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Published in:
Konjunkturpolitik

Publication date:
1993

KONJUNKTURPOLITIK, 39. Jahrg. H. 5 (1993)
Verlag Duncker & Humblot GmbH, 12165 Berlin

Technology and a firm's export intensity: The need for adequate innovation measurement

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Introduction

The hypothesis that innovation activities (often proxied by R&D or patents) have a positive impact on export performance is a crucial implication in modern trade theory (see Siebert 1991 for a recent survey) as well as an important rationale behind government technology policy. The empirical evidence in favor of this hypothesis is far from clear-cut, however. For example, Wolter (1977) in Germany and Tuyl (1987) in the Netherlands found a positive impact of R&D on export performance at the sector level, whereas, in a comparable study for The Netherlands, Hulsman-Vejsovà and Koekkoek (1987) arrived at a negative conclusion. Moreover, in his study of several OECD countries, Grunert (1990) concluded that R&D had no significant impact on export performance.

While these studies mainly used R&D as an innovation indicator, others took patenting data. For example, Soete (1981) concluded from his study of 40 sectors in a large number of OECD countries that a positive association exists between foreign patenting and export success. However, Cotsomitis et al. (1991), using patent data in a time-series analysis of five high tech industries in 14 OECD countries, concluded that 'the results do not provide much support of the Posner-Hufbauer technology-gap theory. Contrary to Soete's findings . . . the sign of the technology gap effect is more often than not contrary to that expected' (1991: 797).

Other studies arrived at mixed results. In the Netherlands, Kleinknecht and Verspagen (1990) concluded that the (gross) export performance of 31 manufacturing sectors was related positively to their R&D

* SEO, Foundation for Economic Research of the University of Amsterdam. This paper draws on the SEO national survey on R&D and innovation in The Netherlands, carried out with financial support from the Ministry of Economic Affairs. The research underlying this paper was sponsored by the same ministry.

intensity. When using a measure of 'net' export (including import penetration), however, the positive coefficient for R&D became insignificant. In a recent five countries study, Van Hulst et al. (1991) also obtained mixed results. In Germany, in the Netherlands, and (after inclusion of sector dummies) in Japan, they found a positive relationship between patenting in the USA and their measure of foreign trade performance. In the case of France there was no such relationship, and in Sweden the positive relationship between patenting in the USA and export performance became weaker during the observation period (1979 to 1987).

In our view, these contradictory outcomes are due to several reasons. The first is that deficient innovation data are used. For example, Tuyl (1987) and Hulsman-Vejsovà and Koekkoek (1987) used R&D data from the Dutch Central Statistical Office which are highly aggregated by sector for reasons of secrecy; this is an important drawback, as several of their sectors are highly inhomogeneous. Moreover, these R&D data strongly underestimate the R&D efforts undertaken by small and medium-sized firms (see Kleinknecht and Reijnen 1991). As a consequence, the R&D intensity of 'low technology' sectors, in which smaller firms play an important role, is also underestimated. It is another weakness of the R&D variable that it does not take into account the R&D incorporated in capital goods that are bought from other industries and firms, i. e. it neglects technology transfer. Patent data also have their well-known drawbacks, the two most important being that only a minority of innovations is based on patented inventions, and that many patent inventions are never introduced as innovations on a market. Another problem with several of the above-named studies is that they include very few control variables apart from R&D or patents, thus increasing the chance of finding pseudo correlations.

This is not the place in which to examine studies at the sector level in detail, our concern being with the relationship between innovation and exports at the firm level. Firm level studies are also contradictory. For example, Hirsch and Bijaoui (1985) found a positive relationship between the R&D input of 111 firms in Israel and their exports, while Schlegelmilch and Crook (1988) found no such result in a similar study of 130 British mechanical engineering firms. We report here on a comparable test of the impact of R&D and other variables on the export performance of some 2000 Dutch manufacturing firms. We present outcomes that confirm the results attained by Hirsch and Bijaoui (1985) while emphasizing that it is product — (as opposed to process) — related

R&D that is significant for foreign trade performance. At the same time, we can explain why Schlegelmilch and Crook (1985) arrived at opposite conclusions.

Analysis

In the recent SEO national survey on R&D and innovation in the Netherlands, information about the percentage share of exports in the total sales of some 2000 firms was obtained for the following classes (in brackets: percentages of firms in a class): 'no export' (18.7%), exports are: 'less than 10% of sales' (23.4%), '10-25% of sales' (17.1%), '25-50% of sales' (12.1%), '50-75% of sales' (12.4%) and 'more than 75% of sales' (16.3%). As our dependent variable is given in classes, we use the multinomial logit model in order to test which factors influence the probability that a firm will be in one of the various classes. The results are summarized in Table 1. In Table 2 we list the insignificant variables. Before interpreting these tables, it should be noted that, after some initial estimates, we tested whether some of the export classes could be merged, using the test by Cramer and Ridder (1991). It proved that the classes of '10-25% exports' and '25-50% exports' could be taken together.

