Firms' innovation objectives and knowledge acquisition strategies: a comparative analysis

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ABSTRACT

External partnerships play an important role in firms' acquisition of the knowledge inputs to innovation. Such partnerships may be interactive – involving exploration and mutual learning by both parties – or non-interactive – involving exploitative activity and learning by only one party. Examples of non-interactive partnerships are copying or imitation. Here, we consider how firms' innovation objectives influence their choice of interactive and/or non-interactive connections. We conduct a comparative analysis for the economies of Spain and the UK, which have contrasting innovation eco-systems and regulation burdens. Four empirical results emerge. First, we find strong and consistent support for complementarity between non-interactive and interactive connections across firms in all sectors and sizebands for both economies. Second, we find that innovation objectives related to new products and services are linked to both interactive and non-interactive connections in Spain, with mixed evidence for the UK. Third, we find that the need to meet regulatory requirements has no effect on firms' knowledge acquisition strategies in the UK, but a strong impact on non-interactive connections in Spain. Fourth, the extent of firms' interactive connections is strongly related to firms' human capital endowments in both economies. This latter result suggests interesting second-order innovation effects from human capital improvements.

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INTRODUCTION

Innovation stems from knowledge; be it commercial, technological or organisational. Individual firms' internal stocks of knowledge are limited, however, emphasising the importance of acquiring external knowledge to enable effective innovation. Firms may of course decide not to innovate, or to innovate on the basis of proprietary knowledge developed purely within the firm. While this type of independent technological development strategy has been linked to the success of some groups of firms (Simon 1996), it is increasingly uncommon among innovative smaller firms (van de Vrande et al. 2009). Where a firm does decide to seek knowledge for innovation outside the firm it faces a number of choices relating to its knowledge acquisition strategy. What types of partner should it connect with? Which specific partners should be approached? How should these relationships be structured? Should the firm develop collaborative or interactive links with partners to jointly develop new knowledge? Or, should the firm simply access previously codified knowledge through imitation, copying or learning strategies (Glückler 2013)?

Some antecedents of firms' knowledge acquisition strategies have been discussed elsewhere, with a focus on the influence of firms' internal capabilities and structure. Absorptive capacity, for example, typically measured using R&D and human capital measures, has been shown to play a significant role in shaping firms' ability to take advantage of external knowledge (Spithoven, Clarysse, and Knockaert 2011; Moon 2011). Xia and Roper (2014) also identify a positive relationship between realised absorptive capacity and the extent of partnering activity of small bio-technology firms. In a related study, Freel and Aslesen (2013) consider the role of organisational structure on firms' partnering strategies, providing evidence that less hierarchic firms develop more diverse connections, and that team or project-based working may be particularly conducive to the development of deep or strong links between firms. A similar study by (Moon 2011) links the breadth of firms' (interactive) knowledge search activities to their use of IP protection.

Existing research on the determinants of firms' knowledge acquisition strategies has four main limitations which we seek to address. First, existing studies tend to focus on firms' structural characteristics such as R&D, skills and organisational structures and their implications for external knowledge acquisition (Freel and Aslesen 2013; Spithoven, Clarysse, and Knockaert 2011). Here, following Moon (2011), we argue that firms' innovation objectives may also be important in shaping firms' knowledge acquisition strategies. Second, existing studies focus predominantly on knowledge acquisition through innovation partnering, paying little attention to the potential value of non-interactive knowledge sourcing mechanisms such as imitation or copying (Glückler 2013). Here, we seek to understand how firms' innovation objectives shape both interactive partnering and non-interactive knowledge acquisition. Firms seeking to develop new-to-the-market innovation, for example, will need to develop new knowledge, a process which is most likely to involve interactive relationships, characterised by collaboration and mutual learning. Examples of such interactive relationships would be collaborative R&D projects with universities or other firms. Firms seeking to develop new-to-the firm innovation – or imitations - on the other hand, may be able to acquire the knowledge needed through copying or reverse-engineering. Such non-interactive relationships emphasise the exploitation of pre-existing knowledge and are characterised by selfish, one-sided-learning. Thirdly, we examine size and sectoral differences, recognising that the rationale for external knowledge search may differ significantly between larger and smaller companies and between different sectors (Moon 2011; Vahter, Love, and Roper 2014). Vahter et al. (2014) argue, for example, that external knowledge search is of more value for smaller companies due to their weaker internal knowledge base. Finally, existing studies of knowledge search focus on a single country or region, although firms' ability to develop either interactive or non-interactive knowledge search strategies will depend critically on the nature of the innovation eco-system within which they are operating. Here, we focus on the contrasting economies of Spain and the UK, with previous studies suggesting that firms may find it more difficult within the Spanish innovation system to access those collective resources which can support innovation. This may be particularly important where, like Spain, a country has an economic structure based largely on small firms which depend more strongly on externally acquired knowledge than larger firms (Royo 2007). Spanish companies also face a greater burden of regulation and legislation, 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).

The remainder of the paper is organised as follows. Section 2 presents the conceptual framework and derives our hypotheses. Section 3 sets out the research context of the two economies Spain and the UK, and Section 4 describes the data and methods. Section 5 provides our estimation results, while Section 6 discusses these and concludes.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

Defining Firms' Innovation Objectives

Discussions of firms' innovation objectives typically reflect the diversity of firms' innovation activities, the relative risks and rewards of each type of innovation, and the need to balance resources and capabilities across different activities. A key distinction is that between innovation-based and imitation-based strategies (Shenkar 2010; Schnaars 1994; Bolton 1993). Both may involve the introduction of new products or services to the market, with innovation-based strategies involving new-to-the-market innovations, while imitations are new products or services, which are new-to-the-firm but not new-to-the-market. Imitation may, of course, be of very different types ranging from licensed or unlicensed (counterfeit) copying of a product or service, through mimic products which copy some or all of the features of an innovative product or service, to products which emulate an existing product but may actually be better than the established market leader (Ulhoi 2012). Innovation-based and imitation-based strategies have very different risks and rewards and involve very different tactical choices, viz 'exploitative innovation strategies primarily build on improvements and refinements of current skills and processes and lead to incremental product changes … Exploratory innovation primarily involves the challenging of existing approaches … Outcomes of exploratory innovation strategies are superior new products with significant consumer benefits: they can enable the firm to enter or even create new markets' (Mueller, Rosenbusch, and Bausch 2013, p. 1607).

So, innovation may create first-mover advantages for the innovating firm. These may lead to higher returns from a desirable and unique product or service but may also have other advantages in terms of helping the first mover to learn rapidly about the markets and build brand loyalty among customers (Kopel and Loffler 2008)[1]. For imitators on the other hand the potential for 'second mover advantages' are also evident. Perhaps the key advantage for imitators is that the market leader has already taken much of the uncertainty out of the initial product or service introduction[2]. On the production side this may mean that the imitator can copy, emulate or reverse engineer the product design or service delivery of an innovator. On the demand side, the imitator can learn from the innovator about consumers' appetite for a particular product or service and what consumers are prepared to pay. The imitator's problem however is not always simple as they try to establish a position in a market share in which there is already at least one established player (Ulhoi 2012). Second mover advantages can certainly occur at a firm level and there is some evidence –

[1] A key issue for innovators in any market place, however, is their ability to sustain their position of market leadership. In some sectors – biotechnology or engineering – this may involve formal strategies such as patenting to protect intellectual property; in other sectors more strategic approaches may be adopted such as frequent changes or upgrades to product or service design. Aggressive pricing also provides a way in which market leaders may protect any first mover advantages (Ulhoi 2012).

[2] Imitation may also be a stepping stone towards innovation as firms build innovative capabilities. This process is perhaps clearest in developing economies where firms have steadily developed their R&D and creative competencies. On Korea see (Kim 1997), on Taiwan (Hobday 1995), on China (Lim and Kocaoglu 2011) and on Brazil, (Dorion, Pavoni, and Chalela 2008).

particularly in less dynamic markets – that imitation may be a more profitable strategy than innovation (Lieberman and Asaba 2006)[3].

Innovation strategy may also involve process innovation objectives which can yield significant performance gains to the innovating firm (Rasiah, Gopal, and Sanjivee 2013). Strategies involving the adoption of advanced management techniques (AMTs), for example, may enable firms to develop more flexible and adaptive production systems allowing smaller batch sizes and enabling firms to cope better with perceived environmental uncertainty (Hofmann and Orr 2005; Zammuto and Oconnor 1992), changes to regulation etc. More flexible production systems may also allow firms to adopt more complex innovation strategies with potentially higher returns (Hewitt-Dundas 2004). Process innovation may also facilitate more radical innovation strategies as firms seek to create market turbulence by engaging in disruptive innovation in order to establish a position of market or technological leadership (Anthony et al. 2008; Hang, Chen, and Subramian 2010).

