Participation in Export Markets and the Role of R&D: Establishment-Level Evidence from the UK Community Innovation Survey 2005

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ABSTRACT

There is a strong expectation in the literature that exporting and innovation activities (particularly R&D) are strongly related, and that the need to be innovative is increasing over time due to globalisation. In this study, we find that R&D is endogenous in a model that determines which British establishments enter export markets, and when such simultaneity is taken into account the strength of the export-innovation relationship is generally quite weak (especially in the non-manufacturing sector). Rather, we find that the size of establishments and firms; foreign ownership; the extent of international co-operation; and most importantly the industry sector to which the establishment belongs; are the most significant in explaining which establishments are able to overcome entry barriers into overseas markets.

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I. INTRODUCTION

It is often argued that the link between innovation activities, such as R&D, and exports has become increasing interdependent as part of the process of globalisation. Innovativeness is commonly taken as a proxy for productivity and growth, and exporting for the competitiveness of an industry or country. At the macroeconomic level this relationship between trade and innovation often relates to several distinct paradigms, such as the Schumpetarian idea of creative destruction (Schumpeter, 1950), the government's pursuit of export-promotion policies, as well as the Prebisch-Singer model of the trade patterns between developed and less developed countries (Prebisch, 1950; Singer, 1950).

From the perspective of the firm, several earlier theoretical studies maintain that innovating firms have incentives to expand into other markets so as to earn higher returns from their investment, as appropriability is improved when the product market widens (e.g. Teece, 1986). As the domestic market is usually limited in size, firms often face an increasingly strong need to expand their product market by different modes of internationalisation, with exporting being one of the most conventional ways. In this process of international expansion, innovation activities play an important role in the development of competitive advantage as well as growth potential. For one thing, the advantage conferred by innovation will give firms an incentive to enter global markets and subsequently enhance their performance and international competitiveness in these new markets; in addition, the more competitive international environment that firms are exposed to *per se* may provide a source of new ideas spurring more and better innovations from them. A resource-based approach[1] has been employed in recent studies, offering new insights into this export-innovation relationship by focusing on the development of the firm's technological capacity, which is required for the firm to gain access and subsequently operate successfully in global markets (e.g. Dhanaraj and Beamish, 2003).

In comparison with the well-established trade-innovation theoretical framework established as part of the macroeconomics literature[2], the majority of the microeconomic evidence on the role of innovation in internationalisation is empirics-led. Despite a number of theoretic attempts to study the firm's decision to export (particularly based on a framework of sunk costs and firm-level heterogeneity), these studies do not explicitly model innovation as one of the determinants of exporting (e.g. Bernard *et al.*, 2003; Yeaple, 2005). Despite the lack of a solid theoretical foundation, studies at the micro level usually provide a useful way to disentangle this export-innovation relationship, by taking into account the heterogeneous characteristics of exporting and non-exporting firms. Thus, in this paper, we concentrate on the export decision at the level of the establishment[3], incorporating the role of innovation activities and other factors determining export-market entry (rather than export performance post entry[4]). Despite the importance of this area,

[1] Refer to Penrose (1959) and Barney (1991) for more details on the resource-based view.
[2] 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 technology (Davis, 1995); and also neo-technology models which predict innovative industries will be net exporters instead of importers (Greenhalgh, 1990). The latter type of models provides an extension of the conventional technology-based models such as the product life cycle theory (Krugman, 1979; and Dollar, 1986), and technology-gap theory of trade (Posner, 1961).
[3] Establishments were chosen as the level of analysis primarily because the Community Innovation Survey 2005 collected data at the establishment level (as opposed to the firm level). In the dataset, establishments can cover more than one plant (if the firm is a multi-plant organisation), and thus we have the advantage of conducting analysis at this more disaggregated level, allowing for the characteristics of multi-plant firms to be taken into account.
[4] Unfortunately, we are not able to measure export performance using the current dataset, as the information on export volume has been omitted in the Community Innovation Survey (2005, CIS4).

there are still only a limited number of micro-based studies in the literature, especially with regard to UK-based empirical analysis, and generally it is expected that exporting and R&D will be positively related without there being much evidence in support.

In what follows, Section II reviews some relevant literature relating to the exporting-innovation nexus, while Section III discusses the datasets used and the construction of certain variables that enter our export model. Section IV sets out the model in more detail and discusses certain methodological issues surrounding estimation. Section V reports results for both manufacturing and non-manufacturing sectors whilst the last section concludes with a discussion of the limitations of the current paper and some implications for policy makers.

II. EARLIER EMPIRICAL STUDIES

Export orientation at the firm level has been extensively investigated in the literature: various empirical studies have emphasised the role of technology and innovation as one of the major factors facilitating entry into global markets and thereafter maintaining competitiveness and boosting export performance. For instance, studies covering UK firms include: Bishop and Wiseman (1999), Bleaney and Wakelin (2002) and most recently, Harris and Li (2008); for Canadian manufacturing firms, Baldwin and Gu (2004); for Italian manufacturing firms, Basile (2001); for Spanish manufacturing, Cassiman and Martinez-Ros (2004); for German services, Blind and Jungmittag (2004); in comparative studies, Roper and Love (2002), for both UK and German manufacturing firms, Dhanaraj and Beamish (2003) for U.S. and Canadian

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In an earlier paper using the previous wave of UK Community Innovation Survey (2001, CIS3), Harris and Li (2008) provide an analysis of both export-market entry as well as performance, in a different setting.

firms; in the context of the rest of the world, Alvarez (2001) for Chilean manufacturing 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 frequently been found (e.g. Sterlacchini, 2001).