In the case of dummy variables, the figures in Table 1 can be interpreted as the percentage changes of the probability (with respect to the average probability of a randomly selected firm from our sample) that a firm is in a certain export class (the class of 'no exports' serves as a reference). For example, if a firm has the property of being 'part of a conglomerate with its headquarters abroad', the probability of being in the size class of '0-10% export' is 5.5% lower than the sample average. In the case of continuous variables, the figures in Table 1 can be interpreted as 'quasi-elasticities' (Cramer 1991: 40). For example, the figure of 0.53 in the last column and last row of the table indicates that a one percent increase in the number of employees results in an increase by 0.53 percentage points of the probability that a firm will be in the highest export class.

Table 1

Factors that influence the probability that a firm belongs to a certain class of export intensity. Summary of logit estimates

	percentage share of exports in sales:			
	0-10%	10-50%	50-75%	75-100%
Dummy variables+				
The firm:				
- is part of a group which has its headquarters abroad	-5.5	-7.9	5.7**	18.4**
- is strongly dependent on the mother company when developing new products	-1.6**	-8.2**	-1.3**	0.8*
- has an establishment abroad	-13.2	12.0**	5.2**	0.9**
- belongs to the textiles industry	-7.6**	7.7**	9.9**	13.7**
- belongs to the paper industry	6.1**	21.1**	11.2**	7.6**
- belongs to a high technological opportunity sector++	-5.0**	3.7**	4.6**	12.2**
- is located in the periphery of the Netherlands	7.2	-2.0**	-6.0**	-6.4**
- collaborates on R&D with a foreign firm or R&D institution	-3.9	2.0	2.8*	8.1**
- buys advanced equipment for production automatization	-1.2	2.7**	1.1*	2.7**
- buys advanced equipment for purposes other than automatization	-4.4	0.3	6.4**	5.3**
Continuous variables+++				
Percentage of product-related R&D	-0.01**	0.03**	0.02**	0.04**
Seller concentration (C-4 ratio)	-0.04	0.03**	0.02**	0.05**
Firm size (number of employees)	-0.25**	0.16**	0.21**	0.53**

* effect is significant at a 95% level

** effect is significant at a 99% level

\+ in the case of dummy variables, the coefficients are 'derivatives' which give the change of the probability (in percentage points) if the independent variable shifts from zero to one.

++ Following Pavitt's (1984) 'taxonomy' of sectors, we consider the following as low technological opportunity sectors: food, beverages and tobacco, textiles and clothing, leather and shoes, wood and furniture, paper and cardboard, printing and publishing, building materials, earthenware and glass. High technological opportunity sectors are: chemicals and petroleum, rubber and plastics, basic metal and metal goods industry, machinery, electro-technical and electronics industry, automobiles and other transportation equipment (incl. aircraft), instruments and optical industry. Pavitt's taxonomy, derived from cases of discrete innovations in Great Britain, is largely confirmed by our observations on patterns of R&D behavior in the Netherlands (see Kleinknecht, Reijnen and Verweij 1990).

+++ in the case of continuous variables, the coefficients are 'quasi-elasticities'; they reflect the change of the probability (in percentage points) if the independent variable changes by one percent.

The effects of the various variables can also be illustrated by means of base line observations. In this case, we define a hypothetical enterprise with certain properties. By adding or omitting certain properties, we can show how this changes the probability that the firm will fall into a certain export class. In Figure 1 this has been done for the following properties:

PRODRD: a high share of the firm's R&D is product-related;

SIZE: the firm is relatively large (in terms of logs of employees);

Table 2

Variables that have *no* impact on the probability that a firm will be in a high or low class of export intensity

Dummy variables:

- at least 10% of the personnel attended a training course in 1988;
- the firm collaborated on R&D with firms and/or R&D institutions in the Netherlands, with foreign firms, with foreign R&D institutions (only a combined dummy for R&D collaboration with foreign firms and R&D institutions is significant);
- the firm applied in 1988 for one or more European or US patents;
- the firm bought advanced equipment for office automatization;
- the firm bought one or more licences;
- design was considered important to the innovation process;
- the firm was linked to an external computer network;
- the firm is part of a conglomerate with its head office inside the Netherlands.

Continuous variables:

- the total R&D-intensity (R&D man years as a percentage of the total work force). In our initial estimates, this variable was significant. However, due to multicollinearity, it became insignificant after inclusion of the percentage share of product-related R&D in the model
- software expenditures (Dutch guilders per employee).

