

Discussion Paper No. 05-73

**Exports versus FDI in  
German Manufacturing:  
Firm Performance and Participation  
in International Markets**

Jens Matthias Arnold and Katrin Hussinger

**ZEW**

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## Non-Technical Summary

Even within narrowly defined manufacturing industries, firms display very different patterns of participation in international markets. While some firms do well serving only customers in their home country, others export into foreign markets, or set up a foreign subsidiary in order to produce abroad.

Only recently has economic theory been able to produce an explanation for such differences between firms, in a paper by Helpman, Melitz and Yeaple (2004). This new strand of theory traces back different patterns of internationalization to innate differences in productivity levels between firms, and predicts a productivity ordering of firms according to their degree of participation in international commerce: Low productivity firms are predicted to serve only the home market, while better performers can afford to expand their market towards foreign buyers through exporting. Finally, the highest productivity firms are predicted to serve foreign markets by establishing production plants abroad, and thus engage in foreign direct investment (FDI). It is this productivity ordering that we test in this paper, using firm-level data from the German manufacturing sector.

For this purpose, we have been able to merge a representative firm-level data set from the Mannheim Innovation Panel, which is the German part of the Community Innovation Survey (CIS) of the European Commission, with complete records on foreign subsidiaries from the micro-data base MiDi (Micro Database Direct Investment) provided by the German Bundesbank.

We group firms into three categories according to their participation in international commerce, and undertake productivity comparisons, using a testing technique that makes comparisons over the entire distribution of productivity in the three groups of firms rather than only comparing means. We show that German exporters outperform firms that serve only the domestic market. In a similar manner, German multinational firms, defined as firms with subsidiaries abroad, are more productive than both domestically focused and exporting firms in Germany. These findings hold true for each year from 1996 to 2002. Our results from German manufacturing firms are thus consistent with one of the key predictions from theory about the determinants of different trade orientations among firms within the same industry.

# Exports versus FDI in German Manufacturing: Firm Performance and Participation in International Markets

Jens Matthias Arnold\* and Katrin Hussinger\*\*

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## Abstract

This paper tests some of the predictions of recent advances in trade theory that have focused on different trade patterns of firms within the same sector. Helpman, Melitz and Yeaple (2005) develop a model in which innate productivity differences between firms determine the degree of international engagement of firms: The least productive firms produce for the domestic market, better performers engage in export activities, and the top firms establish foreign subsidiaries. Using German firm-level data from 1996 to 2002, we test this prediction using non-parametric methods, by examining the distribution functions of the three subsets of firms for stochastic dominance. Rather than just comparing first moments, this technique allows us to compare productivity over the entire distribution. Our results show robust support for the prediction from theory.

**Keywords:** Exports; FDI; Heterogeneous firms, Total Factor Productivity.

**JEL-Classification:** F10, F21, F23, F14, D21, D24, L60

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## 1 Introduction

It is a well-established empirical fact that even within narrowly defined manufacturing industries, firms display considerable heterogeneity with regard to the extent to which they serve foreign markets. While some firms do well serving only their home market, others are able to generate additional gains in export markets, or find it profitable to set up a foreign subsidiary in order to produce for demand in foreign countries. Both the ‘traditional’ and ‘new’ trade theories rely on representative firms and are thus unable to explain how firms belonging to the same sector can display heterogeneous behavior. However, a recent strand of theory initiated by Melitz (2004) and Bernard et al. (2003) has been able to explain heterogeneity with respect to foreign trade in a formal framework. Firm heterogeneity is traced back to innate differences in productivity levels, which are modeled as draws from a common distribution function. Helpman, Melitz and Yeaple (2004) (henceforth HMY) extend the framework of Melitz (2004) to incorporate the possibility that firms engage in foreign direct investment (FDI). One of the key predictions of their model is a productivity ordering of firms according to their patterns of participation in international commerce.