With respect to the issue of causality associated with this linkage, the early consensus in the literature was that causality runs from undertaking innovation activities to internationalisation. In line with the predictions of both more conventional product-cycle models as well as recently developed neo-technology models (see Footnote 2 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[5]. However, 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) 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 competence base, and hence such learning from global markets can foster increased innovation within firms.

In conjunction with the role of innovation, a number of other firm-specific factors have also been suggested in the literature that impact on export entry, and therefore moderate the way export and R&D activity affect (and interact with) each other. Above all, in a seminal paper, Cohen and Levinthal (1990) put forward the notion of

[5] For empirical evidence on this causation, see Bleaney and Wakelin, 2002; Roper and Love, 2002; and Barrios *el. al.*, 2003.

“absorptive capacity” [6] and demonstrate that the ability to exploit external knowledge is a critical component of a firm’s capabilities. Essentially, absorptive capacity constitutes an analytical link between the firm’s in-house resources and the external stock of knowledge in enhancing its resource base and generating competitive advantage.

There is also well-documented evidence on how the size of firms affects the probability of entering foreign markets, as larger firms are expected to have more (technological) resources available to initiate an international expansion (e.g. Roberts and Tybout, 1997; Bleaney and Wakelin, 2002). Higher productivity in general constitutes another significant factor determining the firm’s internationalisation decision. This positive impact of productivity on export-market entry is in line with the self-selection hypothesis, which assumes that the existence of sunk entry costs means exporters have to be more productive to overcome such fixed costs before they can realise expected profits (for recent surveys of the literature surrounding this export-productivity nexus, see López, 2005 and Greenaway and Kneller, 2007).

The external position of the firm is also generally found to determine export behaviour, in terms of sectoral, regional effects or market structure. For instance, 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 (e.g. Bleaney and Wakelin, 2002, for empirical evidence). The role of spatial factors are also important; for example, see Overman *et al.*’s (2003) survey of the literature on the economic geography of

[6] They argue that “...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’.”

trade flows and the location of production. If information on costs and foreign-market opportunities is asymmetric, then it is reasonable to expect firms to cluster within the same industry/region so as to achieve information sharing and therefore minimise entry costs; such co-location provides better channels through which firms distribute their goods (e.g. Greenaway and Kneller, 2004). Lastly, market concentration is also expected to positively impact upon a firm's propensity to export. 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 information on the demand characteristics of foreign consumers.

III. DATASET

The dataset employed for the current study comprises the merged Community Innovation Survey 2005 (henceforth CIS4) and the 2003 Annual Respondents Database (henceforth ARD 2003). The features of the two datasets as well as the matching procedure are discussed in more detail in the Appendix. Table 1 sets out the list of variables we use in this study, along with the source of the datasets. Note, the establishment's R&D activity is used to proxy for its innovation activities, with R&D spending defined as intramural R&D, or acquired external R&D or acquired other external knowledge (such as licences to use intellectual property).[7]

(Table 1 about here)

Of particular importance is the absorptive capacity of the establishment (*c.f.* Page 4-5 for more details). No direct information on this variable is available, but CIS4

[7] There is other spending that is categorised in the CIS4 database relating 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 CIS totals with those obtained from the Business Enterprise Research and Development (BERD) data source.

contains information on key elements of internal and external knowledge that can be related to absorptive capacity. 'Internal' absorptive capacity is proxied using data on the impact on business performance of the implementation of new or significantly changed corporate strategies; advanced management techniques (e.g. knowledge management, Investors in People); organisational structures (e.g. introduction of cross-functional teams, outsourcing of major business functions); and marketing concepts/strategies[8]. 'External' absorptive capacity was proxied using data on the relative importance of different sources of information used for innovation related activities. These are grouped under the following sub-headings with associated elements: market - suppliers, customers, competitors, consultants, commercial labs/R&D enterprises; institutional - universities, government research organisations; other - professional conferences, meetings, professional and trade associations, technical press, fairs, exhibitions, technical, industry or service standards.[9]

To obtain a single index of absorptive capacity, a factor analysis was undertaken using all the 14 variables listed above. We found that the first principal component had an eigenvalue of 6.2 and could explain 44% of the combined variance of the variables. Thus, we use this principal component (with a mean of zero and a standard deviation of 1) as an adequate proxy of absorptive capacity. Note, our measure of absorptive capacity indicates mostly the ability of the establishment to internalise external knowledge for innovation activities rather than for a range of other activities, such as overcoming barriers to exporting. That is, we assume (as detailed in Section IV) that our measure directly determines whether R&D is undertaken or not, while undertaking R&D is then used as a determinant of whether the

[8] For each set of information, respondents to CIS4 were asked whether the change had taken place in the three-year period up to 2004.
[9] For each element, respondents were asked to rank from 0 'not used' to 3 'high importance'.

establishment exports or not. Thus, absorptive capacity impacts on exporting, but indirectly through R&D activities. We empirically test whether the model structure that we impose is supported by the data, by considering the significance of our absorptive capacity indicator when directly entered into a model which tests for the determinants of exporting. If absorptive capacity is significant as a direct determinant of R&D activities but insignificant as a direct determinant of whether an establishment exports, this is taken as support for our approach.

