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Sectoral and Firm-Specific Determinants of Export Performance: Evidence from the United Kingdom

by

Michael Bleaney and Katharine Wakelin

Centre for Research on Globalisation and Labour Markets, School of Economics, University of Nottingham

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The Authors

Michael Bleaney is Professor of Macroeconomics and Katharine Wakelin is Research Fellow in the School of Economics, University of Nottingham.

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Abstract

Trade-theoretic and firm-specific determinants of the share of output exported are investigated for a sample of British manufacturing firms. Export shares are higher in sectors with higher R&D expenditures as a proportion of output. We find that R&D expenditures allocated by first application of the innovation (e.g. through purchases of new capital goods produced in another sector) perform better than the standard measure. There is only weak evidence in support of factor endowment theories of trade. The firm-specific influences emerge as important and are consistent with previous research that finds better-performing firms to be more likely to export.

Outline

1. Introduction
2. Theory
3. The Empirical Model
4. The Results
5. Conclusions

1 Introduction

There is a long history of empirical testing of trade theory based on data aggregated to a sectoral level, with somewhat mixed results (Bowen and Sviekauskaus, 1992; Leamer and Levinsohn, 1995). Very recently, the export activity of individual firms has been the focus of a significant body of research (Aitken *et al*., 1997; Bernard and Jensen, 1999; Bernard and Wagner, 1997; Clerides *et al*., 1998; and Roberts and Tybout, 1997). The theme of this recent research is that (perhaps in part because of product market imperfections) there can be substantial differences in efficiency between firms at any point in time. Issues investigated include: whether exporting generates learning that improves firm performance; whether exporting is more likely if more local firms are exporters; and whether prior export experience matters. The underlying theory is that there are fixed costs of exporting which deter those firms that are below a threshold level of efficiency, because their prospective profits from exporting do not compensate for the additional costs; the findings of the papers cited above tend to be consistent with this model.

The idea of firm heterogeneity is not difficult to integrate into traditional trade theory by allowing for a stochastic X-efficiency element in the production function at the firm level. In cross-industry regressions this heterogeneity would just add an extra element to residual variance and, provided that the number of firms per industry per country is not too small, net export flows at the sectoral level should remain largely unaffected because of the averaging effect.

The existence of firm-level data on exports raises the possibility that such a data set might be exploited to test the predictions of trade theory simultaneously with the relationship between exporting and firm performance. Nevertheless, previous work on export behaviour of firms has always concentrated on intra-sectoral variation, taking out inter-sectoral effects with industry dummies. The innovation of the present paper is that we model firms' export activity in both intra-sectoral and inter-sectoral dimensions, by nesting firm-specific and trade-theoretic variables within the same model. We apply this procedure to a data set of manufacturing firms in the United Kingdom. We find both sectoral and firm-specific effects to be important. The sectoral effects are more consistent with product cycle theories of international trade than with factor endowment theories: research and development (R&D) expenditure significantly affects export activity, but human and physical capital intensities do not. A feature of our model is that we consider two different measures of R&D expenditure, one based on the sector's own expenditures and one that allows for the effect of being the first user of an innovation developed in another sector. We find that the latter measure performs better.

The paper is structured as follows. Theory is discussed in Section 2. The empirical model is set out in Section 3. Empirical results are presented and evaluated in Section 4. Section 5 concludes.

2 Theory

If firms within an industry vary significantly in efficiency and other characteristics, then one would expect the export activity of an individual firm to be influenced by a combination of comparative advantage factors – acting at the level of the sector – and the characteristics of the individual firm. Thus the export activity X_{ji} of firm i in sector j will be a function of sectoral characteristics S_j and firm characteristics relative to the sector average F_{ji}.

$$X_{ji} = X(S_j, F_{ji}) \quad (1)$$

The sectoral characteristics which we investigate are the standard ones suggested by trade theory: factor endowments (human and physical capital intensities) and technical innovations. The inclusion of technical innovations reflects the technology gap theory of trade originally suggested by Posner (1961) and formalised by Krugman (1979) and Cimoli (1988), amongst others, together with the product cycle theory of Hirsch (1965) and Vernon (1966). Both these theories assign a crucial role to technological innovation in the structure of trade.

