Internationalisation, Productivity, and Information Technology Use: An Investigation at the Level of the Firm *

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Irene Bertschek
ZEW Mannheim and
Mannheim University

Jan Hogrefe
ZEW Mannheim and
Tübingen University

Fabienne Rasel
ZEW Mannheim and
Mannheim University

Abstract

Using a unique German firm-level data set, we provide empirical evidence for productivity sorting along two dimensions: international activity and technology choice. We consider domestic, exporting and multinational firms and measure technology choice by firms' use of advanced information technology (IT). The results imply that multinational high-tech firms are more productive than high-tech exporters. The latter are more productive than low-tech exporters which in turn dominate the group of domestic low-tech firms. This sorting pattern is significant and robust for West German manufacturing firms and is similar for East German manufacturing firms. The results for service firms are less clear although indicating the same tendency. Overall, the observed sorting pattern is consistent with recent models of heterogeneous firms and technology choice.

keywords: exports, multinational, productivity, sorting, information technology, firm-level data
JEL codes: F14, F23, L23

*Corresponding author: Irene Bertschek, Centre for European Economic Research (ZEW) Mannheim. Address: L7,1 68161 Mannheim, Germany. Email: bertschek[at]zew.de. Phone: +49 (0)621 1235 178

1 Introduction

The distinct sorting pattern of relatively more productive firms into export activities has become one of the stylized facts of international economics.[1] The pattern has also been extended to include foreign direct investment (FDI) as the most profitable option of serving a foreign market for the most productive firms Helpman et al. (2004). Recently, the productivity sorting has been shown not only to exist between groups of firms with different international activities but also within them. In particular, Bustos (2011) has developed a theory of firm selection into exporting that highlights heterogeneity among exporters in terms of technology use: The relatively more productive exporters also use more advanced technologies. The mechanism underlying this heterogeneous structure is a combination of fixed market entry costs, for both the domestic and the export markets, and fixed technology adoption costs, the benefits of which unfold themselves in proportion to revenue. Thus, only the most productive exporters have revenues high enough to cover the fixed technology adoption cost; all other firms keep using technology at a lower level. This setting, as documented by Bustos (2011) for Argentinean firms, gives rise to additional gains from trade liberalization through increased use of advanced technologies. The sorting pattern inherent in this setting, a prerequisite for the aforementioned gains to arise, has not been investigated much outside of the scope of the study for Argentina. In his recent study Wagner (2012) divides German manufacturing firms into three groups according to their export status and their spending on research and development (R&D) and shows the R&D-exporters to be the most productive, followed by exporters without R&D spending and purely domestically active firms without R&D spending.

In this paper, we extend the empirical investigation of the idea presented in Bustos (2011) and analysed by Wagner (2012) for the German manufacturing sector in three dimensions. First, we include multinational enterprises (MNEs) with foreign affiliates and check whether the productivity sorting extends to this enlarged group of firms. Secondly, we define technology

[1] Bernard et al. (2012) and Wagner (2011) provide recent surveys that include numerous extensions of the initial patterns with respect to, among others, imports, multiple markets, and different products as well as a discussion on causality in the exports and productivity relation.

choice based on a unique survey data set of German firms giving a detailed account of which information technology (IT) systems firms have actually implemented rather than relying on indirect measures such as R&D spending. The role of information technology as a key driver of productivity is well documented at the firm level as well as at the aggregated level (see for example Draca et al. (2007) for a review). And finally, we investigate whether the sorting patterns known from the manufacturing industry can be established in the service sector as well.

Our findings confirm the sorting of the most productive firms into being multinational as well as the within group heterogeneity of technology use among exporters for West German manufacturing firms and for two alternative technology indicators. Similar results are obtained for East German manufacturing firms, which seem to somewhat depend on the definition of the technology-use index, however. The picture turns out to be less clear for services firms although indicating the same tendency as in the manufacturing sector.

The paper is organized as follows. The next section introduces the general empirical approach, while the following one gives details about the data we use and provides descriptive results. Section 4 presents the econometric results and the last section provides a brief conclusion.

2 Empirical Strategy

We implement three familiar empirical strategies to explore the link between a firm's international market participation, technology choice and productivity. The general idea is to define groups of firms combining internationalisation and technology choice and to compare productivity and other firm characteristics across these two-dimensional groups. First, we conduct so-called premia regressions, a common way in the literature for assessing whether a certain performance measure or firm characteristic of one group significantly dominates the measure of a reference group within the same industry affiliation.[2] The premia reports the average per-

[2]One of the first applications of the premia analysis in the international trade literature is provided by Bernard and Jensen (1999) who compare performance measures of exporters with those of non-exporters.

centage difference of the respective group, e.g. exporters, in comparison to the reference group, e.g. non-exporters, controlling for industry affiliation and firm size. In this paper, the firm characteristics analysed as dependent variables are labour productivity, firm size, human capital and R&D intensity.