Most other variables included in Table 1 are self-explanatory. In particular, industrial agglomeration is included to take account of any Marshall-Romer external (dis)economies of scale (*c.f.* Henderson, 2003). 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. Note, agglomeration is measured as the percentage of industry output (at the 5-digit SIC level) located in the local authority district in which the establishment is located; diversification is measured as the percentage of 5-digit industries (from over 650) that are located in the local authority district in which the establishment is 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 both export and to undertake 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. The data on the age of (manufacturing) establishments and their capital-labour ratios were obtained from updating the series on plant & machinery capital stocks computed by Harris and Drinkwater (2000). Capital stock estimates are not available for the non-manufacturing sector (as gross investment data are only available from 1998); however, we can provide an indicator of the age of non-manufacturing establishments based on a question asked in the CIS4 questionnaire (i.e. whether the enterprise was established after 1 January 2000).

All the data are weighted to ensure it is representative of the UK distribution of establishments (i.e. it is not biased towards the CIS4 sample). Initial inspection shows that 25.1 per cent of manufacturers engaged in both exporting and spending on R&D; while only 8.5 per cent undertook both activities in the non-manufacturing sectors.

IV. MODEL SPECIFICATION

Separate models are estimated for manufacturing and services (given the known differences between these two sectors in terms of their propensities to export). For each sector, we estimate a model of what determines whether exporting is undertaken or not, where undertaking R&D is included as a likely major determinant;[10] thus, to account for simultaneity between exporting and R&D we use the structural probit model approach first presented by Maddala (1983).[11] This involves using instruments to replace the endogenous variables and thus obtain

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[10] In this study R&D activity is employed to proxy for an establishment's innovation behaviour. Note, we have also attempted to include in our model other proxies from the output side such as product/process innovations; nevertheless, the estimation results obtained using alternative measures are considerably less robust, and therefore we only report results based on the current model using the R&D measure.

[11] Other simultaneous approaches have been employed in several empirical studies treating innovation and exports as endogenous (e.g. Cassiman and Martinez-Ros, 2004; Lachenmaier and Woessmann, 2006).

unbiased estimates of the impact of R&D on exporting. There is also a procedure for correcting the resulted standard errors when the instrumented R&D is incorporated in the exporting model (since this instrument is generated from a different model).

In choosing the likely determinants of whether exporting (or R&D spending) takes place or not, we include those variables that have been shown to be important in the literature and that are available in the CIS4-ARD database. Thus all the variables listed in Table 1 are included in our empirical models.

We begin with the following probit model determining whether an establishment exports or not:

$$EXP = f\,(R\&D, \mathbf{X}_1) + u_1; \qquad u_1 \sim N(0,1) \qquad (1)$$

where *EXP* is a 0/1 dichotomous variable which takes on the value 1 if the establishment exports; *R&D* is a 0/1 dichotomous variable which takes on the value 1 if the establishment spends on R&D; $\mathbf{X}_1$ is a vector of other (exogenous) variables that determine exporting; and u_1 is an error term that includes all other random effects.

As written, Equation (1) assumes that R&D is an exogenous determinant of exporting. To allow for a simultaneous relationship we also estimate a (probit) model to determine whether an establishment spends on R&D or not:

$$R\&D = f\,(EXP, AC, \mathbf{X}_2) + u_2; \qquad u_2 \sim N(0,1) \qquad (2)$$

where *AC* measures the absorptive capacity of the establishment in terms of its ability to internalise external sources of knowledge related to its (potential) innovation activities; $\mathbf{X}_2$ is a vector of other (exogenous) variables that determine R&D (with some variables in $\mathbf{X}_2$ also likely to be included in $\mathbf{X}_1$, but $\mathbf{X}_2 \not\in \mathbf{X}_1$); and u_2 is a random error term.

The reduced-form model that determines R&D is therefore obtained by substituting Equation (1) into (2) and rearranging:

$$\text{R\&D} = \text{f}\ (\text{AC}, \mathbf{X}_1, \mathbf{X}_2) + u_3 ; \quad \text{EXP} = \text{f}\ (\text{AC}, \mathbf{X}_1, \mathbf{X}_2) + u'_3 ;$$

$$u_3 ,\ u'_3 \sim N(0,1) \qquad (3)$$

Estimating Equation (3) and obtaining predicted values for *R&D* allows us to replace R&D in Equation (1) by its instrument ($R\hat{\&}D$), thus obtaining the following structural model of the determinants of whether an establishment exports or not (allowing for endogeneity between exporting and R&D):

$$\text{EXP} = \text{f}\ (\text{R}\hat{\&}\text{D}, \mathbf{X}_1) + u_1' ; \qquad u_1' \sim N(0,1) \qquad (4)$$

We have assumed that absorptive capacity enters the model determining R&D, but does not directly determine exporting (although *AC* enters the reduced-form model for exporting, through Equation (2) which shows that R&D – as a determinant of exporting – is itself determined by absorptive capacity). In addition to formally testing whether R&D is endogenous in Equation (1), using a form of the Smith-Blundell test for exogeneity, we also estimate another version of (1) that includes *AC* to test whether this variable is significant or not, with non-significance being an indication that *AC* only determines exporting indirectly through its impact on *R&D*.

