organisation	Strategy	Management	Marketing
Regional or local support (0/1)	0.029	0.033*	0.105***	0.063***	0.075***	0.038*
	(0.021)	(0.018)	(0.019)	(0.020)	(0.019)	(0.020)
National innovation support (0/1)	0.081***	0.026	-0.006	-0.004	-0.018	-0.020
	(0.022)	(0.018)	(0.020)	(0.021)	(0.019)	(0.020)
EU innovation support (0/1)	-0.047	-0.049**	-0.023	0.001	-0.035	-0.082***
	(0.029)	(0.023)	(0.026)	(0.028)	(0.026)	(0.025)
Log (employment)	0.001	0.011***	0.016***	0.024***	0.019***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Design spend (0/1)	0.062***	0.038***	0.020***	0.031***	0.015***	0.025***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Science and engineering graduates (%)	0.000***	0.000	0.001***	0.001***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Other graduates (%)	0.000***	0.000	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Exporting firm (0/1)	0.035***	0.007*	0.008*	0.014***	-0.002	0.015***
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Number of innovation partners (0-7)	0.039***	0.030***	0.024***	0.025***	0.022***	0.020***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
In house R&D (0/1)	0.128***	0.062***	0.053***	0.050***	0.034***	0.050***
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
External R&D (0/1)	0.000	0.004	0.014***	0.012**	0.009	0.008
	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Training spend (0/1)	0.040***	0.062***	0.032***	0.045***	0.075***	0.025***
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Acquisition of external knowledge (0/1)	0.012**	0.011**	0.031***	0.032***	0.022***	0.021***
	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Acquisition of market intelligence (0/1)	0.149***	0.044***	0.086***	0.085***	0.056***	0.201***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.004)
Machinery spend (0/1)	0.067***	0.114***	0.055***	0.027***	0.068***	0.047***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
N	37585	37585	37585	37585	37585	37585.000 3
chi2	4561.051	10780	9413.746	9422.483	8978.198	10828.945 1

Notes and sources: UK: UKIS accessed in the Secure Data Service. Pooled data from UKIS waves 4-8. UK observations are weighted to give representative results. No weights are available in the PITEC database. All models include sectoral and wave dummies. Marginal effects at variable means are reported.

Table 6: The probability of innovating: Spain

	Product/service	Process	Organisation	Strategy	Management	Marketing
Regional or local support (0/1)	0.225**	0.171	0.330***	0.162	0.376***	0.449***
	(0.094)	(0.107)	(0.127)	(0.107)	(0.103)	(0.105)
National innovation support (0/1)	0.378***	0.142	0.081	0.188*	0.089	-0.109
	(0.092)	(0.104)	(0.114)	(0.097)	(0.098)	(0.104)
EU innovation support (0/1)	0.050	-0.165	0.089	0.347***	0.272***	0.035
	(0.105)	(0.102)	(0.113)	(0.104)	(0.105)	(0.112)
Log (employment)	-0.005	0.036***	0.052***	0.094***	0.0891***	-0.005
	(0.006)	(0.006)	(0.008)	(0.007)	(0.007)	(0.007)
Design spend (0/1)	0.052*	0.266***	0.134***	0.170***	0.171***	0.226***
	(0.030)	(0.024)	(0.027)	(0.025)	(0.025)	(0.025)
Superior education graduates (%)	-0.000	-0.003***	0.001***	0.000	-0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Exporting firm (0/1)	0.097***	0.110***	0.000	0.001	0.003	0.136***
	(0.019)	(0.018)	(0.024)	(0.021)	(0.021)	(0.022)
Number of innovation partners (0-7)	0.115***	0.109***	0.118***	0.082***	0.083***	0.059***
	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
In house R&D (0/1)	0.349***	0.168***	0.232***	0.327***	0.318***	0.317***
	(0.017)	(0.017)	(0.024)	(0.020)	(0.019)	(0.020)
External R&D (0/1)	0.015	0.012	0.139***	0.082***	0.091***	0.079***
	(0.018)	(0.016)	(0.021)	(0.018)	(0.018)	(0.019)
Training spend (0/1)	0.087***	0.211***	0.253***	0.396***	0.358***	0.241***
	(0.022)	(0.020)	(0.024)	(0.022)	(0.022)	(0.022)
Acquisition of external knowledge (0/1)	0.091**	0.039	0.100***	0.094**	0.060*	0.051
	(0.038)	(0.034)	(0.038)	(0.037)	(0.036)	(0.036)
Acquisition of market intelligence (0/1)	1.204***	0.092***	0.202***	0.170***	0.174***	0.386***
	(0.025)	(0.018)	(0.022)	(0.019)	(0.019)	(0.020)
Machinery spend (0/1)	-0.092***	0.446***	0.104***	0.220***	0.223***	0.099***
	(0.019)	(0.018)	(0.022)	(0.019)	(0.019)	(0.020)
N	52576	52576	52576	52576	52576	52576
chi2	20613.315	18664.480	16354.227	17436.940	17273.889	16639.085