Intra-industry trade represents a complicating factor. Traditional empirical tests of trade theory use net exports of a commodity as the dependent variable, so two-way flows cancel out. In our data set, this does not happen. Firms export or produce for the home market; imports are the products of foreign firms. Export ratios are likely to be higher for UK firms in sectors characterised by intra-industry trade, other things being equal. To control for these effects, we include the Grubel-Lloyd index of intra-industry trade as a regressor.

Firm-specific influences on export activity have been revealed as important in a series of recent studies for the US (Bernard and Jensen, 1999), Germany (Bernard and Wagner, 1997), and a number of developing countries (Aitken *et al*., 1997; Aw and Hwang, 1995; Clerides *et al*., 1998; Roberts and Tybout, 1997). Studies of firm behaviour, whether analysing productivity, profitability, or patterns of innovation, have found that firms differ greatly, and that these differences are often prolonged over time[1]. To quote Bernard and Jensen (1999, pp. 1-2):

"Exporters are better than non-exporters. A growing body of empirical work has documented the superior characteristics of exporting plants and firms relative to those producing solely for the domestic market. Exporters are larger, more productive, more capital-intensive, more technology-intensive, and pay higher wages."

The most obvious reason for this is that there are fixed costs associated with entering export markets, for instance in collecting information, establishing a foreign distribution network and adapting the product to foreign tastes and regulations. To the extent that these costs are sunk costs, uncertainty may cause persistence in export participation: firms may continue to export even though it is temporarily unprofitable, or hesitate to enter the market, because of the option value of awaiting more information (Roberts and Tybout, 1998). Empirical studies to date have treated exporting as a zero-one variable, dividing the sample of firms into exporters and non-exporters. If there are many different export markets, however, with fixed costs associated with each, we can expect to find a relationship between export revenues (appropriately scaled) and performance variables, even amongst those firms that participate in export markets, since the least efficient will find it profitable to export to fewer foreign markets.

3 The Empirical Model

We estimate equation (1) for a sample of 110 UK manufacturing firms quoted on the UK stock market[2]. Only quoted firms are included in the sample as R&D expenditure data are not available for non-quoted firms. The sample is made up of firms chosen randomly from Datastream, which covers all UK quoted firms, but stratified in order to create a bias

[1] See for instance Geroski and Machin (1993) for profitability, Hart and Shipman (1992) for productivity.
[2] For details of the data sources and the sector definitions see the Appendix, and for more detail on the selection and choice of firms see Wakelin (1997) and (1998).

towards firms with a history of major innovations (which form 50% of the sample but a smaller proportion of all quoted firms). The reason for this bias is that only firms with a history of major innovations are included in the Science Policy Research Unit (SPRU) survey of technical innovation, which we use to construct our alternative R&D variable based on the sector of first use of an innovation. Biasing the sample towards firms included in the SPRU survey raises the probability that the alternative R&D measure accurately reflects the situation of the firms in the sample. The data for each firm are for five years from 1988 to 1992 inclusive.

Basic descriptive statistics of the sample are given in the Appendix. Most of the firms export: only 5 out of 110 firms do not do so. For this reason we use the ratio of exports to total sales as the dependent variable, rather than a binary export/non-export specification that is typical of the literature on firm-specific effects on export activity. The chosen specification of the dependent variable is preferable with respect to trade-theoretic determinants of a firm’s exports, since we would expect the trade-theoretic variables to help predict not only whether a firm exports but also how much.

For the purposes of constructing the trade-theoretic variables, we subdivide manufacturing into ten sectors, and generate sector-average values of the set of variables discussed in the previous section. The sector averages are based on published statistics; firm-specific variables are then defined as deviations from this sector average.

