Exporting, R&D and Absorptive Capacity in UK Establishments [*]

by

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Abstract

This paper models the determinants of exporting (both in terms of export propensity and export intensity), with a particular emphasis on the importance of absorptive capacity and the endogenous link between exporting and undertaking 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 establishment size plays a fundamental role in explaining exporting. Meanwhile, alongside other factors, undertaking R&D activities and having greater absorptive capacity (for scientific knowledge, international co-operation, and organisational structure) significantly reduce entry barriers into export markets, having controlled for self-selectivity into exporting. Nevertheless, conditional on entry into international markets, only greater absorptive capacity (associated with scientific knowledge) seems to further boost export performance in such 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; O24; O32; R11

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

I. Introduction

Exporting is important to the UK economy; it accounted for 28.4% of UK GDP in 2006, while the UK is the fifth largest exporter of manufactures in the world. Moreover, data from the UK Community Innovation Survey of 2001 and 2005 show that around 26% of all firms producing marketable output were involved in exporting (the figure was around 45% for manufacturing firms). Thus, a better understanding of what determines exporting activities is important for the UK economy.

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[1], and Melitz, 2003). 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; 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 increased export opportunities are associated with both intra- and inter- industry reallocations which account for 40% of TFP growth in the manufacturing sector; while for the UK Harris and Li (forthcoming) confirm that exporting

[1] For example, Bernard and Jensen (2004a), Bernard *et. al.* (2003) and Bernard *et. al.* (2007).

firms experience faster productivity growth than non-exporters and therefore contribute more to overall productivity growth. In particular, 'within' productivity gains for exporters are relatively large and new export entrants (through being either taken-over or merged, or as new start-ups) also contribute about 38 per cent each of the overall growth in UK aggregate productivity during 1996-2004. Thus, higher productivity levels as well as faster growth rates are associated with exporters, providing an important reallocative channel for explaining aggregate productivity growth.

In this paper 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[2]. 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 analyses.

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 exporting. Section III discusses the data used, which comprises establishment data from the 2001 Community Innovation Survey along with the 2000 Annual Respondents Database for the UK. This is followed by estimating a Heckman-type sample-selection model of exporting in Section IV. Finally, the paper concludes with a summary, a discussion of the policy implications and some caveats of this study.

II. Literature Review

Absorptive Capacity

In this sub-section we define what is meant by absorptive capacity, and its role in determining both exporting and R&D (how absorptive capacity is measured is taken up in the next section). As will become evident, we argue that absorptive capacity is expected to help firms break down barriers to both operating in international markets as well as undertaking R&D (it is also likely to have an impact on how much a firm exports and/or spends on R&D, subject to having overcome entry barriers to doing either or both activities). We also will argue that absorptive

[2] For recent surveys of the literature on this export-productivity linkage, see López, 2005; Greenaway and Kneller, 2005, 2007; Wagner, 2007

capacity can be treated as pre-determined, given that it is based on prior accumulated abilities and competencies embodied in the firm, and thus is not endogenous to current R&D and exporting.

Absorptive capacity is defined here as the ability to exploit knowledge (obtained both internally and especially externally) that is embodied in intangible assets, with the latter being recognised as a key driver of enterprise performance. Knowledge and learning can be expected to have a fundamental impact on growth in that 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 and Levinthal (1990) demonstrate that the ability to exploit external knowledge is a critical component of a firm's capabilities. They argue that: '...the ability to evaluate and utilise 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). Given these arguments, it is possible to conclude that when a firm internationalises, it must have sufficient resources and capabilities through absorbing new knowledge to overcome the initial (sunk) costs of competing in international markets in order to organise for foreign competition, thus facing the dual challenge of overcoming rigidities and taking on novel knowledge (Eriksson and Johanson, 1997). Similarly, when a firm engages in R&D, it has to apprehend, share, and assimilate new knowledge to overcome barriers to innovation (Aw *et. al*., 2007).

Furthermore, Cohen and Levinthal argue that the development of absorptive capacity is history- or path- dependent (see also David, 1985, and Arthur, 1989). This results from the effective assimilation of new knowledge being dependent on accumulated prior knowledge. For example, the possession of related expertise permits a firm to assess more accurately the nature and commercial potential of technological advances and/or operation in new markets. This in turn will affect the incentive to make further investments in developing capabilities in that domain. Further, where a firm has not invested in a domain of expertise early on, it is liable to find it less attractive to invest in subsequently even where it is a promising field because of the impact on current output. The result is that firms may become locked into inferior procedures, locked out of technological opportunities and/or new markets, and exhibit high degrees of inertia with respect to changes in their external environment. This notion that absorptive capacity is path-dependent therefore leads to the assumption that it can be treated as a pre-determined variable and it is not endogenous to current R&D spending and exporting.

