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The Export-Growth Relationship: Estimating a Dose-Response Function

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Estimating a Dose-Response Function**

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Zentrum für Europäische
Wirtschaftsforschung GmbH

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Non-technical Summary

The relationship between individual firms' export behaviour and firm performance has been studied extensively in the economic literature. Most studies from the field of economics only distinguish between exporting and non-exporting companies. Whether or not exporting has a positive effect on firm performance might, however, not only depend on a firm's export status, but might be a function of the *extent* of the firm's export activities. On the one hand, there are firms that only occasionally receive some unsolicited orders from abroad, whereas, on the other hand, some firms pro-actively exploit the potential of the foreign market, generating a high percentage of their total sales abroad.

This paper introduces the newly developed generalised propensity score method (GPS) to the literature examining the export-performance relationship. Similar to traditional matching techniques that are based on a binary treatment variable (e.g., the firms' export status), the GPS method removes all the bias associated with firm-specific differences between exporting and non-exporting firms. However, the GPS method allows for continuous treatment, that is, in our case, different levels of the firms' export activities.

The GPS method is illustrated using a data set of about 200 young technology-oriented firms in Germany and the UK. Using the GPS method, a dose-response function is estimated that depicts the conditional expectation of the firms' sales growth rate (as a measure of firm performance) given the level of export activities and the generalised propensity score. The estimated dose-response function confirms the inverted *U*-shaped relationship between the degree of internationalisation (measured as the share of exports in total sales) and firm performance that has frequently been found in studies from the field of international management.

The Export-Growth Relationship: Estimating a Dose-Response Function

by

Helmut Fryges*

April 2006

Abstract: The relationship between individual firms' export behaviour and firm performance has been studied extensively in the economic literature. However, most studies from the field of economics only distinguish between exporting and non-exporting companies, using the firms' export status as a binary treatment variable and comparing the performance of exporting and non-exporting firms. This paper introduces the newly developed generalised propensity score (GPS) methodology to the literature of individual firms' export behaviour. Instead of a binary treatment variable, the GPS method allows for continuous treatment, that is, different levels of the firms' export activities. Based on the GPS methodology, a dose-response function is estimated, depicting the relationship between the firms' pre-treatment export-sales ratio and their subsequent sales growth rate as a measure of firm performance.

Keywords: *Degree of internationalisation, continuous treatment, generalised propensity score, dose-response function, high-technology industries.*

JEL Classification: *F23, L60, L86*

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1 Motivation

The relationship between individual firms' export behaviour and firm performance has been studied extensively in the economic literature since the mid 1990s. Wagner (2005) surveys 45 microeconomic studies with data from 33 countries published between 1995 and 2004. He concludes that "exporters are more productive than non-exporters, and that the more productive firms self-select into the export markets, while exporting does not necessarily improve productivity" (Wagner 2005: 12). In addition to the firms' productivity, other measures of firm performance have been examined, among them (employment and sales) growth (e.g., Bernard and Jensen 1999; Fryges 2004), wages (e.g., Wagner 2002) and the probability of survival (e.g., Bernard and Wagner 1997; Bernard and Jensen 1999). In most cases, these studies confirm Wagner's conclusion: The superior performance of internationally active firms is a result of self-selection of "good" firms into the international market. Conversely, there is little evidence that internationalisation has a causal effect on firm performance.

However, most of the studies cited above only distinguish between exporting and non-exporting companies. The firms' export status is used as a binary treatment variable and the performance of exporting and non-exporting firms is compared applying different econometric methods (e.g., simultaneous equation models, matching techniques). Whether or not exporting has a positive effect on firm performance might, however, not only depend on a firm's export status, but might be a function of the *extent* of the firm's export activities. On the one hand, there are firms that only occasionally receive some unsolicited orders from abroad, whereas, on the other hand, some firms pro-actively exploit the potential of the foreign market, generating a high percentage of their total sales abroad.

