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R&D activities and extensive margins of exports in manufacturing enterprises: First evidence for Germany*

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Abstract:

This paper uses a new tailor-made data set to investigate for the first time the links between innovation activities (measured by employees active in research and development) and the extensive margins of exports (number of destination countries; number of goods exported) for manufacturing enterprises in Germany, the third largest exporter of goods on the world market. It documents that more innovative firms outperform less innovative firms at both margins of exports – they export more goods and they export to a larger number of countries. All these differences are statistically highly significant and large from an economic point of view.

Keywords: Extensive margins of exports, Germany, innovation, research and development

JEL Classification: F14

* All computations were done at the Research Data Centre of the Statistical Office of Berlin-Brandenburg in Berlin. The firm-level data used are strictly confidential but not exclusive; see http://www.forschungsdatenzentrum.de/datenzugang.asp for information on how to access the data. To facilitate replications the Stata do-file used is available from the author on request.

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1. Motivation

Firms with innovative products and innovative production processes can be expected to have an advantage compared to their competitors not only on their home market but on foreign markets, too. A large number of empirical studies document this positive link between innovation activities and exports of firms. A recent example is the study by Altomonte et al. (2013) that uses a representative and cross-country comparable sample of manufacturing firms from seven European countries (Austria, France, Germany, Hungary, Italy, Spain, United Kingdom). The authors report a positive correlation between exports and innovation. This is in line with the findings of a large number of studies for other countries.[1]

Germany, the third-largest exporter of goods in the world market (according to the World Trade Organization (2014), p. 34), is a case in point. Wagner (2011b) uses a large representative panel data set for German manufacturing firms to demonstrate that both the share of expenditures in research and development (R&D) in total sales and the share of employees in R&D are positively related to the probability that a firm exports and to the share of exports in total sales. These links are statistically highly significant after controlling for a number of firm characteristics that are related to exports. Similar results were found in other studies with different German firm level data sets (see Wagner (2011a) for a survey).

That said, innovative firms cannot only be expected to outperform non-innovative firms with respect to export participation and the share of exports in total sales. More innovative firms can be expected to serve more foreign markets because their advantage compared to local producers of competing similar goods can be

[1] A survey of this large literature is far beyond the scope of this note. Unterlass (2013, p. 3) lists several studies that confirm this positive link between exports and innovation and presents new evidence on it based on firm level data for 22 countries from the European Community Innovation Survey (CIS 3) for 1998-2000.

expected to be not limited to only one foreign market (or a small number of markets). Furthermore, they can be expected to export more different goods because innovation activities are often not concentrated on the development of one single good only, but spread over several lines of production.

However, while a positive link between innovation and both the participation in exports and the share of exports in total sales can be seen as a stylized fact that has been found in many studies for a large number of countries, evidence on the link between a firm's innovation activities and the extensive margins of exports – the number of countries exported to and the number of goods exported – is scarce. This comes as a surprise because information on these extensive margins is widely available from transaction level data on exports (that are usually collected by the customs of a country), and this kind of data has been used in a large number of empirical studies for many countries to investigate the links between various firm characteristics (like productivity, size, or age) and these margins (see Wagner (2015a) for a survey). To the best of my knowledge, however, in this literature only Halpern and Muraközy (2012) look at innovation and the extensive margins of exports. Using data for Hungarian firms they document that innovative firms export more products to more countries.

This paper contributes to the literature by investigating for the first time the links between German firms' innovation activities and the extensive margins of exports. To anticipate the most important result, it is found that more innovative firms outperform less innovative firms at both extensive margins of exports – they export more goods and they export to a larger number of countries. All these differences are statistically highly significant and large from an economic point of view after controlling for a number of firm characteristics that are related to exporting.

The rest of the paper is organized as follows. Section 2 introduces the new data set used, details the definition of variables included in the empirical models and reports some descriptive statistics. Section 3 discusses the results of the econometric investigation. Section 4 concludes.