In the theoretical model, firms receive a random productivity draw from a given distribution. Subsequently, entrants self-select themselves into one of 3 categories depending on the outcome of their draw. Entrants may produce for the domestic market only, export or establish a foreign subsidiary. Increasing participation in international markets is a strictly monotonous function of a firm’s productivity: Low productivity firms serve only the home market, while better performers can afford to pay the additional fixed cost of expanding their market towards foreign buyers through exporting. Finally, the highest productivity draws will establish production plants in foreign markets, and thus engage in horizontal foreign direct investment (FDI).<sup>1</sup> It is this productivity ordering that we test in this paper, using firm-level data from the German manufacturing sector.

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<sup>1</sup> Licensing arrangements are not a predicted pattern of this model, and are not dealt with in this paper. An additional prediction of their model, which is not examined here either, is that FDI will be relatively more prominent in sectors with higher dispersion of firm productivities.

While theoretically attractive, and thus far the only theoretical explanation of firm heterogeneity with respect to both trade and investment, the HMY model still lacks a solid empirical foundation. Most of the existing empirical evidence covers only parts of the heterogeneity explanations offered by HMY. For instance, it has been documented that exporting firms tend to outperform non-exporters, and that subsidiaries of multinationals are more productive than domestic firms in the host country.

The scarcity of comprehensive empirical evidence so far may be due to the fact that micro-data with records on export behavior and outward foreign investment on the same firms are not readily available for many countries. This paper makes use of a newly merged dataset on German manufacturing firms to test the model predictions using the concept of stochastic dominance. Rather than comparing first moments alone, this concept tests for differences over the entire distribution of firm productivities. Intuitively, a distribution dominates another one if its cumulative distribution function lies entirely to the right of the other one. Stochastic dominance can be tested non-parametrically using one- and two-sided Kolmogorov-Smirnov tests (KS-tests). In our eyes, this empirical concept is close in spirit to the self-selection mechanism in the HMY model. We apply these tests to the distribution of total factor productivity (TFP) of German firms. Our TFP estimates are obtained using a semi-parametric estimation technique following Levinsohn and Petrin (2003). This estimator delivers consistent estimates even in the presence of a possible correlation of factor input choice and unobserved shocks to productivity.

Our results display a remarkable fit of the productivity distributions of German firms with the pattern predicted by the HMY model. Exporting firms clearly outperform non-exporting firms over the entire productivity distribution, and the same holds for German multinational firms vis-à-vis the former group. The empirical confirmation of the rank ordering of firms with different patterns of international commerce in terms of productivity is a novel empirical result, and is consistent with the mechanisms at work in the HMY model.

## 2 Theory

The firm choice between exporting at arms' length and foreign direct investment has traditionally been modeled as a proximity-concentration trade-off (Brainard 1993, 1997). Increasing returns to scale at the plant level create incentives to concentrate production in one place, while transaction costs associated with distance between the locations of production and sale provide a countervailing force towards establishing a production plant closer to the foreign market. This trade-off has found support in data at the industry level, but it cannot explain heterogeneous choices of firms within sectors.

In the heterogeneous firms model by Helpman, Melitz and Yeaple (2004), firms within each sector display heterogeneous levels of productivity. Decisions are made according to the following sequence: Potential entrants pay a sunk cost  $f_E$  in order to enter an industry. Upon paying this sunk cost, which has almost the interpretation of a lottery ticket, an entrant receives a random productivity draw in the form of a labor input coefficient  $a$  per unit of output from a known distribution  $G(a)$ .<sup>2</sup> Having learned about its draw, a firm may decide to leave the market altogether (in which case it has profits  $\pi = -f_E < 0$  and will ex post regret having participated) or to pay an additional fixed cost  $f_D$  of setting up production at home. After paying the fixed cost  $f_D$  the firm produces a unique variety of a differentiated good for the home market at a marginal labor cost equal to its productivity draw  $a$ .

The degree of participation in international markets that a firm chooses is governed by the following parameters: An additional fixed cost  $f_X$  has to be incurred in order to export, while setting up a foreign production plant has a (higher) fixed cost of  $f_f$ . The concentration force is embodied in the difference between these two parameters, whereas the proximity force stems from the fact that exporting adds to marginal cost by commanding iceberg-type transport costs of  $\tau > 1$  per unit of output sold in the export market. That is to say, it is assumed that  $\tau$  units of output have to be shipped in order for one unit to arrive at the foreign destination.