Knowledge Acquisition for Innovation

There are two main mechanisms through which firms may seek to acquire knowledge for innovation[4]. First, firms may form deliberate, purposive connections with other firms or organisations as a means of acquiring or accessing new knowledge. These might be partnerships, network linkages or contractually-based agreements entered into on either a formal or

[3] Imitation – second-mover - strategies may provide individual firms with a less risky option than innovation. At an industry and social level, however, imitation can have either positive or negative effects. On the positive side imitation may help to maximise the social and consumer benefits of the original innovation by making products or services available to more consumers. Imitation may also have negative effects, however, by reducing the variety of products or services within a market and increasing the collective vulnerability to external competition (Lieberman and Asaba 2006).

[4] Firms may also acquire knowledge vicariously and unintentionally through informal spill-over mechanisms such as social contacts between employees and those in other firms, media publicity or demonstration effects, or through the mobility of labour between enterprises. These pure knowledge spill-overs represent un-priced gains to the firm, effectively increasing the social returns to knowledge (Beugelsdijck and Cornet 2001).

informal basis. This type of connection is characterised by strategic intent and mutual engagement of both parties, and may be characterised as a form of interactive learning (Glückler 2013). Second, firms might acquire knowledge deliberately but without the direct engagement of another party. Examples of this type of mechanism include imitation, reverse engineering or participation in network or knowledge dissemination events. Here, there is a clear strategic intent on the part of the focal firm but no mutuality in the learning process, and this may be characterised as non-interactive learning. For example, in their analysis of university-business connections (Hewitt-Dundas and Roper 2011) distinguish between knowledge connections 'characterised by a two-way flow of knowledge, e.g. through formal or informal joint ventures or collaborative R&D projects', and knowledge suppliers 'characterised by a more uni-directional transfer of knowledge'.

Interactive learning is initiated by firms' strategic decision to build links and connections with other firms and economic actors (e.g. research institutes, universities and government departments) to capitalise on the knowledge of the linked parties, co-operate with the linked parties, and/or to exploit the knowledge together (Borgatti and Halgin 2011). Three characteristics seem important in measuring the potential benefits of interactive learning: the number of connections the firm has; the mode of interaction adopted; and the nature of the embeddedness of the networks in which firms are involved (Borgatti and Halgin 2011; Glückler 2013).

At its simplest, interactive learning and knowledge acquisition can be positively affected by a firms' number of connections. In purely statistical terms, since the payoff from any given innovation connection is unknown in advance, the chances of obtaining benefit from any connection in a given distribution of payoffs increases as the number of connections increases (Love et al, 2014). Having more connections increases the probability of obtaining useful external knowledge that can be combined with the firm's internal knowledge to produce innovation (Leiponen and Helfat 2010). The extent or breadth of a firm's portfolio of external connections may also have significant network benefits, reducing the risk of "lock-in" where firms are either less open to knowledge from outside its own region (Boschma 2005), or where firms in a region are highly specialised in certain industries, which lowers their ability to keep up with new technology and market development (Camagni 1991). However, the capacity of management to pay attention to and cognitively process many sources of information is not infinite, since the span of attention of any individual is limited (Simon 1947). This attention issue means that while the returns to additional connections may at first be positive, eventually the firm will reach a point at which an additional connection actually serves to diminish the innovation returns of external networking (Laursen and Salter 2006; Leiponen and Helfat 2010; Grimpe and Sofka 2009; Garriga, von Krogh, and Spaeth 2013).

Non-interactive learning is characterised by the absence of reciprocal knowledge and/or resource transfers between actors. The most frequently discussed modes of non-interactive learning are: imitation, where a firm absorbs the knowledge of other actors through observation of the actions/behaviour of the source actor; reverse engineering, where a firm derives knowledge from the final product of another firm, obtained from the market or through supply chain interaction; and the codification of knowledge, where a firm obtains knowledge through knowledge which is a public good such as news, patents and regulations etc. (Glückler 2013). As with interactive connections, the chances of obtaining useful knowledge from any non-interactive connection will increase as the number of non-interactive connections increases. Or, put another way, having more non-interactive connections will increase the probability of obtaining useful external knowledge.

The contrasting nature of the learning processes involved in interactive and non-interactive connections, and consequent differences in the types of knowledge they generate, suggests the potential for a complementary relationship. Two groups of alternative explanations for this complementarity are possible relating to the contrasting functional contents of each type of connection and/or their management and co-ordination. First, in terms of connection content, it may be that the different types of learning processes - exploratory and exploitative – implicit in interactive and non-interactive connections generate knowledge which plays a complementary role in firms' innovation activity. Collaborative connections with universities or research centres, for example, may facilitate exploratory activity, while non-interactive connections with customers or equipment suppliers may contribute more directly to exploitation (Faems et al. 2010; Lavie and Rosenkopf 2006). Second, there may be economies of scope as firms learn how to better manage and co-ordinate their external connections (Love, Roper, and Vahter 2014). This leads to our first hypothesis:

> Hypothesis 1: Interactive and non-interactive connections are complementary elements of firms' knowledge acquisition strategies.

Firms' Innovation Objectives and Knowledge Acquisition Strategies

The knowledge necessary for successful innovation includes technical, commercial and market data, both codified and tacit. The types of knowledge needed will, however, depend significantly on the technological novelty, the focus of the innovation (i.e. product, service, process) and the stage of development of any innovation. Developing new-to-the-market innovations, for example, is likely to involve exploratory R&D activity and the development of new technological knowledge either by a firm itself or through an external connection. Such partnership projects have a number of potential advantages – speed, risk sharing, access to a broader resource base – which can increase innovation quality and ameliorate both technological and commercial risk (Astebro and Michela 2005). Here, there is likely to be mutual learning as innovation partners interact to generate new knowledge. This suggests:

> Hypothesis 2: Knowledge acquisition through interactive relationships will be most important where firms' innovation objectives emphasise new product or service innovation

Alternative knowledge acquisition strategies are non-interactive, involving mechanisms such as copying, imitation or the purchase of intellectual property through mechanisms such as licensing (Anand and Khanna 2000). In each case the emphasis is on the exploitation of existing knowledge. Such exploitative, non-interactive mechanisms may, however, allow firms to rapidly establish positions in new technical areas without undertaking a discovery process, and to avoid both the technological and commercial uncertainties implicit in such a process. A recent Korean study, for example, suggested that: 'technology acquisition may be one of the most efficient collaborative activities when this activity can be simply conducted to complement insufficient resources' (Suh and Kim 2012, p. 361). Ulhoi (2012) outlines the range of outcomes which may arise from non-interactive imitation strategies: Replica – licensed or unlicensed (counterfeit) copying of a product or service; Mimicry – copying some or all of the features of an innovative product or service; Analogue – developing a different product or service but with similar functionality. The implication is that:

> Hypothesis 3: Non-interactive knowledge acquisition will be most important where firms' innovation objectives emphasise product or service improvement.

Different types of innovation – product, process or service – will also require different types of knowledge (Roper, Du, and Love 2008). Connections with knowledge search among customers, for example, might impact most strongly on product innovation (Su, Chen, and Sha 2007), while search with suppliers or external consultants might impact most directly on process change (Horn 2005; Smith and Tranfield 2005). The majority of process change is likely to be incremental and "firms frequently rely on machinery suppliers and outside consultants as sources of embodied process innovation, the challenges posed by change can draw on a variety of technical sources with different knowledge bases and aims" (Robertson, Casali, and Jacobson 2012, p. 822). Therefore we might argue that:

Hypothesis 4: Non-interactive knowledge acquisition will be most important where firms' innovation objectives emphasise process innovation.

RESEARCH CONTEXT: SPAIN AND THE UK

Although both are within the EU, the UK and Spain have contrasting institutional and policy structures which may shape firms' innovation objectives and knowledge acquisition strategies. Hall and Soskice (2001), for example, develop the notion of comparative institutional advantage suggesting that in different countries 'institutions set the rules of the game, determine the capacity of co-ordination among businesses and, consequently their competitive advantage in world markets … Differences across countries in the quality and configuration of these institutional frameworks help explain disparities in firms' behaviour and performance' (Royo 2007, p. 48). Previous studies of innovation in the two countries have emphasised the stronger government influence on the innovation system in Spain (Mate-Sanchez-Val and Harris 2014), the more difficult regulatory environment for innovation in Spain (Mate-Sanchez-Val and Harris, 2014) , and the more regionalised and fragmented support system for innovation in Spain (Roper et al. 2007)[5]. Each may mean that the innovation system in Spain may be less able to provide the collective goods which can support competitive development than that in the UK.