V. ESTIMATION RESULTS

Manufacturing

The results for the reduced-form models for the manufacturing sector are presented in Table 2. Table 3 presents the results of exporting modeling for the manufacturing, treating R&D as either exogenous (cf. Equation (1)) or endogenous (cf. Equation

(4)), respectively. Note, stepwise (probit) regression models are estimated[12], and marginal effects are reported. Also the *z*-statistics reported in Table 3 have been 'corrected' when R&D is instrumented, since the latter is generated from the reduced-form model. Maddala (1983, pp. 246-247) provides the relevant formula for the variance-covariance matrix, which we have adopted to use in STATA (although we find very little difference between the standard errors obtained using the standard and corrected variance-covariance matrices).

Comparing the reduced-form results for exporting and R&D (Table 2) shows that certain variables are only significant in one or other of the two equations estimated, and it is these (unique) variables that separately identify structural models for exporting (and R&D).[13] We use this information on which variables are unique to the exporting and R&D reduced-form models in order to test for exogeneity using the Smith-Blundell test available in STATA.[14] As shown in Table 3, the null hypothesis that R&D is exogenous is rejected at better than the 1 per cent significance level.

(Table 2 about here)

(Table 3 about here)

As to the issue of whether absorptive capacity (*AC*) should enter the structural model determining exporting, we found this variable to be insignificant when estimating

[12] Variables were retained in each model that had associated parameter estimates significant at the 15% or better level. In addition, the null hypothesis that the variables dropped had jointly coefficients equal to zero was not rejected at better than the 10% significance level. The full list of variables that entered each model is shown in Table 1.

[13] The presence of such (unique) variables is necessary in order to obtain a valid instrument for R&D in Equation (4). Note, we also treat absorptive capacity (*AC*) as an instrument, given our modelling approach (cf. Equations (1) to (4)) and the fact that (see below) this variable is not significant in the export model (based on estimating Equation (1)).

[14] The *probexog* routine in STATA is used. This is based on the methodology devised by Smith and Blundell (1986), revised for probit (and logit) models. In practice, the *EXP* variable is regressed on both those variables that are significant in determining the reduced-form export model (see Table 2), plus an instrumented R&D variable where R&D was instrumented by the establishment size dummies, *AC*, single-plant status, and the ">1 SIC multiplant" dummy. 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).

Equation (1). The reduced-form models for exporting and R&D (Table 2) also show that *AC* has a much larger impact in determining R&D and a relatively small effect upon exporting. Thus, we take this as evidence that this variable impacts on whether an establishment exports (or not) via its (highly significant) impact on R&D, rather than through any direct impact of its own.

In terms of the determinants of exporting, when R&D is treated as exogenous, the impact of an establishment undertaking R&D spending is to significantly increase the probability that it also exports by almost 17 per cent. However, this impact of R&D on exporting drops to less than 7 per cent, when we take into account the simultaneous relationship between exporting and R&D.[15] Thus incorrectly treating R&D as exogenous leads to an upward bias in the strength of the exporting-R&D relationship, and in general undertaking R&D has only a relatively small impact on the decision to export at the establishment level in Great Britain.

In what follows, we concentrate on the results where R&D is taken to be endogenous, although generally there is little difference in estimated parameter values for the other (non-R&D) determinants of exporting. First and foremost, establishment-specific characteristics seem to play a major role in determining the probability of entering into international markets. For instance, 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 exporting by 8.4%; while having 50-199 workers increased the probability by 13.1%. This confirms the results found in the literature that size and the propensity to export are positively related (see Section II for a

[15] We have also estimated the model of the determinants of R&D, with exporting treated as exogenous/endogenous, with associated marginal effects of 0.144 and 0.049, respectively (both estimates are significant at the 1% level or better). Full details are not reported here but are available on request.

discussion). In addition to establishment size, the size of the enterprise was also important in determining which establishments had non-zero exports. A doubling of enterprise size (from the mean of 34 employees) resulted in a 5.1% increase in the likelihood of the establishment exporting in 2004. Meanwhile, doubling the age of establishments from its mean value of nearly 11 years increased the probability of exporting by just over 3%.

Establishments with higher labour productivity were also more likely to enter export markets; a doubling of this variable (from its mean value of just over £68k turnover per worker) increased the probability of exporting by nearly 8%. Establishments that belonged to enterprises that operated plants in more than one region were (*cet. par.*) over 8% less likely to export. In contrast, foreign-owned establishments had significantly higher export propensities (e.g. being US-owned resulted in a 34.2% higher probability of exporting, while other foreign-owned establishments were 23% more likely to export, compared with their UK-owned counterparts).

Selling to national markets had a significant impact on increasing the likelihood that the establishment was also engaged in exporting abroad (the probability of exporting was over 32% greater for such establishments). Data are also available on whether establishments had engaged in co-operation on innovative activities with overseas organisation; the results presented in Table 3 show that (*cet. par*.) those that did were some 17 % more likely to export. Moreover, as indicated by the insignificant estimated parameters of some variables related to market failures, in the context of the establishment's innovation activities (e.g. a lack of information on technology, high innovation costs, impact of regulations, etc.), none of these factors capturing obstacles to innovation seemed to constitute barriers to export-market entry.