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<sup>2</sup> It should be clear that the HMY model adds nothing to the understanding of which specific firm will have productivity advantages vis-à-vis its competitors because the draws are random. The contribution of the model lies in explaining how heterogeneous productivity levels and trade patterns can coexist in equilibrium rather than explaining the productivity and trade pattern of a specific firm.

Production by a foreign affiliate, on the other hand, does not incur per-unit transport costs and is produced using the same firm-specific level of efficiency  $a$  as in the home country.<sup>3</sup>

From this distinction between fixed and marginal costs assumed in the model, it becomes clear that the sales volume in the foreign country will play a crucial role in determining the optimal degree of internationalization of a firm. Suppose for simplicity that wages are equal between the two countries. Consumers are assumed to have CES preferences over differentiated products with an elasticity of substitution  $1/(1-\alpha)$ , and market structure is assumed to be monopolistic competition.<sup>4</sup> A firm's variety in a given market will then be priced at  $p=a/\alpha$  if produced in the same country, or at  $p = \tau a/\alpha$  if it incurs transport costs. It will face a demand  $D^i = A^i p^{1/(\alpha-1)}$ , where  $A^i$  is a measure of the market size of country  $i$ . Hence, regardless of how a firm decides to serve a market, its sales volume in that market will be a decreasing function of its marginal cost parameter  $a$ , or in other words a strictly increasing function of its productivity.

Since firms charge markups above unity and thus enjoy positive operating profits, the volume of sales determines a firm's ability to recoup the fixed costs associated with different choices. First, consider the decision to produce for the domestic market and incur fixed costs  $f_D$ . Only firms above a certain productivity threshold can expect a sales volume large enough to recoup  $f_D$ . Firms with a productivity below this threshold will hence decide not to enter the market. The marginal firm that decides to enter the domestic market, however, will find it unprofitable to serve a foreign market through exports: Since it faces higher marginal costs in that market due to transport costs, it will not be able to generate the sales volume necessary to recoup the additional fixed costs of exporting  $f_X$  in the foreign market. By the same token, it will not be able to pay  $f_f > f_X$ . Going up in the productivity ordering of firms, however, there

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<sup>3</sup> This holds true if there are no factor cost differences between the home and the host country. Head and Ries (2003) show that these can alter and in the extreme case invert the predictions of the model. In other words, the concept of FDI underlying the HMY model is a horizontal one, in which FDI is motivated by market access. Given that the overwhelming majority of the firms in our sample invest in other OECD countries (see section 4), it seems reasonable to test this model on our data.

<sup>4</sup> Head and Ries (2003) show that CES preferences and iceberg costs are not necessary to derive the results of the model. They use a quadratic utility function.

will eventually be a firm whose expected sales volume meets the threshold necessary to expect positive profits in the foreign market from exporting, but not from FDI. Going further up in the productivity ranking, there will be a threshold firm whose expected sales volume in the foreign market is high enough so that it would rather pay the higher fixed cost  $f_1$  than the per-unit transport costs. This is the proximity-concentration tradeoff at the level of the firm, whose balance is determined by the sales volume of the firm in the foreign market, which in turn is a function of firm productivity.

Summing up, the model predicts three well-defined cut-off productivity levels: One at which firms decide to set up production in the home market, a second one at which they will export in addition to their domestic sales, and a third one at which FDI begins to dominate exporting. These cut-offs imply that firms with a productivity level above the highest threshold will engage in FDI, while a set of firms with productivity levels strictly below the FDI firms will export but not set up foreign affiliates. Finally, the productivity of purely domestic firms lies strictly below that of the exporting firms.

### 3 Related Empirical Literature

The present paper investigates the productivity patterns of firms that fall into three categories: Domestic non-exporters (D), domestic exporters (DX) and multinational firms with outward investment in a foreign country (DI). The argument entails two partial elements, which have been the subject of prior empirical research.