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[5] These contrasting institutional frameworks are reflected in the literature on the varieties of capitalism which typically place the UK in the group of Liberal Market Economies, in which factor allocation 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). Spain, by contrast, has been characterised as a Mixed Market Economy (or MME) (Molina and Rhodes, 2007) or having a 'Mediterranean' VoC (Hall and Soskice 2001) in which clientelism is more pronounced, and the state plays a compensatory rather than enabling role, intervening to compensate for competitive or financial shocks rather than facilitating competitive strategies in firms.

First, 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. 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 (Figure 1). Since 2008, however, R&D spend in Spain has fallen sharply both in aggregate (Figure 1) and in the business sector (Figure 2)[6]. 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 Spain, and government spend proportionately less important in the 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 (Figure 2, part a). 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 that R&D undertaken by firms (Table 1, part B). Government funding for business R&D 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 (Figure 2, part b). International funding for R&D is significantly more important in the UK (Table 1, part b). The relative importance of public R&D

[6] The result of these lower levels and instability of R&D spend is that Spain is classified with, for example, Hungary, Portugal and Italy in the group of 'moderate' innovators by the Innovation Union Scoreboard 2015, The UK ranks slightly higher than Spain as an 'innovation follower', a similar status to that of Ireland, Luxembourg and the Netherlands (EU 2015).

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)[7] (see also (Roper et al. 2007).

A second key difference 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)[8]. Elements of the regulatory structure for firms in Spain and the UK are common due to both countries EU membership. National differences persist, however, as suggested by the two nations' very different ranking on indicators such as the World Bank's 'Doing Business' index. This ranks the UK 8th globally in terms of the regulatory and legislative environment for commercial activity, with the UK 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). The implication is that the burden of business regulation is greater in Spain which (Capelleras et al. 2008) demonstrate hinders the legality

[7] 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.
[8] 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).

although not growth of new ventures[9]. 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[10].

Finally, there is some evidence from both supply-chain studies and more econometric analysis that innovation systems in Spain are more differentiated spatially than those in the UK. For example, Nijhoff-Savvaki et al, 2010 examined pork meat supply chains in the UK and Spain with developments focussed on traceability in the UK and a geographically defined and protected designation of origin (PDO) in Spain. They conclude: '…in the UK niche pork netchains mainly strive for operational excellence and leadership, both in Greece and Spain niche pork netchains are working towards preserving tradition and culture' through more localised supply-chain relationships. (Nijhoff-Savvaki et al, 2010, p. 1113). 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.

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[9] Firm evidence on the innovation impacts of regulation is mixed, however, with Blind (2012) summarising the effects of liability laws and intellectual property rights on innovation as 'ambivalent', bankruptcy law as 'negative' and employee protection laws as 'mostly positive'. This mixed evidence has led to recent suggestions that innovative responses to regulation will depend on the capabilities of firms themselves, and that firms facing regulatory barriers may co-ordinate or partner in order to develop innovative responses (Ford, Steen, and Verreynne 2014).

[10] 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).

It is difficult a priori to be certain how the stronger public sector influence, or the more localised nature of Spanish innovation systems, will influence innovation ambition or firms' knowledge acquisition strategies. The effects of stronger regulation in the Spanish economy are perhaps easier to anticipate. First, a heavier regulatory burden may discourage ambition, although the available evidence relates to ambitious entrepreneurship rather than innovation per se (Levie and Autio 2013). Second, stronger regulation increases the regulatory risks associated with new to the market innovations where innovators face uncertainty as to whether or not new developments may contravene regulation, potentially leading to more incremental innovation strategies due to regulatory-risk aversion (Eichler et al. 2013; Sass 1997), which may suggest non-interactive knowledge acquisition strategies being favoured over interactive strategies.

DATA AND METHODS

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 Business Register, with structuring by sizeband, region and sector. Surveys are non-compulsory and achieved response rates ranging from 51.1 per cent in CIS7 (2010) to 58 per cent in CIS4 (2004)[11]. 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[12]. 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

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

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 the objectives of firms' innovation activity and their knowledge acquisition activities. In addition both surveys provide information on a range of other workplace level characteristics which we use as control variables.

We define two dependent variables relating to the extent of firms' interactive knowledge search activity and non-interactive knowledge search. In the UK Innovation Survey and the PITEC we find the following question: 'Which types of co-operation partner did you use and where were they located?', with seven potential innovation partner types being identified[13]. We use this data on 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. Innovating firms in the UK had an average of 1.58 interactive partnerships compared to 1.04 in Spain (Table 2). Similarly, we measure the extent of firms' non-interactive knowledge search in a similar way using responses to the question: 'How important to your firm's innovation were each of the following data sources?' Here, we focus on three groups of knowledge sources which are available on a consistent basis for the UK and Spain and different waves of the UKIS and PITEC: (1) conferences, trade fairs, exhibitions; (2) scientific journals and trade/technical publications; and, (3) professional and industry

[13] These were: other enterprises within the group; suppliers of equipment, materials, services or software; clients or customers; competitors within the industry or elsewhere; consultants, commercial labs or private R&D institutes; universities or other higher education institutions; government or public research institutes. In the PITEC, the latter is split into two, public research institutes and technological centres, which we summarized so as to be consistent with the UKIS.

associations. Our indicator of non-interactive knowledge search therefore takes values between 0, where the firm is not engaging in any non-interactive knowledge search activity, and 3 where it uses each non-interactive data source. On average innovating firms in the UK were using 0.98 non-interactive knowledge sources compared to 1.06 in Spain (Table 2). While the differences are small, non-interactive partnerships seem somewhat more important in the more highly regulated economy Spain, which tentatively suggests lower ambition. Interestingly in terms of Hypothesis 1 which suggests complementarity between interactive and non-interactive knowledge search activity we also find a weak positive correlations (0.22-0.24) between the two variables (Tables A1 and A2).

The other key variable in our analysis reflects the objectives of firms' innovation activity. This is derived from a PITEC/UKIS question which asks: 'How important were each of the following factors in your decision to innovate in goods or services and/or process(es)?'. Eight alternative objectives for engaging in innovation are distinguished in the various waves of the UKIS and PITEC (Table 2) which we associate with one of the three broad innovation objectives which are the foci of our hypotheses (i.e. new products/services; improved products/services; process innovation). New products/service innovation we associate with objectives either to increase firms' range of goods or services and/or increasing market share. New products or services were highlighted as innovation objectives by 81-83 per cent of innovating firms in the UK and 70-73 per cent in Spain (Table 1). Improving products or services we measure using the objectives of improving the quality of goods and services, increasing value added[14], and meeting regulatory or health and safety requirements. 65-89 per cent of innovating firms in the UK cited these objectives compared to 50-79 per cent in Spain. Finally, process improvements are measured by objectives to either improve flexibility and the capacity for producing goods. These were the least common innovation objectives cited as important by 60-63 per cent of innovating firms in the UK and 50-64 per cent in Spain (Table

[14] This objective is missing from the PITEC questionnaire.

2). Interestingly, consistent with the discussion in section 3, these statistics overall suggest that firms in the less highly regulated UK economy are more innovation-ambitious than firms in Spain.

We also include in our analysis four variables which previous studies have linked to dimensions of innovation activity. First, we include a binary indicator of whether or not a firm has an in-house R&D capability (Love and Roper, 2001, Love and Roper, 2005, Griffith et al., 2003) which we anticipate will be positively associated with acquisition In our sample of innovators 88 per cent of UK firms had an R&D capability compared to 71 per cent in Spain. The lower percentage for Spain is consistent with the lower levels of R&D activity in Spain, as discussed in section 3. Second, we include a variable reflecting the strength of firms' human capital – the percentage of the workforce which are graduates (Leiponen, 2005, Freel, 2005, Hewitt-Dundas, 2006). On average, 19.7 per cent of innovating firms' workforce are graduates in the UK compared to 28.7 per cent in Spain (Table 2). Third, we include 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 innovating firms which were exporting was 49.9 per cent in the UK and 69.9 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).