Notes and sources: PITEC. Pooled data from 2004, 2006, 2008, 2010 and 2012 waves to match UK waves 4-8. UK observations are weighted to give representative results. No weights are available in the PITEC database. All models include sectoral and wave dummies. Marginal effects at variable means are reported.

Table 7: Probability of new-to-the-market innovation and percentage of innovative sales: UK and Spain

	UK			Spain		
	Probability of new-to-market innovation	Innovative sales – new only	Innovative sales – new and improved	Probability of new-to-market innovation	Innovative sales – new only	Innovative sales – new and improved
Regional or local support (0/1)	0.023	0.053***	0.071***	-0.287**	-0.009	0.220**
	(0.017)	(0.019)	(0.025)	(0.114)	(0.092)	(0.094)
National innovation support (0/1)	0.078***	0.017	0.020	0.261**	0.270***	0.374***
	(0.019)	(0.020)	(0.024)	(0.108)	(0.085)	(0.091)
EU innovation support (0/1)	-0.015	-0.018	-0.038	0.372***	0.281***	0.039
	(0.025)	(0.027)	(0.031)	(0.117)	(0.096)	(0.105)
Log (employment)	0.000	-0.012***	-0.010***	0.002	-0.002	-0.004
	(0.001)	(0.001)	(0.002)	(0.008)	(0.006)	(0.006)
Design spend (0/1)	0.065***	0.041***	0.050***	0.118***	0.099***	0.048*
	(0.005)	(0.005)	(0.007)	(0.026)	(0.023)	(0.027)
Science and engineering graduates (%)	0.000***	0.001***	0.001***			
	(0.000)	(0.000)	(0.000)			
Other graduates (%)	0.000	0.001***	0.001***			
	(0.000)	(0.000)	(0.000)			
Superior education graduates (%)				0.003***	0.002***	-0.000
				(0.000)	(0.000)	(0.000)
Exporting firm (0/1)	0.040***	0.027***	0.031***	0.086***	0.112***	0.098***
	(0.004)	(0.005)	(0.005)	(0.023)	(0.019)	(0.019)
Number of innovation partners (0-7)	0.029***	0.024***	0.029***	0.071***	0.102***	0.116***
	(0.001)	(0.002)	(0.003)	(0.006)	(0.005)	(0.006)
In house R&D (0/1)	0.111***	0.102***	0.119***	0.313***	0.406***	0.349***
	(0.004)	(0.008)	(0.014)	(0.021)	(0.018)	(0.017)
External R&D (0/1)	0.002	0.000	-0.005	0.051***	0.048***	0.015
	(0.006)	(0.005)	(0.005)	(0.019)	(0.016)	(0.018)
Training spend (0/1)	0.032***	0.031***	0.042***	0.059***	0.083***	0.087***
	(0.004)	(0.005)	(0.007)	(0.023)	(0.020)	(0.022)
Acquisition of external knowledge (0/1)	0.012**	0.011**	0.012**	0.037	0.078**	0.097**
	(0.005)	(0.005)	(0.006)	(0.038)	(0.034)	(0.038)
Acquisition of market intelligence (0/1)	0.131***	0.118***	0.131***	0.160***	0.567***	1.202***
	(0.004)	(0.009)	(0.014)	(0.019)	(0.017)	(0.025)
Machinery spend (0/1)	0.046***	0.055***	0.070***	-0.018	-0.050***	-0.092***
	(0.004)	(0.005)	(0.009)	(0.021)	(0.018)	(0.019)
N	37,559	37567	37567	52576	52576	52576
chi2	13456.44	10441.8	11988.95	14842.196	18691.615	20596.404