Second, we focus on labour productivity only and employ a t-test for differences in the means of productivity. Thereby, a firm's productivity is computed in relation to the respective industry mean. The productivity mean of one group of firms is then compared to the productivity mean of the next group following the sorting sequence suggested by theoretical hypotheses such as in Bustos (2011) and the empirical extension with respect to MNEs which we introduced in the premia regressions. In contrast to the comparison of different groups to one base group, this step aims at testing whether or not the hypothesized *sorting* is empirically significant.

Third, we employ the non-parametric Kolmogorov-Smirnov (KS) test for differences in the overall cumulative productivity distribution.[3] Again, the distribution of each group is compared to that of the next group according to the hypothetical productivity sorting order. The two-sample approach allows to test for first order stochastic dominance of one distribution over the other. Methodologically, the second and the third step of this analysis closely follow Wagner (2012).

3 Data and Descriptives

The data used for the empirical analysis stems from the ZEW ICT survey 2010 designed by the Centre for European Economic Research (ZEW) and conducted via computer-aided telephone interviews. The survey focuses on the diffusion and use of information and communication technologies (ICT). Moreover, it provides information about firm characteristics and performance measures such as the number of employees, the qualification structure of the labour force, total turnover, international market participation and R&D activity. The sample comprises firms from

[3]For a brief illustration and application of the KS test, see for instance Kohler and Smolka (forthcoming) and Wagner (2012).

the manufacturing and service sector with five or more employees and is stratified according to sector, size class and region (East/West Germany). In order to circumvent the influence of outliers we drop firms above and below the 99th and 1st percentile of the productivity distribution, respectively.

Since we intend to assess the productivity ranking according to a firm's international orientation and intensity of technology we construct an IT indicator that counts the number of IT applications used at the firm level as a measure of IT intensity. The IT applications considered are Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM) and Content or Document Management Systems (CDMS). These systems are all highly complex enterprise software systems. While ERP may be applied for processing and controlling various resources of a firm, CRM focuses on the interaction with customers, and SCM may refer to IT-based processing of up to all steps of the value chain (see for example Engelstätter (2012) for further details on these applications). Based on the number of IT systems, we classify the firms into two groups: A firm is said to be a "high technology" (high-tech) firm if it uses at least two of the considered systems. Otherwise, the firm is grouped into the "low technology" (low-tech) category.[4] Looking at firms' IT intensity takes account of the fact that firms may buy and implement new technologies and thus might have technology-intensive business processes without being involved in R&D activity.

Taken together, six possible combinations of internationalisation and technology choice exist (see table 1). Two groups, however, are not considered in our analysis: domestic high-tech firms and multinational low-tech firms. These groups comprise the smallest groups in the sample. Furthermore, the domestic low-tech firms are excluded in Bustos (2011) and Wagner (2012) since they do not feature in the theoretical model which explicitly places the technology cutoff within the group of exporting firms.[5] The group of low-technology multinational firms commands little

[4]Using the IT systems individually in a binary fashion yields largely similar results, which are available upon request.

[5]The group of purely domestically active firm using advanced technologies is relatively small in the manufacturing sector (11%). However, this group is larger for the service sector (38%), indicating a different technology adoption pattern. We nevertheless compare the same groups of firms for manufacturing and services in the main analyses of this paper.

relevance simply due to its small size. Based on just 3% of firms in manufacturing and 2% in services, respectively, it seems reasonable not to consider a further technology cutoff within the group of multinational firms.[6] Although the technology adoption cutoff productivity remains within the exporting group as in Bustos (2011), it is nevertheless important to introduce the MNE group into the analysis since it affects the composition of the exporter group. Although the theory in Helpman et al. (2004) states that firms either export or set up an affiliate abroad, in a sample which does not hold information by destination country, firms often report both exporting activity and foreign affiliates. This is consistent with different countries having different fixed cost of market entry and thus firms having different strategies of internationalisation by country. Counting all these firms as exporter will generate a higher productivity of the exporter group compared to a situation in which the exporters which at the same time have a foreign affiliate are separately studied. Not looking at multinational firms can thus lead to biased results in the sense that a sorting pattern is too easily verified.