Our estimation strategy follows previous studies which have considered the determinants of the extent of firms' interactive connections (Moon 2011). As the dependent variables both in the models for the extent of firms' interactive and non-interactive connections are count variables either Poisson or Negative Binomial models are appropriate. However, in both cases a relatively large proportion of innovating firms have no external connections and so we also consider the zero inflated Poisson (ZIP) and zero inflated negative binomial models (ZINB)[15]. Vuong tests consistently suggest the superiority of the ZIP and ZINB models and both are reported here[16]. 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 include sector dummies at the 2-digit level and wave dummies in each model.

ESTIMATION RESULTS

We divide the presentation of results into two main sections. First, we report baseline models for the whole group of innovating firms relating interactive and non-interactive connections to their innovation objectives. Second, as previous studies have suggested potential differences in the determinants of firms' interactive connections by sector (Moon 2011), and the differential value of external connections for firms of different sizes (Vahter, Love, and Roper 2014), we report sub-sample estimates for specific groups of firms by industry and sizeband. These sub-sample estimates also provide a robustness check on the full sample estimates.

Baseline models of the extent of firms' interactive and non-interactive search strategies for the whole group of innovating firms are reported in Tables 3 for the UK and 4 for Spain. Our first hypothesis relates to the potential for a complementary connection between interactive and non-interactive search in firms' knowledge acquisition strategies[17]. Positive and strongly significant coefficients on both interactive and non-interactive search in the UK and Spanish models provide strong support for this hypothesis, a result which proves robust across different estimation approaches. The implication is that firms engaging in interactive knowledge

[15] For our whole sample of innovating firms 52 per cent of firms have no interactive relationships while 37 have no non-interactive relationships.
[16] Estimation of either Poisson or negative binomial models suggest almost identical results to those presented here.
[17] We have little insight from previous studies about any complementary relationship between firms' interactive and non-interactive relationships. There is some evidence however of complementarities between specific types of interactive relationships (Roper, Du, and Love 2008).

search are also more likely to be engaging in non-interactive search and vice versa. As indicated above, this complementarity may arise either from the different types of learning processes - exploratory and exploitative – implicit in interactive and non-interactive search, and/or from economies of scope as firms learn how to better manage and co-ordinate their external search activity (Love, Roper, and Vahter 2014).

Our remaining hypotheses focus on the connections between firms' innovation objectives and their knowledge acquisition strategies. Hypothesis 2 argues that interactive search, which facilitates exploratory learning processes, will be more strongly related to innovation strategies which emphasise the introduction of new rather than improved or upgraded products. The evidence from our baseline models for the UK and Spain, however, provides little support for this view. In Spain both new product/service objectives and improvement objectives are associated with more extensive interactive *and* non-interactive search (Table 4). In the UK, the picture is slightly more complex: new product/service objectives linked to an increased range of goods or services are – as in Spain - linked to both interactive and non-interactive knowledge acquisition strategies; new product/service strategies linked to increasing market share are, however, linked more strongly to non-interactive knowledge acquisition strategies (Table 3). There is similarly mixed evidence from the improvement objectives in the UK. Our results therefore provide little support for Hypothesis 2 with one potential explanation relating to the nature of the innovation objectives included in the UKIS/PITEC surveys. These relate specifically to 'near-market' development activity focussed specifically on the introduction of new products/services and processes and exclude more basic technological development activities. It may be that interactive, more exploratory learning processes are more strongly linked to basic research with a less clear distinction between the more applied activity covered by our data sources[18].

[18] The OECD Frascati manual defines the types of R&D activity as follows: Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts without any particular application or use in view; Applied research is also original

Hypothesis 3 suggests that where firms' innovation objectives relate to product or service improvements, non-interactive connections will be more common. We find only weak support for this hypothesis in both Spain and the UK: of the product/service improvement objectives considered more are significantly associated with non-interactive knowledge acquisition strategies in both Spain and the UK. In Spain, each of the three product/service improvement objectives is positively associated with non-interactive knowledge acquisition strategies while in the UK this is true of two of the four product/service improvement objectives considered (Tables 3 and 4). In our baseline models the equation coefficients therefore provide weak support for Hypothesis 3.

One notable contrast between the UK and Spain here is the impact of the need to meet regulatory requirements on firms' innovation strategy. In the UK, regarded as having the less onerous system of business regulation (Capelleras et al. 2008; World Bank Group 2015, 2015), meeting regulatory requirements has no significant effect on firms' knowledge acquisition strategies. In Spain, there is no significant effect on interactive knowledge acquisition strategies but a strong positive impact on non-interactive knowledge search (Table 4). In other words, the need to meet more complex regulatory needs in Spain is linked to more non-interactive knowledge search by firms. Two issues are worth noting here. First, Spanish firms are seeking to address the regulatory challenges they face through non-interactive rather than interactive knowledge search, i.e. through copying, imitation or using already codified knowledge rather than more exploratory partnering. This may reflect the risk-reward balance in innovative activity focussed on meeting regulatory requirements rather than, say, on market expansion. Secondly, even this type of non-interactive knowledge acquisition is likely to be imposing a cost burden on Spanish

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investigation undertaken in order to acquire new knowledge. It is however, directed primarily towards a specific practical aim or objective; Experimental development is systematic work … that is directed to producing new materials products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed (OECD 2002) firms, something not experienced by UK businesses (Mate-Sanchez-Val and Harris 2014).

Our final hypothesis suggests that non-interactive knowledge acquisition will be most strongly associated with process innovation objectives. We find some support for this in Spain but not in the UK. In the UK, innovation objectives related both to process flexibility and capacity are associated both with interactive and non-interactive knowledge acquisition strategies (Table 3). In Spain, however, while process flexibility is also associated with both types of knowledge acquisition strategies, although more strongly so with non-interactive strategies, capacity and cost per unit are only associated with non-interactive knowledge acquisition (Table 4). One possibility is that that this narrower range of knowledge acquisition strategies in Spain may be linked to weaknesses in the Spanish innovation system relative to that in the UK. Where other firms or support organisations have weaker internal capabilities for example, the benefits of developing interactive relationships may be lower. Roper et al. (2008), for example, find that interactive or cooperative knowledge search is more important for process innovation in the West Midlands and Wales regions than that for firms in Catalonia. Another possibility is that in Spain the link between process innovation and incremental innovation strategies, which favour non-interactive knowledge acquisition strategies, is strengthened through the heavier regulatory burden. Interactive linkages may also have less value where levels of absorptive capacity are lower. As Mate-Sanchez-Val and Harris (2014, p. 457) comment: 'innovation spillovers in the Spanish case are more likely to be pecuniary and based on market (i.e. buyer-seller transactions) while those in the UK … are based on non-market interaction usually involving the sharing of a general pool of knowledge and expertise'.

Given the established differences between innovation behaviours of firms of different sizes and sectors, and the rather different composition of industry in the UK and Spain (Mate-Sanchez-Val and Harris 2014) it is interesting to examine the consistency of these aggregate results for sample sub-groups. Tables 5 and 6 report estimation results for different firm sizebands, while Tables 7 and 8 report sub-sample estimation for manufacturing and services firms. In each case the models follow the same structure as the baseline models and include wave dummies.

Our aggregate models suggest strong support for Hypothesis 1 and the complementarity between interactive and non-interactive knowledge search. This result is consistent across both manufacturing and services firms (Tables 7 and 8) and by sizeband (Tables 5 and 6) in both countries. Similarly, consistent evidence relates to the link between firms' objectives related to new products or services and search strategies. Across sizebands and sectors both interactive and non-interactive search strategies are more common where firms emphasise new product or service development. Hypothesis 3 suggests a stronger association between non-interactive knowledge search and product/service improvement and at an aggregate level we find some support for this contention. This too is relatively consistent across sizebands and broad sectors although the evidence for Spain is more consistent than that for the UK. The value of non-interactive knowledge search for meeting regulatory requirements evident in our aggregate analysis for Spain also carries over into each firm sizeband and broad sector. Hypothesis 4, relating to the association between process innovation objectives and non-interactive knowledge search is also more strongly supported for Spain than the UK in our sub-sample estimation.