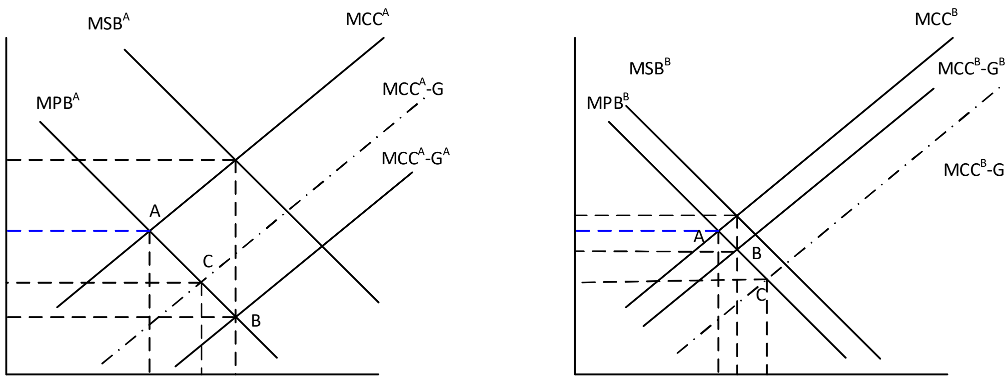
Notes and sources: PITEC and UKIS. UKIS accessed in the Secure Data Service. Pooled data from UKIS waves 4-8. UK observations are weighted to give representative results. No weights are available in the PITEC database. All models include sectoral and wave dummies. Marginal effects at variable means are reported.

Table 8: Symbolic summary of key relationships

	UK			Spain		
	Regional	National	EU	Regional	National	EU
Probability of innovation						
Product/service	(+)	+	(-)	+	+	(+)
Process	+	(+)	-	(+)	(+)	(-)
Organisational	+	(-)	(-)	+	(+)	(+)
Strategic	+	(-)	(+)	(+)	+	+
Managerial	+	(-)	(-)	+	(+)	+
Marketing	+	(-)	(-)	+	(-)	(+)
New-to-the-market innovation	(+)	+	(-)	-	+	+
Innovation Success						
New only	+	(+)	(-)	(-)	+	+
New and improved	+	(+)	(-)	+	+	(+)

Notes: +/- indicate statistically significant effect. Parentheses indicate effect is not statistically significant.

Figure 1: Allocation of subsidies with high and low social returns



Region A: High social benefit

Region B: Low social benefit

Annex 1: Variable definitions

Innovation measures	
Product or service innovation (0/1)	A binary variable taking value 1 if the firm has introduced any new or significantly improved goods or services over the last three years.
Process innovation (0/1)	A binary variable taking value 1 if the firm has introduced any new or significantly improved process for producing or supplying goods or services over the last three years.
Organisational innovation (0/1)	A binary variable taking value 1 if the firm has implemented major changes to organisational structure (e.g. cross-site or team-working) over the last three years.
Strategic innovation (0/1)	A binary variable taking value 1 if the firm has implemented a new or significantly changed corporate strategy over the last three years
Management innovation (0/1)	A binary variable taking value 1 if the firm has implemented new management techniques (e.g. just in time) over the last three years.
Marketing innovation (0/1)	A binary variable taking value 1 if the firm has implemented new marketing concepts or strategies over the last three years.
New to market product innovation (0/1)	A binary variable taking value 1 if the firm has introduced any new or significantly improved process for producing or supplying goods or services over the last three years.
New to market process innovation (0/1)	A binary variable taking value 1 if the firm has introduced any new or significantly improved process for producing or supplying goods or services over the last three years.
% of innovative sales - new products	Percentage of sales derived from products or services newly introduced over the last three years.
% of innovative sales - new and improved products	Percentage of sales derived from products or services newly introduced or significantly improved over the last three years.
Policy indicators	
Regional or local support (0/1), National innovation support (0/1), EU innovation support (0/1)	A binary variable taking value 1 if the firm received public financial support for innovation activities from local or regional authorities/ central government/ EU institutions or programmes over the last three years.
Explanatory variables	
Log (employment)	Employment three years prior to survey date (log)
Design spend (0/1), In house R&D (0/1), External R&D (0/1), Training spend (0/1), Acquisition of external knowledge (0/1), Acquisition of market intelligence (0/1), Machinery (0/1).	Binary variables taking value 1 if the firm invested in design etc. as part of its innovation activities over the last three years.
Science and engineering graduates (%), Other graduates (%)	The proportion of the firm's workforce who are science and engineering/other graduates (UK only)
Superior education graduates (%)	The proportion of the firm's workforce who are graduates (Spain only)
Exporting firm (0/1)	A binary variable taking value 1 if the firm is exporting
Number of innovation partners (0-7)	A count variable indicating the number of different partner types with which the firm is collaborating for innovation.