The Export-R&D Nexus

The linkage between innovation activities (such as R&D) 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. Export orientation at the firm level has been extensively investigated in the literature, and various empirical studies have emphasised the role of technology and R&D as one of the major factors facilitating entry into global markets and thereafter maintaining competitiveness and boosting export performance (see Harris and Li, 2005, for further details). For instance, recent studies include Bleaney and Wakelin (2002), and Gourlay and Seaton (2004), for the UK; Baldwin and Gu (2004), for Canada; Basile (2001), for Italy; and finally in comparative studies, Roper and Love (2002), for both UK and German manufacturing firms. Still evidence at this micro level does not seem to be conclusive, as inconsistent results have been found by Lefebvre *et. al.* (1998) and Sterlacchini (2001).

With respect to the causality issue associated with the linkage between R&D and exports, the early consensus in the literature was that causality runs from undertaking innovation activities to internationalisation. This can be easily understood from the perspective of product differentiation or 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 that have tended to dominate the well-established trade-innovation theories in the macroeconomics literature (e.g. Posner, 1961; Dollar, 1986; and Krugman, 1979). In short, product differentiation/innovation translates into competitive advantages that allow the firm to compete in international markets.

It can also be argued that 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), and Aghion and Howitt (1998). 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 markets can foster increased R&D and innovation within firms. This learning effect induced by participation in international markets is often not directly measured but considered indirectly 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.

Given that causality can run in both directions, this two-way linkage between a firm's exporting and innovating activities (such as undertaking R&D) has also been tested and confirmed empirically, particularly in studies of firms operating in emerging economies (e.g. Alvarez, 2001, for Chile), where the learning effect is likely to be more pronounced, from the perspective of technology catching-up or economic convergence (Ben-David and Loewy, 1998). Overall, 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. In general, we would *a priori* expect that undertaking R&D and exporting are endogenous; hence, we both test and allow for this in our empirical work in Section IV.

Other Determinants of Exporting Activities

A number of other factors have been suggested in the literature to exert an impact on a firm's exporting behaviour, and therefore moderate the way exporting and R&D activities affect (and interact with) each other. To begin with, there is 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 (e.g. Roberts and Tybout, 1997; Gourlay and Seaton, 2004; and Kneller and Pisu, 2007). Nevertheless, conditional on having overcome entry barriers, the size effect on export performance could become negative - as firms grow larger (and presumably 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.*, 2004). 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. Wagner, 1995; Bernard and Jensen, 1999; and Bleaney and Wakelin, 2002).

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 in conditioning the firm's export-innovation relationship (for instance, Hirsch and Bijaoui, 1985; Hughes, 1986; and Gourlay and Seaton, 2004).

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 effect and an industrial effect. The former comprises the spatial concentration of exporters (from various industries) whereas the latter effect is where exporting firms from the same industry co-locate. Greenaway and Kneller (2004) provide empirical evidence that shows 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 for instance, Aitken *et. al.* (1997) for Mexico.

Lastly, in a similar fashion, market concentration is also expected to positively impact on exporting activities. 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 (see Greenaway and Kneller, forthcoming, for evidence from UK manufacturing).

In summary, we expect absorptive capacity and R&D spending, plus a number of other factors (such as firm size and industrial sector) to impact on whether exporting takes place, and conditional on this, how much is sold abroad. We also expect that R&D spending is likely to be endogenous in any model estimated.

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 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)[3]; and (ii) the Annual Respondents Database (ARD)[4].

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 CIS3 survey only achieved a 43% response rate and over-represents large establishments (with only firms employing 10 or more included), but the weights available in CIS3 can be used to ensure the sample obtained is representative of the population of all UK establishments. The dataset covers all sectors of the economy and can be linked into the ARD, since the Inter Departmental Business Register (IDBR) reference numbers are common to both datasets. Thus ancillary information (particularly on ownership and spatial characteristics) available in the 2000 ARD has been added to the CIS3 data for use in our subsequent analysis of what determines exporting[5]. Of the 8172 establishments covered in CIS3, it was possible to locate 7709 of these in the ARD at the reporting unit level; where necessary, plant level ARD information (e.g. on capital stocks in manufacturing) was aggregated to reporting unit level to ensure comparability with CIS3[6].