Table 1: *Classification of firms into groups*

technology	internationalisation		
	domestic	export	MNE
low	1	2	x
high	x	3	4

With the above considerations in mind, we thus consider four groups of firms in the analysis:

1. Firms that serve only the domestic market and are low tech ($DOMLT$),
2. exporters with low technology ($EXPLT$),
3. exporters with high technology ($EXPHT$),
4. multinational firms with high technology ($MNEHT$),

[6] These numbers are based on the sample with full information on labour productivity.

As emphasized above, a firm is multinational if it has a foreign affiliate and either exports or does not export.[7] Exporters are firms that export but do not have foreign affiliates.

In order to check the validity of our results, we use the share of the employees working mainly at the computer as alternative measure for a firm's IT intensity.[8] We compute the industry mean of this variable at the three-digit Nace 2.0 level and then classify a firm to be a high technology firm if its share of employees working mainly at the computer is above the respective industry mean and as a low technology firm if it is below.

Firm productivity is captured by labour productivity which is measured as sales per employee. The share of highly skilled employees as a proxy for human capital intensity includes employees with a degree from university, university of applied sciences or university of cooperative education with respect to all employees. R&D intensity is measured as the expenditure on R&D relative to total sales. All computations are performed separately for East and West Germany as well as for the whole sample, and separately for the manufacturing and service sector.

The estimation sample includes 921 manufacturing firms and 587 service firms in West Germany.[9] For East Germany, the sample is composed of 391 firms in the manufacturing and 234 firms in the service sector. Table 2 shows the composition of firms across the four groups of international orientation and technology intensity. In West and East Germany, the largest group is the third one of exporters with high technology (West: 41 %; East: 40 %).[10] By contrast, in the service sector most firms are in the first group of non-exporters and low technology (West: 39 %; East: 64 %). Descriptive statistics for the manufacturing sector in West and East Germany are shown in Table 3. In the manufacturing sector, average productivity levels across the four groups are as expected by the productivity sorting pattern proposed in the motivation: The mean

[7]Most of the firms in the data that indicate to have a foreign affiliate are also exporters (72 percent, based on the estimation sample for labour productivity). Only 28 percent indicate to have a foreign affiliate but do not export.

[8]For instance, Bertschek et al. (2006) and Engelstätter (2012) use this measure of IT intensity.

[9]The figures for the estimation sample are based on the number of observations with information on labour productivity.

[10]These numbers appear large compared to shares commonly found in the literature as in e.g. **?** due to the fact that firms with less than 5 employees are excluded here.

productivity levels are increasing from the first group of domestic firms with low technology to the last group of MNEs with high technology. The sorting pattern principally remains the same for the other firm characteristics, i.e. the more a firm is involved in operating on international markets and the more technology-intensive it is, the larger, more human-capital intensive and more R&D-intensive this firm is. For East Germany, the productivity sorting across the four groups is not as clear since the group of exporters with low technology has a higher labour productivity mean than the group of exporters with high technology. However, the ascending sorting order is again established in the median labour productivity levels of the four groups (not reported). With respect to the other firm characteristics, the ranking is the same across the four groups as in the West German sample.

Table 4 shows descriptive statistics for the service sector in West and East Germany. The empirical sorting order for mean labour productivity does not correspond to the one in manufacturing neither for service firms in East nor in West Germany. In West Germany, the mean labour productivity of the low-tech exporters is lower than the level of the domestic low-tech firms while for East Germany, the mean labour productivity for low-tech exporters is higher than the mean level of high-tech exporters. For East Germany, the mean advantage of low-tech exporters compared to high-tech exporters remains in the median comparison, too (not reported). Nevertheless, the general picture is that the labour productivity levels are increasing from the group of domestic firms with low technology to the high technology MNEs group.

4 Empirical Results

The results of the premia regressions for manufacturing firms are depicted in Table 5. In the West German manufacturing sector, all premia for the different firm characteristics are significant for all groups of firms with the exception of the R&D premia for low-tech exporters. Moreover, the premia are increasing in magnitude across the three groups with international market participation compared to the reference group of domestic firms with low technology, hinting at the expected sorting pattern. For the case of labour productivity as the dependent variable, this

result confirms the postulated productivity sorting already present in the descriptive statistics. For instance, exporting high technology firms have a 30 % higher labour productivity than non-exporters with low technology. For the sample of East German manufacturers, only the premia of the low-tech exporting group and the high-tech MNEs are significant whereas the premia for the high-tech exporters is insignificant at conventional levels.