For one, an extensive empirical literature has investigated productivity patterns across exporting and non-exporting firms. Evidence is now available for a number of countries, including the United States (Bernard and Jensen 1999, 2004), the UK (Girma et al. 2004), Germany (Arnold and Hussinger 2005, also Fryges 2004 for a comparison of young high-tech firms in the UK and Germany), Taiwan and Korea (Aw et al. 2000) and for developing countries such as Chile (Pavcnik 2002), Colombia, Mexico and Morocco (Clerides, Lach and Tybout 1998). The general message coming from this evidence is that exporters tend to outperform non-exporting firms,

and that the causality mostly runs from productivity to export status.

Second, some studies investigate productivity differences between multinational companies and domestic companies both in the home and host countries. Doms and Jensen (1998) show that US multinationals have an above-average productivity with respect to all US companies. Yeaple (2005) shows that lagged productivity is a significant predictor of US firms establishing foreign subsidiaries, and Castellani and Barba Navaretti (2004) finds similar results for Italian companies. With respect to the host country, Arnold and Javorcik (2005) show that foreign ownership has a significant positive effect on plant performance in Indonesia. Barba Navaretti and Venables (2004) provide a survey of the literature.

Apart from these studies lending partial support for the pattern suggested by theory, three studies undertake a more complete look at the issue. Head and Ries (2003) look at a sample of 1070 publicly listed Japanese firms for which they have information on exports and outward FDI. The study compares average TFP across firms with different degrees of internationalization, and finds some support for the predicted ordering, although the differences tend to be statistically insignificant. Head and Ries also estimate an ordered linear probability model, and again find mixed results. While the association between TFP and degree of internationalization is often positive, it is in many instances not statistically significant and on occasions even negative.

Girma, Görg and Strobl (2005) compare the productivity distributions of D, DX and DI firms in the Republic of Ireland, using data for the year 2000. Their study finds only partial support for the predictions from theory: They find no significant productivity differences between D and DX plants, while the productivity distribution function of DI firms statistically dominates the remaining two. However, their analysis is restricted to partial measures of firm productivity such as sales, value added and profit per employee. Lacking information on capital stocks of firms, they cannot control for possible underlying differences in capital intensity across the three groups of firms. Hence if firms with international engagement employ a more capital-intensive production technique, the findings run the risk of overestimating the performance of these firms.

Girma, Kneller and Pisu (2005) compare the productivity distributions of firms with different trade orientations using UK data. While this study examines total factor productivity (TFP) rather than labor productivity, the trade-related information in the principal data set used includes only information on the export status and on ownership. They make an effort to complement this with information on foreign investment activities from other sources, but are not able to achieve full systematic coverage of all firms in their sample with respect to FDI. Moreover, the information on foreign subsidiaries they gather is available only for one year, and is then backcast. They complement this analysis by examining foreign multinationals in the UK (on which they have full information for the latest year) rather than UK multinationals as the third category. While this is a clear departure from the theoretical model, it is expected to deliver similar results in the special case of symmetric countries. Their results are consistent with the HMY model for most but not all of the years in their observed time frame.

Finally, Wagner (2005) analyzes information from personal interviews on a sample of firms from the German state of Lower Saxony for the year 1995 and finds supportive evidence for the HMY model using value added per worker.

Our paper represents an improvement on existing studies in several regards: For one, our data have a panel structure covering the years 1996 to 2002, and they are not restricted to publicly listed firms. We use a stratified sample including also small and medium enterprises, some of which tend to be heavily engaged in international activities in the German case. Second, our productivity measure is total factor productivity and not a partial productivity measure. Third, in contrast to other studies our productivity estimations control for a possible simultaneity bias in input choice by using a semi-parametric estimator suggested by Levinsohn and Petrin (2003). Fourth, we use reliable information on the foreign activities of German firms, which is collected by the German central bank on a mandatory basis. Using this information, we undertake comparisons of the entire TFP distributions of samples by testing for stochastic dominance, for each of the 7 years between 1996 and 2002.