Table 1 sets out the list of variables we use in this study, along with the data sources used. 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). 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[7]; partnerships with external bodies on innovation co-operation[8]; and the introduction of changes in organisational structure and human resource management (henceforth HRM) practices which will be related to internal aspects of absorptive capacity[9].

[3] The more up-to-date Community Innovation Survey 2005 (CIS4) is also available but does not contain information on how much was sold abroad (only whether the establishment engaged in exporting).
[4] For a detailed description of the ARD, see Oulton (1997), Griffith (1999), and Harris (2002, 2005).
[5] The 2000 ARD data is used as the CIS3 sample was drawn from the 2000 version of the IDBR, and thus matches ARD data on establishments operating in that year.
[6] Non-matched observations were mostly in those sectors not covered in the ARD (i.e. financial services).
[7] See question 12.1 in the CIS3 questionnaire (available at http://www.dti.gov.uk/files/file9686.pdf). Table A1 lists the 16 variables included in CIS, and respondents were asked to rank how important each factor is (from 0 – not used, to 4 – high importance).
[8] See question 13.2 in the CIS3 questionnaire and Table A1 for the 8 variables included in CIS. Since respondents were asked to indicate whether cooperation was with organisations that were 'local', 'national', 'European', 'US' or in 'other' countries, we could separately identify cooperation at the national and international level.
[9] See question 17.1 in the CIS3 questionnaire and Table A1 for the 4 variables included in CIS.

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 R&D continuously (coded 1) or not during 1998-2000	CIS3
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+	CIS3
Enterprise size	Number of employees in the enterprise	ARD
Age	Age of establishment in years (manufacturing only)	ARD
Employment	Current employment for establishment in 2000	ARD
Capital	Plant & machinery capital stock for establishment in 2000 (source: Harris and Drinkwater, 2000, updated) (£m 1980 prices)	ARD
Labour productivity	Establishment turnover per employee in 2000	CIS3
Multi-plant	Dummy coded 1 when establishment *i* belongs to a multiple-plant enterprise	ARD
>1 SIC multiplant	Dummy variable =1 if establishment belongs to a multiple-plant enterprise operating in more than 1 (5-digit) industry	ARD
>1 region multiplant	Dummy variable =1 if establishment belongs to multiple-plant enterprise operating in more than 1 UK region	ARD
US-owned	Dummy coded 1 if establishment *i* is US-owned	ARD
Other foreign-owned	Dummy coded 1 if establishment *i* is other-owned	ARD
Absorptive capacity (5 factors, see text for details)	AC for external knowledge	CIS3
	AC for national co-operation	CIS3
	AC for organisational structure & human resource management (HRM)	CIS3
	AC for international co-operation	CIS3
	AC for scientific knowledge	CIS3
Barriers to innovation[a] (10 factors identified in CIS)	Excessive perceived economic risks	CIS3
	High costs of innovation	CIS3
	Cost of finance	CIS3
	Availability of finance	CIS3
	Organisational rigidities within the enterprise	CIS3
	Lack of qualified personnel	CIS3
	Lack of information on technology	CIS3
	Lack of information on markets	CIS3
	Impact of regulations/standards	CIS3
	Lack of customer responsiveness	CIS3
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 (from over 650) located in local authority district in which establishment is located	ARD
Herfindahl	Herfindahl index of industry concentration (5-digit level)	ARD
Density	Population density in 2001 in local authority district in which establishment is located	CoP, 2001
Industry	Dummy variable =1 if establishment located in particular industry SIC (2-digit)	CIS3
GO regions	Dummy variable =1 if establishment located in particular region	CIS3
Greater South East	Dummy variable =1 if establishment belongs to enterprise operating in Greater South East region	ARD

[a] Each dummy variable is coded 1 if the barrier is of medium-to-high importance to the establishment.

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 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 seen in Table A1, 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"[10] 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 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[11]. Comparing these 5 distinct dimensions of absorptive capacity, we could expect the absorptive capacity for scientific knowledge to be particularly important in indicating the technological opportunities an establishment possesses, as this 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.

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, 1990; Arora and Gambardella, 1990; Veugeler, 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

[10] 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.

[11] The correlations with the highest values for each factor have been highlighted (using bold, italicised values) in Table A1 to show why a particular factor is interpreted as representing a specific aspect of absorptive capacity.

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. 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.

