SERC
Spatial Economics Research Centre

SERC DISCUSSION PAPER 73

R&D, Innovation and Exporting

Richard Harris (SERC, CPPR, University of Glasgow)
John Moffat (SERC, CPPR, University of Glasgow)

March 2011

This work is part of the research programme of the independent UK Spatial Economics Research Centre funded by the Economic and Social Research Council (ESRC), Department for Business, Innovation and Skills (BIS), the Department for Communities and Local Government (CLG), and the Welsh Assembly Government. The support of the funders is acknowledged. The views expressed are those of the authors and do not represent the views of the funders.

R&D, Innovation and Exporting

Richard Harris* and John Moffat*

March 2011

***** SERC, CPPR and the University of Glasgow

Acknowledgements
This work contains statistical data from ONS which is Crown copyright and reproduced with the permission of the controller of HMSO and Queen's Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

Abstract

This study considers the determinants of whether a firm exports, undertakes R&D and/or innovates, and, in particular, the contemporaneous links between these variables using three waves of the UK Community Innovation Survey (CIS). Where appropriate, an instrumental variables procedure is employed to overcome problems of endogeneity. The results show that in both manufacturing and services, being involved in exporting increased the probability that an establishment was engaged in spending on R&D. Spending on R&D in manufacturing had a much larger impact on the probability of exporting which implies that spending on R&D was not simply to boost the probability of producing new goods and services, but also to improve the establishment's knowledge assets which would in turn help it break down barriers to international markets. In non-manufacturing, spending on R&D increased the probability of innovating but had no significant impact on whether the establishment exported; rather, innovating increased the probability of exporting. Exporting had no direct impact on whether innovation occurred in either sector. Given the key role of R&D, innovation and exporting in determining productivity, it is important that government understands these complex interactions between R&D, innovation and exporting and takes advantage of them when devising and implementing productivity-enhancing policies at the micro-level.

Keywords: R&D, innovation, exporting, endogeneity.
JEL Classifications: C35; O32; R11

1. Introduction

It is increasingly recognised in the more recent micro-econometrics literature that the link between exporting and productivity is not exogenous (as was first assumed in initial theoretical work by Bernard and Jensen, 1999, and Melitz, 2003). Firms improve their productivity prior to exporting, and potentially gain additional productivity benefits post-entry (Aw et. al., 2009). In short, undertaking R&D and/or innovating are likely to both impact on the firm's decision to export or not, and in turn to be influenced by the experience of exporting (i.e., through a 'learning-by-exporting' effect).

As is shown in the next section, there are now a growing number of papers that have begun to look at not just the (causal) links between exporting and productivity, but also whether there are (causal) links between R&D/innovation and exporting. However, most studies only consider causality in one direction (the most popular being whether undertaking R&D/innovation results in firms having a higher probability of exporting), and they often do not allow for contemporaneous links between exporting and R&D/innovation. That is, an endogenous determining variable is usually dealt with by entering it into the model in lagged form. Moreover, and as far as we know, no study looks at contemporaneous links between all three variables: exporting, R&D, and innovation. And yet, we also know from data sources like the European Union Community Innovation Survey (the data source used here) that not all innovation is supported by R&D; some firms undertake R&D and do not innovate; and exporting does not necessarily require R&D/innovation beforehand, nor result in R&D/innovation post-entry. So, the first innovation of this paper is that we have considered the contemporaneous links between all three variables in order to better understand the underlying processes that firms engage in with regard to improving their level of productivity. We do this using probit regressions that determine the probability of a firm engaging in all three activities, and we instrument the dichotomous endogenous variables using other variables in the dataset.

A second contribution is that this study uses a much larger data set than is normally available, and takes account of the economic relationships between the three dependent variables over time. Three waves of the UK Community Innovation Survey (CIS) carried out in 2005, 2007 and 2009 were merged; giving a nationally representative account of the innovation activities of the reporting enterprises for the period covering 2002-2008.

Thirdly, we cover not just manufacturing but the service sector as well. Most of the previous work in this area has only had access to manufacturing data, but exporting and innovation activities have become increasingly important in the sale of marketed services, and there are interesting comparisons to be made through comparing the results across the two sectors.

We only deal with the issue of whether firms engage in exporting, R&D and/or innovation, and not how much is exported, spent on R&D or the proportion of sales obtained from new products. While such 'intensities' are interesting, it is our view that what is even more important, when trying to understand why there is considerable heterogeneity in firm-level productivity, are the 'extensive' margins – i.e., the numbers involved in such activities. From a policy perspective, increasing the take-up of these productivity-related activities (especially among those firms with the greatest potential for improvement), is more likely to increase overall aggregate UK productivity levels, than existing firms doing more.

In the next section we review the literature on the relationship between R&D, innovation and exporting (concentrating on more recent micro-level studies); section 3 discusses the data used and our modelling strategy. The results are presented in section 4, followed by a summary and conclusion that also attempts to relate our findings to the policy options available to government in this area.

2. Relationship between R&D, Innovation and exporting

2.1 Theory

There is a well-established trade-innovation macroeconomic framework that offers at least two mainstream theoretical models to account for a relationship between R&D/innovation and exporting (with the causation running from the former to the latter). Usually little distinction is made between R&D and innovation – the most common assumption being that innovation inputs (R&D) lead to new product and process outputs. Neo-endowment models concentrate on specialisation and thus competitive advantage on the basis of factor endowments, such as materials, skilled/unskilled labour, capital and technology (Davis, 1995); while neo-technology models (Greenhalgh, 1990; Greenhalgh et. al, 1994) are an extension of conventional technology-based models based on, for example, product life cycle theory (Vernon, 1966; Krugman, 1979; Dollar, 1986) and the technology-gap theory of trade (Posner, 1961). More recent macroeconomic models (e.g., Grossman and Helpman, 1995) allow firms to improve the quality of their products, which shifts outward a country's export demand curve.

A parallel literature allows firms to learn from internationalisation and thus the possibility that causality runs from exporting to R&D and innovation. Such endogenous growth models (Romer, 1990; Grossman and Helpman, 1991; Young, 1991; Hobday, 1995; Aghion and Howitt, 1998) cover the need for firms to innovate to meet stronger competition/different standards in foreign markets, they allow for a 'learning-by-exporting' effect (through exposure to superior foreign technology and knowledge), and they allow for economies of scale and thus firms to cover the large fixed costs of undertaking R&D (and innovating).

In contrast, theoretical modelling at the microeconomic level has (until recently) not formally considered how R&D and innovation are linked to exporting. Despite a number of theoretical attempts to study the firm's decision to export (particularly based on a framework of sunk costs and firm-level heterogeneity) these studies (Bernard et. al., 2003; Yeaple, 2005; Melitz, 2003) assume that a firm's productivity is exogenous.[1] Recently, however, efforts have been made to endogenise firm heterogeneity with firms engaging in productivity enhancing investment prior to exporting. Aw et. al. (2009) have developed a dynamic, structural model of exporting and R&D that allows the return to R&D and exporting to both increase with the underlying productivity of the firm, so high-productivity producers will self-select into both investment activities; R&D and exporting also directly affects future

[1] Literature in the strategic management area does assume productivity to be endogenous; e.g., that innovating firms have incentives to expand into other markets so as to earn higher returns from their investment, as the appropriability regime is improved when the product market widens (e.g. Teece, 1986). Moreover, the resource-based approach (Penrose, 1959; Barney, 1991) has been explicitly employed in recent studies (viz. Dhanaraj and Beamish, 2003; and Lopez Rodriguez and Garcia Rodriguez, 2005; Harris and Li, 2009, 2010), offering new insights into this export-innovation relationship, in light of the development of a firm's technological capacity. In addition, Bustos (2009) has recently extended the Melitz model to allow not only for firm productivity to be determined by a draw from a random exogenous distribution, but also that firms can invest in R&D to upgrade their technology and therefore become more competitive.

productivity, reinforcing the selection effect; and "… each activity alters the future return from undertaking the other activity, thus current R&D directly impacts the probability of exporting and current exporting alters the return to R&D" (Aw et. al. (op. cit., p.3).

Note, Aw et. al. (op. cit.) assume that productivity depends on the firm's R&D, its participation in export markets, and a random shock. Thus they only consider R&D and exporting, and not a separate role for innovation (empirical studies also consider exporting and R&D or exporting and innovation, but not the relationship between all three variables). However, R&D (as an input into the innovation production function – see Geroski, 1990; Harris and Trainor, 1995; Mairesse and Mohnen, 2002) does not always lead to innovation, and there may be a (considerable) lag between R&D and the introduction of an innovation. Additionally, product and/or process innovations do not always require R&D to be undertaken (as shown in a number of surveys of such activities including the Community Innovation Survey used in this study[2]), and yet we should expect a potential relationship between innovation and exporting which may be understated if R&D alone is included. Moreover, R&D can be undertaken not just to support innovation but also to increase a firm's (intangible) knowledge assets, and thus the absorptive capacity of the firm (the ability to internalise external knowledge). This is the 'second face' of R&D as developed by Cohen and Levinthal (1989, 1990),[3] and tested by, inter alia, Griffith et al. (2004), Kneller (2005), Cameron et al. (2005), and Lokshin et. al. (2008). In short, this points to the need for both variables (innovation and R&D) to enter into any model that considers the productivity-exporting relationship at the micro-level.

[2] This may be a reflection of the timing issue that has just been raised; innovation in t may be due to R&D in t–1 rather than current R&D; although, firm level surveys usually ask for information on R&D and innovation covering a number of consecutive years (3 years in CIS). Alternatively, some innovations may be developed outside the firm and introduced without the need for R&D investment itself (for example, process innovations – such as new types of plant or machinery – are often product innovations developed by firms in other capital producing industries).

[3] Cohen and Levinthal (1990) argued that: '...the ability to evaluate and utilize outside knowledge is largely a function of prior related knowledge. At the most elemental level, this prior knowledge includes basic skills or even a shared language but may also include knowledge of the most recent scientific or technological developments in a given field. Thus, prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends. These abilities collectively constitute what we call a firm's "absorptive capacity"… ' (p. 128). Put another way, firms must apprehend, share, and assimilate new knowledge in order to compete and grow in markets (e.g., export markets).

2.2 Empirical evidence

Ample evidence has been provided at the macroeconomic level, regarding the linkage between a country's export performance and its creativity/innovation. A uniformly positive correlation has led to a consensus that a nation's exports are positively associated with its knowledge accumulation/innovative activities (for more recent studies see Fagerberg, 1988; Greenhalgh, 1990; Verspagen and Wakelin, 1997; Narula and Wakelin, 1998; Leon-Ledesma, 2005; DiPietro and Anoruo, 2006; and Salim and Bloch, 2009). For instance, using data for Australia, Salim and Bloch (op. cit.) have recently applied causality analysis to show that business expenditure on R&D Granger-causes exports.

In contrast, empirical studies at the firm level provide a rather different and unique perspective to disentangle this export-innovation/R&D relationship, taking into account the heterogeneity of firm characteristics amongst exporting and non-exporting firms.[4] Various empirical studies have emphasised the role of technology and innovation as one of the major factors contributing to facilitating entry into global markets, and thereafter maintaining competitiveness and boosting export performance. For instance, studies covering UK and Irish firms include: Wakelin (1998), Roper and Love (2001), Bleaney and Wakelin (2002), Gourlay and Seaton (2004), Hanley (2004), Roper et. al. (2006), Girma et. al. (2008), Harris and Li (2009, 2010) and Ganotakis and Love (2010); for Canadian manufacturing firms, Bagchi-Sen (2001), and Lefebvre and Lefebvre (2001); for Italian manufacturing firms, Sterlacchini (1999) and Basile (2001); for Spanish manufacturing, Cassiman and Martinez-Ros (2007), Lopez Rodriguez and Garcia Rodriguez (2005) and Caldera (2010); for Germany, Lachenmaier and Wößmann (2006) and Becker and Egger (2009); for Belgium, Van Beveren and Vandenbussche (2010); in comparative studies, Roper and Love (2002), for both UK and German manufacturing plants and Dhanaraj and Beamish (2003) for US and Canadian firms; in the context of the rest of the world, Hirsch and Bijaoui (1985) for Israel; Alvarez (2001) for Chilean manufacturing firms (although in this study innovation had no impact on whether a

[4] Note, we only cover studies that directly consider the relationship between R&D/innovation and exporting; there is a parallel literature that considers whether productivity is a determinant of firm-entry into export markets (and similarly there are a number of studies that consider if exporting impacts on productivity through learning-by-exporting). This productivity-exporting literature is surveyed in, for example, Greenaway and Kneller (2007) and Wagner (2007).

plant exported); Zhao and Li (1997) and Guan and Ma (2003) for China and lastly, Ozcelik and Taymaz (2004) for Turkish Manufacturing firms. Most of these studies deal with manufacturing, although Gourlay et. al. (2005), Love and Mansury (2009), and Harris and Li (2009, 2010) found that R&D and/or innovation impacted on exporting services in the UK or the US.

It is important to note that (with the exception of Zhao and Li, 1997) none of these studies directly tested for a simultaneous relationship allowing exporting to determine innovation/R&D (and vice versa) although some allowed for a potentially endogenous feedback by instrumenting innovation/R&D (e.g., Cassiman and Martinez-Ros, 2007; Caldera, 2010; Harris and Li, 2009, 2010; Van Beveren and Vandenbussche, 2010; Ganotakis and Love, 2010)[5,6] while others (e.g., Girma et. al., 2008; Damijan et. al., 2010) modelled jointly the decision to export and undertake R&D, but entered only lagged values of the potentially endogenous variable in each model.[7]

Evidence on causality going from exporting to innovativeness also exists; as stated above (footnote 4) the conventional approach to testing this 'learning-by-exporting' hypothesis is to analyse performance-related variables (such as labour productivity, TFP, average variable costs and the like) as proxies of a firm's learning behaviour. However, Salomon and Shaver (2005) advocate that using innovation as a measure of learning provides a "more direct appraisal of the phenomenon", showing that firms can strategically access foreign knowledge bases and enhance innovation capabilities through engaging in exporting activities. This positive impact of exporting on learning/knowledge accumulation is also documented in Cassiman and Veugelers (1999), Bishop and Wiseman (1999), Alvarez (2001) and Blind and

[5] Cassiman and Martinez-Ros (2007) used industry and time dummies as instruments for innovation; Caldera (2009) uses whether the firm received public support for R&D; Harris and Li (2009, 2010) used instruments such as firm size and age, firm-level absorptive capacity, location, industry sector, and ownership when taking account of the potential endogeneity of R&D; Van Beveren and Vandenbussche (2010) use R&D and training as instruments; while Ganotakis and Love (2010) also use R&D as well as government support and collaborative agreements with suppliers/customers. The use of R&D as an instrument (implying R&D did not impact on exporting, which was determined by innovation, but R&D did determine innovation) is discussed again later.

[6] Some studies have used a 'matching' approach instead, to take account of selection effects; e.g., Becker and Egger (2009) and Damijan et. al. (2010). These studies compare exporting performance for innovators and non-innovators, where the two innovator sub-groups comprise firms with similar characteristics.

[7] Some, like Alvarez (2001) do consider whether exports impact on the probability of innovating (and vice versa) but without any control for potential endogeneity between the variables. Others (e.g., Love and Mansury, 2009) consider the simultaneous relationship between exporting intensity and labour productivity, with innovation included as an exogenous determinant of exporting intensity.

Jungmittag (2004). Others have found that entering export markets has no impact on innovation (e.g., Baldwin and Gu, 2004, for Canada); rather firms that export are better innovators pre- and post-entry. More recently, Damijan et. al. (2010), and Van Beveren and Vandenbussche (2010) find that exporting positively impacts on a firm's innovativeness. Girma et. al. (2008) found this was also the case for Irish firms, but not British exporters; and Zhao and Li (1997) found a two-way causal relationship between exporting intensity and R&D spending in a sample of Chinese firms. Others provide evidence in favour of exporting having an impact on innovation/R&D but in less direct terms; Aw et. al. (2009) found that exporting boosts productivity, with exporting firms investing in R&D having higher productivity when compared to exporters not investing in R&D. Criscuolo et. al. (2010) also found that exporters had more innovation outputs than non-exporters, although most of the greater innovativeness was due to higher R&D by such firms rather than exporting per se. The studies of both Aw et. al. (op. cit.) and Criscuolo et. al. (op. cit.) suggest that exporting alone is not enough; it needs to be accompanied by R&D to generate productivity gains. More recently, using data on Italian manufacturing firms, Hall et al. (2008) found that international competition fostered R&D intensity, which was especially true in high-tech firms.