However, establishments that received government support for innovation activities were also more likely to export (an increase of nearly 8%).

As far as the market or industry is concerned, the results in Table 3 indicate that industry/market concentration and agglomeration were both 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), increased the (*cet. par.*) probability of exporting by around 14%. Similarly, a 5-fold increase in the percentage of industry output (at the 5-digit SIC level) in the local authority district in which the establishment was located would have resulted in a 7% increase in the probability of exporting.

Regional impacts are significant as well – being located in the South East region resulted in a higher propensity to export by some 7.3%; the other regions included in the results were between 6 – 8% less likely to export. Sector also mattered; those with the highest propensities to export were (*cet. par.*) *chemicals, basic metals*, and *machinery & equipment*. None of the other variables entered (see Table 1) proved to have a significant impact on establishment's entry into international markets (e.g. industry diversification, whether the establishment belonged to an enterprise operating in more than one industry or the Greater South East).

Non-manufacturing

Table 5 presents the results for non-manufacturing, again based on different models involving the different treatment of R&D. We use the information on which variables are unique to the exporting and R&D reduced-form models (based on their statistical significance levels in Table 4) in order to test for exogeneity using the

Smith-Blundell test.[16] As shown, the null hypothesis that R&D is exogenous is rejected.

(Table 4 about here)

(Table 5 about here)

As to the issue of whether absorptive capacity (AC) should enter the structural model determining exporting, we find this variable to be insignificant when estimating Equation (1). The reduced-form models for exporting and R&D (Table 4) also show that absorptive capacity had a much larger impact in determining R&D and a relatively small effect upon exporting. Thus, as with the case for the manufacturing results, we take this as evidence that this variable impacts on whether an establishment exports (or not) via its (highly significant) impact on R&D, rather than through any direct impact of its own.

When R&D is treated as exogenous, the impact of R&D spending was to increase the probability that an establishment also exported by more than 6%. However, when we take account of the simultaneous relationship between exporting and R&D, the impact of R&D on exporting was (as expected) much smaller at around 2.5%.[17] Compared with the results for manufacturing, the exporting-R&D relationship was much weaker in the non-manufacturing sector.

As with manufacturing, we concentrate on the parameter estimates obtained for the second model where R&D is taken to be endogenous. The size of the establishment

[16] The EXP variable is regressed on both those variables that are significant in determining the reduced-form export model (see Table 4Table 4), plus an instrumented R&D variable (R&D was instrumented by establishment size 50-199 and 200+ employees, *ln* enterprise size, *AC*, and dummies for barriers to innovation covering lack of qualified staff and availability of finance).
[17] We have also estimated the model of the determinants of R&D in non-manufacturing, with exporting treated as exogenous/endogenous, with associated marginal effects of 0.068 and 0.037, respectively (both estimates are significant at the 1% level or better). The full results are available on request.

had a positive impact on whether any exporting took place; vis-à-vis the baseline group (establishments employing less than 20), *cet. par.*, moving to 20-49 employees increased the probability of exporting by 1.8%; 50-199 workers increased the probability by 1.9%. These values are considerably smaller than those reported for manufacturing (Table 3).

Those establishments with higher labour productivity were also more likely to enter export markets; a doubling of this variable (from its mean value of just over £62k turnover per worker) increased the probability of exporting by nearly 6%. Again, this is a smaller impact than that obtained for manufacturing. Establishments that belonged to enterprises that operated plants in more than one region were (*cet. par.*) over 3% more likely to export, which is in contrast with the manufacturing model where the impact of this variable was negative. However, and in line with manufacturing, being under foreign control increased exporting, with US-owned establishments nearly 18% more likely to export, while other foreign-owned had 10.8% higher probabilities of selling overseas.

Selling to national markets had a significant impact on increasing the likelihood that the establishment was also engaged in exporting abroad (i.e. the probability of exporting was nearly 19% greater for such establishments, although this is significantly lower when compared with the results presented in Table 3 for manufacturing). Establishments engaged in international co-operation on innovative activities were around 11% more likely to export. Establishments that received government support for innovation activities were also some 6% more likely to sell overseas. In line with the results obtained for manufacturing, none of the variables capturing innovation-related market failures had any adverse impact on the export-market entry.

Contrary to the case in manufacturing, the external localisation of establishments in the services sector does not seem to play a significant role in determining their decision to export. Specifically, the results in Table 5 show that industry agglomeration was only marginally linked to a greater probability of exporting in the non-manufacturing sector; a 5-fold increase in the percentage of industry output (at the 5-digit SIC level) in the local authority district in which the establishment was located would have resulted in a merely 4% increase in the probability of exporting. This could in part be explained by lower level of industrial agglomeration in the services compared with the manufacturing sector. Moreover, vis-à-vis the results from the manufacturing sector, increasing the Herfindalh index of market concentration did not boost the probability of an establishment going international.

Regional impacts exhibited a different pattern to those in manufacturing. For instance, all the regions of southern England plus Scotland had higher propensities to export (between 3 – 6% more likely to export). Sector also mattered; the sectors with the highest propensities to export were (*cet. par.*) *the R&D sector, transport support, wholesale trade* and *computing*. Again, none of the other variables entered in the model (see Table 1) proved to impact on the establishment's propensity to export.