2. Data, definition of variables and descriptive statistics

The empirical investigation uses a tailor-made data set that combines high quality firm-level data from four official sources. The first source of firm level information is the regular survey of establishments from manufacturing industries by the Statistical Offices of the German federal states. The survey (known as the *Monatsbericht,* or monthly report) covers all establishments from manufacturing industries that employ at least twenty persons in the local production unit or in the company that owns the unit. Participation of firms in the survey is mandated in official statistics (see Malchin and Voshage (2009) for details). For this study the monthly establishment data were aggregated to annual data and at the enterprise level to match the unit of observation in the other data sources (described below).[2] The use of the enterprise (the legal unit) instead of the establishment (the local production unit) as the unit of analysis is mandated by the use of the enterprise as the unit of observation in the other data sources used in this study. It seems appropriate here because decisions about export activities are taken at the enterprise level, taking the characteristics of all establishments in a multi-establishment enterprise into account.

The second source of data is the cost structure survey for enterprises in the manufacturing sector. This survey is carried out annually as a representative random

[2] Note that beginning with reporting year 2007 firms with more than 20 but less than 50 persons no longer have to report to the *Monatsbericht*. However, these firms have to report information on total sales, exports, number of employees and the sum of wages and salaries paid in the so-called *Jahresbericht* (the annual report), and this information is added to the data set used here.

sample survey in about 15,000 firms. The sample is stratified according to the number of employees and the industries; all firms with 500 and more employees are covered by the cost structure survey (see Fritsch et al. 2004).

Information on the goods traded internationally is available from the statistic on foreign trade (*Außenhandelsstatistik*). This statistic is based on two sources. One source is the reports by German firms on transactions with firms from countries that are members of the European Union (EU); these reports are used to compile the so-called *Intrahandelsstatistik* on intra-EU trade. The other source is transaction-level data collected by the customs on trade with countries outside the EU (the so-called *Extrahandelsstatistik*).[3] Data in the statistic of foreign trade are transaction-level data, i.e. they relate to one transaction of a German firm with a firm located outside Germany at a time. For the reporting year 2010 these transaction-level data have been aggregated at the level of the exporting firm (see Wagner 2014). This dataset is the third source of data used in this study.

These data were matched with the enterprise register system (*Unternehmensregister-System*) and with the enterprise level data from the two other sources discussed above. The enterprise register system is used as the fourth source of data. With these linked four data sets it is possible to investigate the margins of exports in manufacturing firms from Germany.

The study looks at two extensive margins of exports. The first is the *Number of exported goods,* where a good is defined as an eight-digit number from the official nomenclature for the statistics of foreign trade. The second extensive margin of exports investigated is the *Number of export destination countries.* Information on the

[3] Note that firms with a value of imports from EU-countries that does not exceed 400,000 Euro do not have to report to the statistic on intra-EU trade. For trade with firms from non-member countries all transactions that exceed 1,000 Euro are registered. For details see Statistisches Bundesamt, Qualitätsbericht Außenhandel, Januar 2011.

number of exported goods and the number of export destination countries is taken from the third source of data (the statistic on foreign trade). This information is available for each year starting in 2009; the most recent year the data were available when the computations for this paper were performed is 2010. Note that by construction this information is only available for exporting firms covered by the statistic on foreign trade.

On average, the firms included in the sample used in this empirical study exported 36.18 different goods to 24.54 different countries in 2010 (see the descriptive statistics reported in Table 1). Many firms exported only a small number of goods and to a small number of countries with the median number being much smaller than the mean. Note that the maximum number of goods and countries is confidential (because these numbers refer to single firms), but from the values for the 99th percentile we see that some firms export a large number of goods and to a large number of countries.

[Table 1 near here]

Innovation is measured by a firm's activities in research and development (*R&D) t*hat are closely related to product and process innovations. These activities are known to be positively linked to firms' participation in exports and to export intensity in German firms (see Wagner (2011a, 2011b)). R&D activity is measured here either as a dummy variable that takes on the value of one if a firms employs at least one person that is active in R&D (and zero otherwise), or by the share of employees that are active in R&D in all employees in a firm. This intensity measure is also included in squares in the empirical model to take care of any non-linearity in the link between R&D activities and the extensive margins of exports. Information on

R&D employees and total employees are taken from the second data source (the cost structure survey).