In the economic literature, only few studies investigate the influence of varying degrees of internationalisation on performance, among them the studies by Liu *et al.* (1999) and Castellani (2002) which both find a positive effect of the share of exports in total sales on firm performance. The impact of varying degrees of a firm's international business activities on its performance has, however, frequently been discussed in the international business literature since the 1980s. Early studies hypothesise and empirically confirm a (in most cases positive) linear relationship between the degree of internationalisation and performance (e.g., Bühner 1987 and Grant 1987). More recently published studies postulate a curvilinear relationship: Internationally active firms are assumed to realise economies of scale in production and access new technologies, leading to a higher level of performance the higher the firm's extent of international business activities. However, when a firm increases its international engagement the costs of coordination and control also rise and sometimes begin to escalate when a critical threshold of internationalisation is exceeded. Thus, any further international expansion induces a decrease in performance.¹ Such an inverted *U*-shaped relationship is empirically supported by research by Geringer *et al.* (1989) and Gomes and Ramaswamy (1999). Some empirical studies even argue in favour of multiple waves in the relationship between a firm's level of foreign involvement and its performance (cf. Hitt *et al.* 1994, Sullivan 1994a, and Riahi-Belkaoui 1998).

The studies from the field of economics and those from the field of international business research differ from each other with respect to the applied econometric method. Wagner (2002) introduced matching techniques to the literature that empirically analyses the export-performance relationship. His analysis was restricted to the case where

¹ See Gomes and Ramaswamy (1999) for an overview of theoretical arguments on how a firm's degree of internationalisation may be linked with its performance.

the treatment is binary: All exporting firms are matched to a non-exporting firm with the same or a very similar propensity score that results from a probit regression estimating the individual firm's probability of having international sales. Imbens (2000) and Hirano and Imbens (2004), however, extend this traditional propensity score methodology that was developed by Rosenbaum and Rubin (1983) by defining a generalisation of the binary treatment propensity score, which they label the generalised propensity score (GPS). The GPS method allows for continuous treatment, that is, in our case, different levels of the firms' export activities. Imbens (2000) shows that, similarly to the case of binary treatment, adjusting for the GPS removes all the bias associated with differences in pre-treatment variables between treated and non-treated individuals or firms. Based on the GPS, Hirano and Imbens (2004) further estimated a dose-response function that depicts the conditional expectation of outcome (firm performance in our case) given the continuous treatment (level of export activities) and the GPS, evaluated at any level of the continuous treatment variable.

In this paper, I will introduce the GPS method to the literature examining the export-performance relationship and estimate a dose-response function of firm performance in dependence of firms' degrees of internationalisation. The application of the GPS method will be illustrated using a data set of about 200 young technology-oriented firms in Germany and the UK that was collected by means of two surveys conducted in 1997 and 2003, respectively. In the related literature, numerous measures of a firm's degree of internationalisation and its performance are used. The share of total revenues generated abroad, denoted export-sales ratio or export intensity, is the most widely adopted measure of the degree of internationalisation (see Sullivan 1994b for an extensive review) and is therefore also used in this paper. Firm performance is measured as the firm's sales growth rate. Since the foreign market could be regarded as an expansion of the domestic market, firms can realise economies of scale and an ensuing increase in

sales (and employment) by carrying out export activities. This mechanism is known in the related literature as export-led growth (see Feder 1982). In fact, the potential of the international market to sustain long-term company growth was ranked as the most important motive for international business activities by the majority of both German and UK firms in our sample in 1997 (see Bürgel *et al.* 2004). However, an exporter that has already attained a relatively high export intensity prior to the regarded growth period (i.e., in our case, from 1997 to 2002) can be expected to grow at a smaller rate than a firm with a medium-level export-sales ratio. If a firm already generates a high share of its total sales abroad, a further international expansion will become difficult because of the increasing costs of coordination and control that tie up the firm's (financial) resources and restrict its growth potential.

Before estimating the dose-response function in section 3, however, I will present the data set used for the analysis along with some descriptive statistics (section 2). Implications and possible extensions of the analysis will briefly be discussed in section 4.