Annex 2: Correlation matrix, UK

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1)	Log (employment)	1.00														
(2)	Design spend (0/1)	0.13	1.00													
(3)	Science and engineering graduates (%)	0.03	0.16	1.00												
(4)	Other graduates (%)	0.06	0.07	0.14	1.00											
(5)	Exporting firm (0/1)	0.18	0.24	0.23	0.11	1.00										
(6)	Number of innovation partners (0-8)	0.14	0.32	0.19	0.08	0.18	1.00									
(7)	In house R&D (0/1)	0.16	0.49	0.22	0.10	0.30	0.35	1.00								
(8)	External R&D (0/1)	0.13	0.35	0.13	0.08	0.17	0.33	0.43	1.00							
(9)	Training spend (0/1)	0.12	0.36	0.14	0.09	0.13	0.28	0.43	0.30	1.00						
(10)	Acquisition of external knowledge (0/1)	0.08	0.33	0.12	0.08	0.12	0.27	0.30	0.38	0.36	1.00					
(11)	Acquisition of market intelligence (0/1)	0.14	0.47	0.14	0.10	0.20	0.35	0.48	0.33	0.40	0.30	1.00				
(12)	Machinery spend (0/1)	0.11	0.34	0.11	0.06	0.15	0.27	0.40	0.27	0.48	0.30	0.39	1.00			
(13)	Regional or local support (0/1)	0.01	0.15	0.11	0.01	0.10	0.18	0.17	0.14	0.15	0.13	0.14	0.14	1.00		
(14)	National innovation support (0/1)	0.05	0.16	0.23	0.04	0.16	0.22	0.22	0.18	0.16	0.14	0.15	0.13	0.27	1.00	
(15)	EU innovation support (0/1)	0.02	0.09	0.16	0.02	0.09	0.17	0.11	0.11	0.08	0.08	0.09	0.08	0.24	0.28	1.00

Annex 3: Correlation matrix: Spain

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	Log (employment)	1.00													
(2)	Design spend (0/1)	0.05	1.00												
(3)	Superior education graduates (%)	-0.32	-0.01	1.00											
(4)	Exporting firm (0/1)	0.14	0.05	-0.12	1.00										
(5)	Number of innovation partners (0-8)	0.18	0.10	0.16	0.08	1.00									
(6)	In house R&D (0/1)	-0.02	0.10	0.18	0.17	0.25	1.00								
(7)	External R&D (0/1)	0.09	0.10	0.07	0.10	0.31	0.27	1.00							
(8)	Training spend (0/1)	0.10	0.34	0.07	0.02	0.19	0.18	0.18	1.00						
(9)	Acquisition of external knowledge (0/1)	0.10	0.22	0.03	0.00	0.10	0.04	0.12	0.26	1.00					
(10)	Acquisition of market intelligence (0/1)	0.04	0.31	0.05	0.10	0.16	0.22	0.14	0.32	0.15	1.00				
(11)	Machinery spend (0/1)	0.13	0.23	-0.05	0.00	0.08	0.00	0.09	0.32	0.22	0.22	1.00			
(12)	Regional or local support (0/1)	-0.07	0.08	0.16	0.03	0.27	0.25	0.26	0.11	0.05	0.10	0.05	1.00		
(13)	National innovation support (0/1)	0.08	0.08	0.18	0.11	0.35	0.29	0.27	0.13	0.06	0.13	0.05	0.28	1.00	
(14)	EU innovation support (0/1)	0.04	0.04	0.17	0.02	0.31	0.15	0.13	0.09	0.05	0.06	0.02	0.19	0.26	1.00

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