The trade-theoretical variables used in the analysis are: (1) the sectoral average wage (total remuneration over total employment), as a measure of human capital intensity; (2) the sectoral capital intensity, as measured by the ratio of capital to sales revenue; and (3) technological innovation in the sector, as captured by the ratio of R&D expenditure to sales revenue. Since firms can gain a technological advantage not only through their own innovations but also through purchases of new capital or intermediate goods from other sectors, we also explore an alternative measure of technological innovation based on information from the SPRU survey about where the innovation is first applied. In this alternative measure, a sector’s own R&D expenditure only counts if it is first used in that sector, because all sectors’ R&D expenditures are reallocated according to the survey information about the sector of first application. To give a simple two-sector example, if the

SPRU survey indicated that 90% of sector A's innovations were first used in sector A and 10% in sector B, but all of sector B's innovations were first applied in sector B, then 10% of sector A's R&D expenditure would be reallocated to sector B. To calculate the alternative R&D measure for sector B, the reallocated R&D expenditures from sector A would be added to sector B's expenditures and then divided by the sales revenue of sector B, as before.

An obvious application of this principle is where R&D expenditure in the mechanical engineering sector is embodied in new capital goods purchased from that sector; the alternative measure reallocates this R&D from mechanical engineering to the sector purchasing the capital goods. The idea is that the purchasing sector reaps benefits from the technical innovation even though it is not recorded as paying for it through its own R&D expenditure. The details of the SPRU survey data and the construction of this alternative measure of R&D use are given in the Appendix[3].

The purpose of measuring R&D by sector of first use in this way is to capture the possibility that R&D expenditures may not be a good measure of the application of technological innovations across sectors, because these costs can be embodied in the price of capital goods which are used in other parts of the economy. As far as we know data on first use of innovations have never previously been used to construct such an alternative measure of the distribution of technological innovations across sectors. There are some parallels, however, with previous efforts to measure the technological proximity of firms. Jaffe (1986) uses patent data classified into 49 technological categories in order to estimate externalities from the R&D effort of firms that have obtained patents in "similar" areas. A distribution vector of patents across different classes is treated as a proxy for each firm's technological space, and the spillover variable is constructed as a weighted average of the R&D expenditures of other firms, with the weights based on the degree of technological proximity (i.e. similarity of the patent distribution vectors). Jaffe finds that patents obtained are positively correlated with both own R&D expenditure and that of "related" expenditure by other firms.

[3] There has been a good deal of literature on knowledge spillovers following the seminal article of Griliches (1979); spillovers arise where the full price of the innovation is not paid by the firm purchasing the capital good. This is not our concern here.

The firm-specific variables that we test include deviations from the sector average in the average wage, capital intensity, R&D expenditure, unit labour costs and firm size as measured by number of employees. These are all variables that have been found significant in previous studies of firms' export activity, as indicated in the earlier quotation from Bernard and Jensen (1999). In the case of firm size, we also test for non-linearities by including the square of the variable in the regression. Firm size is expected to have a positive relationship to exports as larger firms have more resources with which to enter foreign markets. This may be particularly important in overcoming fixed costs to exporting such as gathering information or covering the uncertainty of a foreign market. There may also be economies of production and marketing that benefit large firms.

The complete model is given below in Equation 2:

$$PX = \alpha_t + \beta_1 KSA_s + \beta_2 AW_s + \beta_3 R\&D_s + \beta_4 KSAdev + \beta_5 AWdev + \beta_6 ULCdev + \beta_7 R\&Ddev + \beta_8 SIZE + \beta_9 SIZE^2 + \beta_{10} IIT + \varepsilon \quad (2)$$

Dummy variables are included for each of the five years to capture any variation over time, such as the business cycle or the exchange rate, that may influence the export activity of all firms. The variables are defined as follows: PX is the propensity to export of the firm, measured as exports over output; KSA_s, AW_s, $R\&D_s$ are respectively the sectoral capital intensity, average wage and R&D drawn from published data. We also present results for the alternative measure of R&D, based on R&D first used in the sector (R&D USE). KSAdev, AWdev, ULCdev, R&Ddev are all firm deviations from the sector average, where ULC denotes unit labour costs. They are computed as the firm value less the sector average. SIZE is measured by the number of employees in the firm and IIT is a measure of intra-industry trade in the sector, as measured by the Grubel-Lloyd index (Grubel and Lloyd, 1985), which is equal to one minus the sectoral ratio of the absolute value of the trade balance to the sum of exports and imports. This is necessarily non-negative and would take the value of zero if there was no two-way trade in the sector.