2 Data and Descriptive Analysis

This paper examines the export-growth relationship of technology-based firms in Germany and the UK. Technology-oriented firms are identified using the definition of high-technology manufacturing sectors in the UK established by Butchart (1987). The identified manufacturing industries are listed in Table 1 and augmented with a number of selected service sectors (cf. Bürgel *et al.* 2004).

>>> insert Table 1 about here <<<

The data for the empirical analysis result from two surveys simultaneously carried out in Germany and the UK. The source data set originates from Dun & Bradstreet in the

UK and Creditreform² in Germany. From each country's population of firms that were operating in at least one high-tech sector as defined by Butchart (1987) and were founded as legally independent companies between 1987 and 1996, a stratified random sample of 2,000 firms was drawn and subsequently contacted in winter 1997/1998 via a written questionnaire. The first survey was carried out by the London Business School in the UK and the Centre for European Economic Research (ZEW) in Germany. 362 completed questionnaires returned from the UK along with 232 questionnaires from Germany.

In order to assess the development of this sample of 600 new technology-based firms, a joint research team from the University of Exeter and the ZEW prepared a new survey in which firms that had previously responded were to be contacted a second time. The second survey was conducted in 2003 via computer-aided telephone interviews (CATI). 244 interviews were successfully completed. After performing several consistency checks, 217 companies were retained in the data set for empirical analyses.

In both countries, more than two-thirds of the responding firms had international sales in 1997 (German firms: 68.4%; UK firms: 76.5%). In the same year, the firms in our sample generated an average of 23.5% of total sales in the foreign market (German firms: 16.5%; UK firms: 28.9%). It is important to note that these numbers do not only include exporting firms but also cover companies without international sales. The latter group of firms decided that their optimal volume of exports was zero. The average share of total turnover the sample's *exporters* generated through foreign sales in 1997 amounted to 32.7% (German firms: 24.2%; UK firms 38.8%). The percentage of exporting firms in which non-domestic revenues exceeded 50% of total revenues was 26.5%

² As Germany's largest credit rating agency, Creditreform has the most comprehensive database of German firms at its disposal. Creditreform provides data on German firms to the Centre for European Economic Research (ZEW) for research purposes. Dun & Bradstreet is the UK equivalent.

(German firms: 15.4% ; UK firms: 34.4%). As shown by the figures in parentheses, the extent of UK firms' export activities exceeds that of their German rivals. As Bürgel *et al.* (2004) argued, this might be the case because UK exporters more pro-actively exploit the sales potential of foreign markets or because German firms are less dependent on the international market due to the larger size of their domestic market.

On average, in 1997 the firms in our sample employed 19 individuals (German firms: 17 employees; UK firms: 21 employees). In the period between the two surveys, the average number of employees rose by 7 individuals to 26 employees in 2002 (German firms: 27 employees; UK firms: 26 employees). Similarly, the firms' average volume of sales increased from 1.6 million euro in 1997 (German firms: 1.6 million euro; UK firms: 1.7 million euro) to 3.6 million euro in 2002 (German firms: 3.7 million euro; UK firms: 3.6 million euro; all sales data measured in euro of 2002).³ The implied annualised sales growth rate amounts to 12.9% (German firms: 16.1%; UK firms: 10.5%). The average volume of (discounted) sales of exporting firms grew significantly faster (according to a conventional t-test) in the period from 1997 to 2002 compared with firms without international business activities. Exporters were able, on average, to realise an annual sales growth rate of 14.6%, whereas firms with only domestic sales grew by 8.3% per year. This result corresponds to the stylised facts documented by many other studies (e.g., Clerides *et al.* 1998, Bernard and Wagner 1997, Bernard and Jensen 1999): Firms with international sales exhibit a superior performance (sales growth in our case) when compared with non-exporting firms.