VI. CONCLUSION

There is a strong expectation in the literature that exporting and innovation activities (particularly R&D) are strongly related, and that the need to be innovative is increasing over time due to globalisation. In this study, we find that R&D is endogenous in a model that determines which British establishments enter export markets, and when such simultaneity is taken into account the strength of the export-innovation relationship is generally quite weak (especially in the non-manufacturing sector).

Rather, we find that establishment and firm size, foreign ownership, the extent of international co-operation, and most importantly the industry sector to which the establishment belongs, are more important in explaining which establishments are able to overcome entry barriers into overseas markets. There are some important differences between the manufacturing and non-manufacturing sectors; for example, agglomeration and market structure have a stronger role in manufacturing, and there are some interesting differences when looking at the impact of location (in terms of region) on who exports.

From a policy perspective, given the differing needs of (potential) exporters (i.e. the internal resources available to them), our results suggest that government assistance needs to be flexible so as to reflect the heterogeneous nature of firms. In particular, we find little evidence (given the data available) to suggest that market failure is a key barrier to exporting, and this suggests that policies might instead need to concentrate on helping firms in particular sectors to acquire certain characteristics (e.g. larger size, higher productivity, greater absorptive capacity and learning capabilities) so as to confer the ability to overcome sunk costs that act as barriers to entry into international markets.

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APPENDIX

Construction of the merged CIS-ARD dataset

The Community Innovation Survey 2005 dataset (CIS4) is a cross-sectional survey of innovation activities covering 2002-2004, including the characteristics of the reporting unit surveyed (e.g. turnover, employment and, most importantly here, whether it exported). Covering most sectors of the economy, the CIS4 dataset contains 16,445 observations from a selected sample of 28,000 who were approached by the ONS, and thus the survey response rate was nearly 59%.[18] Ancillary information in the 2003 Annual Respondents Database (2003 ARD), mostly related to ownership characteristics and external localisation of the establishments, is merged into the CIS4 to create the current dataset for use in analysis of what determines exporting, since IDBR reference numbers are common to both datasets. Here ARD data are used at reporting unit (i.e. establishment) level to ensure comparability with the CIS4 data; where necessary, plant level ARD information has been aggregated to reporting unit level. We have been able to match 14,299 of these establishments in CIS4 with the 2003 ARD. The non-merged CIS4 data mostly include Northern Ireland (accounting for 63% of the non-matched observations) and financial services (accounting for 31%), both of which are not included in the 2003 ARD. The remaining 5% of non-matched observations comprise mostly those that started operations in 2004.

The matching procedure seems to give rise to two potential problems in our merged dataset. Firstly, strictly speaking, CIS4 should be merged with the 2004 ARD (rather than the 2003 version), since the CIS4 sample were based on the population of establishments as existing in the 2004 IDBR, but 2004 data are not yet available.

[18] See http://www.dti.gov.uk/innovation/innovation-statistics/cis/cis4-sample/page11777.html.

Therefore using only 2003 data for the ARD means that CIS4 establishments that started up in 2004 are excluded from any matching of CIS4 and the 2003 ARD. Nevertheless, this is unlikely to be problematic as those start-ups in 2004 only comprise less than 5% of the non-matched observations. In addition, CIS4 covers only those with 10+ employees; nevertheless, in practice this results in some 8% (weighted) of the establishments covered having employment of less than 10, for the IDBR information includes a level of inaccuracy due to the timing of the information obtained on employment, and some units when sampled may have downsized by the time they received the CIS questionnaire. Table 1 below sets out the list of variables used in our empirical modelling.

Table 1. Variable definitions used in CIS-ARD merged dataset for 2004

Variable	Definition	Source
Export	Whether the establishment sold goods and services outside the UK (coded 1) or not at any time over the period 2002-2004	CIS4
R&D	Whether the establishment undertook any R&D as defined in the text (coded 1) or not over the period 2002-2004	CIS4
Size	Establishment size broken down into size-bands	CIS4
Enterprise size	Enterprise size (no. of employees)	ARD
Age	Age of establishment in years (manufacturing only)	ARD
New	Dummy coded 1 if establishment was started after 1 January 2000.	CIS4
Labour productivity	Establishment turnover per employee in 2004	CIS4
Absorptive capacity	Establishment level index (see text for details)	CIS4
Single plant	Dummy coded 1 when establishment *i* is a single plant in year *t*	ARD
>1 SIC multiplant	Dummy variable =1 if establishment belongs to enterprise operating in more than one (5-digit) industry	ARD
>1 region multiplant	Dummy variable =1 if establishment belongs to multiplant enterprise operating in more than 1 UK region	ARD
US-owned	Dummy coded 1 if establishment *i* is US-owned at time *t*	ARD
Other foreign-owned	Dummy coded 1 if establishment *i* is other-owned at time *t*	ARD
Sales market	Which market sold to (separate dummy variables for local, regional, national and international)	CIS4
Co-op	Whether the establishment had engaged in co-operation on innovative activities (coded 1) in 2004	CIS4
International Co-op	Whether the establishment had engaged in overseas co-operation on innovative activities (coded 1) in 2004	CIS4
Support	Whether the establishment had received any public support (financial or other) for innovation-related activities (coded 1) in 2004	CIS4
Barriers to innovation[a] (10 factors identified in CIS)	Excessive perceived economic risks	CIS4
	High costs of innovation	CIS4
	Cost of finance	CIS4
	Availability of finance	CIS4
	Lack of qualified personnel	CIS4
	Lack of information on technology	CIS4
	Lack of information on markets	CIS4
	Market dominated by established enterprises	CIS4
	Uncertain demand for innovation	CIS4
	Impact of regulations	CIS4
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
Industry	Establishment industry SIC (2-digit)	CIS4
GO regions	Dummy variable =1 if establishment located in particular region	CIS4
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.