The share of firms with R&D activities in all firms in the sample used here is 43 percent. This is a rather large share, but it should be kept in mind that by construction only exporting firms are included in the sample, and that R&D activities and participation in exports is positively related. The overall average share of employees in R&D is 3.1 percent in the firms in the sample (see Table 1). Some firms are rather intensively engaged in R&D activities. Again, information on the maximum of the variable is confidential, but note that firm at the 99th percentile of the distribution has 30.5 percent of its employees working in R&D.

In the empirical investigation of the extensive margins of exports a number of firm characteristics are included as control variables. The relation of these variables to export activities and the definition of variables is discussed in detail below.

West Germany: It is well known that there are large differences in export activities between firms located in West Germany and those located in the former communist East Germany even 20 years after the unification of both parts of Germany. West German firms outperform East German firms in all margins of exports (Wagner 2016). A dummy variable that takes on the value of one if a firm is from West Germany (and zero otherwise) is included in the empirical models to control for the location of the firm. 86 percent of all firms in the sample come from West Germany (see Table 1).

Firm size: A positive link between firm size and margins of exports qualifies as a stylized fact. This positive link is due to fixed costs of exporting and efficiency advantages of larger firms due to scale economies, advantages of specialization in management and better conditions on the markets for inputs. Large firms can be expected to have cost advantages on credit markets while small firms often face

higher restrictions on the capital market leading to a higher risk of insolvency and illiquidity. Furthermore, there might be disadvantages of small firms in the competition for highly qualified employees. There are limits to the advantage of size, because coordination costs mount as the scale of operations increases, and at some point any further expansion might cease to be profitable. Therefore, a positive relationship between firm size and exports, at least up to a point, is expected. For Germany empirical evidence in line with this is reported in a number of studies (see Wagner (2011a) for a survey). Firm size is measured here by the number of employees in a firm (also included in squares to take care of non-linearity). The source is the first data set (the monthly report).

On average, the firms in the sample have 306 employees, which is quite large. Note, however, that by construction the data set used is limited to exporting firms, and these exporters tend to be considerably larger on average than non-exporting firms.

Labor productivity: The positive link between exports and productivity qualifies as a stylized fact that has been documented in hundreds of studies for countries from all over the world (see Wagner (2007) for a survey). According to findings from this literature an important reason for the positive productivity differential between exporters and non-exporters is self-selection of more productive plants on export markets. Furthermore, there is evidence for a market driven selection process in which exporters that have low productivity fail as a successful exporter, while only those that are more productive continue to export. The reason for this is that there exist additional costs of selling goods in foreign countries. The range of extra costs include transportation costs, distribution or marketing costs, or production costs in modifying current domestic products for foreign consumption. This implies that firms that export to a larger number of foreign markets and a larger number of different

goods have to be more productive, because at least some of the extra costs mentioned (e.g., preparing a user's manual in another language, or checking the relevant national laws) recur for each foreign market served and for each good exported. Empirical evidence for Germany reported in Wagner (2012b) is fully in line with this.

Labor productivity is measured here by value added per employee; the information on sales and costs used in the computation of this productivity variable are taken from the cost structure survey.[4]

Human capital intensity: Given that Germany is relatively rich in human capital, firms that use human capital intensively can be expected to have a comparative advantage on international markets. Empirical studies find that the qualification of the workforce is an important factor for the international competitiveness of German firms (Wagner 2011b). Human capital intensity is measured here by the average wage per employee. Direct information on the qualification of the employees in a firm is not available in the data used in this study, but Wagner (2012a) demonstrates that the average wage is indeed a good proxy variable for the qualification of the workforce in German manufacturing firms. The source is for information on the amount of wages paid and the number of employees is the first data set (the monthly report).