³ Sales data were discounted by producer price indices (PPI) for the 3-digit NACE code of the respective manufacturing sector in Germany or 4-digit NACE code of the corresponding manufacturing sector in the UK, as they are available online from the time series services of the Federal Statistical Office of Germany (<https://www-genesis.destatis.de>) and the Office for National Statistics in the UK (<http://www.statistics.gov.uk>). In order to obtain comparable sales data between the German and the UK subsamples, exchange rates from the historical exchange rate database of Oanda Corp. were used (<http://www.oanda.com>).

3 Estimating a Dose-Response Function

In order to implement the generalised propensity score (GPS) method, Hirano and Imbens (2004) suggest a three-stage approach. In the first stage, the conditional distribution of the treatment variable given the covariates is estimated. In our case, the distribution of the treatment variable, i.e. the firms' export-sales ratio, is highly skewed. In particular, it has many limit observations at the value zero, representing firms without any international sales. The latter group of firms decided that their optimal volume of exports was zero. Following Wagner (2001, 2003), I apply the fractional logit model developed by Papke and Wooldridge (1996) for estimating the export intensity of the firms in our sample.⁴ The estimation procedure maximises the Bernoulli log-likelihood function given by

$$(1) \quad l_i(\beta) \equiv D_i \cdot \log[\Lambda(X_i\beta)] + (1 - D_i) \cdot \log[1 - \Lambda(X_i\beta)]$$

(with D as the firm's export-sales ratio [the treatment], X as the vector of covariates, and $\Lambda(\cdot)$ as the cumulative distribution function of the logistic distribution) using the generalised linear models (GLM) framework developed by McCullagh and Nelder (1989). The derivation of the estimation equation of the fractional logit model as well as a discussion of the results are presented in detail in a companion paper to this study (cf. Fryges 2006) and are therefore omitted for reasons of space. In Table 2, I only reprint the results of the fractional logit model that regresses the 1997 export intensity on a vector of covariates. In short, the results show that for young technology-oriented firms in Germany and the UK neither youth nor smallness is necessarily an obstacle to realising a high export-sales ratio. However, this requires that the firms possess firm-specific assets in order to overcome barriers to entry into the foreign market. These firm-specific

⁴ Hirano and Imbens (2004) use a normal distribution for (the logarithm of) the treatment variable of their model. However, they emphasise that more general models may be considered.

assets may be acquired via conducting own R&D activities, or by employing internationally experienced managers.

>>> insert Table 2 about here <<<

Let $r(d, x)$ be the conditional density of the treatment given the covariates:

$$(2) \quad r(d, x) = f_{D|x}(d|x).$$

Then the GPS is defined as $R = r(D, X)$ (Hirano and Imbens 2004: 2). Thus, the estimated GPS based on the Bernoulli likelihood function defined in equation (1) is

$$(3) \quad \hat{R}_i = \left[\Lambda(X_i \hat{\beta}) \right]^{D_i} \cdot \left[1 - \Lambda(X_i \hat{\beta}) \right]^{(1-D_i)}.$$

Hirano and Imbens (2004) prove that using the GPS eliminates any biases associated with differences in the pre-treatment variables. This bias removing property of the GPS corresponds to that of the traditional binary propensity score as demonstrated by Rosenbaum and Rubin (1983) and used by most of the literature that applied matching techniques.⁵

In the second stage of Hirano and Imbens' GPS methodology the conditional expectation of outcome Y_i is modelled as a function of the treatment D_i and the (estimated) generalised propensity score \hat{R}_i . The outcome variable used in this paper is the logarithmic annualised sales growth rate G (see, for example, Evans 1987a, 1987b) which is given by:

⁵ The bias removal property of the GPS is based on the assumption of weak unconfoundedness which is a generalisation of the (strong) unconfoundedness assumption made by Rosenbaum and Rubin (1983) for binary treatments (cf. Imbens 2000): The treatment D is weakly unconfounded, given pre-treatment variables X , if $Y(d) \perp D | X$ for all realisations d of the treatment D , with $Y(d)$ as the outcome associated with treatment level d .