2.3 Other factors

This section will begin by discussing the factors likely to influence R&D and innovation. Schumpeter (1950) assumed that in a mature capitalist society, innovative activity in terms of R&D expenditure/intensity increases more than proportionally with firm size. This assumption could be justified on the grounds that larger firms (*cet. par*.) are better tuned to exploit economies of scale and scope in the process of conducting R&D (Schumpeter, 1950; Cohen and Levin, 1989). Another reason for expecting a positive relationship between size and R&D is if size allows the spreading of fixed costs and risk over output (Cohen and Klepper, 1996; Legge 2000). It can also be argued that in a capital market characterised by asymmetric information and market imperfection, large firm size may enable the firm to access financial capital with greater ease by spreading risks over a portfolio of projects and stabilising internally-generated funds.

Cohen et. al (1987) argue that the arguments in favour of the Schumpeterian hypothesis often ignore inter-industry differences in the size-R&D relationship, which may result in a spurious statistical relationship between them. Indeed, one would expect the association between size and innovation activity to vary across industries, in terms of different technological opportunities, market structures, as well as demand characteristics. In Cohen et. al. (1987), the impact of size on R&D became statistically insignificant after controlled for industry effects. A negative connection between size and firm R&D intensity has also been identified amid innovating firms once controlling for industry effects (Cohen et. al., 1987; Cohen and Klepper, 1996; Almeida et. al., 2003). Arguments linked to inefficiency due to bureaucracy and loss of managerial control, and also a lower average productivity induced by more R&D expenditure prevalent in large firms, have cast doubt on a straightforward and positive relation between size and innovation productivity (Griliches, 1980; Acs and Audretsch, 1991; Graves and Langowitz, 1993; Klepper, 1996; Cohen and Klepper, 1996).

Market power[8] has been widely perceived to exert considerable influence on a firm's innovative decision. Angalmar (1985) found that market concentration was negatively associated with R&D investment in technologically progressive industries, since it effectively reduced the need to introduce new technology/products. Conversely, Schumpeter (1950) argued that the expectation of a monopoly position conferring market power (i.e. raising price above average costs) was a necessary reward to make innovative activities worthwhile. Geroski (1990) considered actual monopoly power in terms of its direct and indirect effects. The former includes the ability of monopolists to use high current monopoly profits to provide more (and/or cheaper) internal finance and resources for R&D, while indirect effects acting through current market power increase the expected post-innovation price-cost margin which, in turn, has a positive effect on current R&D spending. Thus Geroski found a significant positive impact of market power upon the extent of innovation activity, having controlled for inter-industry differences in technological opportunity. Tingvall and Poldahl (2006) estimate the relationship between competition and R&D using Swedish firm-level data. Using the Herfindahl Index as a measure of competition,

[8] This is usually measured using a concentration index, such as the Herfindahl index.

they find evidence of an inverted U-shaped relationship between competition and R&D.

Ownership status may also have an impact on innovative activities. Harris (1991) showed that plants operating in Northern Ireland that had their headquarters' outside the region were some 40 per cent less likely to have an R&D department in the Province. This can be attributed to plants owned by foreign companies in Northern Ireland having the status of branch plants while innovative activities are generally undertaken in headquarters plants. Roper (2000) looked at the relationship between ownership and the innovation propensity of UK plants, using data from a large survey in 1995. They also found that (*cet. par.*) externally-owned plants were less likely to innovate than their UK-owned counterparts.[9] More recently, Dachs and Ebersberger (2009) generally found no significant relationship between foreign ownership and innovation using the Austrian CIS. Falk (2008), using CIS data from 12 European countries, found that foreign owned firms are more likely to introduce new products than domestically owned firms.

In a seminal paper, Cohen and Levinthal (1990) demonstrated that the ability to exploit external knowledge is a critical component of a firm's capabilities. They argued that: '...the ability to evaluate and utilize outside knowledge is largely a function of prior related knowledge. At the most elemental level, this prior knowledge includes basic skills or even a shared language but may also include knowledge of the most recent scientific or technological developments in a given field. Thus, prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends. These abilities collectively constitute what we call a firm's "absorptive capacity".[10] This absorptive capacity will have an impact on extent and success of innovative activities. Koch and Strotmann (2008) provide evidence showing the importance of absorptive capacity in generating innovation using data on start-ups in the German knowledge intensive business sector. Similarly, Smit et. al. (2010) use data from the Dutch CIS to demonstrate the importance of absorptive capacity in determining innovation performance.

[9] Thus note that the definition of external ownership in this study was whether the plant was foreign-owned, and not just whether the headquarters of the plant was located outside the region.

[10] Note, absorptive capacity was developed by Cohen and Levinthal (*op. cit.*) in the context of innovation for which outside sources of knowledge are critical. However the usefulness of the concept extends to all questions relating to the identification, assimilation and application of new, external information (Bessant et. al.et. al. 2005).

There are various specific barriers to innovation that are likely to impact on whether R&D is undertaken. These barriers are often discussed within the context of market failure arguments for government intervention whereby it is argued that because R&D involves a significant level of risk and uncertainty coupled with large (irreversible) sunk costs, there is a tendency for the private sector to invest at a lower level than is warranted by the higher social returns associated with R&D. There are two aspects to market failure that need to be considered: firstly, that because of spillovers firms cannot appropriate the full returns from any investment and therefore will under-invest (i.e. social returns are higher than private returns); and secondly, there are market imperfections particularly in information and the ability of firms to raise finance for R&D (with such imperfections most likely to impact on smaller firms). Masso and Vahter (2008) are able to show that such barriers to innovation play a role in determining innovation expenditure using Estonian data.

It is generally acknowledged that a firm's decision to innovate varies significantly across industries because of distinct technology dimensions such as technological opportunity, market dynamics, appropriability regimes, and demand pull factors. Technological opportunity is the concept widely used in the literature to capture various technological advances for each industry occurring at different speeds and with varying degrees of difficulty (Klevorick et. al., 1995). Jaffe (1986) defines technology opportunity as exogenous variations in the cost and difficulty of innovation in different technological areas. The type and nature of the technological results acquired by a firm are directly determined by the technological opportunity a firm faces, which will eventually exert a crucial impact upon the firm's competence base and the probability of investment in innovative activity. It follows that firms operating in technological and scientific environments with a higher level of technological opportunity tend to be more motivated for undertaking R&D. Cohen et. al. (1987) found that sector dummy variables explained half the variance in R&D intensity in their data; Geroski (1990) found that at least 60% of the variation in R&D could be explained by industry effects.

Spatial factors may also be important determinants of the innovative activities of establishments. Because knowledge spillovers may be technologically restricted (e.g. to the industry to which a firm belongs or to other industries that share a common technology base), it is likely that they will also be geographically restricted since external firms need to be close in order to absorb tacit knowledge (which is likely to be transmitted only in face-to-face contacts and through other mechanisms that require spatial proximity). Morgan (2004) argues that tacit knowledge is person-embodied and context-dependent and therefore is, by its location, 'sticky'. Others (e.g. Nonaka and Takeuchi, 1995; Malmberg, 1997) stress that the exchange or transmission of tacit knowledge relies on reciprocity and trust and that the operationality of these relational assets requires physical proximity; von Hippel (1994) stressed the importance of transmission costs such that the information required by a firm and the problem solving capabilities it needs to assimilate such information must be brought together at a single locus. Audretsch and Feldman (1996) find evidence on the spatial concentration of innovation activity in the US and, more importantly, that the impact of knowledge spillovers is more significant in determining the clustering of innovation than the mere geographic concentration of production. Cabrer-Borras and Serrano-Domingo (2007) provide similar evidence for Spain and give econometric evidence supporting the existence of spillovers across regions.

We now turn to those factors that have been considered in the literature as determinants of exporting performance. A number of firm-specific factors have also been suggested in the literature that impact on export entry, whether the firm engages in R&D activity, and whether it innovates. First and foremost, knowledge and learning can be expected to have a fundamental impact in that internationalising firms must apprehend, assimilate and exploit newly acquired knowledge in order to compete and grow in markets in which they have little or no previous experience (Autio *et al.,* 2000). Empirical evidence showing the importance of knowledge as a barrier to exporting for Portuguese SMEs is given by Pinho and Martins (2010). In a seminal paper, Cohen and Levinthal (1990) put forward the notion of "absorptive capacity" and demonstrated that the ability to exploit external knowledge is a critical component of a firm's capabilities. We shall attempt to bring together and compare in our empirical analysis the role of absorptive capacity and R&D activity in determining a firm's decision to export, since our reading of the literature leads us to believe that this is a particularly important area that can help us understand more fully the internationalisation process.

There is also well-documented evidence on how the size of firms affects the probability of entering foreign markets, as larger firms are expected to have more (technological) resources available to initiate an international expansion (for instance, Aw and Hwang, 1995; Roberts and Tybout, 1997; Bleaney and Wakelin, 2002; Cassiman and Martinez-Ros, 2003; Gourlay and Seaton, 2004; Kneller and Pisu, 2007 and Iyer, 2010, to name just a few). Higher productivity in general constitutes another significant factor determining the firm's internationalisation decision. Evidence for this relationship between exports and productivity was initially empirically driven; and it is universally found in the literature that exporting is positively associated with firm performance (see Greenaway and Kneller, 2004 and 2007, for a recent surveys).[11] This positive impact of productivity on export-market entry is in line with the self-selection hypothesis[12], which assumes that plants that enter export markets do so because they have higher productivity prior to entry (relative to non-entrants), i.e. firms that internationalise are forced to become more efficient so as to enhance their survival characteristics; while, the existence of sunk entry costs means exporters have to be more productive to overcome such fixed costs before they can realise expected profits (see, for example, Alvarez and Lopez, 2005; Wagner, 2007; Burger et. al., 2008; Yang and Mallick, 2010, Schank et al, 2010 for studies that empirically investigate the self-selection hypothesis).[13]

The external position of the firm is also generally found to determine export behaviour, in terms of sectoral, regional effects or market structure. For instance, the sector in which a firm operates is likely to be important since belonging to a specific industry may condition the firm's strategy of international expansion as well as performance to some degree (both in terms of innovation and internationalisation activities). As industries are neither homogeneous in their technological capacity nor exporting patterns, this sectoral effect (reflecting technological opportunities and product cycle differences) is usually expected to be significant. This is confirmed in numerous empirical studies (for instance, Hirsch and Bijaoui, 1985; Hughes, 1986;

[11] See Alvarez (2001) for Chile; Kraay (1999) for China; Clerides *et al.* (1998) for Colombia; Mexico and Morocco; Bernard and Wagner (1997) for Germany; Castellani (2002) for Italy; Delgado *et al.* (2002) for Spain; Greenaway and Kneller (2004) for the UK; Bernard and Jensen (1999) for the US; Aw and Hwang (1995) for Taiwan, etc.

[12] See footnote 4 for studies in support of the other direction of this exports-productivity relationship, i.e. the learning effect of exporting.

[13] However there are still some studies where exporters are not necessarily more efficient than non-exporters, e.g. Bleaney and Wakelin (2002) with regard to UK manufacturing when controlling for innovating activity; Greenaway *et al*. (2005) for Swedish manufacturers with a relatively high level of international exposure on average; and Damijan *et al*. (2005) on firms in Slovenia where higher productivity is required only in those firms that export to advanced countries rather than those who export to developing nations.

Soete, 1987; Wagner, 2001; Bleaney and Wakelin, 2002; Gourlay and Seaton, 2004; Lopez Rodriguez and Garcia Rodriguez, 2005; and Harris and Li, 2009).

The role of industry and spatial factors are also important; for example, see Overman *et al.*'s (2008) survey of the literature on the economic geography of trade flows and the location of production. If information on costs and foreign market opportunities is asymmetric, then it is reasonable to expect firms to cluster within the same industry/region so as to achieve information sharing and therefore minimise entry costs; such co-location provides better channels through which firms distribute their goods. Greenaway and Kneller (2008) provide empirical evidence to show that the industrial dimension of agglomeration appears to be more important for the UK. Koenig (2009) finds that being located near other exporters has a positive impact on the probability of exporting using French data but does not test for the impact of broader measures of agglomeration on exporting. On the other hand, Bernard and Jensen (2004a,b) find agglomeration to be insignificant in explaining the probability of exporting in the US.[14] The benefits brought about by the co-location of firms on the decision to export have also been documented in other empirical studies, for instance Aitken *et al.* (1997) for Mexico.

Lastly, market concentration is also expected to positively impact upon a firm's propensity to export and its performance post entry. A high level of concentration of exporters within an industry may improve the underlying infrastructure that is necessary to facilitate access to international markets or to access information on the demand characteristics of foreign consumers. Evidence for UK manufacturing covering 1988-2002 is provided by Greenaway and Kneller (2003) and for international airline firms covering 1987-1992 by Clougherty & Zhang (2009).

[14]Such negligible spillover effects for plants in the US may be explained by their sample selection criteria (restricted to large plants only), measures of industry (2 digit level) and regions (measured by states).

3. Data and modelling strategy

3.1 Data

This study uses three waves of the UK Community Innovation Survey (CIS) carried out in 2005, 2007 and 2009, covering activities in 2002-2004, 2004-2006, and 2006-2008 (referred to as CIS4/5/6, respectively). This is a nationally representative survey carried out by the Office for National Statistics (ONS) on behalf of the UK Government, covering the innovation activities of the reporting unit for a 3-year period.[15] We merged each survey with the ONS Annual Respondents Database (ARD) for 2004, 2006 and 2007 (the 2008 ARD data not being available at the time of our analysis) using comparable reporting unit information in the ARD covering additional variables such as the age of the establishment, ownership characteristics, and capital stock.[16] Table 1 sets out the list of variables we use in the current study, along with the source of the datasets. Note, the establishment's R&D activity is defined as intramural R&D, or acquired external R&D or acquired other external knowledge (such as licences to use intellectual property).[17]

(Table 1 about here)

Of particular importance is the absorptive capacity of the establishment. No direct information on this variable is available, but CIS contains information on key elements of internal and external knowledge that can be related to absorptive capacity. 'Internal' absorptive capacity is proxied using data on the impact on business

[15] See http://www.bis.gov.uk/policies/science/science-innovation-analysis/cis/ for details on the questionnaires used, sampling design, and 'official' analysis of the UK CIS data. Note, as the CIS is based on a sample drawn from the ONS Inter-departmental Business Register (IDBR), weights can be constructed to provide nationally represented information.

[16] Reporting units in the IDBR have unique codes, allowing us to merge almost every surveyed unit in the CIS with data in the ARD; only establishments in Northern Ireland and certain sectors (such as financial services) were omitted because they are outside the scope of the ARD carried out in Great Britain by the ONS. Because we only had data from the 2007 ARD, a very small number of reporting units from CIS6 that started operations in 2008 could not be merged and therefore are omitted from the analysis. Note, from this point on we shall refer to the establishment rather than reporting unit. The latter is the accounting unit of the company that provides the ONS with the data it requires; for a single-plant enterprise, establishment and plant (or local unit) are the same – which covers about two-thirds of the respondents in CIS. For multi-plant firms, the establishment can comprise several plants, and larger multi-plant firms may return several reporting units to the ONS (see Harris, 2002, and Robjohns, 2006).

