Exporting, R&D and Absorptive Capacity in UK Establishments: Evidence from the 2001 Community Innovation Survey[1]

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Abstract

This paper models the determinants of exporting (both export propensity and export intensity), with a particular emphasis on the importance of absorptive capacity and the endogenous link between exporting and R&D. Based on a merged dataset of the 2001 Community Innovation Survey and the 2000 Annual Respondents Database for the UK, our results suggest that alongside other factors, undertaking R&D activities and having greater absorptive capacity (for scientific knowledge, co-operation with international organisations, and organisational structure and HRM practices) significantly reduce entry barriers into export markets, having controlled for self-selectivity into exporting and the endogenous link between exporting and R&D. Nevertheless, conditional on entry, only greater absorptive capacity (for scientific knowledge) seems to further boost export performance in international markets, whereas spending on R&D no longer has an impact on exporting behaviour once we have taken into account its endogenous nature.

JEL codes: L25; R11; R38

Keywords: exports; R&D; absorptive capacity; sample selection

I. Introduction

Recent literature has tended to concentrate on the microeconomic approach to trade, reinforcing the importance of exporting for (national) economic growth (e.g. the various studies by Bernard and associates[3]; Melitz, 2003; and Helpman *et. al.*, 2004a). Exporting tends to be concentrated among a (very) small number of firms who nevertheless are large and account for the preponderance of trade undertaken. Such firms have a greater probability of survival (vis-à-vis those not exporting); higher growth rate; greater productivity; higher capital-intensity; they pay higher wages; and employ 'better' technology and more skilled workers (after controlling for other relevant covariates). To put things in context, Bernard and Jensen (2004a) show that foreign exposure does indeed foster productivity growth and in particular, increased export opportunities are associated with both intra- and inter- industry reallocations

[3] For example, Bernard and Jensen (1995, 1999, 2004a, 2004b, 2004c), Bernard *et. al.* (2003), and Bernard *et. al.* (2005).

which account for 40% of TFP growth in the manufacturing sector. Thus, higher productivity levels as well as faster growth rates that are found in exporters provide an important reallocative channel for explaining aggregate productivity growth.

In this paper we do not consider directly this aggregate reallocations effect; rather, we attempt to obtain a better understanding of the firm's behaviour when facing intense international competition, so as to shed light on this important export-productivity nexus[4]. Hence this study concentrates on what determines who exports (and thus barriers to exporting) and how much is exported, and which factors are most important in driving such exporting activities. In particular, we are interested in the linkage between exporting and R&D, and how any (causal) relationship between these variables is affected by introducing other variables (particularly 'absorptive capacity'). Despite the importance of this area there are still only a limited number of micro-based studies in the literature, especially with regard to UK-based empirical analysis.

Thus, the next section summarises some recent literature on the links between exporting, absorptive capacity and innovation activities (such as R&D spending), while also recognising other factors that determine whether a firm exports or not, and how much to export. Section III discusses the data used, which comprises establishment data from the 2001 Community Innovation Survey (CIS3) for the UK along with additional variables (mostly related to ownership and spatial factors) merged into CIS3 from the Annual Respondents Database (ARD) for 2000. This is followed by estimating a Heckman-type sample-selection model of exporting, which also takes into account the endogeneity of the R&D related variables. Finally, the paper concludes with a summary and a discussion of the policy implications and some caveats of this study.

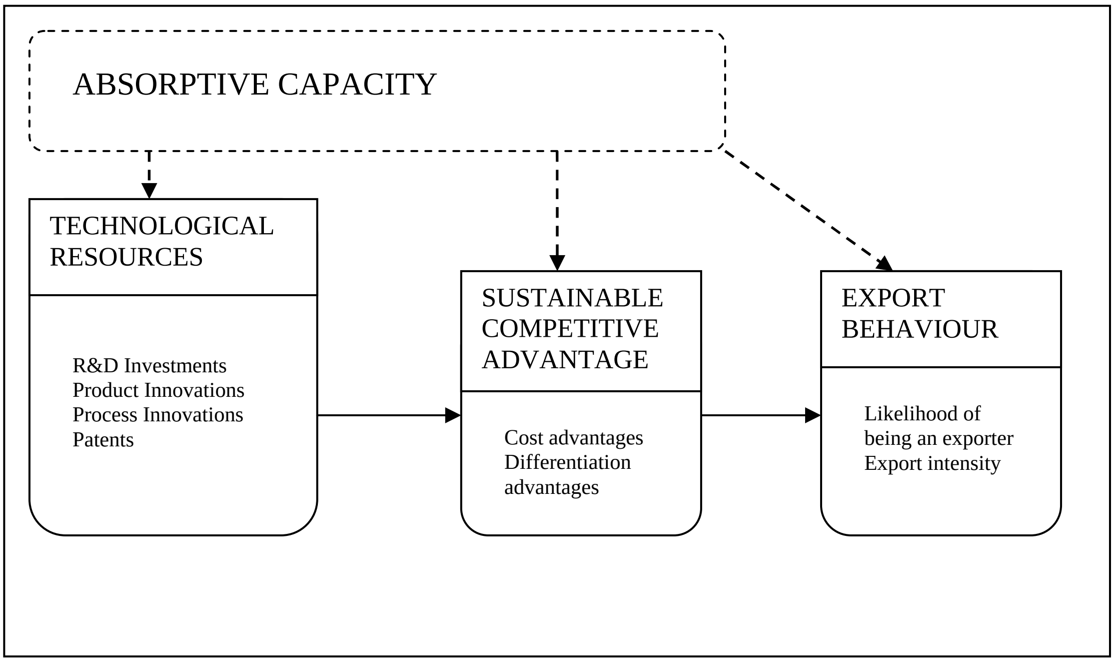
II. Literature Review

Knowledge and learning can be expected to exert a fundamental impact on international growth in that internationalising firms must apprehend, share, and assimilate new knowledge in order to compete and grow in markets in which they have little or no previous experience (Autio *et. al.,* 2000). In a seminal paper, Cohen

[4] The evidence for countries other than the U.S. also provides similar results, e.g. Bernard and Wagner (1997) for Germany; Clerides *et. al.* (1998), for Columbia, Mexico and Morocco; Delgado *et. al.* (2002), for Spain; Baldwin and Gu (2003) for Canada; and Falvey *et. al.* (2004) for Sweden. For the U.K., see for example, Girma *et. al.* (2004) and Greenaway and Kneller (2004).

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.

Figure 1: Technological resources and export behaviour



Source: expanded version of Lopez Rodriguez and Garcia Rodriguez (2005)

When a firm internationalises, it must absorb new knowledge of how to organise for foreign competition, thus facing the dual challenge of overcoming rigidities and taking on novel knowledge. In this sense, we could expect the development of absorptive capacity to be a necessary condition for the successful exploitation of new knowledge gained in global markets. Lopez Rodriguez and Garcia Rodriguez (2005) proposed a conceptual model to explain how technological resources impact upon a firm's export behaviour through conferring cost/product differentiation advantages (Figure 1). We extend this model to include the notion of absorptive capacity – as it provides the firm with the ability to internalise new knowledge some of which is gained in global markets – and we could expect the development of absorptive capacity to be a necessary condition for the materialisation of all these stages depicted in this model.

Underlying this approach is the overlapping assumption that international activities are determined by the resources and capabilities that a firm possesses and that allow it to overcome the initial (sunk) costs of competing in international markets. Here there is a direct link to the notion of absorptive capacity and the role of R&D and innovation activities in the internationalisation process, which are areas generally not considered in any detail in the economics literature. 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 enter and thereafter its performance in international markets, 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.

The linkage between innovation and exports has been characterised by increasing interdependence in the process of globalisation, and is often regarded to be of paramount importance to an economy: innovation is commonly taken as a proxy for productivity and growth, and exporting for competitiveness of an industry/country. From the perspective of firms, several of the early theoretical studies maintain 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). In this process of international expansion, innovation is of particular significance for the development of the firm's competitive advantage as well as its growth potential. For example, this competitive advantage conferred by innovation will give the firm an incentive to enter global markets and subsequently enhance its performance and international competitiveness in new markets; in addition, the more competitive international environment *per se* may provide a source of new ideas spurring more and better innovation by the firm. In comparison with the well-established trade-innovation theoretical framework in the macroeconomics literature[5], most micro evidence is empirics-led. Despite the lack of a solid theoretical foundation, studies at the firm level usually provide a way to disentangle this export-innovation relationship, taking into account the heterogeneous characteristics amongst exporting and non-exporting firms.