We again find the service sector to confirm less clearly to the patterns observed in manufacturing. Several of the premia are not significant for West and East German firms (see Table 6), although the size of the coefficients mostly increases in the familiar way across groups. Yet, in the subsequent more detailed empirical analysis we only consider manufacturing firms in order to check the sorting pattern in a step-wise fashion, comparing one group to the next. [11]

Proceeding with manufacturing firms, the results from the t-test for differences in the mean labour productivity levels, computed in relation to the 3-digit Nace 2.0 industry mean, yield, as already suggested by the results from the premia regression for labour productivity, that the complete productivity ranking is statistically significant (see Table 7) in the manufacturing sector in West Germany. For East German manufacturers, only the difference in mean productivity between the domestic low-tech firms and the exporting low-tech firms and the difference between the high-tech exporters and high-tech MNEs are significant. The difference between the two middle groups within the sorting, i.e. between exporting low technology firms and exporting high technology firms, by contrast, is insignificant.

Figure 5 compares the empirical cumulative distribution functions of two neighbouring groups according to the postulated productivity ranking. The graphical comparisons suggest that the productivity sorting holds in terms of the whole distribution for West Germany, too. Formally, the KS test (see Table 7) yields that the productivity distribution of the high technology MNEs significantly dominates the distribution of the high technology exporters, and the distribution of high technology exporters significantly dominates the distribution of low technology exporters.

[11] Although the premia regressions indicate the same sorting pattern as in the case of manufacturing, the picture remains inconclusive for services when checking the sorting by looking at the difference in mean productivity and in the cumulative distribution function. Results are available on request.

However, the KS-test for first order stochastic dominance is just outside conventional significance levels when comparing the distribution of exporting low-tech firms to domestic low-tech firms. For East Germany, the productivity distribution of low-tech domestic firms is dominated by the distribution of low-tech exporters and the distribution of high-tech exporters is dominated by the one of high-tech MNEs. As already indicated by the t-test, the comparison of the distributions of the two middle groups of exporters in the sorting is not significant.

The central finding from the KS tests is that for the majority of the groups of firms, the productivity distributions differ significantly according to the productivity ranking as hypothesized by Bustos (2011) and the extension to MNEs in the spirit of Helpman et al. (2004).

With the alternative IT indicator based on the share of employees working mainly with the computer for building the four groups (see Table 8 and Table 9), the premia regressions for labour productivity, the t-test and the KS test confirm the hypothesized productivity sorting for manufacturing firms in West Germany even more strongly. All t-tests for differences in productivity and all KS tests for first order stochastic dominance across the order of the groups are significant.[12] Also, for East German manufacturers the productivity sorting is more evident when using this alternative measure of IT intensity. Only the low-tech exporter premia is not significant for labour productivity as well as the corresponding t-test between the low-tech domestic firms and the low-tech exporters. All other t-tests for differences in the mean labour productivity levels and all KS tests are significant, at least at the 10% significance level, for East German manufacturers, too. Thus, the results for East Germany somewhat depend on the exact definition of the technology-use indicator.

[12]Since the technology classification is different with this alternative IT indicator in comparison to the IT indicator based on the number of applied IT systems, the group composition of the four groups used in the analysis is slightly different across the two IT indicators. Hence, also the estimation sample is not completely identical.

5 Conclusions

In this paper, we provide empirical evidence for the productivity sorting between groups of firms with different international activities and with different levels of technology use. Compared to previous empirical studies, our analysis considers domestic, exporting and multinational firms and measures the stage of technology by firms' actual use of IT. Based on a unique German firm-level data set, our results support the hypotheses derived from a combination of Bustos (2011) and Helpman et al. (2004) and imply that multinational high-tech firms are more productive than high-tech exporters which are more productive than low-tech exporters. The latter, finally dominate the group of domestic low-tech firms. This sorting pattern is significant and robust for West German manufacturing firms. It goes into the same direction for East German manufacturing firms, with a certain dependence on the technology-use indicator, however. Our results for exporting manufacturing firms are in line with the empirical findings by Bustos (2011) for Argentinean industrial firms and with Wagner (2012) for the German manufacturing sector. We furthermore show that the productivity sorting extends to multinational firms with high-technology. For service sector firms, productivity generally increases with internationalisation and technology use but the sorting can not be always be confirmed for each group with conventional significance.

Table 2: *Group composition - Shares*

	manufact. firms		**service firms**	
	West	East	West	East
domestic, low tech	15	28	39	64
	(137)	(111)	(228)	(150)
exporter, low tech	16	21	10	12
	(148)	(83)	(58)	(28)
exporter, high tech	41	40	29	19
	(374)	(156)	(171)	(45)
MNE, high tech	28	10	22	5
	(262)	(41)	(130)	(11)
Total observations	921	391	587	234

Notes: The table presents the shares of the firms in a particular group in percent. The total number of observations in each group is in parentheses below the corresponding share.