[17] There is other spending that is categorised in CIS, such as acquisition of machinery and equipment (including computer hardware), training and marketing in connection with product and process innovation, but we chose to exclude these from our narrower and more traditional definition of R&D after some initial analysis of the data (see Harris and Li, 2010, especially Chapter 3) and by comparing the CIS totals with those obtained from the BERD.

performance of the implementation of new or significantly changed corporate strategies; advanced management techniques (e.g. knowledge management, Investors in People, JIT and Sigma 6); organisational structures (e.g. introduction of cross-functional teams, outsourcing of major business functions); and marketing concepts/strategies[18]. 'External' absorptive capacity was proxied using data on the relative importance of different sources of information used for *innovation related* activities and/or the types of cooperation partner on innovation activities. Sources of information can be grouped under the following sub-headings with associated elements: market – suppliers customers; competitors; consultants, commercial labs/R&D enterprises; institutional – universities; government/public research organisations; other – conferences, trade fairs, exhibitions; scientific journals and trade/technical publications; professional and industry associations; technical, industry or service standards.[19] Co-operation partners comprised similar elements: suppliers; customers; competitors; commercial labs/R&D enterprises; universities; and government/public research organizations.[20]

To obtain measures of absorptive capacity, we use the approach taken by Harris and Li (2009) and undertake a factor analysis for each CIS wave using all the (26) variables listed above. Based on the Kaiser criterion (Kaiser, 1960), five principal components were retained (with eigenvalues greater than 1), accounting for between 61-69% of the combined variance of the variables. In order to obtain a clearer picture of the correlation between those variables related to absorptive capacity and the five factors extracted, the factor loadings matrix for each CIS wave was transformed using the technique of variance-maximising orthogonal rotation (which maximises the variability of the "new" factor, while minimising the variance around the new variable). All 26 input variables used to measure absorptive capacity are supported by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy – most of the KMO values are above 90% and an overall KMO value of between 83-

[18] For each set of information, respondents were asked whether the change had taken place in the three-year period up to 2004, 2006, and 2008, respectively across CIS4/5/6.
[19] For each element, respondents were asked to rank from 0 'not used' to 3'high importance'. We recoded these to 1 (medium and high importance) and 0 (low importance or not used).
[20] Respondents were asked to state if they had collaborated with any of these based on the location of the partner which we grouped into national (i.e., UK) or international (i.e., other European or other countries). Thus we had two measures for each element.

94% across the different CIS waves suggests the contribution of the raw variables was adequately accounted for.[21]

Based on the correlations between these 26 underlying variables and the five varimax-rotated common factors (each with a mean of zero and standard deviation of 1), we were able to interpret these factors as capturing the establishment's capabilities of exploiting external sources of knowledge; co-operating with external bodies at the national level; implementing new corporate strategies and management techniques; building up partnerships with other enterprises or institutions at the international level; and acquiring and absorbing codified scientific knowledge from research partners respectively (which we have labeled 'global specialized knowledge' below). The different factor analyses undertaken using CIS4/5/6 resulted in very similar outcomes, which helps to validate the approach we have taken to measuring absorptive capacity.[22]

Various hypotheses on the components of absorptive capacity have been put forward in the literature (particularly, in management studies), such as human capital, external network of knowledge and HRM practices as in Vinding (2006), and potential and realised absorptive capacity as re-conceptualised by Zahra and George (2002). Nevertheless, there continues to be an imbalance between the relative abundance of various definitions of absorptive capacity and a deficiency of empirical estimates of this concept, with R&D-related variables most commonly used as proxies (e.g. Cohen and Levinthal, 1990; Arora and Gambardella, 1990; Veugelers, 1997; Cassiman and Veugelers, 2002; Belderbos et. al., 2004). However, given the path-dependent nature of absorptive capacity, R&D fails to capture the realisation and accumulation of absorptive capacity, not to mention its distinct elements (Schmidt, 2005). Notably, whilst allowing R&D to be potentially endogenous, we treat the 'path-dependent' absorptive capacity as predetermined in our empirical models, i.e. such capacity takes a (relatively) long time to build.

Others have taken a different approach with regard to how the above variables used to measure 'external' absorptive capacity should be classified. For example, Dachs et. al. (2008) use the information on sources of knowledge from suppliers and customers to compute a variable that attempts to capture vertical spillovers (of

[21] Historically, the following labels are given to different ranges of KMO values: 0.9-1 Marvellous, 0.8-0.89 Meritorious, 0.7-0.79 Middling, 0.6-0.69 Mediocre, 0.5-0.59 Miserable, 0-0.49 Unacceptable.
[22] Full details on the factor analysis are available in an unpublished appendix (see http://www.cppr.ac.uk/media/media_187300_en.doc)

knowledge). We have chosen not to take a similar approach. The pragmatic reason is that in our statistical analysis (Section 4) we find these spillover measures are generally insignificant in the models determining exporting, innovation and R&D, whereas our measures of absorptive capacity are found to be important determinants. In addition, the proportion of establishments that stated that such sources of knowledge had 'high' importance is relatively small; taken together, over 90% of establishments have a zero value for spillovers; whereas the absorptive capacity measures are based on much more information and span a greater range. Lastly, there is a high correlation between these types of spillover measures and our measures of absorptive capacity; therefore it is clear that knowledge spillover effects will be captured within the absorptive capacity measures we use in this study. Indeed, by definition absorptive capacity captures the ability of firms to internalise external knowledge spillovers.

Most other variables included in Table 1 are self-explanatory. In particular, industrial agglomeration is included to take account of any Marshall-Romer external (dis)economies of scale (Henderson, 2003; David and Rosenbloom, 1990). The greater the clustering of an industry within the area in which the establishment operates, the greater are the potential benefits from spillover impacts. Conversely, greater agglomeration may lead to congestion, and therefore lower productivity. The diversification index is included to pick up urbanisation economies associated with operating in an area with a large number of different industries (Jacobs, 1970, 1986). Higher diversification is usually assumed to have positive benefits to producers through spillover effects. The Herfindahl index of industrial concentration is measured at the 5-digit 1992 SIC level to take account of any market power and hence competition effects (which are expected to be associated with the propensity to both export, innovate and to undertake R&D). The variable that measures if the establishment belongs to an enterprise operating in more than one (5-digit) industry (multi-industry) is included to proxy for any economies of scope. The data on the age of establishments and their capital-labour ratios were obtained from the ARD and from updating the series on plant & machinery capital stocks computed by Harris and Drinkwater (2000) and extended to cover the service sectors (see Harris and Moffat, 2011). In addition, information is available on whether the establishment was located in a particular Government Office region and/or city.[23]

(Table 2 about here)

All the data are weighted to ensure they are representative of the UK distribution of establishments (i.e. rather than just the CIS4/5/6 samples).[24] Table 2 reports the (weighted) mean values for the pooled CIS-ARD data covering all three CIS waves, spilt into manufacturing and non-manufacturing sectors. There are two sets of means for each sector; the first refers to all the pooled data available while the second refers to just the data used in the model estimation carried out below. When modeling the relationships between R&D, innovation and exporting, we allow for lagged values to enter and therefore only those establishments that have at least two consecutive observations in the dataset are retained. That is, we make use of the panel data attributes of the pooled dataset, which results in the loss of a large number of observations that were either only sampled once, or they feature in non-adjacent CIS waves (mostly the former). By including both the full (weighted) dataset and the (weighted) data used when modeling, we are able to show that there is little indication of any bias from using the restricted dataset; the mean values for the vast majority of variables are very similar (cf. data columns 1 – 2, and 3 – 4). Only the measure of industry agglomeration (non-manufacturing data) and the measures of absorptive capacity (mainly non-manufacturing) differ significantly.[25]

Concerning the three key variables we shall be modeling, Table 2 shows that on average some 46% of establishments in manufacturing were engaged in R&D, 41% produced an innovation (product and/or process), and 51% exported in the three year period covered by each CIS; in non-manufacturing, the comparable figures were 29%, 27% and 25%.

(Table 3 about here)

[23] The major cities we identify were either capitals or they met the criteria of (in 2001) employing over 250,000 with a population density of 20+ persons per hectare; or they had employment over 100,000 and densities of 30+ persons per hectare. The full list of cities included was: London, Cardiff, Edinburgh, Tyneside, Manchester, Liverpool, Birmingham, Coventry, Leicester, Nottingham, Bristol, and Glasgow.

[24] The weights used are available in the CIS datasets, rather than the ARD, as the latter is merged into the CIS data.

[25] The differences for the agglomeration variable are presumably reflecting the loss of establishments located in less 'populated' rural areas, which are less likely to have consecutive observations in the pooled CIS dataset. Note the AC indices were calculated using all the CIS data in a particular wave; non-manufacturing establishments had much lower values – which bunch more around the mean (of zero) – when compared to manufacturing.

Information on both the exporting, innovation and R&D activities of establishments is presented in Table 3. As can be seen, over 22% of manufacturers engaged jointly in exporting, producing an innovation and spending on R&D; while only 7.5 % undertook all three activities in the non-manufacturing sector. Conversely, just over 31% in manufacturing did none of these activities (over 55% in non-manufacturing). In manufacturing this leaves nearly half of the establishments engaging in either one or two of the other activities (in non-manufacturing some 37% of establishments did one or two out of the three activities covered). This suggests that while there are relationships between these variables, they may not be quite as strong as expected, and they are likely to involve various feedback relationships that cannot be predicted using the information in Table 3. In particular, and irrespective of the (two-) way relationship between R&D and exporting or innovation and exporting, there does not seem to be any clear evidence that R&D and innovation are interchangeable in any model explaining exporting; e.g., and especially in manufacturing, nearly 9% exported and undertook R&D but did not innovate, compared to just over 4% who exported and innovated but did no R&D. It seems, at least in manufacturing, there is some initial evidence that R&D may help firms to overcome barriers to exporting that is not necessarily linked to producing innovations.

It would also seem that, especially in manufacturing, exporting is somewhat less dependent on innovation and R&D than is innovation on R&D and exporting, or R&D on innovation and exporting; since 14% of manufacturers (8.5% in non-manufacturing) exported without the need for the other two activities, while only 5.1% of innovators did no R&D and did not export (6.5% in non-manufacturing), and 5.7% engaged in R&D but not exporting nor producing an innovation (8.1% in non-manufacturing).

In all there are possibly a number of different relationships between whether an establishment exports, does R&D, and produces an innovation, all of which will be conditional on other variables that intervene in determining how and when establishments break down barriers to entry into these activities. Thus, we now set out the modelling strategy used to try to disentangle the relationships that are so important in determining and influencing long-run productivity.

3.2 Modelling strategy

We have three (0/1) dichotomous variables that we wish to model taking account of the potential simultaneous relationships between them; thus we follow the approach of Maddala (1983) and instrument each endogenous variable using the reduced-form of each equation to guide us towards choosing appropriate instruments. The structural equations in our system are:

$$\begin{aligned} EXP_{it} &= f(INN_{it}, R\&D_{it}, X_{it}^{1}) + u_{it}^{1} \qquad & u_{it}^{1} \sim N(0,1) \\ R\&D_{it} &= f(INN_{it}, EXP_{it}, X_{it}^{2}) + u_{it}^{2} \qquad & u_{it}^{2} \sim N(0,1) \\ INN_{it} &= f(EXP_{it}, R\&D_{it}, X_{it}^{3}) + u_{it}^{3} \qquad & u_{it}^{3} \sim N(0,1) \end{aligned} \tag{1}$$

where *EXP* refers to whether establishment *i* exports in time *t*;[26] *R&D* refers to whether it spends on research and development; and *INN* is whether it introduces a product and/or process innovation during *t*. The X_{it} are vectors of other (exogenous) variables (including lagged values of the dependent variables) that determine the various outcomes for establishment *i* in time *t*, and it is assumed that each X_{it} have some elements that are exclusive – i.e., $X_{it}^{1} \notin X_{it}^{2} \notin X_{it}^{3}$, and there exist variables (labelled Z_{it}^{n}, where $n = 1, 2, 3$, such that $Z_{it}^{n} \in X_{it}^{n}$ but $Z_{it}^{1} \neq Z_{it}^{2} \neq Z_{it}^{3}$) that identify each equation and which can be used as instruments if a single-equation approach is used to estimate (1). Clearly if the covariance is non-zero between u_{it}^{n} and the right-hand-side variables *EXP*, *R&D* and *INN* in (1), then these are endogenous; and since no system approach is available for estimation we use a single-equation IV approach. That is, we replace equation (1) with:

$$\begin{aligned} EXP_{it} &= f(\hat{INN}_{it}, R\hat{\&}D_{it}, X_{it}^{1}) + u_{it}^{1'} \qquad & u_{it}^{1'} \sim N(0,1) \\ R\&D_{it} &= f(\hat{INN}_{it}, \hat{EXP}_{it}, X_{it}^{2}) + u_{it}^{2'} \qquad & u_{it}^{2'} \sim N(0,1) \\ INN_{it} &= f(\hat{EXP}_{it}, R\hat{\&}D_{it}, X_{it}^{3}) + u_{it}^{3'} \qquad & u_{it}^{3'} \sim N(0,1) \end{aligned} \tag{2}$$

where:

$$\hat{EXP}_{it} = f(Z_{it}^{1}, W_{it}); \qquad R\hat{\&}D_{it} = f(Z_{it}^{2}, W_{it}); \qquad \hat{INN}_{it} = f(Z_{it}^{3}, W_{it}) \tag{3}$$

[26] Note, with respect to the dependent variables in equation (1), time *t* refers to the following 3-year periods: 2002-2004, 2004-2006 and 2006-2008. In contrast *t* refers to 2004, 2006 and 2008 with regard to (most of) the variables in *X* (the exceptions are the variables measuring absorptive capacity and barriers to innovation which cover the same period as the dependent variables).

and $W_{it} = X_{it}^1 \cup X_{it}^2 \cup X_{it}^3$. Essentially, equation (3) is the reduced-form counterpart of equation (1), after substituting out the right-hand-side endogenous variables. Note, the variables comprising Z_{it}^1 will differ depending on whether we are instrumenting *EXP* in the second or third equation in (2); this is also the case for the variables included in Z_{it}^2, Z_{it}^3 when *INN* and *R&D* are instrumented. In short, the membership of Z_{it}^n depends on which endogenous variable is being instrumented, and which endogenous variable comprises the left-hand-side variable in (2).

Note, following Angrist and Kruger (2001), who show that using a *nonlinear* first stage to generate fitted values for the second stage does not result in consistent estimates unless the first stage model is exactly correct (Angrist and Kruger, *op. cit.*, p.80), we estimate equation (3) using OLS regression and use these predicted values when estimating (2).[27] A *stepwise* OLS approach was preferred in order to limit the number of insignificant variables used to predict *EXP*, *R&D* and *INN*, and thus to increase the precision of our estimates.[28] The identification of the instruments was based on first comparing the results from estimating the reduced-form model, and searching for those variables that were uniquely significant in determining each dependent variable. However, when equation (2) was estimated we occasionally found that a very small number of variables that were (in)significant in the reduced-form model changed in terms of their significance level, and we used this information in the final selection of the appropriate instrument set for each endogenous variable.

Instruments are only appropriate if they can be shown to strongly determine the endogenous variable, but have no direct impact on the outcome variable in the model estimated. Various tests have been developed for linear IV models based on continuous dependent variables, but not for use with the probit model. Thus we test whether our instruments are appropriate by including them as additional variables when estimating equation (3), and testing if they are jointly-insignificant.[29] If the null of joint insignificance is accepted, then we can be confident that the set of instruments

[27] We also tried using predicted values based on probit estimates of (3), and there was little difference in our results.

[28] Again, it made little difference, when estimating equation (2) using the predicted values in equation (3), whether we used the full-set of exogenous variables available in W, or just those that were significant at the 10% level.

[29] For example, when estimating the equation for *EXP*, in equation (2), we add Z_{it}^2, Z_{it}^3 to the equation and test the joint null that the parameter estimates for these variables are equal to zero. Note, we also ensure that no individual parameter estimate is significant, as additional insurance that we have the correct instrument set.

used are not determining the outcome variable. This testing procedure is similar to undertaking a Sargen-Hansen test of over-identification in the standard IV (or 2SLS) approach. We report the χ^2-statistics obtained from this exclusion test in our tables of results (below). We also test to ensure we do not have weak instruments by testing that the Z_{it}^{n} used to estimate equation (3) are significant; noting (as mentioned above) that the membership of Z_{it}^{n} depends on which endogenous variable is being instrumented and also which endogenous variable comprises the left-hand-side variable in (2). Thus for each equation in (2), there are two sets of tests of the null that each instrument set comprises variables that are jointly significant (one for each variable instrumented), and the results of these F-tests are also reported in the tables of results set out below.

Since we have essentially a panel dataset, comprising three CIS waves, there is also an issue of whether equation (2) should be estimated incorporating fixed-effects, μ_i. However, since we have only 3 cross-sections in our panel, and with a lagged dependent variable this reduces to two, there is essentially insufficient information on many of the establishments to estimate the fixed-effect intercept.[30]

Lastly, instead of using a simultaneous estimator several authors have used lagged values of (potentially) endogenous variables and omitted contemporaneous values to try to overcome any simultaneous bias. There are two main problems with this approach; firstly, if firms do make joint-decisions about whether to export, undertake R&D and innovate, the use of lagged variables will not capture the full extent of the relationships between these variables (indeed if there are more complicated dynamics in the model – such as product and innovation life-cycle effects which impact on the timing of R&D, innovation and exporting – then lagged variables may pick up no or even a wrongly signed impact). The second problem with using lagged variables is that they do not necessararily overcome the simultaneity issue; if firms have prior knowledge of their exporting, R&D and innovation prospects, they are likely to make current decisions on these variables in part based on expectations of the effects of undertaking complementary activities – all of which are expected to

[30] We tried introducing an intercept for every establishment, obtaining implausible results. Similar a fixed-effects logit estimator (available in STATA) had similar problems. This essentially results from a large number of establishments not changing their 'state' over the short period considered (e.g., they are always exporters), so no information is provided concerning the determination of the fixed-effect parameters. Thus there is an identification problem (the so-called mover-stayer problem) as discussed in Lechner et. al. (2008).

impact positively on productivity levels. To this extent lagged values are being (at least in part) determined by expected outcomes in time *t*, and given also that entry into all three activities usually involves significant sunk costs (and associated path-dependency effects), these activities need to be presumed to be endogenous to each other.