4 The Results

There are two points about the empirical model that raise questions concerning the correct estimation procedure. The first is that there is a small number of firms that have no exports. Second, if the propensity to export is used as an indication of export behaviour, it varies by definition between 0 and 1. As a result OLS regression may not be the most suitable estimation procedure, as it can give estimates which imply predictions of the propensity to export outside the feasible range.

One way of dealing with these problems is to use a Tobit model that is appropriate for censored data. The Tobit model incorporates the decision of whether or not to export and the level of exports relative to sales in one model, i.e. it imposes the same coefficients on the explanatory factors for the two decisions; see Lin and Schmidt (1984) for details. Because the sample of non-exporting firms is so small, however, we also estimate the model excluding the non-exporting firms. This model is estimated by OLS.

A Heckman two-stage selection model was also estimated to check for selectivity biases between the two stages. No evidence was found that selectivity existed. This result indicates that the two decisions of exporting and the propensity to export can be estimated separately. Because of this lack of selectivity bias, no allowance was made for the truncation of the sample in the second estimation including the exporters alone.

The results for the two models are given in Table 1; *t*-statistics are given in brackets using robust standard errors; *n* is the number of observations. The first two columns of results are for the Tobit model estimated for all firms, first using R&D expenditure in the sector and second with R&D USE. The last two columns give the results for the OLS model estimated using the exporting firms alone and with the two alternative R&D measures.

Table 1: Tobit and OLS Models

	Tobit	**Tobit**	**OLS**	**OLS**
Sector Variables				
Average Wage	0.014 (1.51)	0.011 (1.17)	0.016 (1.82) *	0.013 (1.46)
Capital intensity	-0.190 (-1.74) *	-0.164 (-1.49)	-0.072 (-0.67)	-0.045 (-0.42)
R&D exp.	1.344 (2.10) **		0.834 (1.40)	
R&D USE		2.092 (2.69) ***		1.697 (2.34) **
Intra-ind. trade	0.161 (1.60)	0.187 (1.86) *	0.220 (2.26) **	0.237 (2.45) ***
Firm Variables (deviation from sector average)				
Average wage	0.029 (7.76) ***	0.028 (7.55) ***	0.027 (7.54) ***	0.026 (7.31) ***
Capital intensity	-0.021 (-0.99)	-0.022 (-1.04)	0.051 (1.81) *	0.051 (1.81) *

Unit labour costs	-0.008 (-0.06)	-0.012 (-0.08)	-0.258 (-1.90) **	-0.272 (-2.01) **
R&D exp.	0.959 (1.44)	1.038 (1.66) *	1.196 (1.94) **	1.431 (2.46) ***
Firm size	$9.26\ 10^{-6}$ (7.37) ***	$9.07\ 10^{-6}$ (7.23) ***	$7.50\ 10^{-6}$ (6.39) ***	$7.33\ 10^{-6}$ (6.25) ***
Firm size^2	$-7.57\ 10^{-11}$ (-6.37) ***	$-7.43\ 10^{-11}$ (-6.34)***	$-6.40\ 10^{-11}$ (-5.78)***	$-6.37\ 10^{-11}$ (-5.85)***
Loglikelihood	-41.75	-40.36		
$\chi^2(10)$/F(10,372)	140.9 ***	143.7 ***	10.56 ***	10.92 ***
Pseudo R^2/ R^2	0.63	0.64	0.29	0.29
n	408	408	383	383

*** Significant at 1%; ** significant at 5%; * significant at 10%. Dependent variable is exports divided by sales. Year dummies included in the regression. Figures in parentheses are heteroscedasticity-robust *t*-statistics.

Overall, the results are similar using the whole sample and just the exporters. The main difference is that more of the firm deviations are significant in the OLS model.

We begin by discussing the results for the sectoral variables. With either Tobit or OLS estimation, the R&D coefficent is noticeably larger using the measure based on the first application of innovations rather than the straightforward expenditure measure, probably because the new measure captures the impact of technological change more effectively than the standard one (this is consistent with evidence that spillovers of R&D from other firms and sectors are important, e.g. Jaffe, 1986). R&D USE is positive and significant at the 5% level in both forms of estimation, whereas the standard measure of R&D expenditures is not significant in the OLS regression.