Table 3: *Descriptive Statistics - Manufacturing Sector*

	West					**East**				
	DOMLT	*EXPLT*	*EXPHT*	*MNEHT*	Obs	*DOMLT*	*EXPLT*	*EXPHT*	*MNEHT*	Obs
labour productivity	106.45	159.91	199.10	256.00	921	99.18	154.86	144.90	239.42	391
(in thousands of Euro)	(89.44)	(182.67)	(180.59)	(230.40)		(98.71)	(125.91)	(117.85)	(205.90)	
no. of employees	44	40	242.77	1474	921	34	56	142	416	391
	(198.86)	(50.65)	(822.73)	(5824.03)		(79.20)	(83.39)	(270.60)	(592.00)	
% high-skilled empl.	5.20	9.55	15.86	18.35	824	8.39	17.42	20.03	28.37	377
	(9.06)	(13.51)	(17.34)	(16.37)		(12.76)	(16.62)	(17.18)	(24.00)	
R&D intensity	1.80	3.47	6.42	6.90	773	3.03	6.54	6.86	10.94	359
	(6.59)	(5.78)	(10.79)	(7.12)		(9.16)	(15.96)	(11.11)	(13.33)	
IT index	0.52	0.65	3.01	3.24	921	0.56	0.71	2,87	3.15	391
	(0.50)	(0.48)	(0.83)	(0.80)		(0.50)	(0.46)	(0.81)	(0.88)	
% empl. working	19.22	29.41	40.70	46.73	917	19.11	29.48	33.34	44.54	390
with PC	(20.03)	(21.90)	(24.17)	(22.22)		(17.43)	(22.81)	(22.83)	(26.53)	

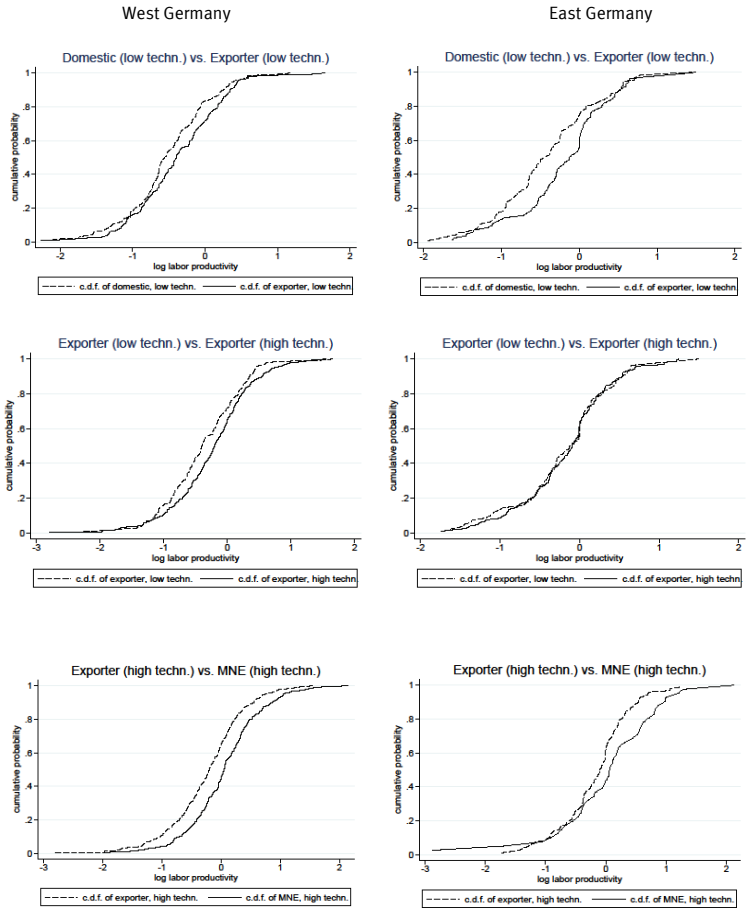
Notes: The table presents the shares of the firms in a particular group in percent.
Standard deviations are in parentheses below.