In summary, our estimation strategy is to first obtain predicted values of the right-hand-side endogenous variables by OLS estimation of equation (3), and then use these in a second-stage (probit) estimation of the structural model as set out in equation (2), also testing to ensure our instruments sets are valid. Finally, since the instrumented endogenous variables are generated regressors, we need to correct the standard errors in the second stage regression; in the two-variable probit simultaneous equations model, Maddala (1983) and Murphy and Topel (1985) provide the appropriate corrections needed to the second-stage variance-covariance matrix. In a three-equation model, such corrections become much more complicated, and therefore we tried the jackknife approach to obtaining standard errors in our model (which is a common approach when the underlying distribution of error term is non-normal).[31] This had almost no impact on the standard errors so the default robust standard errors are presented below.

4. Results

4.1 Manufacturing

The results for manufacturing are presented in Table 4, treating exporting, R&D and innovation as either exogenous (columns 1a, 2a and 3a) or endogenous (columns 1b, 2b and 3b). The results for the reduced-form models are presented in Table A.1 (in the appendix). The latter help to identify the instruments used for each endogenous variable (noting – as explained above – that any set of instruments depends on the equation being estimated and the variable been instrumented, and that the final choice of instruments depended on significant levels achieved when estimating equation 2).

[31] In practice, we were not able (using STATA 9.2) to use the more common technique of bootstrapping with replacement as we estimate weighted regression models; instead we tried a jackknife approach which uses sub-sets of the available observations.

As well as passing the tests for exclusion (as explained in the last section) to ensure the instrument sets are empirically appropriate, they should also be consistent with (or at least not in opposition to) economic theory. This is the case here, with it being particularly relevant that absorptive capacity and barriers to innovation play a key role in determining R&D and innovation but not exporting; while capital intensity, market size and industry/location effects are particularly important as instruments for exporting.

As shown in Table 4, the IV probit results for all three models cannot reject the null that the instruments do not determine the relevant dependent (outcome) variable; excluding these instruments is however strongly rejected in the stage 1 modelling of which variables belong to each instrument set. We thus take this as evidence that we have an appropriate instrument set.

The key results are the (contemporaneous and lagged) interactions between exporting, R&D and innovation. Only with exporting as the dependent variable is there any strong evidence that treating R&D as endogenous makes a large difference[32]; column (3a) in Table 4 shows that establishments involved in spending on R&D were nearly 49% more likely to also export, as opposed to being only 21% more likely if we treat R&D as exogenous. This higher contemporaneous impact of R&D on exporting suggests that spending on R&D was not simply to boost the probability of innovating (Table 4 shows that the probability of innovating was 21% higher in establishments that undertook R&D), but it likely involved an additional impact of overall increasing the importance of the establishment's (intangible) knowledge assets, helping it to break down barriers to international markets. Interestingly, the impact of lagged R&D on the probability of exporting is negative, suggesting that establishments that spent on R&D in the previous period (e.g., during 2002-2004) were 13% less likely to export in the current period (e.g., 2004-2006); this may be indicating that while current R&D is used to help enter export markets in time *t*, as a firm gains exporting experience (and/or as any new products age) some firms revert to selling exclusively in the home market and exploiting their now better

[32] Usually if there are significant differences in parameter estimates when simultaneity is taken into account, this is taken as evidence that such simultaneity exists. Otherwise, with appropriate instruments, there should be little difference in terms of parameter estimates between using, say, an OLS estimator and an IV estimator (like 2SLS). As a check we also report the results of the Smith-Blundell (1986) test for exogeneity, which confirms that we can only reject the null of exogenous R&D in the exporting equation.

technology and knowledge base in what is likely to be a less competitive (or at least easier to exploit) market.[33]

Except for the results that have just been discussed, the differences obtained when assuming exogenous or endogenous relationships is fairly small (e.g., columns 1a and 1b); i.e., there is evidence (confirmed by the Smith-Blundell tests) that the right-hand-side variables with respect to R&D, innovation and exporting can be treated as exogenous. Given that we find contemporaneous interactions between these variables, this implies that while they are economically related (e.g., undertaking R&D impacts on innovation), the establishment is making (largely) independent decisions on whether they should engage in such activities, since exogeneity implies that the three error terms in equation (1) are uncorrelated and therefore decisions on whether to export, undertake R&D and/or innovate are not interdependent. It may be that the (assumed random) determinants picked up in the error terms are in fact observed by the establishment (but unseen by the econometrician), but these results are also consistent with other explanations linked to the inherent uncertainty and unpredictability of the outcomes of such activities as spending on R&D and innovating, especially in a sector like manufacturing where the pace of technical change can be significant. Much of what happens is based on luck, or uncontrollable (or unmeasurable) factors associated with an evolutionary approach to innovation and the 'survival of the fittest' (e.g., Metcalfe, 1997). Given that it is difficult to determine who are the 'fittest' given all the factors that impinge on success, it is argued that innovation processes are (almost) stochastic at the firm level. For manufacturing, there is often little difference between the exogenous and endogenous results (except in the exporting equation) so we will concentrate here on the latter figures.

Exporting increases the probability of engaging in R&D, with Table 4 (column 1a) showing that current exporters were some 14% more likely to also engage in R&D. Therefore, there is evidence of a direct 'learning-by-exporting' effect on R&D, but it is much smaller than the impact of R&D on overcoming barriers to exporting (for the reasons set out above). Establishments that exported in the current period were no more likely to innovate, and innovation had no separate (cet. par.) impact on exporting (we find no significant impacts in either direction). However, innovation and R&D are interrelated; establishments that undertook R&D in any three-year

[33] Other explanations are possible, but without a longer time-series it is difficult to test further the dynamic linkages between R&D and exporting.

period were some 21% more likely to innovate, while those that innovated were over 29% more likely to also undertake R&D. Clearly, in manufacturing the relationships between these two variables are important but they show that when other factors are controlled for, neither is very strong; in particular, spending on innovation inputs does not increase dramatically the likelihood of producing an innovation suggests that much R&D is either misdirected or inefficient, produces other effects, or that successful innovation is about much more, including as suggested above a large element of 'luck' or serendipity.

Other determinants of R&D, innovation and exporting are also included in Table 4; the sunk costs involved in overcoming entry barriers are important in all three equations as shown by the size and significance of the lagged values for R&D, innovation and exporting. Higher labour productivity increases the likelihood of undertaking R&D (a one standard deviation increase in productivity increases the probability of R&D by 4.9%); while higher capital intensity increases the likelihood of exporting (by 5.6% given a standard deviation increase in log capital intensity). Older establishments are (-2.9%) less likely to export; while higher industrial clustering increases the likelihood of exporting (by 4.7%) but decreases the probability of engaging in R&D (by -3.6%). There are economies-of-scope exploited in exporting (establishments operating in more than one industry were nearly 6% more likely to export); and US-owned establishments were some 11% less likely (cet. par.) to innovate. Having more graduates employed in the establishment had a positive impact on all three outcomes, especially for exporting where establishments with no graduates are some 23% less likely to export; however too many graduates reduced the likelihood of an innovation. Different measures of absorptive capacity had positive impacts on whether an establishment undertook R&D and/or innovated, but for exporting these variables were insignificant. The importance of acquiring external knowledge was most influential (e.g., a standard deviation increase in this variable increased the likelihood of innovating by 17%), but more specialised, international knowledge was also important in the innovation equation. Firms stating that the high costs of innovation acted as a barrier were just over 13% more likely to undertake R&D;[34] for innovation the cost of finance acts as a barrier lowering the

[34] Note, respondents to the CIS survey are asked to state whether a factor was a constraint to their innovation activities in influencing a decision not to innovate. The positive impact suggests that this 'barrier' was overcome, with such firms intensifying their efforts to undertake R&D. In demand and

likelihood of new product and/or process innovations, while issues over availability of finance increases the probability of innovating by nearly 11%; lack of qualified personnel acted as a spur to overcoming barriers to R&D, while uncertain demand for innovative goods/services reduced the probability of innovating (excessive perceived economic risks increased the probability of innovating by nearly 6%). There were few industry effects impacting on the decision to undertake R&D and/or innovate, whereas a number of more traditional industries had lower propensities to engage in exporting vis-à-vis the benchmark industries (i.e., those not featuring in Table 4). Finally, we found a small number of location effects were important; for example, manufacturers in Bristol are (cet. par.) more likely to undertake R&D; those in London are just over 12% more likely to innovate; while being located in Scotland, Bristol, Cardiff or Coventry reduced the probability of exporting. This might suggest negative externalities are a feature in those locations, and/or firms in these areas are more likely to supply local firms perhaps because of stronger intra/inter-industry linkages (associated with clusters).

4.2 Non-manufacturing

The results for non-manufacturing are presented in Table 5, with the results for the reduced form given in Table A.2. As in the case for manufacturing, the null that the instruments can be excluded from the outcome equation is not rejected; the null that these variables have no explanatory power for the endogenous variable instrumented is rejected in each case at better than the 1% significance level. They therefore satisfy the conditions to be valid instrumental variables. They are also broadly consistent with economic theory. With the exception of the absorptive capacity for global specialised knowledge variable, the measures of absorptive capacity act as instruments for both R&D and innovation in the exporting equations. Unsurprisingly, many of the barriers to innovation act as instruments for innovation. Labour productivity is an instrument for exporting in both R&D and innovation equations.

---

supply terms, this would mean that while the cost of innovation might move a firm down its demand for R&D curve, there are outward shifts in the supply curve (associated with a higher 'taste' for innovation) that more than fully compensate any 'pure' price/cost effects. Similar results of this type (i.e., positive relationships between such 'barriers' and undertaking innovation-related activities) are fairly common when using CIS (and similar) datasets (see, for example, Masso and Vahter, 2008; Frenz and Ietto-Gillies, 2009 and Smit et al., 2010).

Turning to the results from the Blundell-Smith test, when the dependent variable is R&D the null that innovation and exporting are both exogenous is rejected at the 5% significance level. When the dependent variable is innovation, the null that R&D is exogenous can be rejected at the 15% level, and when the dependent variable is exporting, the null that R&D is exogenous is rejected at the 12% significance level. There is therefore, in our view, sufficient evidence to treat the key contemporaneous variables in all these models as endogenous (especially when we also compare the parameter estimates obtained in the various columns a and b in Table 5). These exogeneity results are quite different when compared to those for manufacturing, where exporting, R&D and innovation were exogenous in the R&D and innovation equations. One possible explanation for such differences across the two sectors is that in manufacturing technical change is much more important,[35] pushing out the technological possibility frontier relatively frequently, which in part is likely to explain why fewer establishments in services undertake R&D, innovation and exporting (Table 2 shows the proportion of establishments in services that engage in R&D and innovation is only around two-thirds of the manufacturing total, while the proportion that export is even lower at 50% of the manufacturing total[36]). Thus, the much slower pace of technical change, and the smaller proportion of establishments engaged in such change, makes it more likely that firms understand and are able to predict the process of such change much better, and therefore are able to plan more effectively. The outcome is that R&D and innovation are interdependent and thus endogenous.[37]

---

[35] Based on production function estimates for 3 manufacturing and 3 service sector groupings that used UK plant level data for 1997-2006, Harris and Moffat (2011, Table 3) show that exogenous technical change was highest in high-tech manufacturing (at around a 4.9% p.a.), while other manufacturing sectors also experienced significant boosts from the use of new technology (on average around 2-2.5% p.a.). Gains in the service sectors were very low, and in the case of low knowledge-intensive services (such as hotels & restaurants, real estate and various labour intensive business services) technological progress was negative. Similar results can be obtained using other sources; e.g., based on the EU KLEMS database (O'Mahony and Timmer, 2009) it is possible to show that average total factor productivity over 1997-2006 was 5.1%, 1.4%, 2.3%, 0.5%, and 0.7% in high-tech manufacturing, medium high-tech manufacturing, medium low-tech manufacturing, low-tech manufacturing and market services respectively.

[36] The explanation for such low levels of exporting are also linked to higher 'distance' costs involved in selling services across national frontiers.

[37] Others using CIS-type data provide corroborating findings. For example, Cosh and Zhang (2011) examined the innovation search procedures of U.S. manufacturing vis-à-vis business services. In manufacturing they argue that innovation comes from more of a technical domain (where knowledge is linked to strong IPR); in services, incremental changes are more common and are linked to adapting to individual clients needs (and where IPR is usually weaker). Note also, in Table 2, we find absorptive

Figure 1 around here

As in manufacturing, the lag of the dependent variable has a positive and significant coefficient in each model which suggests that sunk costs are important. In the R&D model (column 1b), innovation and exporting both have positive and statistically significant impacts. Innovating leads to an increase in the probability of performing R&D of 28% while exporting increases this probability by 13%. These are slightly smaller than the corresponding impacts for manufacturing (cf. Figure 1). There is a bi-directional relationship between R&D and innovation, as performing R&D also increases the probability of innovation (column 2b) by 24%. This relationship was also found in manufacturing. The major difference when compared to manufacturing was that exporting is not found to be determined by R&D (column 3b); instead, innovation exerts a positive influence on the probability of exporting (it is associated with an increase in the probability of exporting of 13%). As with manufacturing, exporting is not found to be a significant determinant of innovation performance.

In terms of the control variables, having lower levels of human capital (as proxied by the 'no graduates' variable) lowered the probability of undertaking R&D while having higher levels of three types of absorptive capacity and facing high costs of innovation (see footnote 14) increased the probability of undertaking R&D. These results were also obtained for manufacturing. The results differ from manufacturing in that a higher capital intensity increased the probability of performing R&D and smaller establishments (with between 10-19 employees) were less likely to invest in R&D. Furthermore, establishments that are part of multi-region enterprises, and establishments operating in a market dominated by established business, had a lower probability of engaging in R&D. Labour productivity, industry agglomeration and a lack of qualified personnel are significant determinants of R&D in manufacturing but not in non-manufacturing. There were also differences in the significance of the industry and region dummies across the two sectors.

In the innovation model, the absorptive capacity variables all had a significant and positive impact and a number of barriers to innovation were also significant. This was also the case for manufacturing. The results differ from manufacturing in that age, being situated in close proximity to other firms from the same industry and a lack

capacity is much lower in non-manufacturing, suggesting that searching for external knowledge is much less important in this sector.

of market information had a negative impact on the probability of innovation. US-owned establishments, establishments with over 75% of graduates and establishments with uncertain demand for innovative goods/services were less likely to innovate in manufacturing but not in non-manufacturing. In addition, being situated in London had a positive impact on the probability of innovating while being located in Manchester had a negative impact in manufacturing whereas none of the spatial dummies were significant in non-manufacturing.

The coefficients on the control variables in the exporting model differ considerably from those obtained for manufacturing. In both sectors, being situated near other establishments from the same industry had a positive impact on the probability of exporting while having no graduates reduced the probability of exporting. The following variables had a significant impact in non-manufacturing but not in manufacturing: labour productivity (a positive impact); diversification (negative); having 20-75% graduates (negative); absorptive capacity for international co-operation (positive); four barriers to innovation; the Greater South East dummy (positive) and the East Midlands dummy (positive). By comparison, the following had a significant effect in manufacturing but not in non-manufacturing: capital intensity (positive); age (negative); being part of a multi-plant enterprise (positive) and five spatial dummies.

5. Summary and conclusions

This study considers the determinants of whether a firm exports, undertakes R&D and/or innovates, and the contemporaneous links between these variables (e.g., undertaking R&D and/or innovating are likely to both impact on the firm's decision to export or not, and in turn to be influenced by the experience of exporting). The major motivation for studying these relationships is that such activities underpin our understanding of productivity differences between firms; and being able to explain more fully the reasons why there is significant heterogeneity across firms should provide in particular policy-makers with better tools for improving aggregate productivity levels across sub-national areas, nations and other regional blocs.