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). We have chosen not to take a similar approach. The pragmatic reason is that in our statistical analysis (Section IV) we find 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. In addition, the proportion of establishments that stated that such sources of knowledge had 'high' importance is relative small (15.1% for vertical spillovers; 3.5% for horizontal spillovers; 1.3% for institutional spillovers; and 4.5% for public spillovers). 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, although a clear distinction needs to be made between the size of the establishment (usually comprising just one plant) and the size of the enterprise (larger than the size of the establishment for multi-plant firms). Moreover, industrial agglomeration is included to take account of any Marshall-Romer external (dis)economies of scale (David and Rosenbloom, 1990; Henderson, 1999). The greater the clustering of an industry within the local authority, the greater the potential benefits from spillover impacts. Conversely, greater agglomeration may lead to congestion, and therefore may lower productivity. The diversification index is also 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 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 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 (i.e. >1 SIC multiplant) is included to proxy for any economies of scope.

Table 2: Distribution of establishments, 2000, 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: authors' own calculations using weighted data from CIS3 (population weights available in CIS3)

Lastly, we present some basic comparisons between exporters, those undertaking R&D and some establishment characteristics before discussing multivariate modelling results in Section IV. 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.

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

Employment size	*Manufacturing*		*Non-manufacturing*		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: authors' own calculations using weighted data from CIS3 (population weights available in CIS3)

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[12]); 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 so). Table 3 also shows establishment size seemed to determine whether goods and services were sold abroad - exporting increased with establishment size.

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 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, and/or being foreign-owned.

IV. Estimating the 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[13].

With respect to the econometric modelling of exporting behaviour (with R&D activities as explanatory variables), 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

[12] Indeed, the CIS3 data show that significant proportions of firms export in only the wholesale trade, computing and R&D sectors of non-manufacturing.

[13] 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.

must be estimated simultaneously (using for example the FIML estimator)[14]. A first issue that needs to be tackled is that of identification in the Heckman model (i.e. which variables appear in the probit estimation but not in the sample selection equation). Our approach is to include variables associated with the fixed costs of exporting (such as the capital/employment ratio, industry agglomeration, the Herfindahl index and the impact of regulations/standards) only in the equation determining whether exporting takes place or not[15]. These variables are *a priori* likely to be associated with breaking down barriers to entering export markets, rather than how much is exported (conditional on entering such markets).

In addition, a method of simultaneous estimation has also been proposed to take into account the endogeneity of exporting and R&D decisions in modelling exporting behaviour. 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; 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 (i.e. the latter is assumed to be 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 A2 in the appendix). The results for the manufacturing sector, as to whether establishments export or not, are provided in Table 4(a), with marginal effects reported[16]. The diagnostic tests provided in the lower part of the table show that the Heckman selection procedure is clearly justified[17]: the correlation between the error terms of the two equations in the model is large (ρ = -0.499) and statistically significant from zero (as suggested by the Wald test of independent equations with a $\chi^2(1)$ = 11.27 value that rejects the null hypothesis that ρ = 0 at better than the 1% significance level). We have also undertaken a Smith-Blundell test for exogeneity based on Model 2, which

[14] Note, the use of the Heckman sample selectivity approach is not about separating out the exporting decision into two stages. The latter has been criticised 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.
[15] Note, in any event these variables were not significant when included in the equation determining export intensity.
[16] The *z*-values for Model 2 have not been corrected for bias that may result from using a generated variable (predicted R&D) based on the model estimated in Table A2; nevertheless, this bias is unlikely to be very large.
[17] An outline of the Heckman model, and thus definitions of the parameters ρ, σ, and λ, is provided in the appendix.

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 Table A2 (e.g. high cost of innovation), whose parameter estimates are also highlighted in Column 1. 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[18].

An establishment undertaking R&D was associated with a significantly higher likelihood of non-zero exports, i.e. a (*cet. par*.) 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 with its predicted value), the marginal effect for this variable falls from 0.175 to 0.118. 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, which enter 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 (i.e. the preferred model).

[18] Note, this test is indicative, as the endogenous variable we instrument is dichotomous (the test would normally require R&D to be a continuous variable).