NDEPMO: the firm is part of a conglomerate but is *not* strongly dependent on the mother company when developing new products;

AUTOMAT: the firm bought advanced equipment for production automatization;

RDCOL: the firm collaborated on R&D with a foreign firm or R&D institution;

CONC: the firm belongs to a sector with a high degree of seller concentration;

PERIPH: the firm is located in the country's periphery (outside the western urban agglomeration).

The probability surfaces in Figure 1 show the cumulative effects of the above variables. We first estimate a bottom probability (BOTTOM) which is that the firm is in a certain export size class if *all* the above variables are assumed to be non-existent or to have a low value.[1] As expected, the bottom probability of 'no exports' is high (about 75%, as compared to the probability of 18.7% for an 'average' firm in the sample); the probability that such a firm will be in a class of high export intensity is almost nil.

[1] 'Low'(and 'high') values are defined such that only 5% of the sample firms have an even lower (or higher) value.

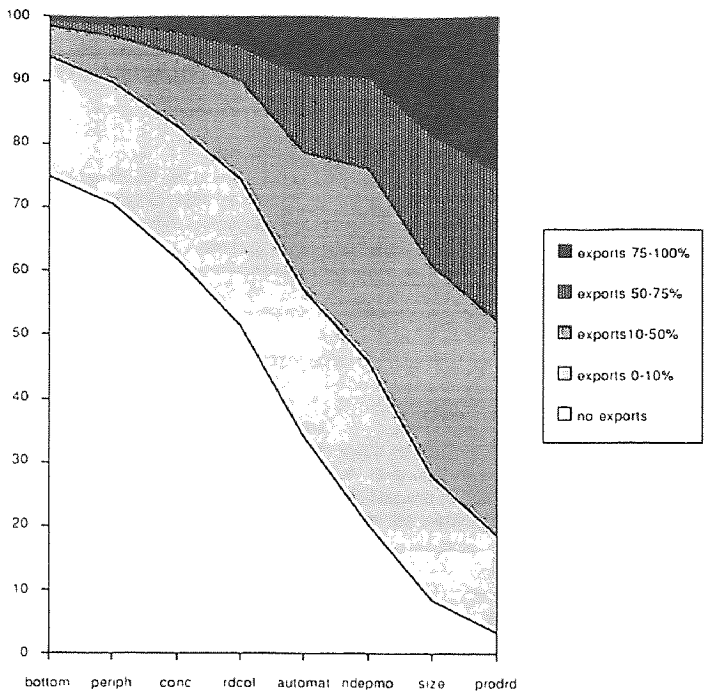

Figure 1: Cumulative effects of several variables on the probability that a firm will be in a certain class of export intensity (baseline observations)

The picture changes as we add certain properties or assume certain variables to have a high value. Only the probability surface for firms with few exports ('0-10% exports') remains almost constant, indicating that our variables have little impact on firms with very low export intensities. In the classes of higher export intensities, our variables have quite powerful effects. For example, the probability that a firm is in the class of '50-75% exports' shifts from about 1% to about 25% (i. e. 78% minus 53%) if all variables are assumed to exist or to have a high value. As expected, the effects of variables differ across export size classes. For instance, in the class of '50-75% exports' the variables 'not dependent on the mother company', 'location in the periphery', or 'high seller concentration' have only weak effects, whereas factors such as the purchase of automatization equipment, firm size and a high percentage of product-related R&D have a strong impact. It is interesting to note the relatively powerful effect of the last two variables on the probability of being in the highest class of export intensity.

The behavior of the concentration and firm size variables clearly shows that scale economies are important for Dutch exports. Sector-specific factors are also important, as can be seen from the positive dummy for high technological opportunity sectors and for the paper and textiles industries within the low technological opportunity sectors in Table 1. The most interesting factor in the context of this paper is the R&D variable. We should mention here that R&D-intensity (i. e. R&D man years as a percentage of a firm's total labor force) showed a somewhat peculiar behavior in our initial estimates. In a number of specifications, the coefficient of the R&D variable was positive but insignificant, greatly resembling the regression results reached by Schlegelmilch and Crook (1988: 293). Only after inclusion of the dummy variable 'the firm is not strongly dependent on the mother company when developing new products' did the R&D variable become highly significant. At the same time, our 'goodness of fit' test indicated that the model improved considerably.