Factor endowments, by contrast, do not appear to play an important role in explaining variations in export activity in this sample. The average wage (a proxy for human capital intensity) has a consistently positive coefficient, but only reaches the 10% significance level in one out of four cases. Likewise, physical capital intensity always has a negative coefficient, but again it is only once significant at the 10% level. The measure of intra-industry trade is always positive (as expected) and statistically significant.

The variables capturing the firm's deviation from the sector average are fairly consistently significant, particularly under OLS estimation. Firms with higher average wages, lower unit labour costs, higher capital intensity and higher R&D expenditures all tend to have higher exports. The unit labour cost variable can be interpreted as a measure of efficiency. The average wage effect is particularly statistically significant but more difficult to interpret. It may reflect the composition of the labour force, suggesting that firms with above-average human capital intensity for their sector export more, or it may simply reflect efficiency again, with some of the benefits of greater efficiency being shared with the workforce in above-average wages.

As expected, there is also a positive relationship between the size of the firm and the propensity to export, with larger firms (and this is within a sample of quoted firms with a large average size) exporting a higher proportion of their output. This relationship shows some non-linearity, however, with a negative coefficient on the quadratic size term indicating that the marginal effect diminishes with size, becoming negligible at about 60,000 employees. Overall, however, these results are fully consistent with Bernard and Jensen's (1999) argument that exporters are "larger, more productive, more capital-intensive, more technology-intensive, and pay higher wages".

5 Conclusions

In this paper we have used a firm-level data set to nest firm-specific and trade-theoretic determinants of export activity within the same model. We find strong firm-specific effects that are consistent with previous research on other countries. Amongst the trade-theoretic variables, technological innovation, as measured by R&D expenditure, emerges as the main determinant of exports from the U.K., with much weaker support for the factor endowment theory. We also constructed an alternative measure of technological innovation, adjusting the R&D variable to take account of survey data on the first application of major innovations. This alternative measure performed rather better than the standard one, which suggests that it is a better representation of the impact of technological innovation on the economy.

Appendix

Data Sources

- Data on innovations come from 'Innovation in the UK since 1945' Science Policy Research Unit, University of Sussex, data obtained from the ESRC archive, Essex.
- Additional firm balance sheet data, total sales, exports, total capital, average remuneration, the number of employees, and R&D expenditure came from Datastream.
- Total UK manufacturing output, output, capital stock, total remuneration, the number of employees at the sector level all came from the Central Statistical Office, Report on the Census of Production Summary Volume, PA 1002, from Business Monitor for various years.
- The sector-level R&D expenditure came from First Release, CSO Number 188, 'Business Enterprise Research and Development' various years.
- Manufacturing is defined as being between 2100 and 4992 of the 1968 SIC classification.

Table A1: Descriptive Statistics

Variable	n	Mean	Std. Dev.
Sector Variables			
Average wage	550	12.881	2.463
Capital intensity	550	0.408	0.148
Unit labour costs	550	0.207	0.053
R&D intensity	550	0.028	0.029
R&D Use	550	0.024	0.021
Intra-industry trade	550	0.865	0.143
Firm Variables			
Propensity to export	409	0.438	0.285
Average wage	462	0.522	3.686
Capital Intensity	452	0.226	0.730
Unit labour costs	452	0.012	0.094
R&D	457	-0.014	0.028
Size (number of employees)	459	13866	23745

The R&D USE variable

For our analysis we take account of the diffusion of innovation from other sectors in the economy using an R&D-based indicator. It is necessary to apply a weighting system to R&D expenditure, as not all sectors in the economy will have the same technological distance from each other. In this case a matrix based on the use and production of innovations has been created from the Science Policy Research Unit (SPRU) survey of major UK innovations. Eighteen sectors are used to calculate the input-output table.