Despite the growing number of papers that have begun to look at whether there are links between R&D/innovation and exporting, most studies only consider causality in one direction (the most popular being whether undertaking R&D/innovation results in firms having a higher probability of exporting), and invariably they do not allow for *contemporaneous* links between exporting and R&D/innovation. Moreover, and as far as we know, no study looks at the relationships between all three variables. This was accomplished here using probit regressions that determine the probability of a firm engaging in exporting, R&D, and innovation, and we instrumented the dichotomous endogenous variables using other (exogenous) variables in the dataset.

This study used three waves of the UK Community Innovation Survey (CIS) carried out in 2005, 2007 and 2009; giving a nationally representative account of the innovation activities of the reporting enterprises for the period covering 2002-2008. The analysis was conducted for both the manufacturing and service sectors. Concentrating on the results showing the (contemporaneous) relationships between exporting, R&D, and innovation, the major difference we found when comparing manufacturing and services was over the issue of exogeneity. In manufacturing, only when exporting was the dependent variable was there any strong evidence that R&D was endogenous; for the R&D and innovation equations there is evidence that the right-hand-side variables with respect to R&D, innovation and exporting can be treated as exogenous. In non-manufacturing, all three variables appeared to be endogenous to each other. Given that in manufacturing we find contemporaneous interactions between these variables, this implies that while they are economically related (e.g., undertaking R&D impacts on innovation), the establishment is making (largely) independent decisions on whether they should engage in such activities; i.e., these results are consistent with explanations (most often emphasised in the evolutionary economics literature) concerning the inherent uncertainty and unpredictability of the outcomes of spending on R&D and innovating, especially in a sector like manufacturing where the pace of technical change can be significant. In contrast, in the service sector the much slower pace of technical change, and the smaller proportion of establishments engaged in such change, makes it more likely that innovative firms understand and are able to predict technological trajectories more easily, and therefore are able to plan more effectively. The outcome is that in non-manufacturing R&D and innovation are interdependent and thus endogenous.

Clearly our results on exogeneity differences need to be corroborated in future theoretical and empirical work before we can be more confident that this was not just a statistical artefact of the present CIS dataset.

We also found that in both manufacturing and services being involved in exporting increased the probability that an establishment was engaged in spending on R&D (although, as expected, innovating in the current period had a larger impact on whether current R&D spending occurred), with the strength of such 'learning-by-exporting' being similar across sectors. However, spending on R&D in manufacturing had a much larger impact on the probability of exporting (about three times larger); this suggests that spending on R&D was not simply to boost the probability of producing new goods and services (in manufacturing the probability of innovating was 21% higher in establishments that undertook R&D), but it likely involved an additional ('second face' of R&D) impact of improving the establishment's (intangible) knowledge assets, helping it to break down barriers to international markets. In non-manufacturing, spending on R&D increased the probability of innovating (by 24%) but had no significant impact on whether the establishment exported; rather, innovating in the current period increased the probability of exporting (but only by some 13%). Thus, there are significant differences across the two sectors in the role played by R&D and innovation in determining whether an establishment exported, in particular that firms need to engage in R&D to become more productive and thus break down the barriers to exporting. We also found that exporting had no direct (contemporaneous) impact on whether innovation occurred in either sector (neither did we find that the lag of exporting impacted on innovation, suggesting that establishments involved in exporting do not experience any short-run requirement to develop new products or processes).

Lastly, while innovation and R&D are interrelated (there are similar causal links in both directions across both sectors), the relationships between these two variables are not as strong as might have (a priori) been expected; in particular, spending on R&D does not increase dramatically the likelihood of producing an innovation, suggesting that much R&D is either misdirected or inefficient, produces other effects, or that successful innovation is about much more (including a large element of 'luck' or serendipity, especially in manufacturing).

Turning to policy, the results obtained show the importance of (inter alia) absorptive capacity, having high(er) levels of human capital, and certain industry and location effects, in determining whether establishments engage in the productivity enhancing activities studied in this paper. Government action to help firms increase their intangible (knowledge-creation) assets should therefore result in an upward trajectory for (aggregate) productivity and thus economic growth. However, we have also shown that (with the exception of the impact of R&D on exporting in manufacturing), many of the links between exporting, R&D and innovation were not particularly strong, suggesting that pursuing policies to boost R&D will not on its own significantly increase the number of innovative British firms, while helping more firms to sell abroad only has a marginal impact on encouraging them to become involved in R&D and/or in producing new products and processes. And yet, as was stated in the introduction (and also covered in the literature review), we know that establishments that engage in any combination of the three activities covered here tend to head firm-level productivity league tables. This therefore points to both the complexity of the underlying processes that determine establishment level productivity, and thus the need to recognise that there are no quick and simple policies that will increase the 'extensive' margins of activity in these areas. However, at the same time, we have established that exporting, R&D and innovation are clearly interconnected in the current period, and therefore policy needs to recognise such linkages and ensure that it takes advantage of them when devising and implementing productivity-enhancing policies at the micro-level. This is especially true for R&D in the manufacturing sector.

References

Acs, Z. J. & Audretsch, D. B. (1991). R&D, Firm Size and Innovative Activity, In: Acs, Z. J. & Audretsch, D. B. (eds.) *Innovation and technological change: An international comparison.* Ann Arbor: University of Michigan Press.

Aghion, P. & Howitt, P. (1998) *Endogenous growth theory.* Cambridge, Mass. ; London: MIT Press.

Aitken, B. J., Hanson, G. H. & Harrison, A. E. (1997) Spillovers, foreign investment, and export behavior, *Journal of International Economics,* 43**,** 103-132.

Almeida, P., Dokko, G. & Rosenkopf, L. (2003) Startup Size and the Mechanisms of External Learning: Increasing Opportunity and Decreasing Ability?, *Research Policy,* 32**,** 301-315.

Alvarez, R. (2001) External Sources of Technological Innovation in Chilean Manufacturing Industry, *Estudios de Economia,* 28**,** 53-68.

Alvarez, R. & López, R. A. (2005) Exporting and performance: evidence from Chilean plants, *Canadian Journal of Economics/Revue canadienne d'économique,* 38**,** 1384-1400.

Angelmar, R. (1985) Market Structure and Research Intensity in High-Technological-Opportunity Industries, *Journal of Industrial Economics,* 34**,** 69-79.

Angrist, J. D. & Krueger, A. B. (2001) Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments, *Journal of Economic Perspectives,* 15**,** 69-85.

Arora, A. & Gambardella, A. (1990) Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology, *The Journal of Industrial Economics,* 38**,** 361-379.

Audretsch, D. B. & Feldman, M. P. (1996) R&D Spillovers and the Geography of Innovation and Production, *American Economic Review,* 86**,** 630-640.

Autio, E., Sapienza, H. J. & Almeida, J. G. (2000) Effects of Age at Entry, Knowledge Intensity, and Imitability on International Growth, *The Academy of Management Journal,* 43**,** 909-924.

Aw, B. Y. & Hwang, A. R. (1995) Productivity and the Export Market: A Firm-Level Analysis, *Journal of Development Economics,* 47**,** 313-332.

Aw, B. Y., Roberts, M. J. & Xu, D. Y. (2009) R&D Investment, Exporting, and Productivity Dynamics, *NBER Working Paper Series,* 14670, National Bureau of Economic Research, Cambridge, MA.

Bagchi-Sen, S. (2001) Product innovation and competitive advantage in an area of industrial decline: the Niagara region of Canada, *Technovation,* 21**,** 45-54.

Baldwin, J. R. & Gu, W. (2004) Trade Liberalization: Export-market Participation, Productivity Growth, and Innovation, *Oxford Review of Economic Policy,* 20**,** 372-392.

Barney, J. (1991) Firm Resources and Sustained Competitive Advantage, *Journal of Management,* 17**,** 99-120.

Basile, R. (2001) Export behaviour of Italian manufacturing firms over the nineties: the role of innovation, *Research Policy,* 30**,** 1185-1201.

Becker, S. & Egger, P. (2009) Endogenous product versus process innovation and a firm's propensity to export, *Empirical Economics***,** 1-26.

Belderbos, R., Carree, M. & Lokshin, B. (2004) Cooperative R&D and firm performance, *Research Policy,* 33**,** 1477-1492.

Bernard, A. B., Eaton, J., Jensen, J. B. & Kortum, S. (2003) Plants and Productivity in International Trade, *American Economic Review,* 93**,** 1268-1290.

Bernard, A. B. & Jensen, J. B. (1999) Exceptional Exporter Performance: Cause, Effect, or Both?, *Journal of International Economics,* 47**,** 1-25.

Bernard, A. B. & Jensen, J. B. (2004a) Exporting and Productivity in the USA, *Oxford Review of Economic Policy,* 20**,** 343-357.

Bernard, A. B. & Jensen, J. B. (2004b) Why Some Firms Export, *The Review of Economics and Statistics,* 86**,** 561-569.

Bernard, A. B. & Wagner, J. (1997) Exports and Success in German Manufacturing, *Weltwirtschaftliches Archiv,* 133**,** 134-157.

Bessant, J., Phelps, B. & Adams, R. (2005) External Knowledge: A review of the literature addressing the role of external knowledge and expertise at key stages of business growth and development, *Report to DTI,* Available at: http://www.aimresearch.org/uploads/file/Publications/Academic%20Publications%202/External_Knowledge.pdf.

Bishop, P. & Wiseman, N. (1999) External Ownership and Innovation in the United Kingdom, *Applied Economics,* 31**,** 443-450.

Bleaney, M. & Wakelin, K. (2002) Efficiency, innovation and exports, *Oxford Bulletin of Economics and Statistics,* 64**,** 3-15.

Blind, K. & Jungmittag, A. (2004) Foreign Direct Investment, Imports and Innovations in the Service Industry, *Review of Industrial Organization,* 25**,** 205-227.

Burger, A., Jaklic, A. & Rojec, M. (2008) Exporting and Company Performance in Slovenia: Self-Selection and/or Learning by Exporting?, *Ekonomicky Casopis/Journal of Economics,* 56**,** 131-153.

Bustos, P. (2009) Trade Liberalization, Exports and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinean Firms, *Economics Working Papers,* Universitat Pompeu Fabra, Barcelona.

Cabrer-Borras, B. & Serrano-Domingo, G. (2007) Innovation and R&D Spillover Effects in Spanish Regions: A Spatial Approach, *Research Policy,* 36**,** 1357-1371.

Caldera, A. (2010) Innovation and exporting: evidence from Spanish manufacturing firms, *Review of World Economics,* 146**,** 657-689.

Cameron, G., Proudman, J. & Redding, S. (2005) Technological convergence, R&D, trade and productivity growth, *European Economic Review,* 49**,** 775-807.

Cassiman, B. & Martinez-Ros, E. (2003) Innovation Driving Export Performance: Evidence from Spanish Manufacturing, *Report to* Available at: http://www.xixjei.uji.es/tra/x2204520qcassiman_martinez.pdf.

Cassiman, B. & Martinez-Ros, E. (2007) Product Innovation and Exports: Evidence from Spanish Manufacturing, *IESE working paper,*

Cassiman, B. & Veugelers, R. (1999) Complementarity between Technology Make and Buy in Innovation Strategies: Evidence from Belgiam Manufacturing Firms, *Research Policy,* 28**,** 63-80.

Cassiman, B. & Veugelers, R. (2002) Complementarity in the Innovation Strategy: Internal R&D, External Technology Acquisition and Cooperation, *CEPR Discussion Papers,* 3284, Centre for Economic Policy Research, London.

Castellani, D. (2002) Export Behavior and Productivity Growth: Evidence from Italian Manufacturing Firms, *Weltwirtschaftliches Archiv/Review of World Economics,* 138**,** 605-628.

Clerides, S. K., Lach, S. & Tybout, J. R. (1998) Is Learning by Exporting Important? Micro-dynamic Evidence from Colombia, Mexico, and Morocco, *Quarterly Journal of Economics,* 113**,** 903-947.

Clougherty, J. A. & Zhang, A. (2009) Domestic Rivalry and Export Performance: Theory and Evidence from International Airline Markets, *Canadian Journal of Economics,* 42**,** 440-468.

Cohen, W. M. & Klepper, S. (1996) A Reprise of Size and R&D, *Economic Journal,* 106**,** 925-951.

Cohen, W. M. & Levin, R. C. (1989). Empirical studies of innovation and market structure, In: Richard, S. & Robert, W. (eds.) *Handbook of Industrial Organization.* New York, NY: North Holland: Elsevier.

Cohen, W. M., Levin, R. C. & Mowery, D. C. (1987) Firm Size and R & D Intensity: A Re-Examination, *The Journal of Industrial Economics,* 35**,** 543-565.

Cohen, W. M. & Levinthal, D. A. (1989) Innovation and Learning: The Two Faces of R & D, *The Economic Journal,* 99**,** 569-596.

Cohen, W. M. & Levinthal, D. A. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly,* 35**,** 128-152.

Criscuolo, C., Haskel, J. E. & Slaughter, M. J. (2010) Global engagement and the innovation activities of firms, *International Journal of Industrial Organization,* 28**,** 191-202.

Dachs, B. & Ebersberger, B. (2009) Does Foreign Ownership Matter for the Innovative Activities of Enterprises?, *International Economics and Economic Policy,* 6**,** 41-57.

Dachs, B., Ebersberger, B. & Pyka, A. (2008) Why do firms cooperate for innovation A comparison of Austrian and Finnish CIS3 results, *International Journal of Foresight and Innovation Policy,* 4**,** 200-229.

Damijan, J. P., Kostevc, C. & Polanec, S. (2010) From Innovation to Exporting or Vice Versa?, *World Economy,* 33**,** 374-398.

Damijan, J. P., Polanec, S. & Prašnikar, J. (2005) Does Exporting Increase Productivity? Firm Level Evidence from Slovenia, *Globalisation and Firm Level Adjustment*. Nottingham.

David, P. A. & Rosenbloom, J. L. (1990) Marshallian Factor Market Externalities and the Dynamics of Industrial Localization, *Journal of Urban Economics,* 28**,** 349-370.

Davis, D. R. (1995) Intra-industry trade: A Heckscher-Ohlin-Ricardo approach, *Journal of International Economics,* 39**,** 201-226.

Delgado, M. A., Fariñas, J. C. & Ruano, S. (2002) Firm productivity and export markets: a non-parametric approach, *Journal of International Economics,* 57**,** 397-422.

Dhanaraj, C. & Beamish, P. W. (2003) A Resource-Based Approach to the Study of Export Performance, *Journal of Small Business Management,* 41**,** 242-261.

DiPietro, W. R. & Anoruo, E. (2006) Creativity, Innovation, and Export Performance, *Journal of Policy Modeling,* 28**,** 133-139.

Dollar, D. (1986) Technological Innovations, Capital Mobility, and the Product Cycle in North-South Trade, *American Economic Review,* 76**,** 177-190.

Fagerberg, J. (1988) International Competitiveness, *Economic Journal,* 98**,** 355-374.

Falk, M. (2008) Effects of Foreign Ownership on Innovation Activities: Empirical Evidence for Twelve European Countries, *National Institute Economic Review***,** 85-97.

Frenz, M. & Ietto-Gillies, G. (2009) The impact on innovation performance of different sources of knowledge: Evidence from the UK Community Innovation Survey, *Research Policy,* 38**,** 1125-1135.

Ganotakis, P. & Love, J. H. (2010) R&D, product innovation, and exporting: evidence from UK new technology based firms, *Oxford Economic Papers***,** forthcoming.

Geroski, P. A. (1990) Innovation, Technological Opportunity, and Market Structure, *Oxford Economic Papers, N. S.,* 42**,** 586-602.

Girma, S., Gorg, H. & Hanley, A. (2008) R&D and Exporting: A Comparison of British and Irish Firms, *Review of World Economics/Weltwirtschaftliches Archiv,* 144**,** 750-773.

Gourlay, A. & Seaton, J. (2004) UK Export Behaviour at the Firm Level, *Economic Issues,* 9**,** 3-20.

Gourlay, A., Seaton, J. & Suppakitjarak, J. (2005) The determinants of export behaviour in UK service firms, *The Service Industries Journal,* 25**,** 879 - 889.

Graves, S. B. & Langowitz, N. S. (1993) Innovative productivity and returns to scale in the pharmaceutical industry, *Strategic Management Journal,* 14**,** 593-605.