Export orientation at the firm level has been extensively investigated in the literature, and 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,

[5] The macroeconomics literature offers at least two mainstream theoretical models to account for this relationship: *neo-endowment* models which concentrate on specialisation on the basis of factor endowments, such as materials, labour capital, knowledge and human capital (Wakelin, 1998; Roper and Love, 2002); and also *neo-technology* models which predict innovative industries will be net exporters instead of importers (Greenhalgh, 1990, 1994). The latter type of models provides an extension of the conventional technology-based models such as the product life cycle theory (Vernon, 1966; Krugman, 1979 and Dollar, 1986), and technology-gap theory of trade (Posner, 1961).

studies covering UK firms include: Wakelin (1998), Anderton (1999), Bishop and Wiseman (1999), Bleaney and Wakelin (2002), Gourlay and Seaton (2004), and Hanley (2004); for Canadian manufacturing firms, Bagchi-Sen (2001), Lefebvre and Lefebvre (2001), and Baldwin and Gu (2004); for Italian manufacturing firms, Sterlacchini (1999) and Basile (2001); for Spanish manufacturing, Cassiman and Martinez-Ros (2003, 2004) and Lopez Rodriguez and Garcia Rodriguez (2005); for German services, Blind and Jungmittag (2004); in comparative studies, Roper and Love (2002), for both UK and German manufacturing firms, and Dhanaraj and Beamish (2003) for U.S. and Canadian firms; in the context of the rest of the world, Hirsch and Bijaoui (1985) for Israel; Alvarez (2001) for Chilean manufacturing firms; Guan and Ma (2003) for China and lastly, Ozcelik and Taymaz (2004) for Turkish manufacturing firms. Still evidence at this micro level does not seem to be conclusive, as inconsistent results have been found by Willmore (1992), Ito and Pucik (1993), Lefebvre *et. al.* (1998) and Sterlacchini (2001).

With respect to the causality issue associated with this linkage, the early consensus in the literature is that causality runs from undertaking innovation activities to internationalisation. This can be easily understood from the perspective of product differentiation/innovation-led exports, in line with the predictions of both the more conventional product-cycle models as well as the recently developed neo-technology models (see footnote 5 for details). The intuition behind this causal chain is straightforward: product differentiation/innovation translates into competitive advantages that allow the firm to compete in international markets[6].

It is also argued that the causality may go from exporting to innovativeness, i.e. there exists a learning-by-exporting effect. This reverse direction of causation is in accordance with the theoretical predictions of global economy models of endogenous innovation and growth, such as those in Romer (1990), Grossman and Helpman (1991), Young (1991) and Aghion and Howitt (1998), and is also consistent with the notion of absorptive capacity. From a resource-based perspective, being exposed to a richer source of knowledge/technology that is often not available in the home market, exporting firms could well take advantage of these diverse knowledge inputs and enhance their competency base, and hence in this sense, such learning from global

[6] There is well-documented evidence on how R&D/innovation related variables are expected to directly raise a firm's export propensity/intensity: Lefebvre *el. al.*, 1998; Wakelin, 1998; Nassimbeni, 2001; Bleaney and Wakelin, 2002; Roper and Love, 2002; Barrios *el. al.*, 2003; Cassiman and Martinez-Ros, 2003.

markets can foster increased innovation within firms. This learning effect induced by participation in international markets is often not directly measured but considered through the link between innovation and productivity growth. The process of going international is perceived as a sequence of stages in the firm's growth trajectory, which involves substantial learning (and innovating) through both internal and external channels, so as to enhance its competence base and improve its performance[7].

The conventional approach to testing this learning-by-exporting hypothesis is to analyse performance-related variables (such as labour productivity, total factor productivity, average variable costs and the like) as proxies for a firm's learning behaviour. More recently, Salomon and Shaver (2005) advocate that using innovation as a measure of learning provides a "more direct appraisal of the phenomenon", and that a firm can strategically access foreign knowledge bases and enhance innovation capabilities through engaging in exporting activities. Furthermore, they maintain that exporting is more than merely an activity to expand the firm's product market; it is an activity that may generate information for it to use to innovate. Therefore, exporting can be considered a strategic action whereby a firm can enhance its competitiveness[8].

Moreover, given that causality can run in both directions, a two-way linkage between a firm's exporting and innovating activities has also been proposed and confirmed empirically (e.g. Cassiman and Martinez-Ros, 2004), particularly in studies of firms operating in emerging economies (e.g. Alvarez, 2001, for Chile; and Guan and Ma, 2003, for China), where the learning effect is likely to be more pronounced (vis-à-vis those in developed economies), from the perspective of technology catching-up or economic convergence (e.g. Ben-David and Loewy, 1998; Guillen, 2001). Notably, the paucity of evidence on this feedback relationship may be partly explained by the limitations of the data as well as the econometric methods available to explore this causality issue.

A number of other factors have been suggested in the literature that exert an impact on a firm's exporting behaviour, and therefore moderate the way export and R&D activity affect (and interact with) each other. To begin with, there is well-documented

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[7] A well-established strand of literature has emphasised the importance of exporting (or internationalisation in general) as a learning/knowledge accumulation process, and the learning effect of exporting has been extensively researched in the literature, particularly in the context of firm's productivity/efficiency gains (Kraay, 1999; Hallward-Driemeier *et. al.*, 2002; Baldwin and Gu, 2003; Girma *et. al.*, 2004; and Greenaway and Yu, 2004).

[8] For empirical evidence on this learning effect in light of technological improvement, see Cassiman and Veugelers (1998) and Salomon and Shaver (*op. cit.*) for Belgian and Spanish manufacturing respectively.

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.[9] Nevertheless, conditional on having overcome entry barriers, the size effect on export performance could even become negative - as firms grow larger (and become more productive), they might have an incentive to expand their foreign-market penetration through FDI (rather than exports), which often constitutes an alternative (and more attractive) strategy for international expansion (c.f. Head and Ries, 2004; and Helpman *et. al.*, 2004b). This possibly explains why a non-linear relationship between size and export activities is frequently captured in empirical studies where export propensity and intensity are not estimated separately (e.g. Willmore, 1992; Brouwer and Kleinknecht, 1993; Kumar and Siddharthan, 1994; Wagner, 1995; Wakelin, 1998; Bernard and Jensen, 1999; Sterlacchini, 1999; Bleaney and Wakelin, 2002; and Cassiman and Martinez-Ros, 2004).

In addition to this size effect, the *sectoral* context in which a firm operates is also likely to be important since belonging to a specific industry may condition the firm's strategy 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, the sectoral effect (reflecting technological opportunities and product cycle differences) is usually expected to be significant. Numerous empirical studies show that significant differentiated industrial patterns condition a firm's export-innovation relationship (for instance, Hirsch and Bijaoui, 1985; Hughes, 1986; Soete, 1987; Wagner, 2001; Bleaney and Wakelin, *op. cit.*; Gourlay and Seaton, 2004 and Lopez Rodriguez and Garcia Rodriguez, *op. cit.*).

Moreover, the role of some *industrial/spatial* factors could also be expected to be important. Firstly, the importance of geographic factors is captured in Overman *et. al.*'s (2003) survey of the literature on the economic geography of trade flows and the location of production. If information on foreign market opportunities and costs 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. Co-location may help improve information about foreign markets and tastes so as to provide better channels through which firms distribute their goods (Aitken *et. al.*, 1997). There are usually two dimensions to these agglomeration effects – a regional

[9] For instance, Aw and Hwang (1995), Roberts and Tybout (1997), Kneller and Pisu (2005), Bleaney and Wakelin (*op. cit.*), Gourlay and Seaton (*op. cit.*) and Cassiman and Martinez-Ros (2003).

effect and an industrial effect. The former comprises the spatial concentration of exporters (from various industries) whereas the industry effect is where exporting firms from the same industry co-locate. Greenaway and Kneller (2004) provide empirical evidence that shows that the industrial dimension of agglomeration would appear to be more important for the UK while Bernard and Jensen (2004b) find it to be insignificant in explaining the probability of exporting in the US. 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.[10]

Lastly, in a similar fashion, *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. Therefore, we might expect a higher propensity for non-participants to go international in a market with a higher degree of concentration of export activity. Evidence for UK manufacturing covering the 1988-2002 period is provided by Greenaway and Kneller (2003).