Table 4: *Descriptive Statistics - Service Sector*

	West					**East**				
	DOMLT	*EXPLT*	*EXPHT*	*MNEHT*	Obs	*DOMLT*	*EXPLT*	*EXPHT*	*MNEHT*	Obs
labour productivity	221.11	166.19	236.29	396.09	587	126.38	144.67	120.40	147.23	234
(in thousands of Euro)	(517.54)	(162.32)	(358.43)	(628.87)		(160.90)	(146.38)	(107.07)	(121.15)	
no. of employees	36	41	351	2096	587	31	31	106	278	234
	(84.18)	(169.34)	(1781.05)	(6560.66)		(43.23)	(35.01)	(203.31)	(484.23)	
% high-skilled empl.	17.54	25.84	34.63	41.85	557	20.78	29.33	38.95	32.47	227
	(25.95)	(32.28)	(32.38)	(30.89)		(25.89)	(31.90)	(34.33)	(27.38)	
R&D intensity	2.80	3.57	9.33	6.63	543	2.96	9.05	15.88	14.34	227
	(10.88)	(10.97)	(19.73)	(12.84)		(12.45)	(21.48)	(26.62)	(19.30)	
IT index	0.57	0.57	2.91	3.25	587	0.58	0.54	2.82	2.91	234
	(0.50)	(0.50)	(0.76)	(0.72)		(0.50)	(0.51)	(0.78)	(0.83)	
% empl. working	49.44	61.44	70.85	74.48	587	46.68	46.71	62.00	55.14	234
with PC	(39.22)	(36.03)	(30.73)	(29.29)		(39.27)	(32.10)	(33.64)	(27.02)	

Notes: The table presents the shares of the firms in a particular group in percent.
Standard deviations are in parentheses below.

Figure 1: *Sorting pattern: cumulative density plots of productivity*



Notes: The figure presents plots of the cumulative density functions of log labour productivity by group. Results are for manufacturing firms from West Germany on the left and East Germany on the right side. Labour productivity is defined as the log of sales per worker in thousands of Euro divided by the 3-digit Nace 2.0 industry mean.

Table 5: *Premia regressions for different groups - Manufacturing sector*

	(1)	(2)	(3)	(4)
	West and East Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.278***	0.584***	0.0383***	1.386
	(0.0674)	(0.113)	(0.0135)	(1.057)
exporter, high tech	0.274***	1.625***	0.0659***	2.449**
	(0.0658)	(0.106)	(0.0138)	(0.956)
MNE, high tech	0.490***	3.050***	0.107***	4.089***
	(0.0854)	(0.122)	(0.0196)	(1.267)
Observations	1,312	1,312	1,201	1,132
R-squared	0.326	0.521	0.330	0.179
	West Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.234***	0.595***	0.0341**	1.093
	(0.0833)	(0.153)	(0.0170)	(0.973)
exporter, high tech	0.302***	1.798***	0.0613***	2.640**
	(0.0802)	(0.146)	(0.0181)	(1.128)
MNE, high tech	0.525***	3.235***	0.0904***	3.491**
	(0.0993)	(0.154)	(0.0232)	(1.406)
Observations	921	921	824	773
R-squared	0.315	0.557	0.321	0.204
	East Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.294**	0.468**	0.0500**	0.881
	(0.129)	(0.194)	(0.0231)	(2.303)
exporter, high tech	0.189	1.269***	0.0678***	2.111
	(0.124)	(0.172)	(0.0218)	(1.742)
MNE, high tech	0.403*	2.350***	0.156***	5.757*
	(0.205)	(0.248)	(0.0432)	(3.197)
Observations	391	391	377	359
R-squared	0.350	0.464	0.463	0.271

Notes: The table presents results of regressions of the following form:

$$Y = \alpha + \beta_1 EXPLT + \beta_2 EXPHT + \beta_3 MNEHT + \gamma lnEMP + \delta_i + \epsilon_i$$

Y is the variable of interest in terms of which the "premia" is measured. The excluded reference group is DOMLT (domestic, low-tech). $EXPLT$ stands for the group "exporter, low technology", $EXPHT$ for "exporter, high technology" and $MNEHT$ for "MNE, high technology". All regressions include dummy variables for 3-digit Nace 2.0 industries (δ_i) to account for industry affiliation and log employment $lnEMP$ (except for the employment regression itself) as a measure of firm size. Labour productivity is defined as sales per worker, the share of high-skilled measures the share of university graduates in total firm employment, and the R&D intensity is R&D expenditure as a percentage of sales. All values above the 99th percentile and below the 1st percentile of the productivity distribution have been dropped to exclude extreme outliers. Robust standard errors are given in parentheses. $***$, $**$, and $*$ represent significance at the 1, 5, and 10 percent level, respectively. The joint regression for West and East Germany includes additionally a dummy variable to indicate if the firm is located in East Germany.
Correcting for a possible correlation between standard errors within an industry affiliation by using clustered standard errors across industry affiliation (not reported), for the whole sample the significance level of the high technology exporter premia is lowered to 5%, in West Germany the significance level of the premia coefficients for the low technology exporters and the high technology exporters is lowered to a 10%-level and to a 5%-level respectively and for East Germany the significance level of the low technology exporter premia reduces to 10%.