$$(4) \quad Y_i = \ln G_i = \frac{\ln S_{i,t_2} - \ln S_{i,t_1}}{t_2 - t_1},$$

where S are (discounted) sales of firm i , t_1 is 1997 and t_2 is 2002. Following Hirano and Imbens, I use a quadratic approximation for the conditional expectation of Y_i :

$$(5) \quad E[Y_i | D_i, R_i] = \alpha_0 + \alpha_1 \cdot D_i + \alpha_2 \cdot D_i^2 + \alpha_3 \cdot \hat{R}_i + \alpha_4 \cdot \hat{R}_i^2 + \alpha_5 \cdot D_i \cdot \hat{R}_i.$$

Equation (5) is estimated by OLS. As Hirano and Imbens point out, the estimated regression coefficients α do not have any direct meaning and are therefore not reported here for reasons of space.

In the last stage of the GPS method, the average expected outcome at treatment level d is estimated, using the regression coefficients $\hat{\alpha}$ from the second stage of the GPS method:

$$(6) \quad \widehat{E[Y(d)]} = \frac{1}{N} \sum_{i=1}^N \left(\hat{\alpha}_0 + \hat{\alpha}_1 \cdot d + \hat{\alpha}_2 \cdot d^2 + \hat{\alpha}_3 \cdot \hat{r}(d, X_i) + \hat{\alpha}_4 \cdot \hat{r}(d, X_i)^2 + \hat{\alpha}_5 \cdot d \cdot \hat{r}(d, X_i) \right),$$

with N as the number of observations in our data set. In order to obtain an estimate of the entire dose-response function, equation (6) is calculated at each level of the treatment, i.e. in our case, at each export intensity in the interval from zero to one, increasing the export intensity successively by one percentage point in each step. Following the same procedure as Hirano and Imbens, the confidence intervals of the dose-response function are determined via bootstrapping.

>>> insert Figure 1 about here <<<

The resulting dose-response function is depicted in Figure 1. Generally speaking, the estimated dose-response function shows the inverted U -shaped relationship between the pre-treatment (i.e., 1997) export intensity and the subsequent sales growth rate which

was already demonstrated by various studies from the field of international management (e.g., Geringer *et al.* 1989 and Gomes and Ramaswamy 1999). The estimated annualised sales growth rate of firms with only domestic sales amounts to 9.5% (non-logarithmic value) which exceeds the mean sales growth rate actually observed within the group of non-exporting firms by 1.2 percentage points. Firms that generate a relatively small share of their total sales abroad (less than 10%) exhibit only a modest increase in their expected sales growth rate when compared with non-exporting firms. The slope of the dose-response function is relatively small within this interval of the pre-treatment export intensity. The maximum value of the expected sales growth rate is reached at an export-sales ratio of 60%, where the expectation value of the annualised sales growth rate amounts to 17.7% (non-logarithmic value). Firms of which the export intensity exceeds this “threshold value of internationalisation” (Geringer *et al.* 1989) exhibit a sales growth rate that falls below its maximum value, probably due to the high costs of coordination and control they are faced with and which confine their growth potential.

The dose-response function displayed in Figure 1 suggests a rather deterministic relationship between a firm’s export intensity and its performance. Its functional form implies that in order to maximise their firms’ performance (i.e. in our case, the future sales growth rate) managers have to realise a predetermined optimal export intensity. However, from a managerial point of view the more important question is how firm managers react once they have recognised a decrease in performance due to “excessive” internationalisation (Sullivan 1994a). Are they able to reorganise their international business activities in order to reduce the costs of coordination and control and reverse the decline in performance? Although this issue is beyond the scope of this paper it should be noted that the firms in our sample are very young (an average of six years old in 1997). Thus, the process of organisational learning on how to deal with the chal-

lenges of a rising export intensity has probably not yet finished for the firms in our sample. If we were able to track the sampled firms over a longer time period it might be that the observed decrease in performance of firms with a high export-sales ratio disappears, or at least abates, because the firms have undergone such learning processes.