Alongside the variables of interest we include four control variables in our analysis which suggest some further contrasts between the determinants of search strategies in Spain and the UK. Firm size, for example, is positively associated with interactive search in Spain but with non-interactive search in the UK. Exporting has no significant association with search strategies in the UK but is positively associated with interactive search and negatively associated with non-interactive search in Spain. This positive association with interactive connections may reflect the need for firms to remain innovative in order to compete effectively in international markets, where competition from more advanced economies may increase the need for more radical and less incremental innovation and hence favour interactive collaboration, although it is surprising that this link does not also operate in the UK. It may be that the link between exporting and innovation or R&D in the UK operates mainly for businesses' own innovative activity rather than external knowledge acquisition; which may find some support from the data showing higher R&D investment by, and R&D capabilities of, firms in the UK than in Spain (Section 3 and Tables 1 & 2). The negative association of exporting with non-interactive strategies which include imitation might be related to imitation increasing vulnerability to external competition (Lieberman and Asaba 2006), in particular perhaps of firms in less advanced economies such as Spain, so other things equal exporting firms may tend to avoid non-interactive search. The proportion of graduates in the workforce is positively associated with interactive search in both countries as well as non-interactive search in the UK. In-house R&D spend is more strongly associated with external knowledge search in Spain than the UK. One possibility is related to recent suggestions that, as mentioned in section 3, innovative responses to regulation will depend on firms' capabilities (Ford, Steen, and Verreynne 2014). Thus where regulation is more stringent, capabilities, including R&D capabilities, may be a more decisive factor in innovation.

DISCUSSION AND CONCLUSIONS

Firms can acquire the knowledge necessary to drive innovation either through internal discovery processes or through external search (Chesbrough 2007; Chesborough 2006). Here, using data on large samples of UK and Spanish companies, we examine the factors which determine two different modes of knowledge acquisition activity: interactive connections which may be exploratory in character and in which there is a mutuality to learning, and non-interactive connections in which knowledge flows from one party to another and learning is therefore one-sided (Glückler 2013).

In terms of our hypotheses two main empirical results stand out. First, we find strong and consistent support for complementarity between non-interactive and interactive connections across firms in all sectors and sizebands and across both countries. In other words, firms which have more interactive connections as part of their innovation activity also have more non-interactive connections. On the basis of our survey data we are, however, unable to distinguish whether this complementarity is due to differences in the functional content of these connections (Faems et al. 2010; Lavie and Rosenkopf 2006), economies of scope in their management and coordination (Love, Roper, and Vahter 2014), or both. Second, we find some evidence that where firms have innovation objectives which relate to product or service improvement they are more likely to establish non-interactive rather than interactive connections. Such connections are likely to be exploitative (rather than exploratory) focussed on the application and commercialisation of existing knowledge rather than the creation of new knowledge which might provide the basis for the introduction of new products or services. The link between product and service improvement and non-interactive search is markedly stronger in Spain than the UK, perhaps reflecting the weaker internal capabilities of potential Spanish partners and lower levels of absorptive capacity.

Our analysis suggests one other consistent result across the two countries. We find a consistent and positive relationship between the quality of firms' human capital and interactive knowledge search. This provides a link between our study and previous analyses which have linked firms' propensity to develop external connections to their internal capabilities – particularly absorptive capacity (Spithoven, Clarysse, and Knockaert 2011; Schmidt 2010; Xia and Roper 2008). It also suggests that one – indirect – benefit of investments or policy initiatives designed to improve firms' human capital will be an increase in inter-organisational connectivity or openness which itself has potentially positive externalities (Roper, Vahter, and Love 2013). Our findings on the impact of human capital on firms' external knowledge search also highlight the contingent nature of such activities. Sectoral factors, such as regulation, may be important but individual firm-level influences – such as skill attributes and firms' innovation objectives – also play a significant role. Such factors may also influence the value which firms' derive from their external connections and in future papers we aim to examine how firms' interactive and non-interactive connections contribute to innovation performance.

Differences also emerge between countries particularly in the impact of regulation on firms' knowledge acquisition strategies. For firms in the less regulated UK market we find no significant relationship between a need to overcome regulatory issues and firms' knowledge acquisition strategies. Conversely, firms in Spain, which face more onerous regulatory pressures, adopt more extensive non-interactive knowledge search strategies with potential implications for both knowledge diffusion and business costs. This result suggests a role for government to make it easier for firms to meet regulatory requirements, and more importantly to reduce the regulatory burden faced by firms. This could raise ambition and could focus innovation on more productive objectives than meeting regulatory requirements.

Our results suggest which different innovation objectives induce firms to seek interactive and/or non-interactive connections to access required knowledge. This suggests that policy initiatives to incentivise innovation collaboration could be aligned to firms' particular innovation objectives. In order for such policy initiatives to be designed more effectively, another issue needs to be explored: Different types of interactive and non-interactive connections face different economic characteristics, incentives and problems, which could be supported by individually targeted policies. For instance, interactive collaboration with customers and suppliers differs markedly from collaboration with direct competitors or with universities and higher education institutions. Hence it would be valuable to know the links between different innovation objectives on the one hand and specific interactive and non-interactive connections on the other hand.

Another important research issue is a more specific identification of which elements of firms' knowledge environment are important for innovation. Are beneficial spillovers, for example, linked more closely to industry, spatial or network inter-relations? Or, to a combination of these factors? And how does each aspect of knowledge context contribute to the extent of interactive and non-interactive learning? Examination of these issues in the context of the different innovation eco-systems and regulatory burdens of the UK and the Spanish economy could provide additional useful insights. These are further avenues of our future research.

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: Summary statistics: UK and Spain

	UK			Spain		
Variable	Observations	Mean	SD	Observations	Mean	SD
Knowledge sourcing strategies						
Interactive	21,748	1.582	2.057	31055	1.044	1.666
Non-interactive	21,748	0.984	1.094	31055	1.062	1.147
New product/service objectives						
Increasing range of goods or service	20,354	0.814	0.389	31055	0.734	0.442
Increasing market share	20,405	0.836	0.370	31055	0.709	0.454
Improved product/service objectives						
Improving quality of goods or services	20,450	0.893	0.309	31055	0.797	0.402
Improving health and safety	20,111	0.710	0.454	31055	0.503	0.500
Meeting regulatory requirement	20,110	0.657	0.475	31055	0.507	0.500
Increasing value added	20,076	0.680	0.466			
Process innovation objectives						
Improving flexibility for producing goods or services	20,122	0.603	0.489	31055	0.629	0.483
Improving capacity for producing goods or services	20,105	0.636	0.481	31055	0.646	0.478
Reduced unit cost of production				31055	0.501	0.500
Control variables						
Log(Employment)	21,134	4.158	1.709	31055	5.710	7.278
Exporter	21,748	0.499	0.500	31055	0.699	0.459
% of graduates	20,799	19.787	29.479	30805	28.746	28.604
R&D spending dummy	21,748	0.878	0.327	31055	0.713	0.452

Table 3: Baseline models for all enterprises - UK

	Interactive		Non-interactive	
	Zero inflated Poisson	Zero inflated negative	Zero inflated Poisson	Zero inflated negative
Non-interactive	0.134***	0.140***		
	(0.010)	(0.010)		
Interactive			0.071***	0.071***
			(0.005)	(0.005)
New product/service objectives				
Increasing range of goods or service	0.091***	0.106***	0.196***	0.196***
	(0.033)	(0.034)	(0.036)	(0.036)
Increasing market share	-0.031	-0.019	0.195***	0.195***
	(0.039)	(0.041)	(0.039)	(0.039)
Improved product/service objectives				
Improving quality of goods or services	-0.018	-0.002	0.201***	0.201***
	(0.047)	(0.048)	(0.050)	(0.050)
Improving health and safety	0.087***	0.088***	0.043	0.043
	(0.029)	(0.030)	(0.032)	(0.032)
Meeting regulatory requirement	0.011	0.01	0.037	0.037
	(0.027)	(0.028)	(0.029)	(0.029)
Increasing value added	0.019	0.029	0.104***	0.104***
	(0.027)	(0.027)	(0.029)	(0.029)
Process innovation objectives				
Improving flexibility for producing goods services	0.107***	0.112***	0.177***	0.177***
	(0.029)	(0.030)	(0.029)	(0.029)
Improving capacity for producing goods services	0.147***	0.152***	0.309***	0.309***
	(0.027)	(0.027)	(0.030)	(0.030)
Control variables				
Log(employment)	-0.004	-0.003	0.030***	0.030***
	(0.007)	(0.007)	(0.008)	(0.008)
Exporter	0.01	0.011	0.002	0.002
	(0.028)	(0.029)	(0.034)	(0.034)
% of graduates	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.001)	(0.001)
R&D spending dummy	0.044	0.051	-0.085	-0.085
	(0.057)	(0.060)	(0.058)	(0.058)
Constant	0.878***	0.769***	-0.890***	-0.890***
	(0.213)	(0.232)	(0.238)	(0.238)
Vuong test (Z value)	51.16***	44.05***	9.62**	na
Observations	18681	18681	18681	18681