III. The Data

The ability to undertake a micro-level analysis of the determinants of exporting, with particular focus on its relationship with innovative activities, depends on the data that is available. There are 2 major micro-based sources of data that are appropriate, both of which include establishment-level data for the UK: (i) the Community Innovation Survey 2001 (CIS3)[11]; and (ii) the data for 2000 from the Annual Respondents Database (ARD)[12,13, 14].

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[10] In contrast, in a recent study of US plants, Bernard and Jensen (2004c) find negligible spillovers resulting from the export activities of other plants; nevertheless, this discrepancy from other studies may be explained by their sample selection criteria (restricted to large plants only) and measures of industry (2 digit level) and regions (measured by states).

[11] The Community Innovation Survey 2005 (CIS4) is more up-to-date but does not contain information on how much was sold abroad (only whether the establishment engaged in at least some exporting).

[12] For a detailed description of the ARD see Oulton (1997), Griffith (1999), and Harris (2002, 2005).

[13] The 2000 data is used as the CIS3 sample was drawn from the 2000 version of the IDBR, and thus matches ABI (and thus ARD) data on establishments operating in that year.

[14] The CIS3 survey did not achieve a 100% response rate (only 43% of establishments replied), but the weights computed ensure the sample obtained is representative of all UK establishments. Of course, there may be sample bias if those who did not respond are not a random sub-group of all establishments who were sent the survey questionnaire. But this is a generic problem, and not particular to the CIS3

Table 1: Variable definitions used in CIS-ARD merged dataset for 2000

Variable	Definitions	Source
Export	Whether the establishment sold goods and services outside the UK (coded 1) or not in 2000	CIS3
Export intensity	Establishment export sales divided by total turnover in 2000	CIS3
R&D	Whether the establishment undertook any R&D as defined in the text (coded 1) or not in 2000	CIS3
R&D continuous	Whether the establishment undertook continuous R&D (coded 1) or not during 1998-2000	CIS3
Labour productivity	Establishment turnover per employee in 2000	CIS3
Size	Establishment size broken down into size-bands	CIS3
Enterprise size	Number of employees in the enterprise	ARD
Industry	Establishment industry SIC (2-digit)	CIS3
GO regions	Dummy variable =1 if establishment located in particular region	CIS3
Absorptive capacity (5 variables)	Establishment level indices (see text for details)	CIS3
Co-op	Whether the establishment had engaged in co-operation on innovative activities (coded 1) or not in 1998-2000	CIS3
International Co-op	Whether the establishment had engaged in overseas co-operation on innovative activities (coded 1) or not in 1998-2000	CIS3
Barriers to innovation	Up to 10 variables representing factors inhibiting ability of establishment to innovate	CIS3
Age	Age of establishment in years (manufacturing only)	ARD
US-owned	Dummy coded 1 if establishment *i* is US-owned at time *t*	ARD
Foreign-owned	Dummy coded 1 if establishment *i* is other-owned at time *t*	ARD
Single plant	Dummy coded 1 when establishment *i* is a single plant in year *t*	ARD
Industry agglomeration	% of industry output (at 5-digit SIC level) located in local authority district in which establishment is located	ARD
Diversification	% of 5-digit industries (over 650) located in local authority district in which establishment is located	ARD
Herfindahl	Herfindahl index of industry concentration (5-digit level)	ARD
>1 SIC multiplant	Dummy variable =1 if establishment belongs to enterprise operating in more than one (5-digit) industry	ARD
SE	Dummy variable =1 if establishment belongs to enterprise operating in Greater South East region	ARD
>1 region multiplant	Dummy variable =1 if establishment belongs to multiplant enterprise operating in more than 1 UK region	ARD
Capital	Plant & machinery capital stock for establishment in 2000 (source: Harris and Drinkwater, 2000, updated) (£m 1980 prices)	ARD
Employment	Current employment for establishment in 2000	ARD
Density	Population density in 2001 in local authority district in which establishment is located	CoP, 2001

The CIS3 dataset is a cross-sectional survey of innovation covering the 1998-2000 period, including the characteristics of the reporting unit surveyed (e.g., turnover, employment and, most importantly, exports). The dataset covers all sectors of the economy (but only firms employing 10 or more), and can be linked into the ARD, since IDBR reference numbers are common to both datasets.[15] Thus ancillary

(and with no specific implications for the CIS-ARD dataset). Other researchers have compared the distribution of R&D across industries from the CIS data and the BERD, finding they have a high correlation (implying the CIS data is representative of the population of firms engaged in R&D).

[15] Of the 8,172 reporting units covered in CIS3, it was possible to locate 7,709 of these in the ARD. Non-matched observations were almost all in those sectors not covered in the ARD (i.e. financial services).

information (particularly on ownership and spatial characteristics) available in the ARD has been added to the CIS3 data for use in our subsequent analysis of what determines exporting.[16]

Table 1 sets out the list of variables we use in this study, along with the source of the data. R&D spending is defined here as intramural R&D, acquired external R&D or acquired other external knowledge (such as licences to use intellectual property)[17]. Of particular importance is the absorptive capacity of the establishment. No direct information on this variable is available, but CIS3 does contain information on key elements of organisational, learning and networking processes that can be related to absorptive capacity, i.e. external sources of knowledge or information used in technological innovation activities and their importance[18]; partnerships with external bodies on innovation co-operation[19]; and the introduction of changes in organisational structure and HRM practices which will be related to internal capabilities and thus (internal aspects of) absorptive capacity[20]. In order to extract core information, a factor analysis (principal component) was undertaken using the 36 relevant variables covering the above dimensions of absorptive capacity (for details see Table A1). Based on the Kaiser criterion (Kaiser, 1960), five principal components were retained (with eigenvalues greater than 1), accounting for some 62% of the combined variance of these input variables. In order to obtain a clearer picture of the correlation between

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[16] Note, ARD data used here is at reporting unit (i.e. establishment) level to ensure comparability with the CIS3 data. Where necessary, plant level ARD information (e.g. on capital stocks in manufacturing) was aggregated to reporting unit level.

[17] There is other spending categorised in the CIS3 related to innovative activities, such as acquisition of machinery and equipment (including computer hardware) 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 and by comparing the CIS3 totals with those obtained from the other major source of micro data on R&D in the UK – Business Enterprise R&D (BERD) data. See http://www.dti.gov.uk/files/file9686.pdf for a copy of the CIS3 questionnaire.

[18] These are grouped under the following sub-headings with associated elements: (a) Market: suppliers; customers; competitors; consultants; commercial labs/R&D enterprises; (b) Institutional: universities; government research organisations; other public sector (e.g. business links, Government Offices); and private research institutes; (c) Other: professional conferences, meetings; trade associations; technical press, computer databases; fairs, exhibitions; and (d) Specialised: technical standards; health & safety; environmental standards and regulations. Respondents were asked to rank how important each factor is (from 0 – not used, to 4 – high importance).

[19] These are grouped under the following sub-headings with associated elements: (a) Market: suppliers; customers; competitors; consultants; commercial labs/R&D enterprises; (b) Institutional: universities; government research organisations; (c) Specialised: private research institutes. Respondents were asked to indicate whether cooperation was with organisations that were 'local', 'national', 'European', 'US' or in 'Other' countries. From this we could identify cooperation at the national (which also includes local) and international level.

[20] These are measured by the implementation of new or significantly changed corporate strategies, advanced management techniques (e.g. knowledge management, quality circles), organisational structures (e.g. Investors in People, diversification), and marketing concepts /strategies. Each set of changes is ranked from 0 (not used) to 3 (high impact) to indicate its effect on business performance.

those variables related to absorptive capacity and the five factors extracted, the factor loadings matrix 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). As can be see in Table A1, the all 36 input variables used to measure absorptive capacity are supported by the Kaiser-Meyer-Olkin (hereafter KMO) measure of sampling adequacy – most of the KMO values are above 90% and an overall KMO value of nearly 95% suggests a "marvellous"[21] contribution of the raw variables.