Firm age: Although some newly founded firms are „born globals" that export from the start, typically it takes years before firms eventually export to one foreign market, and then enter further markets progressively. Firms gain expertise in entering new foreign markets from experience, and this lowers the fixed costs of entry to any further new market. A similar argument can be made with regard to the number of

[4] Note that the data used has no information on the capital stock of the firms, so more elaborate measures of productivity like total factor productivity cannot be computed.

products exported. At any point in time, therefore, firm age and the margins of exports can be expected to be closely linked. Germany is a case in point. Wagner (2015b) reports that older firms are more often exporters, export more and more different goods to more different destination countries. Information on firm age is not available from the data used in this study. However, we know whether a firm was already active in 1995 (the first year data from the monthly report are available for). Firms that were active in 1995, and that were founded before 1996 accordingly, are classified as old firms (based on this information from the first data source, the monthly report).

Foreign owned firm: Firms that are subsidies of a multinational enterprise that has its headquarter in a foreign country are termed foreign owned firms. Foreign ownership is known to have a positive impact on the margins of exports, because these firms can use the international networks and trade contacts of their parent companies and are involved in international supply chains (see Raff and Wagner (2014) for a discussion of the literature, a theoretical model, and empirical evidence for Germany). A firm is considered to be foreign owned if more than 50 percent of the voting rights of the owners or more than 50 percent of the shares are controlled (directly or indirectly) by a firm or a person/institution located outside Germany. Information on foreign ownership status of an enterprise is taken from the fourth source of data, the enterprise register system.

Industry: Dummy variables for 2digit-industries are included in the empirical models to control for industry specific effects like competitive pressure, policy measures, demand shocks etc. The source is the first data set (the monthly report).

3. Econometric investigation

The link between R&D activity of a firm and each of the two extensive margins of the firm's exports – the number of destination countries and the number of different goods exported – is investigated with a set of six differently specified econometric models. In model (1) and model (2) R&D activity is measured by a dummy variable that indicates whether a firm is engaged in R&D or not; model (3) and model (4) include the R&D intensity, measured by the share of employees working in R&D; model (5) and model (6) include both the R&D intensity and its squared value to take care of a non-linear form of the relationship between R&D activity and the export margins. Here, models with an odd number only include the respective R&D variable(s) plus a constant, while models with even numbers include the full set of control variables (discussed in section 2), too.[5]

Note that the results of the empirical models cannot reveal any causal relationship between R&D activity and the extensive margins of exports. The cross-section data at hand are not rich enough to estimate a structural model for the interrelationships between innovation and exports. However, given the scarcity of information on the links between, on the one hand, the number of countries exported to and the number of goods exported, and on the engagement of firms in R&D on the other hand, it seems interesting and important to report descriptive evidence on this topic for Germany, the third largest actor on the world market for goods.

[5] Although the dependent variable in the empirical models is a count variable that can only take positive integer values equal to or larger than one (because by construction only firms that export to at least one country and one good are included in the sample) all models are estimated by OLS. Both the number of destination countries and the number of goods exported are distributed over a broad range (see Table 1). This justifies the use of OLS in estimating the empirical models.

Results for R&D and the number of destination countries are reported in Table 2.[6] The estimation results show that, irrespective of the way R&D is measured and whether control variables are included or not, the link between the number of destination countries and R&D is positive.[7] This positive link is statistically highly significant, and it is large from an economic point of view. Model (2) indicates that, ceteris paribus, a firm which is active in R&D exports on average to 11.5 more countries than a firm that does no R&D at all. This difference is large compared to both the average number and to the median number of destination countries.[8]

[Table 2 near here]

The big picture is identical for the link between R&D and the number of different goods exported. The estimation results reported in Table 3 show that, irrespective of the way R&D is measured and whether control variables are included or not, the link between the number of goods exported and R&D is positive.[9] This

[6] Given the focus of this study the estimation results for the control variables will not be discussed here.

[7] Model (4) and model (6) both show a hump-shaped relationship between R&D intensity and the number of destination countries. The estimated maximum of this relationship, which is 0.19 in the complete model (6), is high compared to the mean of the R&D intensity of 0.03 in the sample, and to the 90th percentile of the R&D intensity distribution which is 0.10. Only a small number of observations lay to the right of the estimated maximum of the hump-shaped relationship. Therefore, the results should be interpreted to point to a non-linearly increase of the number of destination countries in the R&D intensity at a decreasing rate.