Note: Robust standard deviation in parentheses controlled for possible cluster of reporting units belong to the same enterprise. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Baseline models for all enterprises - Spain

	Interactive		Non-interactive	
	Zero inflated Poisson	Zero inflated negative binomial	Zero inflated Poisson	Zero inflated negative binomial
Non-interactive	0.114***	0.126***		
	(0.008)	(0.007)		
Interactive			0.0517***	0.0517***
			(0.004)	(0.004)
New product/service objectives				
Increasing range of goods or services	0.150***	0.161***	0.172***	0.172***
	(0.027)	(0.022)	(0.023)	(0.023)
Increasing market share	0.133***	0.138***	0.203***	0.203***
	(0.025)	(0.022)	(0.022)	(0.022)
Improved product/service objectives				
Improving quality of goods or services	0.118***	0.125***	0.288***	0.288***
	(0.032)	(0.025)	(0.030)	(0.030)
Improving health and safety	0.166***	0.183***	0.159***	0.159***
	(0.025)	(0.021)	(0.019)	(0.019)
Meeting regulatory requirement	0.023	0.020	0.220***	0.220***
	(0.024)	(0.020)	(0.020)	(0.020)
Process innovation objectives				
Improving flexibility for producing goods or services	0.043*	0.045**	0.096***	0.096***
	(0.024)	(0.020)	(0.020)	(0.020)
Improving capacity for producing goods or services	0.030	0.030	0.087***	0.087***
	(0.025)	(0.021)	(0.021)	(0.021)
Reducing cost per unit produced or provided	0.028	0.028	0.063***	0.063***
	(0.021)	(0.018)	(0.016)	(0.016)
Control variables				
Log(employment)	0.132***	0.135***	-0.006	-0.006
	(0.006)	(0.005)	(0.006)	(0.006)
Exporter	0.094***	0.108***	-0.033*	-0.033*
	(0.025)	(0.021)	(0.019)	(0.019)
% of graduates	0.003***	0.003***	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
R&D spending dummy	0.656***	0.672***	0.258***	0.258***
	(0.037)	(0.024)	(0.022)	(0.022)
Constant	-1.145***	-1.243***	-0.745***	-0.745***
	(0.084)	(0.069)	(0.066)	(0.066)
Vuong test (Z value)	42.31***	19.64***	16.89***	225.44***
Observations	29,774	29,774	29,774	29,774

Note: Robust standard errors in parentheses controlled for possible cluster of reporting units belonging to the same enterprise. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Results by enterprise size - UK

	Interactive			Non-interactive		
	Small	Medium	Large	Small	Medium	Large
Non-interactive	0.142***	0.115***	0.092***			
	(0.013)	(0.015)	(0.011)			
Interactive				0.074***	0.066***	0.050***
				(0.006)	(0.007)	(0.005)
New product/service objectives						
Increasing range of goods or service	0.094**	0.107**	0.026	0.215***	0.122**	0.237***
	(0.043)	(0.051)	(0.032)	(0.047)	(0.054)	(0.043)
Increasing market share	-0.061	0.09	0.056	0.194***	0.211***	0.195***
	(0.048)	(0.057)	(0.041)	(0.049)	(0.059)	(0.059)
Improved product/service objectives						
Improving quality of goods or services	-0.026	0.031	-0.032	0.191***	0.242***	0.163**
	(0.058)	(0.070)	(0.050)	(0.063)	(0.070)	(0.067)
Improving health and safety	0.098***	0.070*	0.006	0.028	0.077*	0.118***
	(0.037)	(0.037)	(0.032)	(0.041)	(0.043)	(0.038)
Meeting regulatory requirement	0.013	0.019	0	0.029	0.055	0.088***
	(0.035)	(0.037)	(0.029)	(0.037)	(0.040)	(0.033)
Increasing value added	0.018	0.009	0.084**	0.122***	0.058	0.029
	(0.033)	(0.039)	(0.035)	(0.036)	(0.043)	(0.037)
Process innovation objectives						
Improving flexibility for producing goods or	0.108***	0.088**	0.109***	0.178***	0.144***	0.226***
	(0.036)	(0.039)	(0.032)	(0.037)	(0.045)	(0.038)
Improving capacity for producing goods or	0.142***	0.143***	0.123***	0.310***	0.327***	0.278***
	(0.034)	(0.037)	(0.032)	(0.038)	(0.044)	(0.038)
Control variables						
Log(employment)	-0.044***	-0.035*	0.012	0.039**	0.013	-0.013
	(0.017)	(0.018)	(0.010)	(0.018)	(0.019)	(0.010)
Exporter	0.007	0.022	0.038	-0.015	0.036	0.096**
	(0.034)	(0.041)	(0.032)	(0.049)	(0.048)	(0.043)
% of graduates	0.002***	0.002***	0.003***	0.002*	0.003***	0.002***
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
R&D spending dummy	-0.001	0.234**	0.265***	-0.099	-0.07	0.181***
	(0.068)	(0.092)	(0.062)	(0.073)	(0.091)	(0.062)
Constant	1.049***	0.515***	-13.692***	-0.892***	-14.98	-13.628
	(0.230)	(0.154)	(4.121)	(0.247)	(24.745)	(0.000)
Vuong test (Z value)	31.93***	25.62***	na	6.34***	4.76***	na
Observations	8517	5346	4818	8517	5346	4819

Note: Robust standard deviation in parentheses controlled for possible cluster of reporting units belong to the same enterprise. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Results by enterprise size - Spain

	Interactive			Non-interactive		
	Small	Medium	Large	Small	Medium	Large
Non-interactive	0.144***	0.096***	0.099***			
	(0.014)	(0.015)	(0.013)			
Interactive				0.062***	0.048***	0.048***
				(0.006)	(0.006)	(0.007)
New product/service objectives						
Increasing range of goods or services	0.159***	0.186***	0.081*	0.159***	0.187***	0.191***
	(0.042)	(0.050)	(0.042)	(0.033)	(0.042)	(0.045)
Increasing market share	0.059	0.223***	0.123***	0.229***	0.178***	0.176***
	(0.038)	(0.047)	(0.045)	(0.031)	(0.040)	(0.046)
Improved product/service objectives						
Improving quality of goods or services	0.109**	0.029	0.270***	0.331***	0.245***	0.236***
	(0.047)	(0.051)	(0.066)	(0.042)	(0.050)	(0.066)
Improving health and safety	0.169***	0.133***	0.184***	0.167***	0.137***	0.170***
	(0.038)	(0.040)	(0.047)	(0.026)	(0.033)	(0.048)
Meeting regulatory requirement	0.007	0.007	0.085**	0.212***	0.235***	0.212***
	(0.038)	(0.040)	(0.041)	(0.026)	(0.032)	(0.045)
Process innovation objectives						
Improving flexibility for producing goods or services	0.028	0.075*	0.039	0.082***	0.138***	0.061
	(0.035)	(0.042)	(0.047)	(0.027)	(0.037)	(0.044)
Improving capacity for producing goods or services	0.030	-0.009	0.106**	0.093***	0.063*	0.105**
	(0.039)	(0.043)	(0.046)	(0.028)	(0.036)	(0.049)
Reducing cost per unit produced or provided	-0.020	0.059	0.039	0.062***	0.042	0.118***
	(0.032)	(0.038)	(0.037)	(0.021)	(0.028)	(0.038)
Control variables						
Log(employment)	0.167***	0.101***	0.090***	-0.006	0.044	-0.031
	(0.023)	(0.036)	(0.017)	(0.016)	(0.031)	(0.024)
Exporter	0.065*	0.071	0.136***	-0.023	-0.026	-0.055
	(0.035)	(0.046)	(0.046)	(0.025)	(0.041)	(0.047)
% of graduates	0.003***	0.003***	0.002**	-0.000	-0.001*	0.000
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
R&D spending dummy	0.565***	0.666***	0.728***	0.257***	0.274***	0.250***
	(0.049)	(0.076)	(0.072)	(0.030)	(0.042)	(0.047)
Constant	-0.969***	-1.041***	-1.371***	-0.864***	-0.941***	-0.282
	(0.126)	(0.216)	(0.216)	(0.0961)	(0.177)	(0.174)
Vuong test (Z value)	25.04***	25.34***	20.31***	11.2***	9.00***	8.00***
Observations	14,404	9,601	5,769	14,404	9,601	5,769