## 4 Data and Descriptive Statistics

The data used in the present study come from two main sources, which have been merged for the first time. We use a rich array of firm-level information from a stratified, representative survey of the German manufacturing sector called the Mannheim Innovation Panel (MIP). The MIP is a yearly survey conducted by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry for Education and Research (BMBF). With its principal focus on firms' innovation behavior, the MIP is the German part of the Community Innovation Survey (CIS) of the European Commission, which is conducted every fourth year. Started in 1992, the survey collects yearly information from manufacturing firms all over the country. The MIP contains information on firm-level output and export activities of each firm, in addition to several classes of production inputs.<sup>5</sup>

Our second data source complements this information with complete records on foreign subsidiaries of the firms in our sample. For this study, it was possible to merge firm records from the MIP with the micro-data base MiDi (Micro Database Direct Investment) provided by the German central bank (Bundesbank), which contains a complete listing of German direct investment stocks abroad.<sup>6</sup> Legal reporting requirements of the Foreign Trade and Payments Regulation ("Aussenwirtschaftsverordnung") guarantee the completeness of this information, for firms whose balance sheet total exceed the effective exemption limits. In the case of minority participations these amount to € 5 million. For majority participations, branches and permanent establishments, any engagement exceeding a balance sheet total of € 500 thousand is subject to mandatory reporting to the Bundesbank. Indirect participating interests have to be reported if a primary direct investment branch has a holding of at least 10% in another firm or if the investing firm has participating interests larger than 50% of the

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<sup>5</sup> A detailed description of the Mannheim Innovation Panel can be found in Janz et al. (2001). Note that this data set has been previously exploited in Arnold and Hussinger (2005) to test the causal relationship between firm productivity and export behavior. The findings of that study confirm the partial assessment that German exporters outperform non-exporting firms.

<sup>6</sup> See Lipponer (2003a) for a detailed description of this data base.

capital shares or voting rights of the corresponding primary branch.<sup>7</sup> In our analysis, we consider any firm that reported either direct or indirectly held assets abroad as a multinational firm (DI type).

The merge process, for which sufficient identification information was available from 1996 on, was conducted using a computer-supported text field search algorithm, where matches are assigned according to firm names and addresses. Every potential match found by the search program was checked manually. The data set thus obtained is an unbalanced panel of 6,234 firm-level observations between 1996 and 2002, which corresponds to 2,148 firms. On average, there are 2.90 years of data per firm available. The data contain firms from all over Germany, including the former Eastern part of the country.

All three types of firms are present in each of the industries. With regard to international commercial relations, the largest subset of firms are exporting firms with no foreign investment (DX type). 4,092 observations belong to this group, among which are 1,499 firms with exports in each year. 660 observations belong to the DI type, which corresponds to 248 firms. 103 of those firms invest abroad in every sample year. We also observe the number of FDI projects a firm is engaged in for a given year. The mean of this number is approximately 6, while the median is only 2, implying a right-skewed distribution of the number of projects per firm. Most of the firms of type DI have at least one investment in the EU (72%) and in OECD countries (87%), which hints at a significant relevance of horizontal, market-seeking motivations for German outward FDI.

An interesting fact that emerged from the data was the absence of non-exporting firms with foreign assets in our sample, eliminating the need for a further distinction of firm types. All of the firms of the DI type had at least some exports, although we are not able to determine what proportion of these went to the foreign affiliate. The remainder of the sample consists of non-exporting firms with no foreign investment (D type), and comprises 1,482 observations.

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<sup>7</sup> Note that the reporting exemption limits changed in 1996 and in 2002, which influenced the number of records available (see Lipponer, 2003a, 2003b). Given that our analysis is done separately for each year, and covers the time period 1996-2002, our results are unlikely to be affected by this.