[8] Note that the estimated increase in the number of destination countries is considerably smaller in model (2) compared to model (1) that does not include any control variables.

[9] Model (4) and model (6) both show a hump-shaped relationship between R&D intensity and the number of exported goods. The estimated maximum of this relationship, which is 0.21 in the complete model (6), is high compared to the mean of the R&D intensity of 0.03 in the sample, and to the 90th percentile of the R&D intensity distribution which is 0.10. Only a small number of observations lay to the right of the estimated maximum of the hump-shaped relationship. Therefore, the results should be

positive link is statistically highly significant, and it is large from an economic point of view. Model (2) indicates that, ceteris paribus, a firm which is active in R&D exports on average 18 more goods than a firm that does no R&D at all. This difference is large compared to both the average number and to the median number of goods exported.[10]

[Table 3 near here]

3. Concluding remarks

This paper documents that more innovative firms from manufacturing industries in Germany outperform less innovative firms at both extensive margins of exports – they export more goods and they export to a larger number of countries. All these differences are statistically highly significant and large from an economic point of view after controlling for a number of firm characteristics that are related to exporting. These findings are in line with the expectations stated in the introductory section, and they match results for Hungary reported by Halpern and Muraközy (2012).

When putting these findings into perspective a number of limitations of this study should be kept in mind. First of all, the results are correlations only, and they do not indicate any causal relationship that runs (solely) from innovation activities of firms to the extensive margins of exports. Altomonte et al. (2013, p. 680) argue that there is a growing consensus that both innovation and exporting are the result of the endogenous choices of firms. They are inextricably linked. Firms may invest in R&D to foster innovation because they plan to start to export; they may start to export to

interpreted to point to a non-linearly increase of the number of exported goods in the R&D intensity at a decreasing rate.

[10] Note that the estimated increase in the number of exported goods is considerably smaller in model (2) compared to model (1) that does not include any control variables.

collect rents related to new products on a large number of markets outside the home country; they may be induced or even forced to innovate to stay competitive on export market; or they may learn from customers and competitors in export market how to produce new products and to use new production processes. The data at hand here, however, are not rich enough to estimate a dynamic structural model of these complex interrelationships between R&D activities and exports of firms like in Aw et al. (2011).

Second, the data used are cross-section data for one year only. Therefore, it is not possible to control for the role of (time-invariant) unobserved firm characteristics that might be correlated with both R&D activities and the extensive margins of exports, like the quality of the management of a firm, by including firm fixed effects. However, experience with panel data for German manufacturing firms reveals that the within variation of firm characteristics over time tends to be very small compared to the between variation (see Wagner 2011b). Therefore, panel data are far from being a panacea in an exercise like the one performed here.

Third, R&D activities are related to innovation activities at the firm level, but they are a rather indirect measure of innovativeness of the firm. More direct measures like the number of newly introduced products over a period of time or the share of sales of new products in total sales, are available for samples of firms from innovation surveys. However, firm level data from these surveys cannot be linked to the detailed data on extensive margins of exports investigated in this study.

Nevertheless, the results documented here reveal some interesting and hitherto not known facts on the links between innovation activities and extensive margins of exports in German manufacturing firms.

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Table 1: Descriptive statistics: German manufacturing enterprises, 2010

	Mean	sd	p1	p50	p99
Number of destination countries	24.54	22.41	1	19	98
Number of goods exported	36.18	84.98	1	10	391
R&D activity (Dummy; 1 = yes)	0.43	0.50			
R&D intensity (Share of employees)	0.031	0.063	0.000	0.000	0.305
Control variables:					
West Germany (Dummy; 1 = yes)	0.86	0.35			
Firm size (No. of employees)	306.15	2253	23	104	2469
Labor productivity (Values added / employees)	62,232	46,019	12,500	55,481	191,570
Human capital (Wage per employee)	35,239	11,111	14,207	34,649	65,307
Old firm (Dummy) (1 = founded < 1996)	0.58	0.49			
Foreign owned firm (Dummy; 1 = yes)	0.16	0.37			
Number of firms	7216				

Note: sd is the standard deviation; p1, p50 and p99 are the 1st, 50th, and 99th percentile, respectively. The minimum and maximum values of all variables are confidential.