Table 6: *Premia regressions for different groups - Service sector*

	(1)	(2)	(3)	(4)
	West and East Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.115	0.0308	0.0652**	2.549
	(0.0892)	(0.134)	(0.0258)	(2.041)
exporter, high tech	0.193**	1.175***	0.0664**	3.713**
	(0.0835)	(0.137)	(0.0262)	(1.749)
MNE, high tech	0.355***	2.780***	0.132***	2.217
	(0.113)	(0.182)	(0.0353)	(1.914)
Observations	820	820	783	769
R-squared	0.444	0.465	0.570	0.402
	West Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.0624	-0.0602	0.0538	0.0215
	(0.126)	(0.190)	(0.0337)	(2.322)
exporter, high tech	0.127	1.262***	0.0544*	3.847**
	(0.110)	(0.171)	(0.0325)	(1.732)
MNE, high tech	0.348**	2.942***	0.140***	3.371**
	(0.139)	(0.198)	(0.0406)	(1.599)
Observations	587	587	557	543
R-squared	0.435	0.499	0.562	0.526
Observations	921	921	824	773
R-squared	0.315	0.557	0.321	0.204
	East Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.301**	0.324	0.0907*	4.451
	(0.132)	(0.197)	(0.0468)	(5.284)
exporter, high tech	0.216*	0.997***	0.0962*	-0.180
	(0.127)	(0.248)	(0.0558)	(4.135)
MNE, high tech	0.120	1.026***	0.0393	4.730
	(0.235)	(0.275)	(0.145)	(9.981)
Observations	234	234	227	227
R-squared	0.552	0.460	0.672	0.410

Notes: The table presents results of regressions of the following form:

$$Y = \alpha + \beta_1 EXPLT + \beta_2 EXPHT + \beta_3 MNEHT + \gamma lnEMP + \delta_i + \epsilon_i$$

Y is the variable of interest in terms of which the "premia" is measured. The excluded reference group is DOMLT (domestic, low-tech). $EXPLT$ stands for the group "exporter, low technology", $EXPHT$ for "exporter, high technology" and $MNEHT$ for "MNE, high technology". All regressions include dummy variables for 3-digit Nace 2.0 industries (δ_i) to account for industry affiliation and log employment $lnEMP$ (except for the employment regression itself) as a measure of firm size. Labour productivity is defined as sales per worker, the share of high-skilled measures the share of university graduates in total firm employment, and the R&D intensity is R&D expenditure as a percentage of sales. All values above the 99th percentile and below the 1st percentile of the productivity distribution have been dropped to exclude extreme outliers. Robust standard errors are given in parentheses. $***$, $**$, and $*$ represent significance at the 1, 5, and 10 percent level, respectively. The joint regression for West and East Germany includes additionally a dummy variable to indicate if the firm is located in East Germany.

Table 7: *Sorting pattern: comparison between groups - Manufacturing sector*

comparison	(1) **domestic, low tech** *mean*	(2) **exporter, low tech** *mean*	(3) **exporter, high tech** *mean*	(4) **MNE, high tech** *mean*	**t-test** *p-value*	**KS test** *p-value*
			West Germany			
(1) vs (2)	0.713	0.835			0.061*	0.107
	(0.039)	(0.051)				
(2) vs (3)		0.835	0.959		0.043**	0.014**
		(0.051)	(0.033)			
(3) vs (4)			0.959	1.30	0.000***	0.000***
			(0.033)	(0.060)		
			East Germany			
(1) vs (2)	0.830	1.003			0.069*	0.004***
	(0.059)	(0.073)				
(2) vs (3)		1.003	0.999		0.969	0.994
		(0.073)	(0.049)			
(3) vs (4)			0.999	1.455	0.046**	0.030**
			(0.049)	(0.217)		

Notes: The above table reports the means of labour productivity by group in columns (1)-(4). The four groups are based on the IT index using the number of installed software systems within a firm. Labour productivity is defined as sales per employee in thousands of Euro divided by the 3-digit Nace 2.0 industry mean. Standard deviations are given in parentheses below the means. The t-test compares the means and tests the H_0 of equality of means. The test is a two sample test with different variances across groups. The Kolmogorov-Smirnov (KS) tests assess the H_0 of all productivity values being drawn from the same distribution. Again, labour productivity is computed as percentage of the 3-digit Nace 2.0 industry mean. $***$, $**$, and $*$ represent significance at the 1, 5, and 10 percent level, respectively.