Based on the correlations between these 36 underlying variables and the five varimax-rotated common factors in Table A1 (each with a mean of zero and a standard deviation of 1), we were able to interpret these factors as capturing the establishment's capabilities of exploiting external sources of knowledge; networking with external bodies at the national level; implementing new organisational structures and HRM strategies; building up partnerships with other enterprises or institutions at the international level; and acquiring and absorbing codified scientific knowledge from research partners respectively.[22][23] 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 seems 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, *op. cit.*; Arora and Gambardella, 1990; Veugeler, 1997; Becker and Peters, 2000; Cassiman and Veugelers, 2002; Belderbos *et. al.*, 2004)[24]. However, given the path-dependent nature of absorptive capacity, R&D fails to capture the realisation and accumulation

[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] We have highlighted (using bold, italicised values) the correlations with the highest values for each factor to provide evidence as to why we interpret a particular factor as representing a specific aspect of absorptive capacity.

[23] Here we could expect the absorptive capacity for scientific knowledge to be particularly important in indicating the technological opportunities an establishment possesses, as the notion of "technological opportunities" was originally put forward to reflect the richness of the scientific knowledge base (Scherer, 1992). Moreover, as research grows increasingly expensive and risky nowadays, industry has sought for specialist technology in academia or other government research institutes to complement or substitute their in-house R&D efforts drawn on its own resources.

[24] Other empirical proxies of absorptive capacity include human capital measures (Romijin and Albaladejo, 2002; Vinding, *op. cit.*);while Schmidt (2005), includes diverse measures of knowledge management (i.e. absorptive capacity for intra-industry, inter-industry and scientific knowledge).

of absorptive capacity, not to mention its distinct elements.[25] To our knowledge the approximation of absorptive capacity used in this study provides the most direct, and comprehensive set of empirical measures available for the UK[26].

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.* (2004) use the information on sources of knowledge from suppliers and customers to compute a variable that attempts to capture vertical spillovers (of knowledge). They obtain measures of horizontal spillovers based on how important information was from competitors; institutional spillovers using knowledge emanating from universities and research institutes; and lastly, public spillovers based on the importance of professional conferences and journals, as well as fairs and exhibitions as information sources.

We have chosen not to take a similar approach. The pragmatic reason is that in our statistical analysis (section 4) we find that these spillover measures are insignificant in the models determining exporting and R&D, whereas our measures of absorptive capacity are found to be important determinants. Secondly, and linked to the insignificance of these spillover measures, the proportion of establishments that stated that such sources of knowledge had 'high' importance are relative small (15.1% for vertical spillovers; 3.5% for horizontal spillovers; 1.3% for institutional spillovers; and 4.5% for public spillovers). In contrast, the absorptive capacity measures are based on much more information and span a greater range (rather than, say, over 90% of establishments having a zero value for spillovers). Lastly, there is a high correlation between these types of spillover measures and our measures of absorptive capacity. Given the relationships between spillovers of knowledge (as measured above) and our measurement of absorptive capacity, 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.

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[25] See for instance, the arguments in Schmidt (*op. cit.*). Note also, we treat absorptive capacity as predetermined in our estimated models (unlike R&D which we allow to be potentially endogenous). This is because of its 'path-dependent' nature, which supposes that such capacity takes a (relatively) long time to build.

[26] In a study of the impact of technological opportunities on innovation activities of German firms, Becker and Peters (*op. cit.*) also undertook factor analysis to construct proxies for technological opportunities but narrowly focusing on the opportunities stemming from scientific research. Likewise, in Nieto and Quevedo (2005), their measure of absorptive capacity is also built on a set of factors but only a single index is constructed.

Most other variables included in Table 1 are self-explanatory. However, industrial agglomeration is included to take account of any Marshall-Romer external (dis)economies of scale (Henderson, 1999; David and Rosenbloom, 1990). The greater the clustering of an industry within the local authority in which the plant operates, the greater the potential benefits from spillover impacts. Conversely, greater agglomeration may lead to congestion, and therefore may 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. Higher diversification is usually assumed to have positive benefits to producers through spillover effects. Specifically, agglomeration was measured as the percentage of industry output (at 5-digit SIC level) located in the local authority district in which the establishment was located; diversification was measured as the number of 5-digit industries (over 600) located in the local authority district in which the establishment was located. The Herfindahl index of industrial concentration is measured at the 5-digit 1992 SIC level to take account of any market power effects (which are expected to be associated with the propensity to undertake both exporting and R&D). The variable that measures if the establishment belongs to an enterprise operating in more than one (5-digit) industry (>1 SIC multiplant) is included to proxy for any economies of scope.

Table 2: Distribution of establishments in CIS3 database by whether exported and/or undertook R&D

	Do not export	Export	All
Manufacturing			
No R&D	1492	904	2396
Undertake R&D	149	397	546
Total	1641	1301	2942
Non-manufacturing			
No R&D	3935	661	4596
Undertake R&D	338	186	524
Total	4273	847	5120

Source: weighted data from CIS3 (authors' own calculations)

Table 3: Exporting (and export intensity) in UK establishments, 2000, by size (figures are percentages)

Employment size	Manufacturing		Services		Total	
	% export	exports/sales	% export	exports/sales	% export	exports/sales

0-9	21.7	6.4	9.2	3.7	12.2	4.4
10-49	36.7	8.7	15.4	3.8	22.9	5.5
50-249	64.2	18.4	21.9	4.7	42.6	11.5
250+	72.5	25.9	25.3	4.4	51.5	16.4
Total	43.9	11.8	15.6	3.9	26.1	6.8

Source: weighted data from CIS3 (authors' own calculations)

Lastly, we present some basic comparisons between exporters, those undertaking R&D and some establishment characteristics before presenting multivariate modelling results in Section 4.[27] Firstly, Table 2 shows that in manufacturing some 44% of establishments were involved in exporting, while only 18.6% incurred spending on R&D in 2000. The table also shows that some 30.5% of exporters also engaged in R&D activities (or alternatively, nearly 73% of those manufacturing establishments undertaking R&D also exported). This suggests a strong relationship between the two activities, although there were a substantial number of establishments that exported but without finding it necessary to also engage in R&D.

There was a wide variation across industries in the propensity for firms to export (e.g. nearly 74% of establishments in the Chemicals sector were engaged in exporting, with some 26% of goods sold abroad; in comparison, most non-manufacturing sectors had low levels of exporting[28]); there was a much smaller, although significant, variation across regions in exporting (e.g. over 61% of manufacturing establishments in Northern Ireland exported, while only 35% in London did the same). Establishment size also determined whether goods and services were sold abroad. Table 3 shows that exporting increased with establishment size (especially in the manufacturing sector with over three-quarters of establishments employing 250 or more workers engaged in exporting).

Further details are available in Table 3.4 in Harris and Li (2005), covering the characteristics of those establishments that exported separately from those that did not (for both manufacturing and non-manufacturing sectors),. In summary, this shows that all of the following were higher for exporters: the likelihood of engaging in (continuous) R&D and to be innovative (as measured by whether they produced new product and/or process innovations, whether novel or otherwise); level of co-operation with (international) partners outside the enterprise; capital intensity; age of the

[27] Greater detail is presented in Harris and Li (2005, Chapter 3).
[28] Indeed, the CIS3 data shows that significant proportions of firms export in only the wholesale trade, computing and R&D sectors of non-manufacturing.

establishment; the level of industrial concentration; the importance of agglomeration economies (but not diversification); the propensity to have production capacity in the Greater South East region; and the probability of belonging to a multi-region, multi-plant firm, operating in more than one industry (thus gaining from economies of scope), and/or being foreign-owned. In contrast, exporters were less likely to be single-plant enterprises.