4 Concluding Remarks

This paper introduces the generalised propensity score methodology developed by Imbens (2000) and Hirano and Imbens (2004) to the literature of individual firms' export behaviour. Using the GPS method, a dose-response function is estimated, confirming the inverted *U*-shaped relationship between the pre-treatment export intensity and firm performance (measured by the firms' subsequent sales growth rate) that has frequently been found in studies from the field of international management.

However, there are some caveats to the empirical example presented in this paper, primarily related to data restrictions. The number of observations in our data set is relatively small. In particular, the number of firms of which the export intensity exceeds the estimated threshold of internationalisation is limited (only 13% of the firms sampled), making the estimation of the dose-response function in this region more difficult. Moreover, our sample of newly founded firms was observed only twice with a six year interval between the two surveys. Tracking the firms over a longer time period and building up a panel data set could be a way to get further insights into the export-performance relationship, in particular with respect to its temporal dimension (e.g., learning processes connected with export activities). The analysis should also be extended to measures of firm performance others than the firms' sales growth rate, for example labour productivity, total factor productivity, profits, or wages.

Another caveat to the analysis is linked with the limited size of the data set. Although the estimated dose-response function shows a plausible relationship between the firms' pre-treatment export intensity and the subsequent sales growth rate, the estimated 90% confidence interval is relatively large at each point at which the dose-response function was evaluated. Moreover, the confidence interval increases with the export intensity. It is therefore questionable whether or not the maximum expected sales growth rate is significantly larger than the respective growth rate of non-exporting firms. This analysis, however, is beyond the scope of this paper.

In summary, the generalised propensity score method applied in this paper constitutes a new econometric technique that offers numerous opportunities for future research and promises to provide new insights into the export-performance relationship.

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Appendix

Table 1: Definition of High-Tech Sectors

Aggregated industries used	NACE Rev. 1	Short description according to NACE Rev.1
R&D-Intensive Service Industries	64.20; 72.20; 72.30; 72.40; 72.60; 73.10	Telecommunication, Computer Programming and Software Services, Data Processing, Misc. Computer Services, R&D in Natural Sciences and Engineering
ICT-Hardware	30.01; 30.02; 32.20; 32.30	Office Equipment; Computers and other Information Processing Equipment; Television and Radio Transmitters and Apparatus for Line Telephony and Line Telegraphy; Television and Radio Receivers, Sound or Video Recording and Reproducing Apparatus
Engineering Industries	33.20; 33.30; 33.40	Electronic Instruments and Appliances for Measuring, Checking (except Industrial Process Control); Electronic Industrial Process Control Equipment; Optical Instruments; Photographic Equipment
Health and Life Sciences	24.41; 24.42; 33.10	Pharmaceutical Products and Preparations; Medical and Surgical Equipment and Orthopaedic Appliances
Other High-Tech Manufacturing	24.16; 24.17; 31.10; 31.20; 32.10; 35.30	Plastics and Synthetic Rubber in Primary Form; Electric Motors, Generators and Transformers; Electricity Distribution and Control Apparatus; Electronic Valves, Tubes and other Components; Aircraft and Spacecraft Manufacturing

Source: Manufacturing sector: Butchart (1987); service sector: Bürgel et al. (2004).

Table 2: Fractional Logit Model: Pre-Treatment Export-Sales Ratio (1997)

		Number of observations = 173	
		LL = -70.615	
		$\chi^2(18) = 66.01$	
		Prob > $\chi^2(18) = 0.000$	
		$R^2 = 0.224$	
<i>Exogenous variables</i>	<i>Coeff.</i>	<i>Robust stand. error</i>	
1 Dummy Western Germany	-0.269	0.297	
2 Dummy Eastern Germany	-1.269	0.402	***
3 Dummy engineering industry	0.861	0.357	**
4 Other manufacturing industries	0.671	0.313	**
5 Log (number of employees)	0.582	0.667	
6 Log (number of employees) ²	-0.056	0.111	
7 Log (age in years)	-0.034	0.372	
8 Permanent R&D activities	0.896	0.471	*
9 Occasional R&D activities	0.892	0.489	*
10 Novel self-developed technology	-0.098	0.262	
11 Novel techn., developed elsewhere	0.444	0.284	
12 Working experience abroad	0.630	0.276	**
13 Education abroad	0.219	0.309	
14 Shortage in competencies			
Sales/distribution	-0.126	0.297	
Production/R&D	0.049	0.301	
15 Intense product customisation	-0.470	0.239	**
16 Regular maintenance and upgrades	-0.180	0.291	
17 Dummy consumer good	0.040	0.233	
Constant	-3.498	1.382	**

* 10% level of significance; ** 5% level of significance; *** 1% level of significance.