Table 2: R&D and the number of destination countries of exports in enterprises from manufacturing industries in Germany 2010

Model		1	2	3	4	5	6
R&D activity	ß	17.14	11.48				
(Dummy, 1 = yes)	p	0.000	0.000				
R&D intensity	ß			81.77	221.28	31.19	136.72
(Share of employees)	p			0.000	0.000	0.000	0.000
R&D intensity	ß				-501.05		-363.89
(squared)	p				0.000		0.000
Control variables:							
West Germany	ß		4.82			4.27	4.38
(Dummy; 1 = yes)	p		0.000			0.000	0.000
Firm size	ß		0.007			0.008	0.007
(No. of employees)	p		0.000			0.000	0.000
Firm size	ß		-5.31e-8			-5.73e-8	-5.51e-8
(squared)	p		0.000			0.000	0.000
Human capital	ß		3.63e-4			4.63e-4	4.34e-4
(Wage per employee)	p		0.000			0.000	0.000
Old firm (Dummy)	ß		3.46			3.57	3.39
(1 = founded < 1996)	p		0.000			0.000	0.000
Foreign owned firm	ß		1.91			2.13	1.97
(Dummy; 1 = yes)	p		0.005			0.003	0.005
Labor productivity	ß		3.45e-5			3.01e-5	3.14e-5
(Value added/empl.)	p		0.000			0.001	0.000
Constant	ß	17.16	5.69	22.02	20.17	5.55	5.57
	P	0.000	0.433	0.000	0.000	0.446	0.452
Industry controls		no	yes	no	no	yes	yes
R-squared		0.143	0.350	0.052	0.102	0.302	0.325
Number of firms		7.216	7.216	7.216	7.216	7.216	7.216

Note: All models are estimated by OLS. ß is the estimated regression coefficient and p is the prob-value. Standard errors are based on heteroscedasticity-robust estimates.

Table 3: R&D and the number of exported goods in enterprises from manufacturing industries in Germany 2010

Model		1	2	3	4	5	
R&D activity	ß	38.82	18.04				
(Dummy, 1 = yes)	p	0.000	0.000				
R&D intensity	ß			279.15	664.79	116.59	359.25
(Share of employees)	p			0.000	0.000	0.000	0.000
R&D intensity	ß				-1385.02		-836.72
(squared)	p				0.000		0.000
Control variables:							
West Germany	ß		9.92			10.20	10.47
(Dummy; 1 = yes)	p		0.000			0.000	0.000
Firm size	ß		0.047			0.048	0.047
(No. of employees)	p		0.000			0.000	0.000
Firm size	ß		-2.87e-7			-2.89e-7	-2.84e-7
(squared)	p		0.000			0.000	0.000
Human capital	ß		8.07e-4			8.37e-4	8.17e-4
(Wage per employee)	p		0.000			0.000	0.000
Old firm (Dummy)	ß		1.05			1.55	1.13
(1 = founded < 1996)	p		0.466			0.287	0.436
Foreign owned firm	ß		-1.72			-0.97	-1.35
(Dummy; 1 = yes)	p		0.471			0.685	0.570
Labor productivity	ß		1.14e-5			4.92e-6	7.93e-6
(Value added/empl.)	p		0.449			0.748	0.590
Constant	ß		-20.97	27.60	22.49	-19.83	-19.90
	p		0.021	0.000	0.000	0.016	0.020
Industry controls		no	yes	no	no	yes	yes
R-squared		0.051	0.494	0.042	0.069	0.490	0.499
Number of firms		7.216	7.216	7.216	7.216	7.216	7.216

Note: All models are estimated by OLS. ß is the estimated regression coefficient and p is the prob-value. Standard errors are based on heteroscedasticity-robust estimates.

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