Greenaway, D., Gullstrand, J. & Kneller, R. (2005) Exporting May Not Always Boost Firm Productivity, *Review of World Economics/Weltwirtschaftliches Archiv,* 141**,** 561-582.

Greenaway, D. & Kneller, R. (2003) Exporting, Productivity and Agglomeration: a Difference in Difference Analysis of Matched Firms, *CEP Research Paper,* 2003/45, Centre for Economic Performance, London.

Greenaway, D. & Kneller, R. (2004) Exporting and Productivity in the United Kingdom, *Oxford Review of Economic Policy,* 20**,** 358-371.

Greenaway, D. & Kneller, R. (2007) Firm Heterogeneity, Exporting and Foreign Direct Investment, *Economic Journal,* 117**,** F134-61.

Greenaway, D. & Kneller, R. (2008) Exporting, productivity and agglomeration, *European Economic Review,* 52**,** 919-939.

Greenhalgh, C. (1990) Innovation and Trade Performance in the United Kingdom, *Economic Journal,* 100**,** 105-118.

Greenhalgh, C., Taylor, P. & Wilson, R. (1994) Innovation and Export Volumes and Prices--A Disaggregated Study, *Oxford Economic Papers,* 46**,** 102-135.

Griffith, R., Redding, S. & Van Reenen, J. (2004) Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries, *Review of Economics and Statistics,* 86**,** 883-895.

Griliches, Z. (1980). Returns to Research and Development Expenditure in the Private Sector, In: Kendrick, J. W. & Vaccara, B. N. (eds.) *New Developments in Productivity Measurement and Analysis.* Chicago: The University of Chicago Press.

Grossman, G. M. & Helpman, E. (1991) *Innovation and growth in the global economy.* The MIT Press.

Grossman, G. M. & Helpman, E. (1995). Technology and Trade, In: Grossman, G. M. & Rogoff, K. (eds.) *Handbook of international economics. Volume 3.* Amsterdam; New York; Oxford: Elsevier.

Guan, J. & Ma, N. (2003) Innovative capability and export performance of Chinese firms, *Technovation,* 23**,** 737-747.

Hall, B. H., Lotti, F. & Mairesse, J. (2008) Innovation and Productivity in SMEs: Empirical Evidence for Italy, *NBER Working Papers,* 14594, National Bureau of Economic Research, Cambridge, MA.

Hanley, A. (2004) Exports, Linkages and Innovation, *Occasional Paper Series,* 2004-8, University of Nottingham, Nottingham.

Harris, R. (1991) External Ownership of Industry and Government Policy: Some Further Evidence for Northern Ireland, *Regional Studies,* 25**,** 45-62.

Harris, R. (2002) Foreign Ownership and Productivity in the United Kingdom—Some Issues When Using the ARD Establishment Level Data, *Scottish Journal of Political Economy,* 49**,** 318-335.

Harris, R. & Drinkwater, S. (2000) UK Plant and Machinery Capital Stocks and Plant Closures, *Oxford Bulletin of Economics and Statistics,* 62**,** 243-265.

Harris, R. & Li, Q. C. (2009) Exporting, R&D, and Absorptive Capacity in UK Establishments, *Oxford Economic Papers,* 61**,** 74-103.

Harris, R. & Li, Q. C. (2010) Study of the Relationship between Innovation, Exporting and the use of E-Commerce, *Report to UKTI,* Available at: http://www.ukti.gov.uk/uktihome/aboutukti/ourperformance/research/benefitsofinternationalisation.html.

Harris, R. & Moffat, J. (2011) Plant-level Determinants of Total Factor Productivity in Great Britain, 1997-2006, *SERC Discussion Papers,* 64, Spatial Economics Research Centre, London.

Harris, R. & Trainor, M. (1995) Innovations and R&D in Northern Ireland Manufacturing: A Schumpeterian Approach, *Regional Studies,* 29**,** 593-604.

Henderson, J. V. (2003) Marshall's Scale Economies, *Journal of Urban Economics,* 53**,** 1-28.

Hirsch, S. & Bijaoui, I. (1985) R&D Intensity and Export Performance: A Micro View, *Weltwirtschaftliches Archiv,* 121**,** 238-251.

Hobday, M. (1995) East Asian Latecomer Firms: Learning the Technology of Electronics, *World Development,* 23**,** 1171-1193.

Hughes, K. (1986) *Exports and technology.* Cambridge: Cambridge University Press.

Iyer, K. (2010) The Determinants of Firm-Level Export Intensity in New Zealand Agriculture and Forestry, *Economic Analysis and Policy,* 40**,** 75-86.

Jacobs, J. (1970) *The economy of cities.* London: Jonathan Cape.

Jacobs, J. (1986) *Cities and the wealth of nations.* Harmondsworth: Penguin.

Jaffe, A. B. (1986) Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value, *American Economic Review,* 76**,** 984-1001.

Kaiser, H. F. (1960) The Application of Electronic Computers to Factor Analysis, *Educational and Psychological Measurement,* 20**,** 141-151.

Klepper, S. (1996) Entry, Exit, Growth, and Innovation over the Product Life Cycle, *American Economic Review,* 86**,** 562-583.

Klevorick, A. K., Levin, R. C., Nelson, R. R. & Winter, S. G. (1995) On the sources and significance of interindustry differences in technological opportunities, *Research Policy,* 24**,** 185-205.

Kneller, R. (2005) Frontier Technology, Absorptive Capacity and Distance, *Oxford Bulletin of Economics and Statistics,* 67**,** 1-23.

Kneller, R. & Pisu, M. (2007) Industrial Linkages and Export Spillovers from FDI, *World Economy,* 30**,** 105-134.

Koch, A. & Strotmann, H. (2008) Absorptive Capacity and Innovation in the Knowledge Intensive Business Services Sector, *Economics of Innovation and New Technology,* 17**,** 511-531.

Koenig, P. (2009) Agglomeration and the export decisions of French firms, *Journal of Urban Economics,* 66**,** 186-195.

Kraay, A. (1999) Exports and Economic Performance: Evidence from a Panel of Chinese Enterprises, *Revue d'Economie du Developpement***,** 183-207.

Krugman, P. (1979) A Model of Innovation, Technology Transfer, and the World Distribution of Income, *Journal of Political Economy,* 87**,** 253-266.

Lachenmaier, S. & Wossmann, L. (2006) Does Innovation Cause Exports? Evidence from Exogenous Innovation Impulses and Obstacles Using German Micro Data, *Oxford Economic Papers,* 58**,** 317-350.

Lechner, M., Lollivier, S. & Magnac, T. (2008). Parametric Binary Choice Models, In: Mátyás, L. & Sevestre, P. (eds.) *The Econometrics of Panel Data.* Springer Berlin Heidelberg.

Lefebvre, É. & Lefebvre, L. A. (2001). Innovative capabilities as Determinants of Export Performance and Behaviour: A Longitudinal Study of Manufacturing SMEs, In: Kleinlenecht, A. & Monhen, P. (eds.) *Innovation and Firm Performance: Econometric Explorations of Survey Data.* London; Basingstoke: Palgrave (MacMillan Press).

Legge, J. M. (2000) The Economics of Industrial Innovation, *Review of Policital Economy,* 12**,** 249-256.

Leon-Ledesma, M. A. (2005) Exports, Product Differentiation and Knowledge Spillovers, *Open Economies Review,* 16**,** 363-379.

Lokshin, B., Belderbos, R. & Carree, M. (2008) The Productivity Effects of Internal and External R&D: Evidence from a Dynamic Panel Data Model, *Oxford Bulletin of Economics and Statistics,* 70**,** 399-413.

López Rodríguez, J. & García Rodríguez, R. M. (2005) Technology and export behaviour: A resource-based view approach, *International Business Review,* 14**,** 539-557.

Love, J. H. & Mansury, M. A. (2009) Exporting and productivity in business services: Evidence from the United States, *International Business Review,* 18**,** 630-642.

Maddala, G. S. (1983) *Limited-dependent and qualitative variables in econometrics.* Cambridge: Cambridge University Press.

Mairesse, J. & Mohnen, P. (2002) Accounting for Innovation and Measuring Innovativeness: An Illustrative Framework and an Application, *The American Economic Review,* 92**,** 226-230.

Malmberg, A. (1997) Industrial geography: location and learning, *Progress in Human Geography,* 21**,** 573-582.

Masso, J. & Vahter, P. (2008) Technological Innovation and Productivity in Late-Transition Estonia: Econometric Evidence from Innovation Surveys, *European Journal of Development Research,* 20**,** 240-261.

Melitz, M. J. (2003) The impact of trade on intra-industry reallocations and aggregate industry productivity, *Econometrica,* 71**,** 1695-1725.

Metcalfe, J. S. (1997) *Evolutionary economics and creative destruction.* London: Routledge.

Morgan, K. (2004) The Exaggerated Death of Geography: Learning, Proximity and Territorial Innovation Systems, *Journal of Economic Geography,* 4**,** 3-21.

Murphy, K. M. & Topel, R. H. (1985) Estimation and Inference in Two-Step Econometric Models, *Journal of Business & Economic Statistics,* 3**,** 370-379.

Narula, R. & Wakelin, K. (1998) Technological Competitiveness, Trade and Foreign Direct Investment, *Structural Change and Economic Dynamics,* 9**,** 373-387.

Nonaka, I. & Takeuchi, H. (1995) *The knowledge-creating company.* New York ; Oxford: Oxford University Press.

O'Mahony, M. & Timmer, M. P. (2009) Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database, *The Economic Journal,* 119**,** F374-F403.

Overman, H. G., Redding, S. & Venables, A. J. (2008). The Economic Geography of Trade, Production, and Income: A Survey of Empirics, In: Choi, E. K. & Harrigan, J. (eds.) *Handbook of International Trade.* Oxford: Blackwell Publishing Ltd.

Ozcelik, E. & Taymaz, E. (2004) Does Innovativeness Matter for International Competitiveness in Developing Countries? The Case of Turkish Manufacturing Industries, *Research Policy,* 33**,** 409-424.

Penrose, E. T. (1959) *The Theory of the Growth of the Firm.* Oxford: Oxford University Press.

Pinho, J. C. & Martins, L. (2010) Exporting Barriers: Insights from Portuguese Small- and Medium-Sized Exporters and Non-exporters, *Journal of International Entrepreneurship,* 8**,** 254-272.

Posner, M. V. (1961) International Trade and Technical Change, *Oxford Economic Papers,* 13**,** 323-341.

Roberts, M. J. & Tybout, J. R. (1997) The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs, *American Economic Review,* 87**,** 545-564.

Robjohns, J. (2006) ARD2: The new Annual Respondents Database, *Economic Trends,* 630**,** 43-51.

Romer, P. M. (1990) Endogenous Technological Change, *Journal of Political Economy,* 98**,** S71-102.

Roper, S. (2000) Industry and Location Effects on UK Plants' Innovation Propensity, *Annals of Regional Science,* 34**,** 489-502.

Roper, S. & Love, J. H. (2001) The Determinants of Export Performance: Panel Data Evidence for Irish Manufacturing Plants, *NIERC Working Paper Series,* 69, Northern Ireland Economic Research Centre, Belfast.

Roper, S. & Love, J. H. (2002) Innovation and export performance: evidence from the UK and German manufacturing plants, *Research Policy,* 31**,** 1087-1102.

Roper, S., Love, J. H. & Anon Higon, D. (2006) The Determinants of Export Performance: Evidence for Manufacturing Plants in Ireland and Northern Ireland, *Scottish Journal of Political Economy,* 53**,** 586-615.

Salim, R. A. & Bloch, H. (2009) Business Expenditures on R&D and Trade Performances in Australia: Is There a Link?, *Applied Economics,* 41**,** 351-361.

Salomon, R. M. & Shaver, J. M. (2005) Learning by Exporting: New Insights from Examining Firm Innovation, *Journal of Economics and Management Strategy,* 14**,** 431-460.

Schank, T., Schnabel, C. & Wagner, J. (2010) Higher wages in exporting firms: self-selection, export effect, or both? First evidence from linked employer-employee data, *Review of World Economics,* 146**,** 303-322.

Schmidt, T. (2005) What determines absorptive capacity?, *Dynamics of Industry and Innovation: Organizations, Networks and Systems*. Copenhagen.

Schumpeter, J. A. (1950) *Capitalism, Socialism, and Democracy.* London: George Allen & Unwin.

Smit, M. J., Abreu, M. A. & de Groot, H. L. F. (2010) Micro-Evidence on the Determinants of Innovation in The Netherlands: The Relative Importance of Absorptive Capacity and Agglomeration Externalities, *Tinbergen Institute Discussion Papers,* 10-060/3, Tinbergen Institute,

Smith, R. J. & Blundell, R. W. (1986) An Exogeneity Test for a Simultaneous Equation Tobit Model with an Application to Labor Supply, *Econometrica,* 54**,** 679-685.

Soete, L. (1987) The impact of technological innovation on international trade patterns: The evidence reconsidered, *Research Policy,* 16**,** 101-130.

Sterlacchini, A. (1999) Do Innovative Activities Matter to Small Firms in Non-R&D-Intensive Industries? An Application to Export Performance, *Research Policy,* 28**,** 819-832.

Teece, D. J. (1986) Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy, *Ricerche Economiche,* 40**,** 607-643.

Tingvall, P. G. & Poldahl, A. (2006) Is There Really an Inverted U-Shaped Relation between Competition and R&D?, *Economics of Innovation and New Technology,* 15**,** 101-118.

Van Beveren, I. & Vandenbussche, H. (2010) Product and Process Innovation and Firms' Decision to Export, *Journal of Economic Policy Reform,* 13**,** 3-24.

Vernon, R. (1966) International Investment and International Trade in the Product Cycle, *The Quarterly Journal of Economics,* 80**,** 190-207.

Verspagen, B. & Wakelin, K. (1997) International Competitiveness and Its Determinants, *International Journal of Applied Economics,* 11**,** 177-190.

Veugelers, R. (1997) Internal R&D Expenditures and External Technology Sourcing, *Research Policy,* 26**,** 303-315.

Vinding, A. L. (2006) Absorptive capacity and innovative performance: A human capital approach, *Economics of Innovation and New Technology,* 15**,** 507-517.

Von Hippel, E. (1994). Determining User Needs for Novel Information-Based Products and Services, In: Allen, T. J. & Scott Morton, M. S. (eds.) *Information technology and the corporation of the 1990s.* Oxford; New York; Toronto and Melbourne: Oxford University Press.

Wagner, J. (2001) A Note on the Firm Size-Export Relationship, *Small Business Economics,* 17**,** 229-237.

Wagner, J. (2007) Exports and Productivity: A Survey of the Evidence from Firm-Level Data, *World Economy,* 30**,** 60-82.

Wakelin, K. (1998) Innovation and Export Behaviour At the Firm Level, *Research Policy,* 26**,** 829-841.

Yang, Y. & Mallick, S. (2010) Export Premium, Self-Selection and Learning-by-Exporting: Evidence from Chinese Matched Firms, *World Economy,* 33**,** 1218-1240.

Yeaple, S. R. (2005) A Simple Model of Firm Heterogeneity, International Trade, and Wages, *Journal of International Economics,* 65**,** 1-20.

Young, A. (1991) Learning by Doing and the Dynamic Effects of International Trade, *Quarterly Journal of Economics,* 106**,** 369-405.

Zahra, S. A. & George, G. (2002) Absorptive Capacity: A Review, Reconceptualization, and Extension, *The Academy of Management Review,* 27**,** 185-203.

Zhao, H. & Li, H. (1997) R&D and export: An empirical analysis of Chinese manufacturing firms, *The Journal of High Technology Management Research,* 8**,** 89-105.