IV. Determinants of exporting

In modelling the determinants of exporting using the CIS-ARD merged dataset for 2000, separate models have been estimated for manufacturing and services (given the different export intensities between these two sectors). We only report the results for manufacturing in this study (although those for services are similar), given space constraints and the fact that a much larger proportion of establishments engaged in (higher levels of) exporting in this sector.[29]

With respect to the econometric modelling of exporting behaviour (with R&D/innovation activity as an explanatory variable)[30], we use a Heckman (1979) approach, which recognises that those that export are not a random sub-set of all establishments; rather, modelling export intensity (exports per unit of sales) needs to take into account that those with non-zero exporting levels have certain characteristics that are also linked to how much is exported. Failure to take into account this self-selection element when modelling exporting intensity would lead to results that suffer from selection bias. Note, maximum likelihood estimators have to be employed to obtain both efficient and consistent coefficients (see, for instance, Barrios *et. al.*, 2003), and both equations must be estimated simultaneously (using for example the FIML estimator).[31]

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[29] The CIS3 data shows that 64% of the value of all exports in 2000 originated from the manufacturing sector (even though this sector accounted for some 26.7% of total turnover); manufacturing also accounted for some 74% of total R&D spending (when omitting the R&D sector). Manufacturing establishments accounted for nearly 61% of all those engaged in exporting (and 51% of those engaged in R&D), despite only accounting for 36.5% of UK establishments.

[30] A variety of innovation-related variables have been conventionally included in the empirical estimation of export behaviour, such as dummies indicating whether or not a firm is an innovator; R&D intensity; patents; formal R&D expenditures; the value of the licensing fees and royalties abroad; dummies that distinguish between the producers of capital goods and other types of goods, skills and the capital intensity of operations, imports of technology, number of innovation used/generated either in the firm or industry to which the firm belongs; etc.

[31] Note, the use of the Heckman sample selectivity approach (based on a FIML simultaneous estimation of the model involving both 'who exports' and 'how much is exported') is not about separating out the

In addition, a method of simultaneous estimation has also been proposed to take into account the endogeneity of exporting and innovation decisions[32]. This involves the estimation of simultaneous probit models that treat exports and R&D as jointly endogenous variables. For instance, using a technique first devised by Maddala (1983), it is possible to regress the endogenous variables on the entire set of assumed exogenous variables and construct the predicted variables as instruments. In the second stage, export and innovation variables need to be replaced with these instruments to yield unbiased estimates of the impact of innovation on exports (and vice versa). Similar simultaneous approaches have been employed in several empirical studies treating innovation and exports as inextricably interdependent (Hughes, 1986; Zhao and Li, 1997; Smith *et. al.*, 2002; Cassiman and Martinez-Ros, 2004; and Lachenmaier and Woessmann, 2006).

We have estimated two versions of the Heckman model: the first (denoted Model 1) takes no account of the likely endogeneity between exporting and R&D (we assume that the latter is predetermined). In Model 2 we allow R&D to be endogenous, and replace it with its predicted value obtained from the reduced-form model determining R&D (see Table A.2 in the appendix).[33] The results for the manufacturing sector, as to whether establishments export or not, are provided in Table 4(a), with marginal effects reported. Note a stepwise regression procedure was adopted[34] with variables

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exporting decision into two stages. The latter has been criticized by, for instance, Wagner (2001), who argues that (based on the *ex post* nature of sunk costs) there is no such thing as a two-step decision involving (i) the decision to export and (ii) how much to export. These are not mutually exclusive, as costs are carefully considered when firms decide (by producing the profit-maximising quantity at the given price) whether to participate in such export markets or not.

[32] On the empirical modelling of this innovation-exports relationship, Becker and Peters (*op. cit.*) have also adopted a Heckman-type framework in their model of R&D, with exports intensity included as an explanatory variable. Whilst finding a positive relationship, nevertheless, they did not correct for the endogeneity.

[33] We have also undertaken a Smith-Blundell test for exogeneity based on model 2 (using the 'probexog' command in STATA), which includes all the (significant) variables in the model as determinants of the probability of exporting and with R&D instrumented by those 8 variables highlighted in column 1 of Table A2 (e.g. the high cost of innovation). These instruments were chosen on the basis of whether they were significant determinants of R&D (see Table A2) but not significant in determining whether the establishment exported (i.e. model 2). The test obtained a $\chi^2(1)$ value of 22.6 (which rejects the null of exogeneity at better than the 1% significance level). Note, this test is indicative, as the endogenous variable we instrument is dichotomous (a valid use of the test would require R&D to be a continuous variable).

[34] The null hypothesis that the variables dropped had jointly coefficients equal to zero was not rejected at better than the 10% significance level. See Table 1 for a full list of variables in the model..

Table 4(a): Determinants of exporting in UK Manufacturing, 2000

Dependent variable: exporting undertaken or not	Model 1		Model 2		Means
	$\partial\hat{p} / \partial x$	*z*-value	$\partial\hat{p} / \partial x$	*z*-value	($\bar{x}$)
R&D	0.175	5.45	0.121	6.65	0.186
Establishment size					
20-49 employees	0.165	5.46	0.152	4.93	0.356
50-199 employees	0.248	6.20	0.224	5.73	0.215
200+ employees	0.255	4.23	0.242	4.17	0.074
ln enterprise size	0.039	2.43	0.037	2.54	3.529
Single-plant enterprise	0.103	3.45	0.090	3.38	0.808
Other factors					
Absorptive capacity (external knowledge)	0.060	4.70	–	–	0.133
Absorptive capacity (national co-op)	0.028	1.84	–	–	0.029
Absorptive capacity (org structure & HRM)	0.040	3.44	0.019	1.78	0.057
Absorptive capacity (int'l co-op)	0.058	2.84	0.045	2.83	0.050
Absorptive capacity (scientific knowledge)	0.073	2.20	0.060	2.35	-0.007
ln Capital/employment ratio (£m per worker ARD data)	0.026	2.56	0.019	1.99	-5.645
ln Labour productivity (£'000 per worker)	0.107	5.92	0.104	5.87	4.089
Industry agglomeration	0.007	1.75	–	–	1.456
ln Herfindahl index	0.076	4.60	0.074	4.93	-2.899
Impact of regulations	-0.092	-3.06	-0.079	-2.87	0.165
Industry sector (2-digit 1992 SIC)					
Food & drink	0.284	2.94	0.219	2.49	0.074
Textiles	0.506	10.49	0.473	8.92	0.040
Clothing & leather	0.364	3.97	0.328	3.64	0.032
Wood products	0.261	2.43	0.194	1.98	0.040
Paper	0.327	3.44	0.219	2.21	0.030
Publishing & printing	0.220	2.09	0.194	2.13	0.113
Chemicals	0.511	10.98	0.454	7.80	0.037
Rubber & plastics	0.498	8.75	0.428	6.46	0.065
Non-metallic minerals	0.312	3.03	0.279	2.93	0.033
Basic metals	0.497	9.75	0.449	7.39	0.027
Fabricated metals	0.427	5.01	0.372	4.66	0.186
Machinery & equipment nes	0.493	7.70	0.419	6.08	0.104
Electrical machinery	0.513	10.12	0.451	7.80	0.071
Medical etc instruments	0.495	10.05	0.471	9.33	0.035
Motor & transport	0.420	5.93	0.374	5.31	0.039
Furniture & manufacturing nes	0.427	5.94	0.371	5.20	0.067
Region					
Eastern England	0.076	1.88	–	–	0.086
Northern Ireland	0.254	3.66	0.237	3.48	0.020
ρ	-0.494	-4.03	-0.724	-8.24	
σ	1.723	26.06	1.912	20.69	
λ	-0.852	-3.57	-1.385	-6.02	
(unweighted) N	3,303		3,303		
N (export > 0)	1722		1722		
Log pseudo-likelihood	-3805.9		-3838.0		
Wald test of independent equations $\chi^2(1)$	11.16		24.57		

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of R&D (hence the predicted value is used based on the reduced-form model in Table A2). The reported figures are marginal effects of explanatory variables on the propensity to export (for binary variables, these are the effects of a discrete change from 0 to 1) and their corresponding Z statistics; all are statistically significant at least at the 10% level. Weighted regression using the 'heckman' procedure in STATA 9 is used with merged CIS-ARD data. For variable definitions, see Table 1.

retained in the model that had associated parameter estimates significant at the 15% level or better. The diagnostic tests provided in the lower part of the table also show that the Heckman selection procedure is clearly justified, since the correlation between the error terms of the two equations in the model is clearly large (ρ = -0.34) and statistically significantly different from zero (as tested using the reported likelihood ratio test of the null hypothesis that $\rho = 0$, with a $\chi^2(1) = 4.38$ value that is able to reject the null at better than the 3% significance level).