Note: Robust standard errors in parentheses controlled for possible cluster of reporting units belonging to the same Enterprise. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 7: Results by sector - UK

	Manufacturing		Services	
	Interactive	Non-interactive	Interactive	Non-interactive
Non-interactive	0.126***		0.132***	
	(0.013)		(0.014)	
Interactive		0.078***		0.069***
		(0.007)		(0.007)
New product/service objectives				
Increasing range of goods or service	0.106**	0.212***	0.086**	0.164***
	(0.049)	(0.058)	(0.044)	(0.046)
Increasing market share	0.150**	0.298***	-0.062	0.183***
	(0.067)	(0.067)	(0.047)	(0.049)
Improved product/service objectives				
Improving quality of goods or services	0.118**	0.155**	-0.088	0.205***
	(0.060)	(0.068)	(0.060)	(0.066)
Improving health and safety	0.037	0.112**	0.105***	0.008
	(0.040)	(0.044)	(0.038)	(0.042)
Meeting regulatory requirement	0.033	0.039	0.023	0.036
	(0.038)	(0.038)	(0.037)	(0.039)
Increasing value added	0.016	0.116**	0.011	0.092**
	(0.038)	(0.045)	(0.034)	(0.036)
Process innovation objectives				
Improving flexibility for producing goods or services	0.041	0.207***	0.122***	0.171***
	(0.038)	(0.041)	(0.037)	(0.038)
Improving capacity for producing goods or services	0.061*	0.289***	0.181***	0.306***
	(0.035)	(0.039)	(0.036)	(0.040)
Control variables				
Log(employment)	0.045***	0.045***	-0.027***	0.021*
	(0.011)	(0.011)	(0.009)	(0.011)
Exporter	-0.044	-0.081*	0.025	0.01
	(0.040)	(0.043)	(0.035)	(0.048)
% of graduates	0.004***	0.003***	0.001***	0.002***
	(0.001)	(0.001)	(0.000)	(0.001)
R&D spending dummy	0.109	-0.210**	0.045	-0.083
	(0.107)	(0.087)	(0.067)	(0.070)
Constant	0.132	-0.923***	1.089***	-0.797***
	(0.165)	(0.146)	(0.136)	(0.136)
Vuong test (Z value)	33.09***	8.02***	37.38***	7.16***
Observations	7289	7289	10351	10351

Note: Robust standard errors in parentheses controlled for possible cluster of reporting units belonging to the same enterprise. *** p<0.01, ** p<0.05, * p<0.1

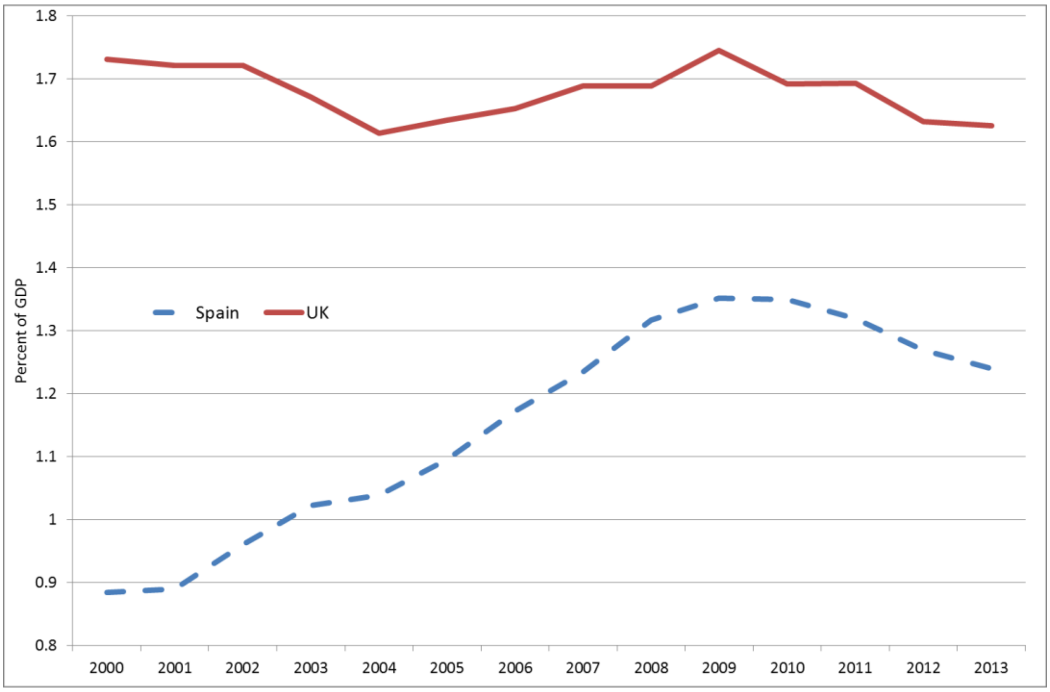
Table 8: Results by sector - Spain

	Manufacturing		Services	
	Interactive	Non-interactive	Interactive	Non-interactive
Non-interactive	0.094***		0.151***	
	(0.011)		(0.013)	
Interactive		0.049***		0.061***
		(0.005)		(0.006)
New product/service objectives				
Increasing range of goods or services	0.154***	0.207***	0.185***	0.139***
	(0.038)	(0.032)	(0.043)	(0.035)
Increasing market share	0.183***	0.240***	0.115***	0.166***
	(0.039)	(0.032)	(0.038)	(0.033)
Improved product/service objectives				
Improving quality of goods or services	0.115***	0.271***	0.096*	0.310***
	(0.045)	(0.040)	(0.049)	(0.047)
Improving health and safety	0.161***	0.147***	0.128***	0.144***
	(0.035)	(0.025)	(0.037)	(0.030)
Meeting regulatory requirement	0.0161	0.258***	0.0429	0.167***
	(0.033)	(0.026)	(0.037)	(0.029)
Process innovation objectives				
Improving flexibility for producing goods or services	0.056	0.096***	0.006	0.088***
	(0.035)	(0.027)	(0.037)	(0.031)
Improving capacity for producing goods or services	0.059*	0.053*	-0.012	0.127***
	(0.035)	(0.027)	(0.038)	(0.033)
Reducing cost per unit produced or provided	0.066**	0.084***	0.003	0.040*
	(0.031)	(0.022)	(0.031)	(0.024)
Control variables				
Log(employment)	0.147***	-0.022**	0.124***	0.005
	(0.010)	(0.010)	(0.009)	(0.009)
Exporter	0.146***	-0.033	0.068**	-0.021
	(0.049)	(0.031)	(0.032)	(0.027)
% of graduates	0.004***	-0.001	0.002***	-0.001
	(0.001)	(0.001)	(0.001)	(0.000)
R&D spending dummy	0.553***	0.293***	0.703***	0.212***
	(0.047)	(0.030)	(0.063)	(0.035)
Constant	-1.507***	-0.966***	-0.941***	-0.481***
	(0.133)	(0.114)	(0.147)	(0.093)
Vuong test (Z value)	36.00***	13.33***	20.38***	9.78***
Observations	18,481	18,481	9,786	9,786

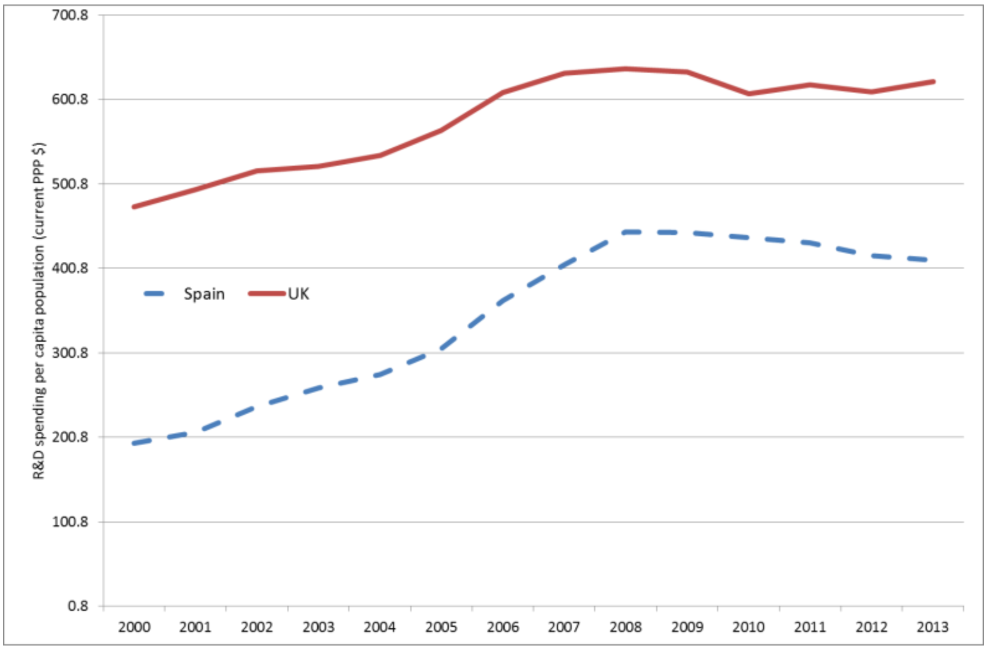
Note: Robust standard errors in parentheses controlled for possible cluster of reporting units belonging to the same enterprise. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Total R&D investment in Spain and the UK