Table 8: *Premia regressions for different groups - Manufacturing sector - Alternative IT index*

	(1)	(2)	(3)	(4)
	West and East Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.185***	0.937***	0.0219**	1.881***
	(0.0559)	(0.116)	(0.0107)	(0.718)
exporter, high tech	0.424***	1.027***	0.109***	3.919***
	(0.0596)	(0.123)	(0.0134)	(0.859)
MNE, high tech	0.580***	2.556***	0.141***	5.673***
	(0.0815)	(0.144)	(0.0200)	(1.193)
Observations	1,248	1,248	1,156	1,087
R-squared	0.380	0.394	0.394	0.201
	West Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.230***	1.051***	0.0178	2.196**
	(0.0702)	(0.162)	(0.0152)	(0.922)
exporter, high tech	0.472***	1.090***	0.0823***	3.786***
	(0.0740)	(0.164)	(0.0177)	(0.906)
MNE, high tech	0.601***	2.691***	0.113***	4.873***
	(0.0947)	(0.179)	(0.0230)	(1.191)
Observations	861	861	780	729
R-squared	0.360	0.430	0.367	0.218
	East Germany			
	log labor productivity	log employment	share of high-skilled	R&D intensity
exporter, low tech	0.128	0.686***	0.0164	0.765
	(0.0991)	(0.174)	(0.0165)	(1.323)
exporter, high tech	0.389***	0.852***	0.154***	4.848**
	(0.108)	(0.206)	(0.0221)	(2.073)
MNE, high tech	0.826***	2.038***	0.241***	8.605*
	(0.230)	(0.313)	(0.0571)	(4.682)
Observations	387	387	376	358
R-squared	0.487	0.365	0.589	0.319

Notes: The table presents results of regressions of the form as in 5. The only difference is that the the share of employees working mainly with the computer is used to construct the IT index on which the splitting of the firms into the four groups is based on. The excluded reference group is again $DOMLT$ (domestic, low-tech). All regressions include dummy variables for 3-digit Nace 2.0 industries (δ_i) to account for industry affiliation and log employment $lnEMP$ (except for the employment regression itself) as a measure of firm size. Labour productivity is defined as sales per worker, the share of high-skilled measures the share of university graduates in total firm employment, and the R&D intensity is R&D expenditure as a percentage of sales. All values above the 99th percentile and below the 1st percentile have been dropped. Robust standard errors are given in parentheses. $***$, $**$, and $*$ represent significance at the 1, 5, and 10 percent level, respectively.
With clustered standard errors, the significance level of the premia coefficient for the low technology exporters lowers to 5% for the whole sample as well as for West Germany.

Table 9: *Sorting pattern: comparison between groups - Manufacturing sector - Alternative IT index*

comparison	(1) **domestic, low tech** *mean*	(2) **exporter, low tech** *mean*	(3) **exporter, high tech** *mean*	(4) **MNE, high tech** *mean*	**t-test** *p-value*	**KS test** *p-value*
			West Germany			
(1) vs (2)	0.700	0.861			0.002***	0.000***
	(0.042)	(0.032)				
(2) vs (3)		0.861	1.066		0.001***	0.005***
		(0.032)	(0.049)			
(3) vs (4)			1.066	1.429	0.000***	0.000***
			(0.049)	(0.080)		
			East Germany			
(1) vs (2)	0.818	0.914			0.125	0.096*
	(0.042)	(0.045)				
(2) vs (3)		0.914	1.160		0.004***	0.014**
		(0.045)	(0.072)			
(3) vs (4)			1.160	2.025	0.045**	0.055*
			(0.072)	(0.400)		

Notes: The above table reports the means of labour productivity by group in columns (1)-(4). The four groups are based on the IT index using the share of employees working mainly with the computer. Labour productivity is defined as sales per employee in thousands of Euro divided by the 3-digit Nace 2.0 industry mean. Standard deviations are given in parentheses below the means. The t-test compares the means and tests the H_0 of equality of means. The test is a two sample test with different variances across groups. The Kolmogorov-Smirnov (KS) tests assess the H_0 of all productivity values being drawn from the same distribution. Again, labour productivity is computed as percentage of the 3-digit Nace 2.0 industry mean. $***$, $**$, and $*$ represent significance at the 1, 5, and 10 percent level, respectively.

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