An establishment undertaking R&D is associated with a significantly higher likelihood of non-zero exports; i.e. (*cet. par.*) a 17.5% higher probability of selling internationally when R&D is treated as exogenous. However, when we allow for R&D to be endogenous (by replacing R&D by its predicted value), the marginal effect for this variable falls from 0.175 to 0.121. The final column in Table 4(a) shows that only some 18.6% of UK manufacturing establishments undertook R&D in 2000; thus, this had an important impact on the propensity to export.

The parameter estimates for the remaining variables, that entered as determinants of whether exporting is undertaken or not, are mostly very similar for models 1 and 2. Thus, we shall refer only to those reported for model 2, where R&D enters as an endogenous variable (which is the preferred model). The size of the establishment had a major impact on whether any exporting took place; vis-à-vis the baseline group (establishments employing less than 20), moving to 20-49 employees increased the probability of exports > 0 by 15.2%, an increase in the probability by 22.4% in the 50-199 group and up to an increase of just over 24% for establishments with 200+ employees.[35] This confirms the results presented in Table 3 that size and the propensity to export are positively related. Given that the last column in Table 4(a) shows the distribution of establishments by size, it can be seen that the UK has relatively fewer establishments in the largest size bands listed, thus to some extent limiting the number of establishments that export. Enterprise size was also positively related to the probability of selling overseas; doubling the size of the enterprise increased the likelihood of exporting by 3.9%.

[35] It is likely that to some extent size and the propensity to export may be (partly) endogenous (e.g. for some firms exporting is a means for achieving growth and thus larger size, as domestic markets may be limited). This will result in some (unknown) likely upward bias in the estimated coefficients, but is unlikely to alter the result that there is a strong positive relationship between size and the ability of firms to overcome barriers to exporting.

Overall absorptive capacity was important in determining whether an establishment had non-zero exports in the manufacturing sector, but the variables representing the acquisition of external knowledge and national co-operation for innovation purposes became insignificant when R&D is treated as endogenous. This suggests that these aspects of absorptive capacity (which by construction are directly based on innovation activities) are important drivers of whether any R&D is undertaken, and then indirectly impact on whether the establishment exports through the inclusion of (endogenous) R&D in the exporting equation.[36] Establishments that had higher internal absorptive capacity (based on their organisational and HRM characteristics) were marginally more likely to overcome barriers into export markets; increasing this aspect of absorptive capacity by one standard deviation from its mean value increased the probability of exporting by just under 2%. The ability to internalise external knowledge gained from international co-operation increased the likelihood of exporting by 4.5% (based on one standard deviation increase in this variable), while absorbing scientific knowledge (from research organisations) resulted in an increase in the likelihood of selling overseas by around 6%. Here the relative magnitude of different dimensions of absorptive capacity is perhaps not surprising. From the perspective of technological opportunities, the science-based technological opportunities generally require a higher level of absorptive capacity than those generated by other sources of knowledge, such as suppliers and customers (Becker and Peters, *op. cit.*). Given that the largest absorptive capacity is likely to be called for to assimilate scientific knowledge stemming from research institutes (Leiponen, 2001), we could therefore expect the absorptive capacity for this type of knowledge to have the largest impact on establishment's internal capabilities (with respect to exporting in this context).

Establishments with higher labour productivity were also more likely to enter export markets; a doubling of this variable (from its mean value of just under £60k turnover per worker to just over £119k) increased the probability of exporting by some 7.2%.[37] More capital-intensive establishments were also more likely to export; doubling the capital-to-labour ratio (from a mean of just over £3.5k per worker in 1980 prices) increased the probability of exporting by about 1.3%. In all, these results confirm

[36] This can also be seen by comparing the results for the structural model 2 in Table 4(a), and for the reduced-form model in Table A2.

[37] If the learning-by-exporting hypothesis is correct, then labour productivity may also be (at least in part) endogenous. However, most of the empirical literature to date finds that establishments have to be more productive prior to entry, while there is much less evidence on productivity gains post-entry into export markets.

those often given in the literature that 'better' establishments (in terms of their ability to internalise external knowledge, productivity, and capital intensity) were more likely to export.

The results in Table 4(a) also indicate that industry/market concentration was linked to a greater probability of exporting. Increasing the Herfindalh index of market concentration, from its mean value of 0.06 to 0.16 (the latter being the average value for the 90th decile group in manufacturing), raised the (*cet. par*.) probability of exporting by 7.9%. The impact of regulations as a barrier to innovation also reduced the likelihood of the establishment exporting (by some 7.9%). Lastly, sector also mattered, with all those industries listed having higher probabilities of exporting (by between 19 to 51%) vis-à-vis mining & quarrying (the baseline group). The sectors with the highest propensities to export were (*cet. par*.) textiles, chemicals, rubber & plastics, basic metals, machinery & equipment, electrical machinery, and medical & precision instruments. Establishments in Northern Ireland were more likely to engage in selling overseas, with a (*cet. par*.) 23.7% higher probability of exporting. There were no other significant 'regional effects' for the manufacturing sector.

None of the other variables entered (see Table 1) proved to be significant barriers to entry into export markets (e.g. age of the establishment, foreign ownership, industry diversification, whether the establishment belonged to an enterprise operating in more than one industry, more than one region, or in the Greater South East).

In modelling how much of turnover is exported, the results for manufacturing are reported in Table 4(b), covering just those with positive export sales (given the 'two-stage' Heckman approach used, these results are conditional on the model determining whether exporting takes place at all). The models presented coincide with the treatment of continuous R&D as being either exogenous or endogenous (in a comparable way to how R&D is treated in Table 4a).[38] In Model 1, this activity was associated with a nearly 53% higher level of export intensity,[39] but when continuous

[38] Again we have undertaken a Smith-Blundell test for exogeneity based on model 2 (using the 'tobexog' command in STATA), which includes all the (significant) variables in the model as determinants of the probability of exporting and with continuous R&D instrumented by those 15 variables highlighted in data column 5 of Table A2 (e.g. US-owned). These instruments were chosen on the basis of whether they were significant determinants of continuous R&D (see Table A2) but not significant in determining exporting intensity (i.e. model 2). The test obtained a $\chi^2(1)$ value of 64.8 (which rejects the null of exogeneity at better than the 1% significance level). Again, as in Table 4.1(a), this test is only indicative.

[39] Since the dependent variable in the model is the natural log of export intensity, the elasticity with respect to a dichotomous variable is given by $\exp(\hat{\beta}) - 1$.

R&D is instrumented it is no longer statistically significant (rather, as discussed below, the importance of the size of the establishment on intensity increases significantly when the continuous R&D variable is omitted, suggesting a positive relationship between the undertaking of continuous R&D and the size of the establishment *conditional on having controlled for entry into export markets*).

Table 4(b): Determinants of exporting intensity in UK Manufacturing, 2000 (cont.)

Dependent variable: *ln* exporting intensity	Model 1		Model 2		Means ($\bar{x}$)
	$\hat{\beta}$	*z*-value	$\hat{\beta}$	*z*-value	
R&D activities					
R&D continuous	0.423	3.07	–	–	0.266
Establishment size					
10-19 employees	-0.363	-1.73	-0.685	-2.54	0.161
20-49 employees	-0.277	-1.99	-0.786	-2.85	0.362
50-199 employees	-0.250	-2.08	-0.914	-2.95	0.308
200+ employees	–	–	-0.747	-2.25	0.127
Other factors					
Absorptive capacity (national co-op)	-0.065	-2.08	–	–	0.113
Absorptive capacity (scientific knowledge)	0.054	2.24	0.065	2.33	0.052
Industry sector (2-digit 1992 SIC)					
Food & drink	-0.470	-2.04	–	–	0.062
Paper	-0.575	-2.02	–	–	0.030
Non-metallic minerals	0.598	2.29	0.746	2.64	0.028
Machinery & equipment nes	0.423	2.36	0.348	1.83	0.134
Electrical machinery	0.474	2.97	0.401	2.24	0.109
Medical etc instruments	0.390	1.93	–	–	0.052
Motor & transport	0.442	3.05	0.476	3.17	0.049
Region					
London	0.615	2.76	0.676	2.98	0.053
Northern Ireland	0.696	3.22	0.428	1.75	0.028
South West	0.356	1.99	0.403	2.24	0.068
Scotland	0.417	2.64	0.314	1.96	0.089
Wales	0.489	2.66	0.416	2.29	0.059

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of continuous R&D (hence the predicted value is used). All figures are statistically significant at least at the 10% level. Weighted regression using the 'heckman' procedure in STATA 9 is used with merged CIS-ARD data. Values of diagnostic tests are the same as in Table 4(a). For variable definitions, see Table 1.