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	5.46	0.118	6.56	0.186
Establishment size					
20-49 employees	0.190	6.77	0.175	6.11	0.356
50-199 employees	0.310	10.42	0.284	9.57	0.215
200+ employees	0.373	10.07	0.357	10.31	0.074
ln enterprise size x Multi-plant	-0.016	-2.66	-0.013	-2.52	0.921
Other factors					
Absorptive capacity (external knowledge)	0.059	4.69	–	–	0.133
Absorptive capacity (national co-op)	0.028	1.86	–	–	0.029
Absorptive capacity (org structure & HRM)	0.041	3.58	0.021	1.94	0.057
Absorptive capacity (international co-op)	0.058	2.87	0.044	2.82	0.050
Absorptive capacity (scientific knowledge)	0.074	2.21	0.060	2.36	-0.007
ln Capital/employment ratio (£m per worker ARD data)	0.026	2.58	0.020	2.09	-5.645
ln Labour productivity (£'000 per worker)	0.107	6.00	0.104	5.88	4.089
Industry agglomeration	0.008	2.01	–	–	1.456
ln Herfindahl index	0.074	4.51	0.074	4.88	-2.899
Impact of regulations/standards	-0.092	-3.06	-0.077	-2.83	0.165
Industry sector (2-digit 1992 SIC)					
Food & drink	0.302	3.16	0.229	2.63	0.074
Textiles	0.512	11.00	0.477	9.18	0.040
Clothing & leather	0.377	4.19	0.336	3.78	0.032
Wood products	0.276	2.60	0.202	2.06	0.040
Paper	0.360	4.06	0.246	2.57	0.030
Publishing & printing	0.234	2.22	0.199	2.20	0.113
Chemicals	0.517	11.55	0.458	7.97	0.037
Rubber & plastics	0.504	9.06	0.431	6.54	0.065
Non-metallic minerals	0.322	3.16	0.282	2.97	0.033
Basic metals	0.506	10.58	0.455	7.71	0.027
Fabricated metals	0.438	5.17	0.377	4.75	0.186
Machinery & equipment nes	0.505	8.14	0.429	6.37	0.104
Electrical machinery	0.519	10.43	0.453	7.88	0.071
Medical etc instruments	0.500	10.30	0.472	9.36	0.035
Motor & transport	0.435	6.43	0.386	5.63	0.039
Furniture & manufacturing nes	0.433	6.06	0.372	5.22	0.067
Region					
Eastern England	0.073	1.82	–	–	0.086
Northern Ireland	0.254	3.63	0.236	3.43	0.020
ρ	-0.499	-4.07	-0.731	-8.30	
σ	1.725	25.66	1.920	20.21	
λ	-0.860	-3.59	-1.403	-6.01	
(unweighted) N	3303		3303		
N (export > 0)	1722		1722		
Log pseudo-likelihood	-3809.2		-3843.2		
Wald test of independent equations: $\chi^2(1)$	11.27		24.23		
Smith-Blundell test of exogeneity of R&D: $\chi^2(1)$			22.65		

Notes: Weighted regression is used (with population weights available in CIS3). 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 parameter estimates are all statistically significant at the 10% level or better. For variable definitions, see Table 1.

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 10), moving to 20-49 employees increased the probability of exports > 0 by 17.5%, an increase in the probability by 28.4% in the 50-199 group and up to an increase of almost 36% for establishments with 200+ employees. This confirms the results presented in Table 3 that size and the propensity to export are positively related[19]. 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 band listed, thus to some extent limiting the number of establishments that export. We have also included the size of the enterprise as well as establishment size, but only for those establishments that belong to multi-plant enterprises (employment size for single-plant enterprises is already accounted for using the dummy variables for establishment size-band). Our results show that increasing the size of the enterprise is negatively related to the probability of selling overseas if the establishment belonged to an enterprise that had multiple plants in 2000, suggesting that (having controlled for the large positive relationship between establishment size and exporting) large multi-plant enterprises have a slightly higher propensity to supply UK markets vis-à-vis single-plant enterprises. To confirm this, we also tried entering the multi-plant dummy variable in addition to the composite variable comprising *ln* enterprise size × multi-plant. If both variables involving multi-plant status are entered, they are both insignificant (due to collinearity problems); if just the multi-plant variable is entered a significant (and large) negative value is obtained for the parameter estimate confirming that enterprises with more than one plant have a (slightly) lower likelihood of selling overseas.

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 become 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[20]. Establishments

[19] Instead of using size-bands (to pick up potential non-linear effects), actual *ln* employment for the establishment (and *ln* employment-squared) can be entered. Using this form of Model 2, we obtain marginal effects of 0.230 (4.04) and -0.015 (-2.26) for *ln* employment and *ln* employment-squared respectively (*z*-values in parentheses). Other parameter estimates in the model change very little (in terms of their value or significance). This (alternative specification) confirms that size and the propensity to export are positively related, and that at (very) large levels of employment there is a flattening of the relationship. However, using *ln* employment and *ln* employment-squared does not pick up any *positive* non-linear effect as shown in Table 4(a), where moving from lower to higher size-bands results in an increasing positive relationship between size and the likelihood of exporting. Moreover, the inclusion of a cubic-term for *ln* employment was not successful (the parameter estimate on *ln* employment becomes insignificant).