Table 2. Weighted reduced-form probit models of determinants of exporting and R&D in GB manufacturing, 2004

Independent variables \ Dependent variable	Exports $\partial\hat{p}/\partial x$	Exports z-value	R&D $\partial\hat{p}/\partial x$	R&D z-value	$\overline{X}$
Establishment size					
10-19 employees	-0.035	-0.62	0.135	2.13	0.299
20-49 employees	0.061	1.05	0.148	2.36	0.360
50-199 employees	0.114	1.76	0.212	3.03	0.222
200+ employees	-0.010	-0.12	0.225	2.65	0.073
Other factors					
ln enterprise size	0.047	2.82	0.016	1.03	3.530
Absorptive capacity	0.043	3.63	0.218	18.71	0.196
Single-plant enterprise	-0.032	-0.93	0.078	2.57	0.799
Age of establishment	0.003	2.35	-0.001	-1.11	10.697
Industry agglomeration	0.013	3.79	-0.001	-0.34	1.557
ln Herfindahl index	0.055	3.80	0.015	1.16	-2.910
ln Labour productivity	0.078	4.77	0.009	0.62	4.226
>1 region multiplant	-0.108	-2.45	0.078	1.77	0.102
>1 SIC multiplant	0.022	0.82	-0.067	-2.83	0.222
Sells to national markets	0.340	15.70	0.123	5.17	0.771
US-owned	0.343	7.84	0.017	0.33	0.031
Other foreign-owned	0.227	5.54	-0.028	-0.79	0.062
International co-op	0.194	4.85	0.197	4.68	0.080
Support	0.109	3.50	0.199	6.33	0.132
Region					
North East	-0.039	-1.05	-0.074	-2.26	0.039
North West	-0.068	-2.05	-0.002	-0.05	0.124
Yorks-Humberside	-0.093	-2.85	-0.042	-1.31	0.104
South East	0.062	1.72	-0.029	-0.92	0.126
Wales	-0.075	-2.06	-0.046	-1.3	0.042
Scotland	-0.081	-2.06	-0.086	-2.39	0.065
Industry (2-digit 1992 SIC)					
Food & Drink	-0.139	-3.53	0.021	0.51	0.070
Textiles	0.120	1.91	-0.039	-0.65	0.029
Wood products	-0.216	-4.26	-0.025	-0.48	0.041
Chemicals	0.230	3.88	-0.013	-0.22	0.036
Rubber, plastics	0.138	3.27	0.005	0.13	0.072
Basic metals	0.218	2.71	0.002	0.03	0.020
Fabricated metals	0.110	3.52	-0.064	-2.24	0.194
Machinery, equipment	0.288	8.55	0.089	2.41	0.102
Electrical machinery	0.114	3.05	0.036	0.98	0.069
Medical etc instruments	0.181	3.72	0.054	1.09	0.042
N	4142		4142		
Psuedo R^2	0.25		0.22		

Note, models of exporting and R&D are estimated based on Equation (3).; population weights are available in CIS4 data.

Table 3. Weighted structural probit models of determinants of exporting in GB manufacturing, 2004

Variables	R&D exogenous		R&D endogenous[a]	
	$\partial \hat{p} / \partial x$	z-stat	$\partial \hat{p} / \partial x$	z-stat[b]
R&D	0.166	7.52	0.067	3.39
Establishment size				
20-49 employees	0.087	3.60	0.084	3.49
50-199 employees	0.136	5.24	0.131	5.01
Other factors				
ln enterprise size	0.053	4.86	0.051	4.58
Age of establishment	0.003	2.64	0.003	2.69
Industry agglomeration	0.014	3.83	0.014	3.85
ln Herfindahl index	0.052	3.57	0.053	3.64
ln Labour productivity	0.080	4.94	0.079	4.88
>1 region multiplant	-0.085	-2.23	-0.084	-2.25
US-owned	0.341	7.66	0.342	7.85
Other foreign-owned	0.230	5.65	0.230	5.66
Sells to national markets	0.331	14.95	0.322	13.86
Impact of regulations	-0.059	-1.82	–	–
International co-op	0.179	4.47	0.165	3.78
Support	0.082	2.63	0.075	2.16
Region				
North West	-0.057	-1.74	-0.065	-1.95
Yorks-Humberside	-0.078	-2.41	-0.083	-2.55
South East	0.083	2.31	0.073	2.05
Wales	-0.062	-1.75	-0.066	-1.84
Scotland	–	–	-0.061	-1.54
Industry (2-digit 1992 SIC)				
Food & Drink	-0.148	-3.72	-0.144	-3.67
Textiles	0.120	1.92	0.127	2.03
Wood products	-0.219	-4.34	-0.214	-4.22
Chemicals	0.242	4.13	0.234	3.95
Rubber, plastics	0.142	3.36	0.136	3.24
Basic metals	0.219	2.68	0.217	2.67
Fabricated metals	0.114	3.65	0.118	3.77
Machinery, equipment	0.275	7.96	0.271	7.89
Electrical machinery	0.116	3.10	0.106	2.28
Medical etc instruments	0.183	3.82	0.171	3.49
N	4142		4142	
Psuedo R^2	0.25		0.24	
Smith-Blundell test χ^2(1 df)	12.87			