Table 1: Variable Definitions used in CIS-ARD merged dataset for 2004-2008

Variable	Definitions	Source[a]
R&D	Whether the establishment undertook R&D (coded 1) or not	CIS
Innovation	Whether the establishment introduced either/both product/process (coded 1) innovations or not	CIS
Exporting	Whether the establishment sold goods and services outside the UK (coded 1) or not	CIS
Labour productivity	Establishment turnover per employee	CIS
Capital Intensity	Capital to employment ratio	ARD
Size	Number of employees in the establishment, broken down into 5 size-bands, i.e. 0-9, 10-19, 20-49, 50-199 and 200+	CIS
Age	Age of establishment in years	ARD
Industry agglomeration	% of industry output (at 5-digit SIC level) located in travel-to-work area in which establishment is located	ARD
Diversification	% of 5-digit industries (from over 650) located in travel-to-work area in which establishment is located	ARD
Multi-region enterprise	Whether the establishment belongs to an enterprise with establishments in more than one region (coded 1) or not	ARD
Multi-industry enterprise	Whether the establishment belongs to an enterprise with establishments in more than one industry (coded 1) or not	ARD
Herfindahl	Herfindahl index of industry concentration (5-digit level)	ARD
Single-plant enterprise	Whether the establishment was a single-plant enterprise (coded 1) or not	ARD
US-owned	Whether the establishment was owned by a US enterprise (coded 1) or not	ARD
Other foreign-owned	Whether the establishment was foreign-owned by a non-US enterprise (coded 1) or not	ARD
Size of graduates workforce	Proportion of employees educated to degree level or above in the establishment, broken down into 5 bands, i.e. no graduates, 0-5% graduates, 5-20% graduates, 20-75% graduates, and 75%+ graduates	CIS
Absorptive capacity (5 factors, see text for details)	AC for external knowledge	CIS
	AC for corporate strategy and management techniques	CIS
	AC for national co-operation	CIS
	AC for international co-operation	CIS
	AC for global specialised knowledge	CIS
Barriers to innovation[b] (10 aspects)	Excessive perceived economic risks	CIS
	High costs of innovation	CIS
	Cost of finance	CIS
	Availability of finance	CIS
	Lack of qualified personnel	CIS
	Lack of information on technology	CIS
	Lack of information on markets	CIS
	Market dominated by established businesses	CIS
	Uncertain demand for innovative goods/services	CIS
	Impact of UK/EU regulations	CIS
Industry	Whether the establishment was located in a particular industry 2-digit SIC (coded 1) or not	CIS
GO regions	Whether the establishment was located in a particular GB region (coded 1) or not	CIS
Greater South East	Whether establishment belongs to enterprise operating in Greater South East region (coded 1) or not	CIS
Cities	Whether the establishment was located in a major GB city (coded 1) or not (defined by NUTS3 code)	CIS
Weight	Population weights based on the ratio between population employment and sample employment	CIS

[a] CIS refers to the CIS4/5/6 datasets covering 2002-2004, 2004-2006, and 2006-2008 respectively; the ARD data covered 2004, 2006, and 2007 matched to CIS4/5/6, respectively (note 2008 ARD data was not available)
[b] Each dummy variable is coded 1 if the barrier is of medium-to-high importance

Table 2: Weighted mean values for variables in CIS-ARD merged dataset for 2004-2008

Variable	Manufacturing		Non-manufacturing	
	All[a]	Model[b]	All	Model
R&D	0.464	0.472	0.295	0.275
Innovation	0.412	0.404	0.275	0.239
Exporting	0.513	0.551	0.252	0.256
Labour productivity	4.315	4.400	4.170	4.174
Capital intensity	9.421	9.643	8.910	9.121
20-49 employees	0.303	0.282	0.365	0.342
50-199 employees	0.357	0.370	0.334	0.359
200+ employees	0.224	0.248	0.159	0.175
ln Age	2.095	2.271	2.179	2.433
ln Industry agglomeration	-0.386	-0.333	-0.051	-0.204
ln Diversification	2.202	2.093	2.463	2.280
Multi-region enterprise	0.188	0.201	0.133	0.139
Multi-industry enterprise	0.294	0.319	0.192	0.194
ln Herfindahl	-2.288	-2.637	-2.097	-2.504
Single-plant enterprise	0.648	0.620	0.684	0.657
US-owned	0.029	0.027	0.010	0.009
Other foreign-owned	0.056	0.060	0.031	0.023
No graduates	0.469	0.447	0.505	0.511
5-20% graduates	0.227	0.235	0.157	0.155
20-75% graduates	0.084	0.085	0.138	0.134
75%+ graduates	0.031	0.030	0.080	0.059
Excessive perceived economic risks	0.396	0.390	0.284	0.271
High costs of innovation	0.425	0.424	0.292	0.278
Cost of finance	0.357	0.356	0.276	0.257
Availability of finance	0.288	0.283	0.236	0.223
Lack of qualified personnel	0.176	0.173	0.125	0.118
Lack of information on technology	0.198	0.192	0.130	0.116
Lack of information on markets	0.291	0.273	0.219	0.212
Market dominated by established businesses	0.337	0.337	0.219	0.208
Uncertain demand for innovative goods/services	0.283	0.278	0.227	0.205
Impact of UK/EU regulations	0.233	0.212	0.211	0.190
AC for external knowledge	0.256	0.332	0.003	0.001
AC for corporate strategy and management techniques	0.079	0.125	0.009	-0.014
AC for national co-operation	0.120	0.125	0.013	-0.018
AC for international co-operation	0.073	0.094	0.011	-0.002
AC for global specialised knowledge	0.058	0.161	-0.005	-0.049
Greater South East	0.391	0.395	0.457	0.432
N	11067	3595	22083	6861

[a] All observations in CIS4/5/6 (excluding Northern Ireland and missing data)
[b] Observations included when estimating equations (2) and (3) (i.e., only establishments with at least two consecutive observations over time are included).

Table 3: Percentage of establishments undertaking R&D, exporting and innovating in CIS-ARD merged dataset for 2004-2008[a,b]

Innovate:	no		yes	
Export:	no	yes	no	yes
(1) Manufacturing				
Undertake R&D:				
no	31.5	14.0	5.1	4.2
yes	5.7	8.7	8.1	22.5
(2) Non-manufacturing				
Undertake R&D:				
no	55.4	8.5	6.5	2.3
yes	8.1	3.2	8.5	7.5

[a] Data are weighted and cells sum to 100% for each sector.
[b] The percentages are based on all observations in CIS4/5/6 (excluding Northern Ireland only).

Table 4: Weighted structural probit models of GB manufacturing establishments, 2004-2008[a]

Dependent variable:	R&D		Innovation		Exporting	
Estimation method:	Probit	IV Probit[b]	Probit	IV Probit[c]	Probit	IV Probit[d]
	(1)	(1a)	(2)	(2a)	(3)	(3a)
$R\&D_{it}$	n.a	n.a	0.254***	0.212***	0.207***	0.487***
$Innovation_{it}$	0.271***	0.295***	n.a	n.a	–	–
$Exporting_{it}$	0.184***	0.145***	–	–	n.a	n.a
$R\&D_{it-1}$	0.290***	0.283***	–	–	-0.061**	-0.135***
$Innovation_{it-1}$	–	–	0.229***	0.236***	–	–
$Exporting_{it-1}$	–	–	–	–	0.595***	0.574***
ln Labour $productivity_{it}$	0.064***	0.062***	–	–	–	–
ln Capital $intensity_{it}$	–	–	–	–	0.047***	0.046***
ln Age_{it}	–	–	–	–	-0.058*	-0.055*
ln Industry $agglomeration_{it}$	-0.020***	-0.016**	–	–	0.022***	0.021***
Multi-industry $enterprise_{it}$	–	–	–	–	0.064**	0.058**
$US\text{-}owned_{it}$	–	–	-0.111**	-0.112**	–	–
No $graduates_{it}$	-0.093***	-0.092***	–	–	-0.257***	-0.228***
5-20% $graduates_{it}$	–	–	–	–	-0.073**	-0.077**
75%+ $graduates_{it}$	–	–	-0.140***	-0.126**	–	–
AC external $knowledge_{it}$	0.095***	0.090***	0.169***	0.170***	0.046***	–
AC national $co\text{-}operation_{it}$	0.053***	0.055***	0.059***	0.061***	–	–
AC corporate strategy and management $techniques_{it}$	0.054***	0.056***	0.044***	0.048***	–	–
AC international $co\text{-}operation_{it}$	–	–	0.022**	0.024**	–	–
AC global specialised $knowledge_{it}$	–	–	0.026**	0.027**	–	–
High costs of $innovation_{it}$	0.145***	0.134***	–	–	–	–
Cost of $finance_{it}$	–	–	-0.104***	-0.089**	–	–
Availability of $finance_{it}$	–	–	0.100**	0.109***	–	–
Uncertain demand for innovative $goods/services_{it}$	–	–	-0.046*	–	–	–
Lack of qualified $personnel_{it}$	0.093***	0.089***		–	–	–
Excessive perceived economic $risks_{it}$	–	–	0.058*	–	–	–
Food & $drink_{it}$	–	–	–	–	-0.230***	-0.212***
$Textiles_{it}$	0.123*	–	–	–	-0.126*	
Wood $products_{it}$	–	–	–	–	-0.264***	-0.241***
$Paper_{it}$	–	–	–	–	-0.147*	-0.131*
Publishing & $printing_{it}$	–	–	–	–	-0.200***	-0.179***
Non-metallic $minerals_{it}$	–	–	–	–	-0.197***	-0.183***
Fabricated $metals_{it}$	–	–	–	–	-0.110***	-0.101***
$Scotland_{it}$	–	–	–	–	-0.120***	-0.121***
West $Midlands_{it}$	–	–	–	–	0.0790**	0.069*
$Yorkshire/Humberside_{it}$	-0.086*	-0.090*	–	–	0.117***	0.134***
$Bristol_{it}$	0.309***	0.267**	–	–	-0.269***	-0.290***
$Cardiff_{it}$	–	–	–	–	-0.369***	-0.366***
$Coventry_{it}$	–	–	–	–	-0.306**	-0.293**
$London_{it}$	–	–	0.123*	–	–	–
$Manchester_{it}$	–	–	-0.093*	–	–	–
Observations	3595	3595	3595	3595	3595	3595
Pseudo- R^2	0.372	0.334	0.341	0.310	0.436	0.424
χ^2-test of exogeneity (1 or 2.d.f.)[c]		0.98		0.95		10.11***
χ^2-test of excluded instruments[d]		27.34		25.97		28.91
F-test of excluded instruments in 1[st] stage regressions[d]		10.22***		21.93***		48.53***
		84.19***		110.7***		62.34***

*/**/*** denotes significance at the 10%/5%/1% levels. – denotes not significant at 10% level. Table with standard errors shown is available at http://www.cppr.ac.uk/media/media_187300_en.doc.

[a] Coefficients are marginal effects ($\partial \hat{p} / \partial x$). Models are based on equation (2). Data used is pooled CIS-ARD data covering 2004-2008

[b] Instruments for $innovation_{it}$ in R&D equation are: $Innovation_{it-1}$, $Exporting_{it-1}$, 20-49 $employees_{it}$, 50-199 $employees_{it}$, *ln* Herfindahl $index_{it}$, Single plant $enterprise_{it}$, $US\text{-}owned_{it}$, Other $foreign\text{-}owned_{it}$, 75%+ $graduates_{it}$, AC international $co\text{-}operation_{it}$, AC global specialised $knowledge_{it}$, Cost of $finance_{it}$, Availability of $finance_{it}$, Excessive perceived economic $risks_{it}$, $Paper_{it}$, Rubber & $plastics_{it}$, Basic $metals_{it}$, Greater $south\text{-}east_{it}$.

Instruments for exporting$_{it}$ in R&D equation are: Exporting$_{it-1}$, *ln* Capital Intensity$_{it}$, Multi-region enterprise$_{it}$, 5-20% graduates$_{it}$, Food & drink$_{it}$, Textiles$_{it}$, Wood products$_{it}$, Paper$_{it}$, Publishing & printing$_{it}$, Non-metallic metals$_{it}$, Fabricated metals$_{it}$, North-east$_{it}$, West Midlands$_{it}$, Cardiff$_{it}$, Coventry$_{it}$.
Instruments for R&D$_{it}$ in innovation equation are: R&D$_{it-1}$, Exporting$_{it-1}$, *ln* labour productivity$_{it}$, *ln* Diversification$_{it}$, *ln* Herfindahl index$_{it}$, No graduates$_{it}$, High costs of innovation$_{it}$, Lack of qualified personnel$_{it}$, Rubber & plastics$_{it}$, Furniture & manuf nes$_{it,}$ Yorkshire/Humberside$_{it}$, Bristol$_{it}$.
Instruments for exporting$_{it}$ in innovation equation are: Exporting$_{it-1}$, *ln* Capital Intensity$_{it}$, *ln* Industry agglomeration$_{it}$, Multi-region enterprise$_{it}$, No graduates$_{it}$, 5-20% graduates$_{it}$, High costs of innovation$_{it}$, Food & drink$_{it}$, Textiles$_{it}$, Wood products$_{it}$, Paper$_{it}$, Publishing & printing$_{it}$, Non-metallic metals$_{it}$, Fabricated metals$_{it}$, North-east$_{it}$, West Midlands$_{it}$, Yorkshire/Humberside$_{it}$, Bristol$_{it}$, Cardiff$_{it}$, Coventry$_{it}$.
Instruments for R&D$_{it}$ in exporting equation are: *ln* Labour productivity$_{it}$, *ln* Diversification$_{it}$, *ln* Herfindahl index$_{it}$, 75%+ graduates$_{it}$, AC external knowledge$_{it}$, AC national co-operation$_{it,}$ AC corporate strategy and management techniques $_{it,}$ AC global specialised knowledge$_{it,}$ High costs of innovation$_{it}$, Lack of qualified personnel$_{it}$, Rubber & plastics$_{it}$, Furniture & manuf nes$_{it}$.
Instruments for innovation$_{it}$ in exporting equation are: Innovation$_{it-1}$, 20-49 employees$_{it}$, 50-199 employees$_{it}$, *ln* Herfindahl index$_{it}$, Single plant enterprise$_{it}$, US-owned$_{it}$, Other foreign-owned$_{it}$, 75%+ graduates$_{it}$, AC external knowledge$_{it}$, AC national co-operation$_{it}$, AC corporate strategy and management techniques$_{it}$, AC international co-operation$_{it}$, AC global specialised knowledge$_{it}$, Cost of finance$_{it}$, Availability of finance$_{it}$, Excessive perceived economic risks$_{it}$, Rubber & plastics$_{it}$, Basic metals$_{it}$, Greater south-east$_{it}$.
[c] Smith-Blundell (1986) test for exogeneity. When two potentially endogenous regressors are included as right-hand-side regressors, the test includes instruments for both (hence there are 2 degrees-of-freedom); otherwise there is only one potential exogenous regression (and 1 d.f.).
[d] see text for explanation.