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

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 over 2%. The ability to internalise external knowledge gained from international co-operation increased the likelihood of exporting by 4.4% (again based on one standard deviation increase), 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, 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, 2000). 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%. In all, these results confirm those often given in the literature that 'better' establishments (in terms of their ability to internalise external knowledge, and productivity) were more likely to export.

Turning to the variables associated specifically with the fixed costs of entry into export markets (and which 'identify' the Heckman model), 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 1.4%. Industry/market concentration was also 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 90^{th} decile group in manufacturing), raised the probability of exporting by 7.3%. The impact of regulations/standards as a barrier to innovation also reduced the likelihood of the establishment exporting (by some 7.7%).

Lastly, sector also mattered, with all those industries listed having higher probabilities of exporting (by between 19.9 to 47.7%) vis-à-vis mining & quarrying (the baseline group). The sectors with the highest propensities to export were 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 23.6%

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 in determining 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 4(a)). Again we have undertaken a Smith-Blundell test for exogeneity based on Model 2, which includes all the (significant) variables in the model as determinants of the probability of exporting and with continuous R&D instrumented by those 17 variables whose estimated parameters are highlighted in 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 an F-statistic of 106.4 (which rejects the null of exogeneity at better than the 1% significance level).

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	0.421	3.04	–	–	0.266
Establishment size					
10-19 employees	-0.348	-1.65	-0.652	-2.42	0.161
20-49 employees	-0.269	-1.92	-0.768	-2.80	0.362
50-199 employees	-0.245	-2.05	-0.908	-2.94	0.308
200+ employees	–	–	-0.748	-2.25	0.127
Other factors					
Absorptive capacity (national co-op)	-0.066	-2.10	–	–	0.113
Absorptive capacity (scientific knowledge)	0.054	2.21	0.064	2.28	0.052
Industry sector (2-digit 1992 SIC)					
Food & drink	-0.467	-2.03	–	–	0.062
Paper	-0.583	-2.05	–	–	0.030
Non-metallic minerals	0.603	2.29	0.763	2.66	0.028
Machinery & equipment nes	0.424	2.37	0.348	1.82	0.134
Electrical machinery	0.473	2.96	0.395	2.19	0.109
Medical etc instruments	0.394	1.95	–	–	0.052
Motor & transport	0.455	3.13	0.496	3.28	0.049
Region					
London	0.613	2.76	0.669	2.96	0.053
Northern Ireland	0.697	3.21	0.428	1.74	0.028
South West	0.351	1.97	0.369	2.06	0.068
Scotland	0.416	2.63	0.349	2.18	0.089
Wales	0.492	2.67	0.429	2.35	0.059
Smith-Blundell test of exogeneity of R&D continuous: F (1, 3298)			106.40		

Notes: Weighted regression is used (with population weights available in CIS3).. Model 1 is the baseline model, while Model 2 controls for endogeneity of continuous R&D (hence the predicted value is used). All parameter estimates are statistically significant at least at the 10% level. Values of diagnostic tests are the same as in Table 4(a). For variable definitions, see Table 1.

In Model 1, undertaking continuous R&D was associated with an over 52% higher level of export intensity[21], but when continuous 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).

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,

[21] 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 $\exp(\hat{\beta}) - 1$.

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 10 employees exported less of their sales[22]. As with the results for export probability, we focus on Model 2 for interpretation. For example, establishments employing between 10-19 employees exported nearly 48% less of their sales, and this rose to a nearly 60% lower export intensity for those employing 50-199 employees before falling back to almost 53% lower intensity for the largest establishments[23]. 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)[24].

Other variables that might have been expected to be important (see Table 1, such as labour productivity, most aspects of absorptive capacity, and ownership) were found not to be statistically significant in determining 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 positively significant parameter estimates having higher export intensities (by between 42 to 114%). The industries with higher

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[22] 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 *z*-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.

[23] If actual (logged) employment for the establishment (and *ln* employment-squared) is entered rather than dummy variables representing size-bands, then for Model 2, we obtain elasticities of -0.758 (-3.09) and 0.074 (3.10) for *ln* employment and *ln* employment^2, respectively (*z*-values in parenthesis). The other parameter estimates in the model change very little (in terms of their value or significance). This (alternative specification) confirms that size and export intensity are negatively related but at large levels of employment there is a flattening of the relationship.

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

intensities covered non-metallic 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 4(a)). Establishments located in London sold over 95% 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 45%, 42%, and 54%, respectively.

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 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 a significant 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). 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 directly; however, 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[25]).