While Table 4(a) shows that the size of the establishment had a major impact on whether any exporting took place (i.e. the larger the establishment, the greater the probability of exporting, presumably reflecting the availability of necessary resources to overcome the fixed costs of internationalisation), Table 4(b) shows that conditional on having overcome such 'entry barriers' (and other covariates included in the model), establishments with more than 9 employees exported *less* of their sales.[40] For example, Model 2 shows that establishments employing between 10-19 employees (*cet. par.*) exported nearly 50% less of their sales, and this rose to a nearly 60% lower export intensity for those employing 50-199 employees before falling back to 53% lower intensity for the largest establishments. This negative relationship between size and export intensity is consistent with the literature (cited earlier) that, conditional on entry into export markets, as the firm grows larger (and presumably becomes more productive) it has an incentive to extend its foreign-market penetration through FDI (rather than exporting). Thus, it opens subsidiaries overseas, whereby (in part) they sell to the host country, leaving a greater proportion of output produced in domestic plants for domestic sales. Unfortunately, we do not have anyway of testing whether this is a plausible explanation with the CIS-ARD data available (as we do not have any indication of whether the establishment belongs to a UK multinational enterprise).[41]

Other variables (see Table 1) that might have been expected to be important (such as labour productivity, most aspects of absorptive capacity, and ownership) were found not to be statistically significant determinants of exporting intensity; only those with relatively higher levels of absorption of external scientific knowledge had higher intensities. Again, this might be explained by the fact that the absorptive capacity related to science-based knowledge reflects the highest level of technological opportunities as well as the strongest internal capability an establishment possesses.

As with the determinants of whether exporting occurred or not, sector also mattered in explaining export intensity, with all those industries with positive parameter estimates having higher export intensities (by between 48 to 82%), while food & drink and the paper sectors had much lower intensities (vis-à-vis all other manufacturing sectors not explicitly listed). The industries with the higher intensities covered: non-metallic

[40] Estimating the intensity equation (for establishments where exporting > 0) by OLS (and thus omitting the inverse-Mills ratio variable associated with the Heckman correction for sample selection) results in the negative relationship between size and intensity largely disappearing. When continuous R&D is exogenous, this variable has a value of 0.64, while the two variables '10-19 employees' and '200+ employees' have parameter estimates of -0.44 and 0.28, respectively (all *t*-values are greater than |2.6|). When continuous R&D is instrumented, it remains as statistically significant (with a value of 0.51), while only the '10-19 employees' variable remains in the model (with an estimated parameter value of -0.37). This suggests (i) that the negative relationship between size and export intensity is obtained only when conditioning on market entry; and (ii) there is a strong positive relationship between size and continuous R&D, after conditioning on market entry.

[41] If such a marker existed, presumably including it would alter the negative size-intensity relationship we obtain here.

minerals, machinery & equipment, electrical machinery, medical and precision instruments, and the motor & transport sectors.

The location of the establishment within the UK was also a major determinant of export intensity (more so than as a determinant of entry into overseas markets – Table 4a). Establishments located in London sold (*cet. par.*) 96% more of their turnover overseas; those in Northern Ireland had a 53% higher export intensity; while establishments in the South West, Scotland, and Wales, had higher intensities of 50%, 37%, and 52%, respectively (based on Model 2 results).

V. Summary and conclusions

In this paper we have used establishment-level manufacturing data from the 2001 Community Innovation Survey for the UK (with some additional – mostly ownership and location – variables added from the Annual Respondents Database) to estimate a model of the determinants of establishment entry into export markets; and conditional on such entry, the proportion of turnover that is sold in overseas markets. Our preferred model uses a Heckman sample selection approach, with R&D activities treated as endogenous (and thus instrumented).

We find that (endogenous) R&D plays an important role in helping an establishment overcome barriers to internationalisation, but conditional on having entered export markets (continuous) R&D does not increase export intensity levels when such R&D is treated as endogenous. Absorptive capacity (proxied by five different measures that attempt to capture various aspects of the ability to internalise external knowledge) also plays a role in overcoming entry barriers, but mostly indirectly through the significant and large impact of absorptive capacity on (endogenous) R&D, which then directly lowers entry barriers.

These results need to be set against (and indeed are influenced by) the impact of the size of the establishment on exporting. We find a strong *positive* relationship between size and whether an establishment can overcome entry barriers; and an even stronger *negative* relationship between size and exporting intensity, conditional on the establishment having internationalised. Indeed, when continuous R&D is instrumented in the export intensity part of the model, it is no longer (positively) significant, and the size-intensity relationship is stronger (but only having controlled for sample selectivity using the Heckman approach[42]). Thus, establishment size plays a fundamental role in explaining exporting, and the literature suggests that what we are likely to be mirroring is the movement of larger firms using FDI (rather than exporting) as a major means of supplying overseas markets as firms become larger. Unfortunately, we cannot test this as we do not have any variable that measures whether the domestically producing establishment belongs to a UK-owned multinational enterprise. We suspect that such a variable would have a crucial role in explaining (some) of our results, and suggest that such a 'marker' would be a useful addition to future surveys (either the CIS or the ARD[43]).

We also find that regional effects have a different role in determining whether an establishment exports vis-à-vis how much is exported: several regional dummies (viz. London, South West, Wales) were not significant in determining whether to enter export markets but became significant in determining how much to export, post entry. We interpret this as follows: being in a particular region does not guarantee the internal resources an establishment needs to expand into foreign markets (thus location does not matter so much at this initial stage). However, once it starts exporting successfully, being in particular regions is likely to intensify its export performance on this international stage, possibly due to competition effects, technological spillovers, knowledge transfers, externalities and accumulated experience within the proximity, all of which allow the improvement of technological capacity within the establishment *per se*. As a result of this learning process, the enhanced competence base will bring about increased competitiveness, which will then positively impact on export intensity in turn.[44]

In terms of policy conclusions, the expected importance of industrial sectors in determining entry into export markets confirms that trade policies benefit from being industry-specific. Secondly, given the relative importance of absorptive capacity (vis-à-vis R&D) in determining an establishment's export orientation, policies designed to encourage investment in such capacity in order to lower barriers to exporting are more desirable than those that promote R&D spending alone (given the complimentarity between R&D and absorptive capacity). However, the major conclusion is the

[42] See footnote 40.
[43] Attempts to date to merge information from Annual Foreign Direct Investment Survey (AFDI) into the ARD have met with limited success in terms of providing an adequate dichotomy of UK enterprises into those that engage in FDI and those that do not.
[44] Thus in the "learning region" (Florida, 1995; Morgan, 1997; Boekema *et. al.* 2001) there is sharing of diverse but overlapping technical knowledge, which is tacit and embedded among individuals and firms located in that region.

importance of the size of the establishment, and its impact on both the likelihood of exporting and the relative amount exported, conditional on overcoming entry barriers. Building up resource capabilities (which is associated with becoming larger) in order to enter overseas markets is the single most important determinant of exporting; but as an establishment becomes larger policy makers need to recognise that exporting is often superseded by the firm becoming multinational, and it is the latter which is probably of greatest benefit to overall aggregate growth.