The survey is a unique source of information on innovation diffusion in the UK. It covers all major innovations to occur in the UK between 1945 and 1983. Firms were surveyed to find information on innovations, and this was subsequently analysed by a group of technical experts for each sector who decided which innovations were to be counted as ‘significant’. Significance was defined as ‘the successful commercial introduction of new or improved products, processes or materials’ to the UK. The aim of the survey was to be exhaustive. The entire period of the survey 1945-1983 is used to make the matrix; however, using the last five years of the survey alone makes little difference to the pattern found. The pattern of use and production of innovations is very stable over time (Wakelin, 1997; see also Pavitt *et al*, 1987 for more information on the data).

The survey covers over four thousand innovations implemented by 1845 firms. The sector in which the innovation is produced is known, as is the sector in which the innovation is first used. Together these are combined to create an input-output matrix of innovation (see later in the Appendix), which indicates the diffusion of innovation between sectors. The diagonal terms of this matrix give the innovations that were produced and first used in the same sector. For instance, in the case of the mechanical engineering sector, out of 856 innovations, 338 were first used within the sector (or 40%). The off-diagonal elements of the matrix give the flows of innovations among sectors. Taking the same sector, 236 innovations originating in the mechanical engineering sector were first used in the chemical and man-made products sector (around 28% of the total).

In order to weight the importance of sector i’s R&D expenditure for sector j, it is multiplied by the proportion of sector i’s innovations first used in sector j over sector i’s total innovations (W_{ji}). In this example the R&D expenditure of the mechanical engineering sector is weighted by 236/856 to give the proportion used to the chemical sector. The weighted R&D gives the diffusion of R&D to sector j in which the firm is located. This is added to the proportion of innovation used in the same sector, which is weighted by the diagonal elements of the matrix over the total innovations in that sector (W_j). This proportion is multiplied by the sector's own R&D expenditure to give the proportion of that sector’s R&D first used within the sector. This composite R&D indicator is then divided by the total sales in sector j in order to give an indicator of the R&D expenditure first used in the sector. The indicator is given by:

$$R\&D\,USE_j = \sum_{i\neq j} W_{ji}R_i + W_j R_j \Big/ Q_j$$

Where R is R&D expenditure, W is the weighting system based on the innovation matrix and Q is output.

The survey has some limitations. Only the place of first use of the innovation is known, so diffusion of the innovation after the first user is not captured. As a result, the matrix may understate the actual diffusion of each innovation that takes place across sectors. In addition, the survey includes only major innovations rather than small or incremental innovations; this omission will also have the effect of underestimating the level of innovation.

Table A2: Sectors used for the spillover matrix

Sector (1980 SIC code)	
1. Metal manufacturing (22)	10. Instrument engineering (37)
2. Non-metallic manufacturing (24)	11. Food, drink and tobacco (41/42)
3. Chemical and man-made products (25 & 26)	12. Textiles (43)
4. Other metal goods (31)	13. Leather goods (44)
5. Mechanical engineering (32)	14. Footwear and clothing (45)
6. Office and data machinery (33)	15. timber (46)
7. Electrical and electronic machinery (34)	16. Paper & printing 947)
8. Motor vehicles and parts (35)	17. Rubber and plastics (48)
9. Other transport (36)	18. Other manufacturing (49)

Table A3: Matrix used in construction of R&D USE

Matrix of Use and production matrix of innovations 1945-1983 in 1980 SIC classification																			
	Using Sector																		
Producing sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1	92			1	21		2	2	2	1						1			122
2	11	69	1	1	6		1	7	6	5	2								109
3	1	3	220		21	1	3	14	4	21	2	4	8	9	2	12	11	4	340
4	2		3	53	15		5	2	19		4				1		1		105
5	34	18	236	6	338	4	3	17	15	61	26	2	6	1	2	82	5		856
6			1		1	35	2		1	3				4		8			55
7		1		2	6	8	179	15	20	43						2			276
8					6			98	4		1								109
9							1	1	125	2		1		1		2			133
10	6	2	41		47	6	31	10	13	115	4			3		11	1	1	291
11										2	53								55
12								1	1			1							3
13								4		2			22						28
14												1		6					7
15					1										6				7
16		1	2		3		1	1	1	2	5					47			63
17			6	2	5		1	11	1	1	1		1		1	1	22	1	54
18																		14	14
Total	146	94	510	65	470	54	229	183	212	258	98	9	37	24	12	166	40	20	2627

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