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, due to (agglomeration) spillovers and externalities associated with different spatial locations. As a result of this process, the enhanced competence base will bring about increased competitiveness, which will then positively impact on export intensity in turn.

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 and its complementarity to 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. However, the major conclusion is the 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 establishment becoming multinational, and it is the latter which is probably of greatest benefit to overall aggregate growth.

[25] 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.

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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 (national)	0.137	***0.666***	0.049	0.332	-0.127	0.912
Suppliers (international)	0.100	0.191	0.059	***0.716***	0.088	0.895
Clients/customers (national)	0.132	***0.678***	0.093	0.349	-0.082	0.910
Clients/customers (international)	0.090	0.257	0.062	***0.686***	***0.215***	0.890
Competitors (national)	0.077	***0.717***	0.049	0.099	-0.097	0.864
Competitors (international)	0.061	0.251	0.027	***0.435***	***0.215***	0.886
Consultants (national)	0.107	***0.683***	0.054	0.201	0.058	0.930
Consultants (international)	0.038	0.040	-0.008	***0.550***	0.153	0.840
Commercial labs/R&D entreprises (national)	0.089	***0.636***	0.039	0.068	***0.251***	0.929
Commercial labs/R&D entreprises (international)	0.052	0.142	0.049	***0.393***	***0.581***	0.879
Universities/other HEIs (national)	0.127	***0.592***	0.084	0.110	***0.228***	0.875
Universities/other HEIs (international)	0.060	0.070	0.060	***0.314***	***0.628***	0.818
Government research organisations (national)	0.088	***0.668***	0.013	-0.105	***0.394***	0.853
Government research organisations (international)	0.052	0.183	-0.001	0.017	***0.749***	0.766
Private research institutes (national)	0.076	***0.683***	0.029	-0.109	***0.278***	0.876
Private research institutes (international)	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 (using population weights available in CIS3), 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*****	2.28	0.087*	1.70	0.028	0.93	0.265
20-49 employees	0.107***	2.73	0.255***	5.40	0.018	0.65	0.356
50-199 employees	0.141***	2.94	0.381***	8.67	0.093**	2.42	0.215
200+ employees	0.176***	2.78	0.442***	10.86	0.195***	3.20	0.074
ln enterprise size x Multi-plant	0.000	0.12	-0.016**	-2.55	0.002	0.86	0.921
***ln* establishment age**	***-0.014*****	-2.06	-0.006	-0.49	***-0.009****	-1.71	1.158
Other factors							
Absorptive capacity (ext. knowledge)	***0.119******	14.59	0.085***	6.73	***0.072******	11.02	0.133
Absorptive capacity (national co-op)	***0.036******	6.83	0.039***	2.61	***0.018******	3.89	0.029
Absorptive capacity (org structure & HRM)	0.045***	7.17	0.048***	4.08	***0.036******	7.23	0.057
Absorptive capacity (international co-op)	0.021***	4.22	0.069***	3.28	***0.021******	4.59	0.050
Absorptive capacity (scientific knowledge)	0.002	0.28	0.077**	2.40	0.010	1.50	-0.007
ln Capital/employment ratio (ARD data)	0.018**	2.50	0.030**	2.30	***0.016******	2.89	-5.645
ln Labour productivity (£'000 per worker)	-0.009	-1.03	0.107***	5.80	0.003	0.44	4.089
Industry agglomeration	0.002	1.45	0.008**	2.01	-0.001	-0.57	1.456
ln Herfindahl index	-0.002	-0.19	0.0768***	4.45	-0.001	-0.11	-2.899
ln Density (‘000 per hectare)	0.004	0.77	-0.011	-1.27	-0.006	-1.58	1.986
Received public sector support	***0.086******	3.19	0.007	0.18	***0.067******	2.82	0.104
Ownership characteristics							
US-owned	-0.033	-0.95	0.095	0.94	***-0.049******	-3.51	0.014
Barriers to innovation							
Lack of info on technology	-0.035	-1.37	0.044	0.82	***-0.057******	-4.81	0.056
Lack of customer responsiveness	***-0.037*****	-2.22	-0.002	-0.06	-0.001	-0.05	0.121
High cost of innovation	***-0.037******	-2.57	-0.011	-0.42	***-0.033******	-2.95	0.256
Impact of regulations/standards	0.008	0.39	-0.087***	-2.66	0.008	0.56	0.165
Industry sector (2-digit 1992 SIC)							
Food & drink	-0.008	-0.15	0.303***	3.12	***0.245*****	2.39	0.074
Textiles	0.018	0.26	0.516***	11.21	***0.239*****	2.13	0.040
Clothing & leather	0.013	0.16	0.398***	4.62	***0.215****	1.69	0.032
Wood products	0.049	0.61	0.299***	2.84	0.072	0.81	0.040
Paper	0.044	0.54	0.373***	4.26	0.094	1.12	0.030
Publishing & printing	-0.039	-0.81	0.241**	2.26	0.073	1.06	0.113
Chemicals	0.130	1.30	0.521***	11.79	***0.331******	2.67	0.037
Rubber & plastics	0.108	1.20	0.523***	10.56	***0.179****	1.82	0.065
Non-metallic minerals	-0.032	-0.63	0.321***	3.12	0.123	1.26	0.033
Basic metals	0.063	0.68	0.504***	10.02	0.131	1.24	0.027
Fabricated metals	0.008	0.13	0.452***	5.37	0.050	0.85	0.186
Machinery & equipment nes	0.128	1.46	0.516***	8.66	0.221**	2.22	0.104
Electrical machinery	0.112	1.32	0.532***	11.50	0.308***	2.86	0.071
Medical etc instruments	0.013	0.20	0.511***	11.23	0.403***	3.30	0.035
Motor & transport	-0.002	-0.04	0.433***	6.26	0.211**	2.03	0.039
Furniture & manufacturing nes	0.060	0.80	0.442***	6.23	***0.266*****	2.47	0.067
Region							
Eastern England	***0.057****	1.90	0.074*	1.72	0.018	0.91	0.086
Northern Ireland	-0.025	-0.57	0.232***	3.08	0.022	0.48	0.020
South East	0.022	0.98	-0.019	-0.49	***0.049*****	2.33	0.106
South West	0.028	1.04	-0.032	-0.79	0.045*	1.86	0.076
Scotland	-0.020	-0.94	-0.052	-1.34	-0.028*	-1.94	0.092
(unweighted) N	3303		3303		3303		