(a) R&D investment as a % of GDP



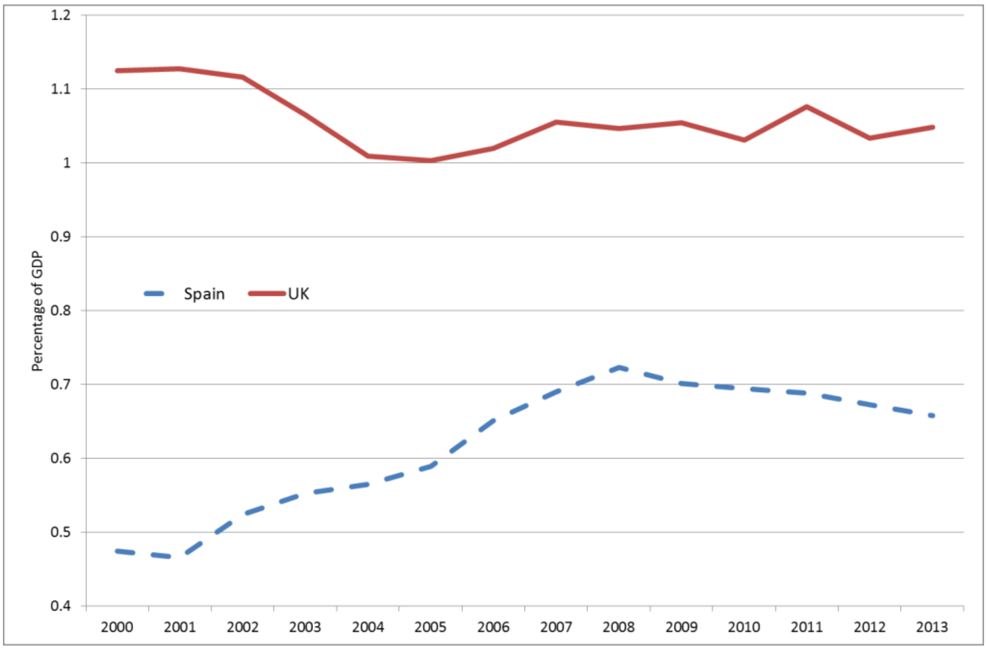
(b) R&D investment per capita ($)



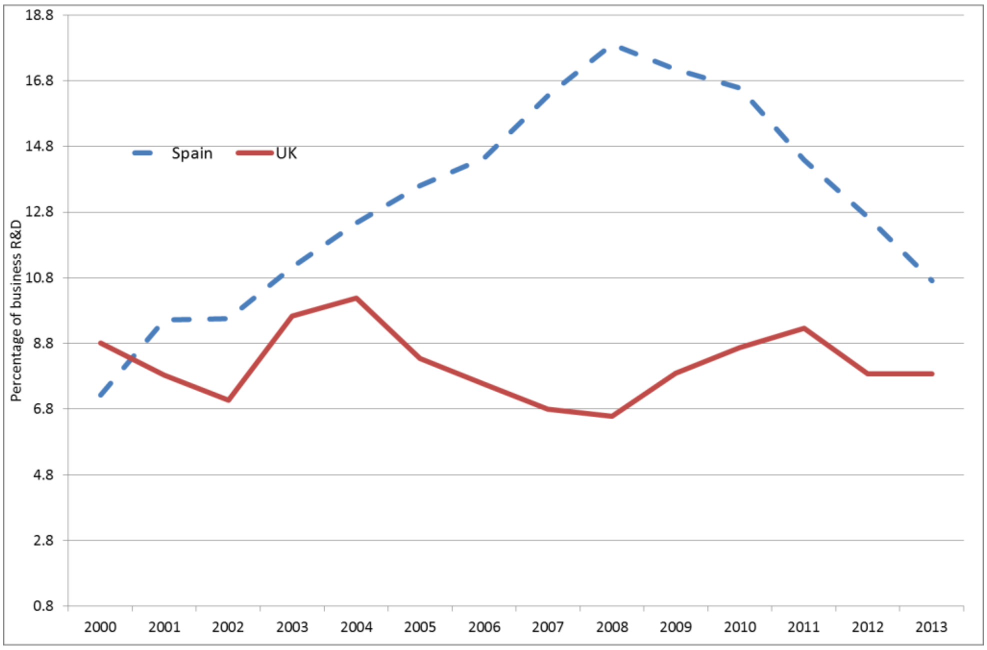
Source: OECD Science and Technology Indicators database.

Figure 2: Business R&D: Investment and government support

(a) Business investment in R&D (percentage of GDP)



(b) Government funding of business R&D (%)



Source: OECD Science and Technology Indicators database.

Table A1: Correlation matrix for UK

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Non-interactive	1													
2	Interactive	0.22	1												
	New product/service objectives														
3	Increasing range of goods or service	0.07	0.15	1											
4	Increasing market share	0.06	0.17	0.36	1										
	Improved product/service objectives														
5	Improving quality of goods or services	0.08	0.17	0.26	0.26	1									
6	Improving health and safety	0.12	0.21	0.16	0.2	0.27	1								
7	Meeting regulatory requirement	0.12	0.26	0.18	0.21	0.28	0.55	1							
8	Increasing value added	0.11	0.18	0.28	0.32	0.38	0.3	0.32	1						
	Process innovation objectives														
9	Improving flexibility for producing goods	0.06	0.17	0.19	0.2	0.34	0.31	0.31	0.43	1					
10	Improving capacity for producing goods	0.04	0.15	0.16	0.21	0.27	0.26	0.27	0.34	0.53	1				
	Control variables														
11	Employment	0.04	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.01	1			
12	Exporter	0.12	0.1	0.09	0.14	0.02	0.01	-0.03	0.07	0.01	0.01	0.01	1		
13	Graduates	0.129	0.144	0.032	0.069	0.022	-0.013	-0.022	-0.069	-0.09	-0.009	-0.03	0.162	1	
14	R&D	0.05	0.08	0.06	0.09	0.07	0.05	0.05	0.09	0.06	0.06	-0.04	0.1	0.08	1

Table A2: Correlation matrix for Spain

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Non-interactive	1.00													
2	Interactive	0.24	1.00												
	New product/service objectives														
3	Increasing range of goods or service	0.14	0.22	1.00											
4	Increasing market share	0.15	0.24	0.56	1.00										
	Improved product/service objectives														
5	Improving quality of goods or services	0.14	0.24	0.44	0.46	1.00									
6	Improving health and safety	0.19	0.25	0.21	0.29	0.29	1.00								
7	Meeting regulatory requirement	0.16	0.27	0.25	0.30	0.32	0.68	1.00							
	Process innovation objectives														
8	Improving flexibility for producing goods	0.12	0.20	0.21	0.24	0.31	0.29	0.31	1.00						
9	Improving capacity for producing goods	0.12	0.20	0.19	0.24	0.30	0.31	0.30	0.64	1.00					
10	Reducing unit cost of production	0.11	0.18	0.17	0.24	0.26	0.35	0.34	0.49	0.52	1.00				
	Control variables														
11	Employment	0.12	0.02	-0.01	-0.01	0.01	0.05	0.04	0.05	0.05	0.05	1.00			
12	Exporter	0.07	0.04	0.11	0.16	0.06	0.11	0.09	0.03	0.02	0.08	-0.03	1.00		
13	Graduates	0.17	0.13	0.09	0.08	0.06	-0.07	-0.05	0.00	-0.01	-0.05	-0.06	-0.13	1.00	
14	R&D	0.24	0.23	0.29	0.28	0.25	0.19	0.19	0.12	0.12	0.12	0.00	0.16	0.17	1.00

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