The reason for this is that the relationship between R&D and exports can be disturbed systematically among firms that depend strongly on the mother company. Within a conglomerate, a firm's R&D results may be used by other companies in the group; vice versa, it can make use of R&D done by other firms in the group. In other words, it may behave as if it did R&D while not reporting R&D activities. This disturbance is (approximately) corrected by including a dummy for strongly dependent firms, thus improving the fit of our model remarkably. Schlegelmilch and Crook (1985) have not made such a correction, which may explain the insignificant coefficient of the R&D variable in their model.[2]

Initially, we used R&D intensity as an innovation indicator. At a later stage, we took the percentage of R&D man years dedicated to new products (as opposed to new processes). However, this variable is multicollinear with R&D intensity: the higher the R&D intensity, the higher is the share of product-related R&D (Kleinknecht et al. 1990: 23-24). When including the percentage of product-related R&D in the model, R&D intensity became insignificant; in other words, the former is the stronger variable. A theoretical explanation of this phenomenon can be taken from life cycle theory. Utterback and Abernathy (1975)

[2] If Hirsch and Bijaoui (1985) found a positive impact of R&D on exports without including such a variable, this can be due to two reasons. Either the correlation in Israel is so strong that it still shows up in spite of not correcting for the disturbance, or there were fewer firms dependent on their mother and sister companies in their sample.

and, in a historical context, Coombs and Kleinknecht (1986) have shown that during the life cycle of an industry, emphasis shifts from product to process improvement. A high share of product-related R&D can be taken as indicating that a firm is engaged with technologies in a relatively early stage of the life cycle. Our results indicate that such firms are important carriers of exports.

It is interesting to note the positive impact of R&D collaboration with foreign (as opposed to domestic) partners on exports, as well as the behavior of the regional location variable. Firms located in the periphery of the Netherlands (close to the German and Belgian frontier) are able to export more easily because part of their home market is on the other side of the frontier. The positive influence on export intensities of activities complementary to R&D such as the purchase of advanced equipment for automatization and other purposes is hardly surprising. This does not hold for purchases of office automatization equipment, licences, and software, however. Given that the SEO survey was held at the end of the 1980s and against the background of the rapid diffusion of informatics during the 1980s, these latter indicators can probably be taken as showing that a firm is lagging behind in the diffusion process, or is certainly not playing a leading role.

The dummy for firms that applied for a European or US patent can be found in the list of insignificant variables, as well as that for firms with considerable man power training efforts. The insignificance of the latter may be explained by its nature as a flow variable. For the purpose of our test, it would have been better if a stock variable (e. g. the percentage of highly qualified people in a firm) had been available. The insignificant score of the patent variable contradicts Soete's (1981) findings of a positive correlation between patents and exports. The divergence may be explained by the fact that our model is tested at the firm level whereas Soete used sectoral data, and that we have better control for a number of other relevant variables.

Finally, in order to examine the firm size variable more closely, we also experimented with a non-linear specification taking, in addition to the logs of numbers of workers, the squared numbers of workers. The latter was weakly significant (at 90 % level) in the higher export classes and should be interpreted with caution, as there are only few really large firms in the Netherlands. Differentiation of the estimated function shows a maximum of around 7 000 to 10 000 workers (depending on the export class). This suggests that, other factors being kept constant, medium-large firms are the most export-intensive. The reason for this

is that small firms may fail to exploit scale economies sufficiently, whereas very large firms may tend to substitute direct foreign investment for exports.

In conclusion, scale economies (market concentration and firm size), structural differences between sectors, location, R&D collaboration with foreign partners (or own subsidiaries abroad) and the purchase of advanced equipment, all have a positive impact on a firm's export intensity. Our most remarkable result is that, after control for all these factors, the R&D variable still has a significant influence on exports. As compared to earlier studies, however, two specific new findings can be added. First, the R&D variable stands or falls with a correction for firms that are part of a group and are heavily dependent on the mother company when developing new products. If the dummy for such firms is omitted from our model, the results are similar to those of Schlegelmilch and Crook (1985) who concluded that R&D is not relevant to export behavior. This is a message to R&D data collectors. Secondly, it is worth distinguishing between product- and process-related R&D when collecting R&D data. The former is important for exports. Nevertheless, total R&D intensity may be expected to be significant, since roughly two-thirds of total R&D is product-related.

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Abstract

Technology and a firm's export intensity:
The need for adequate innovation measurement

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Empirical evidence that technological innovation has a positive impact on export performance appears somewhat shaky. Yet this hypothesis plays an important role in modern trade theory. Examining the influence of technological innovation and related variables on the export share in sales of some 2000 Dutch manufacturing firms, we find that these variables have a positive impact on exports. This result stands or falls, however, with a careful control for variables related to R&D. When using firm level R&D data, it is essential to take account of the technological dependence of firms on their mother and sister companies; moreover, the distinction between product- and process-related R&D adds additional explanatory power, as the former and not the latter proves to be important

for export success. We argue that earlier studies have failed to find a significant impact of R&D on exports because they did not take such refinements into account.

AEA classification: O 30, O 12, F 12, L 16
SEO, Foundation for Economic Research of the University of Amsterdam, Netherlands