Notes: Weighted probit models are used (with population weights available in CIS3). ***Significant at 1%, ** significant at 5%, *significant at 10% level. 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.

Heckman model

The regression model relating to exporting intensity (y_i) to be estimated is:

$$y_i = \mathbf{x}_i\beta + u_{1i}; \quad u_1 \sim N(0,\sigma) \qquad \text{(A1)}$$

while the selection model that determines whether exporting takes place is estimated using the following probit equation:

$$p_i = \mathbf{z}_i\alpha + u_{2i}; \quad u_2 \sim N(0,1) \qquad \text{(A2)}$$

where $\mathbf{x}_i$ and $\mathbf{z}_i$ are sets of determinants of exporting intensity and probability of exporting respectively; p = 0 if exporting = 0 and p = 1 if exporting > 0. Thus the dependent variable y_i is only observed if

$$\mathbf{z}_i\alpha + u_{2i} > 0 \qquad \text{(A3)}$$

The expected value of exporting intensity in (A1) is conditional on selection, i.e.:

$$E[y_i \mid \mathbf{x}_i, p = 1] \qquad \text{and} \qquad \text{corr}(u_1, u_2) = \rho \qquad \text{(A4)}$$

Thus, estimating the regression model equates to estimating the following model:

$$\begin{aligned} E[y_i \mid \mathbf{x}_i, p = 1] &= E[y_i \mid \mathbf{x}_i, \mathbf{z}_i\alpha + u_{2i} > 0] \\ &= \mathbf{x}_i\beta + E[u_{1i} \mid u_{2i} > -\mathbf{z}_i\alpha] \\ &= \mathbf{x}_i\beta + (\rho\sigma)[\phi(\mathbf{z}_i\alpha)/\Phi(\mathbf{z}_i\alpha)] \end{aligned} \qquad \text{(A5)}$$

where ϕ is the normal density and Φ is the cumulative normal function. The parameter coefficient ρ measures the correlation between the error terms u_1 (from the regression model (A1)) and u_2 (the selection model (A2)); while σ measures the standard deviation of the residual u_1. It is common to denote $\lambda = \rho\sigma$ as the composite parameter estimate for the term in square brackets, which is known as the inverse of the Mills' ratio. Estimating Equation (A1) rather than (A5) would lead to biased estimates of $\hat{\beta}$ unless ρ = 0. Thus since observing y_i is conditional on exporting taking place (i.e. exporting > 0), the inverse Mills' ratio term in (A5) takes account of the fact that exporters are not a random sample of the population of all establishments and thus controls for selection bias effectively; in fact, those that do export, such that we observe y_i, overcome a threshold that makes it 'worthwhile' to export, with this threshold being given by Equation (A3).