Table 5: Weighted structural probit models of GB non-manufacturing establishments, 2004-2008[a]

Dependent variable	R&D		Innovation		Exporting	
Estimation method	Probit	IV Probit[b]	Probit	IV Probit[c]	Probit	IV Probit[d]
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
$R\&D_{it}$	n.a	n.a	0.136***	0.243***	0.053**	–
$Innovation_{it}$	0.152***	0.280***	n.a	n.a	0.062***	0.130***
$Exporting_{it}$	0.080***	0.125***	0.052***	–	n.a	n.a
$R\&D_{it-1}$	0.200***	0.185***	–	–	–	–
$Innovation_{it-1}$	–	–	0.187***	0.174***	–	–
$Exporting_{it-1}$	–	–	–	–	0.544***	0.540***
ln Labour $productivity_{it}$	–	–	–	–	0.029***	0.028***
ln Capital $intensity_{it}$	0.017**	0.016**	–	–	–	–
10-19 $employees_{it}$	-0.038*	-0.038*	–	–	–	–
ln Age_{it}	–	–	-0.027**	-0.026**	–	–
ln Industry $agglomeration_{it}$	–	–	-0.008**	-0.007*	0.033***	0.034***
ln $Diversification_{it}$	–	–	–	–	-0.038**	-0.038**
Multi-industry $enterprise_{it}$	-0.051***	-0.050***	–	–	–	–
No $graduates_{it}$	-0.069***	-0.060***	–	–	-0.116***	-0.119***
20-75% $graduates_{it}$	–	–	–	–	0.083**	0.087***
75%+ $graduates_{it}$	–	–	–	–	0.140***	0.138***
AC (external $knowledge)_{it}$	0.094***	0.076***	0.129***	0.117***	–	–
AC (national $co\text{-}operation)_{it}$	0.051***	0.041***	0.046***	0.039***	–	–
AC (corporate strategy and management $techniques)_{it}$	0.042***	0.036***	0.030***	0.025**	–	–
AC (international $co\text{-}operation)_{it}$	–	–	0.016**	0.018**	0.014**	0.014**
AC (global specialised $knowledge)_{it}$	0.022**	–	0.034***	0.029***	–	–
High costs of $innovation_{it}$	0.139***	0.134***	–	–	–	–
Cost of $finance_{it}$	–	–	0.093***	0.087***	–	–
Availability of $finance_{it}$	–	–	-0.071***	-0.073***	–	–
Lack of information on $technology_{it}$	–	–	–	–	-0.088***	-0.088***
Lack of market $information_{it}$	–	–	-0.048**	-0.049**	0.076**	0.072*
Lack of qualified $personnel_{it}$	–	–	–	–	0.064**	0.065**
Excessive perceived economic $risks_{it}$	–	–	0.054**	0.048**	-0.040*	-0.045**
Market dominated by established $businesses_{it}$	-0.039*	-0.040*	–	–	–	–
Sale/repair $motors_{it}$	–	–	-0.114***	-0.113***	–	–
$Retail_{it}$	–	–	–	–	-0.070***	-0.071***
Hotels and $restaurants_{it}$	-0.059**	-0.053**	–	–	–	–
$Financial_{it}$	0.244**	0.180*	0.194*	0.173	–	–
Real $estate_{it}$	–	–	–	–	-0.178***	-0.179***
$Computing_{it}$	0.103**	0.073*	–	–	–	–
$R\&D_{it}$	–	–	-0.124***	-0.120***	–	–
Other $business_{it}$	–	–	–	–	-0.062***	-0.063***
Film etc $services_{it}$	0.215**	0.186**	–	–	–	–
Greater South $East_{it}$	–	–	–	–	0.049**	0.046**
East $Midlands_{it}$	–	–	–	–	0.075**	0.071**
South $East_{it}$	0.085**	0.086**	–	–	–	–
$Wales_{it}$	0.118**	0.122**	–	–	–	–
$Cardiff_{it}$	-0.097**	-0.097**	–	–	–	–
$Edinburgh_{it}$	–	–	–	–	0.121	–
$London_{it}$	0.075**	0.069*	–	–	–	–
$Tyneside_{it}$	0.193***	0.194***	–	–	–	–
N	6861	6861	6861	6861	6861	6861
Pseudo- R^2	0.343	0.332	0.392	0.377	0.377	0.374
χ^2-test of exogeneity (1or 2.d.f.)[c]		6.41**		2.06		2.39
χ^2-test of excluded instruments[d]		24.07		22.07		19.11

F-test of excluded instruments in 1st stage regressions[d]	10.51***	15.32***	45.95***
	67.44***	109.7***	74.22***

*/**/*** denotes significance at the 10%/5%/1% levels. − denotes not significant at 10% level. Table with standard errors shown is available at http://www.cppr.ac.uk/media/media_187300_en.doc.

[a] Coefficients are marginal effects ($\partial \hat{p} / \partial x$). Models are based on equation (2). Data used is pooled CIS-ARD data covering 2004-2008.

[b] Instruments for Innovation_{it} in R&D equation are: Innovation_{it-1}, Exporting_{it-1}, *ln* Labour productivity_{it}, *ln* Age_{it}, *ln* Industry $\text{agglomeration}_{it}$, *ln* $\text{Diversification}_{it}$, AC global specialised knowledge_{it}, Cost of finance_{it}, Availability of finance_{it}, Excessive perceived economic risks_{it}, Lack of market information_{it}, Sale/repair motors_{it}, Wholesale trade_{it}, Retail_{it}, $\text{R\&D}_{it}$, Liverpool_{it}.

Instruments for Exporting_{it} in R&D equation are: Exporting_{it-1}, *ln* Labour productivity_{it}, *ln* Industry $\text{agglomeration}_{it}$, *ln* $\text{Diversification}_{it}$, 20-75% graduates_{it}, 75%+ graduates_{it}, AC international co-operation_{it}, Lack of information on technology_{it}, Lack of market information_{it}, Lack of qualified personnel_{it}, Sale/repair motors_{it}, Retail_{it}, Transport_{it}, Real estate_{it}, Other business_{it}, Greater south-east_{it}, East Midlands_{it}.

Instruments for $\text{R\&D}_{it}$ in innovation equation are: $\text{R\&D}_{it-1}$, Exporting_{it-1}, *ln* Capital Intensity_{it}, Multi-industry enterprise_{it}, Other $\text{foreign-owned}_{it}$, No graduates_{it}, 20-75% graduates_{it}, High costs of innovation_{it}, Market dominated by established businesses_{it}, Wholesale trade_{it}, Computing_{it}, Film etc services_{it}, South-west_{it}, Wales_{it}, Cardiff_{it}, London_{it}, Tyneside_{it}.

Instruments for Exporting_{it} in innovation equation are: Exporting_{it-1}, *ln* Labour productivity_{it}, *ln* $\text{Diversification}_{it}$, No graduates_{it}, 20-75% graduates_{it}, 75%+ graduates_{it}, Lack of information on technology_{it}, Lack of qualified personnel_{it}, Retail_{it}, Hotels and restaurants_{it}, Transport_{it}, Real estate_{it}, Other business_{it}, Greater south-east_{it}, East Midlands_{it}.

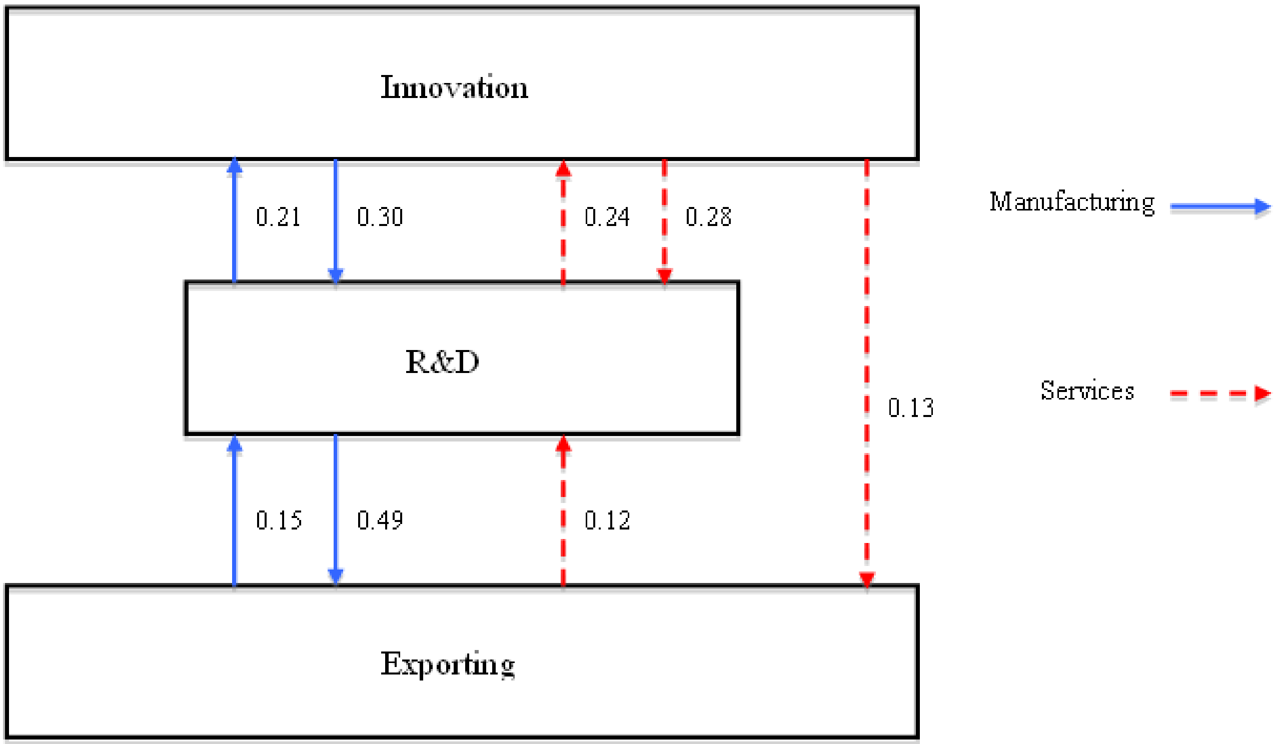
Instruments for $\text{R\&D}_{it}$ in exporting equation are: $\text{R\&D}_{it-1}$, Innovation_{it-1}, *ln* Capital Intensity_{it}, Multi-industry enterprise_{it}, Other $\text{foreign-owned}_{it}$, AC external knowledge_{it}, AC national co-operation_{it}, AC corporate strategy and management techniques_{it}, AC global specialised knowledge_{it}, High costs of innovation_{it}, Market dominated by established businesses_{it}, Wholesale trade_{it}, Financial_{it}, Computing_{it}, Film etc services_{it}, South-west_{it}, Wales_{it}, Cardiff_{it}, London_{it}, Tyneside_{it}.

Instruments for Innovation_{it} in exporting equation are: Innovation_{it-1}, *ln* Capital Intensity_{it}, *ln* Age_{it}, AC external knowledge_{it}, AC national co-operation_{it}, AC corporate strategy and management techniques_{it}, AC global specialised knowledge_{it}, Cost of finance_{it}, Availability of finance_{it}, Sale/repair motors_{it}, Wholesale trade_{it}, Financial_{it}, Computing_{it}, $\text{R\&D}_{it}$, Film etc services_{it}, Liverpool_{it}.

[c] Smith-Blundell (1986) test for exogeneity. When two potentially endogenous regressors are included as right-hand-side regressors, the test includes instruments for both (hence there are 2 degrees-of-freedom); otherwise there is only one potential exogenous regression (and 1 d.f.).

[d] see text for explanation.

Figure 1: Contemporaneous relationships between exporting, innovation and R&D



Source: parameter estimates reported in Tables 4 and 5

Appendix

Table A.1: Weighted reduced-form probit models of GB manufacturing establishments, 2004-2008[a]

	Dependent variables:		
Independent variables:	R&D	Innovation	Exporting
R&D$_{it-1}$	0.243***	–	–
Innovation$_{it-1}$	–	0.202***	–
Exporting$_{it-1}$	0.065***	0.035**	0.537***
ln Labour productivity$_{it}$	0.036***	–	–
ln Capital Intensity$_{it}$	–	–	0.020***
20-49 employees$_{it}$	–	0.037*	–
50-199 employees$_{it}$	–	0.038*	–
ln Industry Agglomeration$_{it}$	–	–	0.009**
ln Diversification$_{it}$	-0.017***	–	–
Multi-regional enterprise$_{it}$	–	–	0.042**
ln Herfindahl Index$_{it}$	0.018*	0.018*	–
Single-plant enterprise$_{it}$	–	0.033*	–
US-owned$_{it}$	–	-0.084**	–
Other foreign-owned$_{it}$	–	-0.056*	–
No graduates$_{it}$	-0.100***	–	-0.182***
5-20% graduates$_{it}$	–	–	-0.040**
75%+ graduates$_{it}$	-0.086*	-0.124***	–
AC external knowledge$_{it}$	0.107***	0.160***	0.040***
AC national co-operation$_{it}$	0.040***	0.052***	–
AC corporate strategy and management techniques$_{it}$	0.037***	0.037***	–
AC international co-operation$_{it}$	–	0.014**	–
AC global specialised knowledge$_{it}$	0.025***	0.030***	–
High costs of innovation$_{it}$	0.106***	–	0.043***
Cost of finance$_{it}$	–	-0.074***	–
Availability of finance$_{it}$	–	0.074***	–
Lack of qualified personnel$_{it}$	0.066***	–	–
Excessive perceived economic risks$_{it}$	–	0.051**	–
Food & drink$_{it}$	–	–	-0.118***
Textiles$_{it}$	–	–	-0.069*
Wood products$_{it}$	–	–	-0.145***
Paper$_{it}$	–	-0.070*	-0.089*
Publishing & printing$_{it}$	–	–	-0.108***
Rubber & plastics$_{it}$	0.068**	0.061*	–
Non-metallic minerals$_{it}$	–	–	-0.103***
Basic metals$_{it}$	–	-0.081*	–
Fabricated metals$_{it}$	–	–	-0.070***
Furniture & manufacturing nes$_{it}$	0.069**	–	–
Greater South East$_{it}$	–	0.041**	–
North East$_{it}$	–	–	-0.072**
West Midlands$_{it}$	–	–	0.045**
Yorkshire/Humberside$_{it}$	-0.061*	–	0.069***
Bristol$_{it}$	0.181*	–	-0.119***
Cardiff$_{it}$	–	–	-0.200***
Coventry$_{it}$	–	–	-0.232*
Constant	0.167**	0.210***	0.167**
N	3595	3595	3595
R^2	0.393	0.372	0.494

/**/*** denotes significance at the 10%/5%/1% levels. – denotes not significant at 10% level. Table with standard errors shown is available at http://www.cppr.ac.uk/media/media_187300_en.doc.

[a] Coefficients are marginal effects ($\partial \hat{p} / \partial x$). Models are based on equation (3). Data used is pooled CIS-ARD data covering 2004-2008.

Table A.2: Weighted reduced-form probit models of GB non-manufacturing establishments, 2004-2008[a]

Independent Variables:	Dependent Variables: R&D	Innovation	Exporting
$R\&D_{it-1}$	0.164***	–	–
$Innovation_{it-1}$	0.035*	0.173***	–
$Exporting_{it-1}$	0.064***	0.039**	0.530***
ln Labour $productivity_{it}$	–	-0.012**	0.014**
ln Capital $Intensity_{it}$	0.013***	0.012**	–
ln Age_{it}	–	-0.026**	–
ln Industry $Agglomeration_{it}$	–	-0.018**	0.028***
ln $Diversification_{it}$	–	0.019*	-0.031**
Multi-industry $enterprise_{it}$	-0.037**	–	–
Other foreign-$owned_{it}$	-0.089*	–	–
No $graduates_{it}$	-0.060***	–	-0.087***
20-75% $graduates_{it}$	0.043*	–	0.078***
75%+ $graduates_{it}$	–	–	0.124***
AC external $knowledge_{it}$	0.113***	0.152***	0.020**
AC national co-$operation_{it}$	0.058***	0.065***	–
AC corporate strategy and management $techniques_{it}$	0.046***	0.043***	–
AC international co-$operation_{it}$	–	–	0.014**
AC global specialised $knowledge_{it}$	0.030***	0.047***	–
High costs of $innovation_{it}$	0.123***	–	–
Cost of $finance_{it}$	–	0.077***	–
Availability of $finance_{it}$	–	-0.074***	–
Lack of information on $technology_{it}$	–	–	-0.086***
Lack of market $information_{it}$	–	-0.048**	0.054**
Lack of qualified $personnel_{it}$	–	–	0.043**
Excessive perceived economic $risks_{it}$	–	0.065***	–
Market dominated by established $businesses_{it}$	-0.040**	–	–
Sale/repair $motors_{it}$	–	-0.088***	-0.077**
Wholesale $trade_{it}$	0.057***	0.045**	–
$Retail_{it}$	–	0.031*	-0.087***
Hotels and $restaurants_{it}$	–	–	-0.061**
$Transport_{it}$	–	–	-0.057***
$Financial_{it}$	0.254***	0.248***	–
Real $estate_{it}$	–	–	-0.185***
$Computing_{it}$	0.126***	0.082**	–
$R\&D_{it}$	–	-0.130*	–
Other $business_{it}$	–	–	-0.080***
Film etc $services_{it}$	0.210***	0.092*	–
Greater South $East_{it}$	–	–	0.033**
East $Midlands_{it}$	–	–	0.049**
South $West_{it}$	0.058***	–	–
$Wales_{it}$	0.073**	–	–
$Cardiff_{it}$	-0.079*	–	–
$Liverpool_{it}$	–	-0.119**	–
$London_{it}$	0.056**	–	–
$Tyneside_{it}$	0.113**	–	–
Constant	0.063	0.117**	0.206***
N	6861	6861	6861
R^2	0.375	0.413	0.425

/**/*** denotes significance at the 10%/5%/1% levels. – denotes not significant at 10% level. Table with standard errors shown is available at http://www.cppr.ac.uk/media/media_187300_en.doc.

[a] Coefficients are marginal effects ($\partial\hat{p} / \partial x$). Models are based on equation (3). Data used is pooled CIS-ARD data covering 2004-2008.

Spatial Economics Research Centre (SERC)
London School of Economics
Houghton Street
London WC2A 2AE

Tel: 020 7852 3565
Fax: 020 7955 6848
Web: www.spatialeconomics.ac.uk

SERC is an independent research centre funded by the Economic and Social Research Council (ESRC), Department for Business Innovation and Skills (BIS), the Department for Communities and Local Government (CLG) and the Welsh Assembly Government.