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Appendix

Table A1: Structure matrix of factor loadings: correlations between variables and varimax rotated common factors*

Input Variables	**Factor 1** External knowledge	**Factor 2** National co-operation	**Factor 3** Organisational structure & HRM	**Factor 4** International co-operation	**Factor 5** Scientific knowledge	**Kaiser-Meyer-Olkin Measures**†
Sources of knowledge/info for innovation						
Suppliers	***0.814***	0.039	0.163	0.075	-0.068	0.983
Clients/customers	***0.825***	0.064	0.185	0.095	-0.033	0.961
Competitors	***0.818***	0.058	0.159	0.056	-0.028	0.965
Consultants	***0.791***	0.052	0.139	0.037	0.004	0.982
Commercial labs/R&D entreprises	***0.822***	0.090	0.072	0.044	0.122	0.971
Universities/other HEIs	***0.798***	0.124	0.076	0.041	0.136	0.960
Government research organisations	***0.858***	0.066	0.028	-0.051	0.115	0.952
Other public sectors	***0.824***	0.064	0.079	-0.027	0.056	0.975
Private research institutes	***0.843***	0.081	0.046	-0.037	0.110	0.969
Professional conferences	***0.818***	0.067	0.167	0.063	0.038	0.979
Trade associations	***0.846***	0.039	0.112	0.022	-0.014	0.976
Technical/trade press	***0.853***	0.041	0.153	0.028	-0.018	0.970
Fairs/exhibitions	***0.821***	0.038	0.166	0.077	-0.022	0.983
Technical standards	***0.837***	0.051	0.170	0.066	-0.006	0.985
Health &safety standards	***0.837***	0.053	0.113	0.034	-0.015	0.923
Environmental standards	***0.840***	0.054	0.108	0.037	0.004	0.930
Co-operation partners on innovation activities (national/international)						
Suppliers (nat'l)	0.137	***0.666***	0.049	0.332	-0.127	0.912
Suppliers (int'l)	0.100	0.191	0.059	***0.716***	0.088	0.895
Clients/customers (nat'l)	0.132	***0.678***	0.093	0.349	-0.082	0.910
Clients/customers (int'l)	0.090	0.257	0.062	***0.686***	***0.215***	0.890
Competitors (nat'l)	0.077	***0.717***	0.049	0.099	-0.097	0.864
Competitors (int'l)	0.061	0.251	0.027	***0.435***	***0.215***	0.886
Consultants (nat'l)	0.107	***0.683***	0.054	0.201	0.058	0.930
Consultants (int'l)	0.038	0.040	-0.008	***0.550***	0.153	0.840
Commercial labs/R&D entreprises (nat'l)	0.089	***0.636***	0.039	0.068	***0.251***	0.929
Commercial labs/R&D entreprises (int'l)	0.052	0.142	0.049	***0.393***	***0.581***	0.879
Universities/other HEIs (nat'l)	0.127	***0.592***	0.084	0.110	***0.228***	0.875
Universities/other HEIs (int'l)	0.060	0.070	0.060	***0.314***	***0.628***	0.818
Government research organisations (nat'l)	0.088	***0.668***	0.013	-0.105	***0.394***	0.853
Government research organisations (int'l)	0.052	0.183	-0.001	0.017	***0.749***	0.766
Private research institutes (nat'l)	0.076	***0.683***	0.029	-0.109	***0.278***	0.876
Private research institutes (int'l)	0.041	0.029	0.050	***0.286***	***0.483***	0.792
Areas of changes of business structure and HRM practices						
Corporate strategies	0.260	0.060	***0.814***	0.048	-0.001	0.919
Advanced market techniques	0.270	0.029	***0.789***	0.016	0.037	0.926
Organisational structures	0.243	0.053	***0.795***	0.024	0.040	0.922
Marketing	0.282	0.064	***0.770***	0.030	0.001	0.937
No. of Observations						8109
LR test: independent vs. saturated: $\chi^2(630)$						2.0e+05
Overall KMO						0.949

Notes: *Factors extracted using principal-component method (5 factors retained) in conjunction with weighting, then rotated using orthogonal varimax technique; †Kaiser-Meyer-Olkin measure of sampling adequacy is employed to assess the value of input variables.

Table A2: Marginal effects based on the reduced forms of exporting, R&D, and continuous R&D

	R&D undertaken or not		Exporting undertaken or not		R&D continuous		
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	Means ($\bar{x}$)
Establishment size							
10-19 employees	***0.099*****	2.27	0.081	1.57	0.026	0.89	0.265
20-49 employees	0.108***	2.66	0.225***	4.54	0.008	0.31	0.356
50-199 employees	0.145***	2.65	0.316***	5.81	0.065*	1.68	0.215
200+ employees	0.186**	2.25	0.331***	4.92	0.130**	1.96	0.074
ln enterprise size	0.000	-0.03	0.041**	2.45	0.013*	1.81	3.529
Single-plant enterprise	0.008	0.46	0.100***	3.08	0.009	0.67	0.808
ln establishment age	***-0.013****	-1.92	-0.007	-0.59	-0.008	-1.56	1.158
Other factors							
Absorptive capacity (ext. knowledge)	***0.119******	14.59	0.085***	6.75	***0.072******	11.05	0.133
Absorptive capacity (national co-op)	***0.036******	6.83	0.039**	2.57	***0.018******	3.86	0.029
Absorptive capacity (org structure & HRM)	0.046***	7.18	0.047***	3.96	0.036***	7.18	0.057
Absorptive capacity (int'l co-op)	0.021***	4.23	0.069***	3.26	***0.021******	4.57	0.050
Absorptive capacity (scientific knowledge)	0.002	0.30	0.075**	2.38	0.009	1.48	-0.007
Capital/employment ratio (ARD data)	0.017**	2.41	0.031**	2.41	***0.015******	2.80	-5.645
Labour productivity (£'000 per worker)	-0.008	-0.98	0.105***	5.70	0.003	0.45	4.089
Industry agglomeration	0.002	1.44	0.006*	1.73	-0.001	-0.81	1.456
ln Herfindahl index	-0.002	-0.18	0.077***	4.52	-0.001	-0.09	-2.899
ln Density (‘000 per hectare)	0.004	0.76	-0.010	-1.18	***-0.006***	-1.55	1.986
Received public sector support	***0.085******	3.16	0.007	0.17	***0.066******	2.78	0.104
Ownership characteristics							
US-owned	-0.032	-0.88	0.056	0.55	***-0.050******	-3.81	0.014
Factors hampering innovation							
Lack of info on technology	-0.035	-1.37	0.046	0.85	***-0.057******	-4.78	0.056
Lack of customer responsiveness	***-0.037*****	-2.22	-0.001	-0.02	-0.002	-0.11	0.121
High cost of innovation	***-0.036*****	-2.56	-0.011	-0.41	***-0.032******	-2.92	0.256
Impact of regulations	0.007	0.39	-0.088***	-2.69	0.008	0.54	0.165
Industry sector (2-digit 1992 SIC)							
Food & drink	-0.011	-0.20	0.284***	2.90	***0.233*****	2.31	0.074
Textiles	0.015	0.21	0.511***	10.78	***0.226*****	2.05	0.040
Clothing & leather	0.009	0.11	0.388***	4.40	0.199	1.60	0.032
Wood products	0.044	0.55	0.286***	2.70	0.064	0.75	0.040
Paper	0.041	0.50	0.340***	3.59	0.077	0.98	0.030
Publishing & printing	-0.042	-0.89	0.228**	2.14	0.066	0.98	0.113
Chemicals	0.126	1.27	0.515***	11.26	***0.319******	2.60	0.037
Rubber & plastics	0.104	1.15	0.518***	10.24	***0.170****	1.76	0.065
Non-metallic minerals	-0.034	-0.66	0.313***	3.03	0.120	1.25	0.033
Basic metals	0.058	0.63	0.495***	9.22	0.111	1.11	0.027
Fabricated metals	0.004	0.06	0.442***	5.23	0.043	0.76	0.186
Machinery & equipment nes	0.123	1.40	0.507***	8.29	0.206**	2.12	0.104
Electrical machinery	0.106	1.26	0.528***	11.20	0.297***	2.79	0.071
Medical etc instruments	0.010	0.15	0.508***	11.01	0.393***	3.23	0.035
Motor & transport	-0.006	-0.10	0.421***	5.92	0.197*	1.93	0.039
Furniture & manufacturing nes	0.055	0.73	0.437***	6.16	***0.256*****	2.41	0.067
Region							
Eastern England	***0.057****	1.91	0.078*	1.81	0.019	0.94	0.086
Northern Ireland	-0.025	-0.58	0.235***	3.14	0.022	0.48	0.020
South East	0.023	1.00	-0.015	-0.39	***0.051*****	2.40	0.106
South West	0.028	1.04	-0.028	-0.68	0.046*	1.92	0.076
Scotland	-0.020	-0.94	-0.049	-1.24	-0.028*	-1.90	0.092

Notes: ***Significant at 1%, ** significant at 5%, *significant at 10% level. Note, highlighted parameter estimates (bold and italics) denote which variables act as the key instruments when R&D and continuous R&D are treated as endogenous.