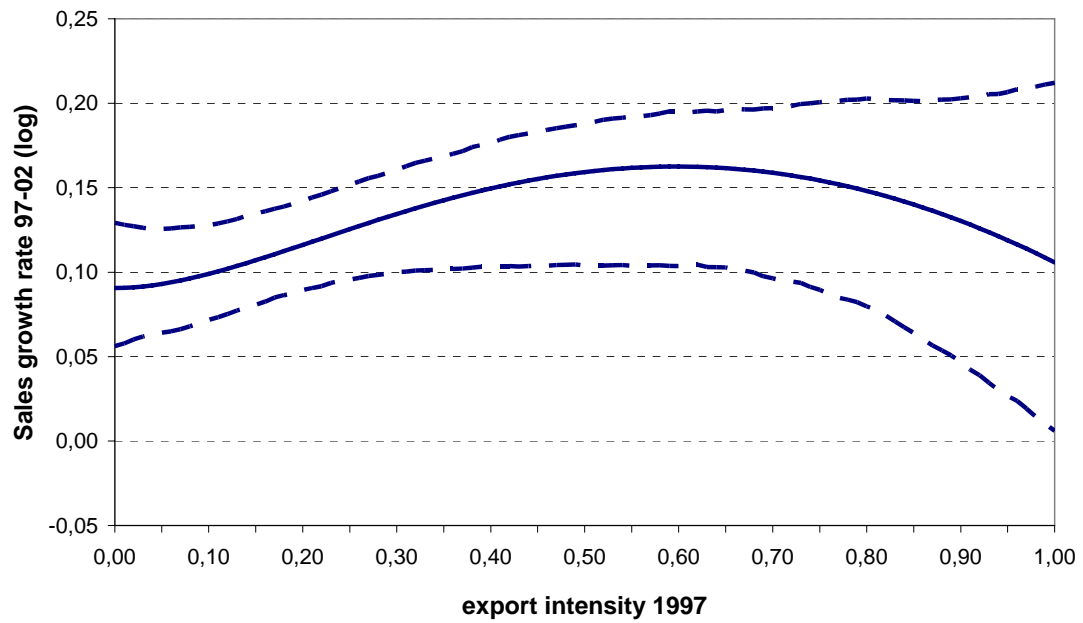
Base category: UK-based software firm without R&D activities.

Definition of exogenous variables:

- 8/9 Permanent and occasional R&D activities as indicated by firm representatives.
- 10 The firm's best-selling product or service incorporates novel technology that had to be developed specifically for this product by the company.
- 11 The firm's best-selling product or service incorporates novel technology that has been developed elsewhere.
- 12/13 At least one member of the firm's management team had work experience abroad or was educated abroad before he made his first international sales.
- 14 Firm managers experience a "serious" or "very serious" shortage of skills in sales/distribution and production/R&D respectively, measured on a five point Likert scale.
- 15/16 Firm managers classified the requirement of "individual client customisation" and "regular maintenance and upgrades" of their best-selling product or service as "important" or "very important", measured on a five point Likert scale.

Source: Fryges (2006).

Figure 1: Estimated Dose-Response Function



Annualised sales growth rates are computed using discounted sales.

Solid line: estimated conditional expectation of the firms' sales growth rate 1997-2002 given the export intensity 1997 and the estimated generalised propensity score (GPS).

Dotted lines: simulated 90% confidence interval, using the 5% and 95% percentiles of the bootstrap distribution (1,000 replications).

Source: own estimation.