[a] R&D was replaced by its predicted value ($R\hat{\&}D$) in the endogenous model. These values were obtained from estimating Equation (3) (*c.f.* Table 2). [b] The z-statistics reported here have been 'corrected' when R&D is instrumented, using the formula for the variance-covariance matrix provided in Maddala (1983).
Population weights are available in CIS4 data.

Table 4. Weighted reduced-form probit models of determinants of exporting and R&D in GB non-manufacturing, 2004

Independent variables \ Dependent variable	Exports $\partial\hat{p}/\partial x$	Exports *z*-value	R&D $\partial\hat{p}/\partial x$	R&D *z*-value	$\overline{X}$
Establishment size					
20-49 employees	0.018	1.41	0.008	0.53	0.347
50-199 employees	0.018	1.08	0.035	1.74	0.162
200+ employees	0.002	0.09	0.091	2.37	0.043
Other factors					
ln enterprise size	0.001	0.14	-0.018	-2.39	3.128
Absorptive capacity	0.017	3.38	0.163	24.01	-0.005
Industry agglomeration	0.009	3.79	0.003	0.96	0.776
ln Labour productivity	0.029	5.75	0.008	1.33	4.134
>1 region multiplant	0.028	1.59	-0.003	-0.15	0.087
Sells to national markets	0.192	16.78	0.042	3.22	0.496
US-owned	0.181	2.56	0.010	0.20	0.012
Other foreign-owned	0.100	2.91	-0.039	-1.42	0.032
International co-op	0.125	3.90	0.096	2.73	0.049
Support	0.078	3.47	0.171	5.62	0.070
Lack of qualified personnel	-0.015	-0.86	0.058	2.45	0.073
Availability of finance	0.027	1.57	0.042	2.02	0.097
Region					
Eastern	0.043	2.31	-0.001	-0.04	0.097
London	0.054	2.95	-0.015	-0.77	0.162
South East	0.028	1.72	-0.004	-0.24	0.152
South West	0.045	2.23	0.001	0.06	0.089
Wales	-0.010	-0.49	-0.038	-1.82	0.037
Scotland	0.056	2.63	-0.020	-0.93	0.082
Industry (2-digit 1992 SIC)					
Wholesale trade	0.254	9.61	0.064	2.58	0.134
Transport	0.107	4.25	-0.023	-1.16	0.036
Transport support	0.258	5.95	0.026	0.83	0.019
Post & telecoms	0.127	3.91	0.073	2.28	0.018
Financial services	0.052	1.65	0.125	3.16	0.016
Machine rental	0.062	1.78	0.025	0.69	0.028
Computing	0.260	6.75	0.233	5.77	0.047
R&D sector	0.320	6.07	0.172	3.56	0.028
Other business services	0.187	9.69	0.087	4.83	0.190
N	9119		9119		
Psuedo R^2	0.29		0.26		

See Table 2 for notes.

Table 5. Weighted structural probit models of determinants of exporting in GB non-manufacturing, 2004

Variables	R&D exogenous		R&D endogenous	
	$\partial\hat{p}/\partial x$	z-stat	$\partial\hat{p}/\partial x$	z-stat
R&D	0.062	5.05	0.025	3.23
Establishment size				
20-49 employees	0.020	1.77	0.018	1.63
50-199 employees	0.023	1.79	0.019	1.53
Other factors				
Single-plant enterprise	0.023	1.73	–	–
Industry agglomeration	0.009	4.35	0.008	3.72
ln Labour productivity	0.029	5.71	0.028	5.53
>1 region multiplant	0.056	2.49	0.031	2.08
US-owned	0.175	2.52	0.179	2.55
Other foreign-owned	0.106	3.00	0.108	3.09
Sells to national markets	0.192	17.14	0.188	16.27
International co-op	0.129	3.94	0.114	3.55
Support	0.072	3.21	0.061	2.64
Region				
Eastern	0.046	2.51	0.043	2.36
London	0.057	3.11	0.057	3.10
South East	0.031	1.94	0.030	1.85
South West	0.044	2.19	0.046	2.28
Scotland	0.060	2.80	0.060	2.82
Industry (2-digit 1992 SIC)				
Wholesale trade	0.247	9.44	0.244	9.27
Transport	0.104	4.22	0.110	4.32
Transport support	0.253	5.87	0.254	5.89
Post & telecoms	0.123	3.78	0.117	3.66
Financial services	–	–	0.038	1.26
Machine rental	0.059	1.72	0.059	1.72
Computing	0.233	6.16	0.227	5.78
R&D sector	0.303	5.90	0.294	5.55
Other Business services	0.176	9.45	0.176	8.98
N	9199		9199	
Psuedo R^2	0.30		0.29	
Smith-Blundell test χ^2(1 df)	4.78			

See Table 3 for notes.