Table 1 shows separate descriptive statistics for firms of the D, DX and DI type. On average, exporters are larger than non-exporters, both in terms of employment and sales or value added. Firms with foreign investment tend to be the largest of the three subsets. Interestingly, this ordering also carries over to the propensity to engage in R&D activities (the variable "Innovator"), and to the amount of investment into such activities. DX and DI firms also tend to pay higher wages to their employees, as measured by the total wage bill relative to the number of employees. Finally, Table 1 also presents information on firm location, with the most interesting distinction for the case of Germany being the East-West divide. East Germany was a centrally planned economy up to 1989 and has been undergoing a transition process into a market economy since then. As several studies suggest, the process of catching-up of East German firms still is not yet completed (see Czarnitzki, 2005, as an example). In this light, it may seem of little surprise that in our (stratified) sample, the proportion of East German firms is highest in the subgroup of firms that serve only the domestic market, and decreases with increasing degree of internationalization.<sup>8</sup>

**Table 1: Descriptive Statistics by Type**

| Variable                                  | Non-Exporters<br>(D)<br>N=1,482 | Exporters<br>(DX)<br>N=4,092 | FDI<br>(DI)<br>N=660 |
|---|---------------------------------|------------------------------|----------------------|
| <i>Number of employees</i>                | 74                              | 440                          | 3,223                |
| <i>Sales</i>                              | 9.67                            | 76.63                        | 688.10               |
| <i>Value Added</i>                        | 5.40                            | 40.73                        | 308.10               |
| <i>Innovator (yes/no)</i>                 | 16%                             | 40%                          | 55%                  |
| <i>R&amp;D expenditure (if innovator)</i> | .23                             | 2.37                         | 38.03                |
| <i>Share of sales from new products</i>   | 5%                              | 7%                           | 5%                   |
| <i>Total wage bill</i>                    | 4.86                            | 39.22                        | 293.51               |
| <i>Wage per employee</i>                  | .06                             | .07                          | .08                  |
| <i>Materials</i>                          | 4.28                            | 35.90                        | 380.00               |
| <i>East Germany</i>                       | 48%                             | 29%                          | 7%                   |
| <i>Export turnover</i>                    | -                               | 37.07                        | 323.61               |
| <i>Export intensity</i>                   | -                               | .28                          | .42                  |
| <i>FDI turnover</i>                       | -                               | -                            | 420.31               |
| <i>FDI intensity</i>                      | -                               | -                            | .86                  |
| <i>Number of FDI projects</i>             | -                               | -                            | 5.99                 |
| <i>At least 1 FDI project in EU</i>       | -                               | -                            | 72%                  |
| <i>At least 1 FDI project in OECD</i>     | -                               | -                            | 87%                  |

All monetary variables are measured in € millions.

<sup>8</sup> In order to avoid the possibility of picking up East-West differences rather than differences in international commerce, we will repeat all the subsequent exercises excluding firms from East Germany. This never affected our results significantly.

## 5 Empirical Strategy

The aim of this paper is to undertake performance comparisons across subsets of firms, defined by their degree of foreign engagement, with our measure of firm performance being total factor productivity (TFP). As a first step, we estimate TFP in the standard way, as the residual of a two-factor Cobb-Douglas production function. The value added of the firm is estimated as a function of labor and capital inputs. All nominal values are deflated using a set of sector-specific deflators from the German Federal Statistical Office. Our production function is estimated separately for each 3-digit sector of the Nace Rev. 1.1.<sup>9</sup>

A number of caveats apply when estimating firm-level productivity. First, partial productivity measures such as labor productivity are biased if there are systematic differences in capital intensity across the subsets of firms to be analyzed. This is a possibility that we cannot rule out in our specific case, which is why we abstain from using partial productivity measures. A second challenge arises due to the fact that firms can observe shocks to their own productivity about which the researcher does not know, and make their factor input choices contingent on these shocks. Such a behavioral pattern would cause the orthogonality of our explanatory variables and the error term (our TFP estimate) in our data to be violated, and thus render OLS estimation techniques invalid. This well-known problem is usually referred to as the simultaneity bias (Marschak and Andrews, 1944). We address this issue by using a semi-parametric estimator, in which a proxy variable is used to account for unobserved productivity shocks.

The literature makes several suggestions for the choice of proxy: Olley and Pakes (1996) suggest the use of firm investment, while Levinsohn and Petrin (2003) propose material inputs of the firm instead. Our choice fell on the latter procedure, for several reasons. For one, not all firms have strictly positive investment in all periods, but only those observations may be retained in order for the procedure to be valid. In our case, this would imply a significant loss of observations. Material inputs, on the other hand, are strictly

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<sup>9</sup> Some sectors had to be grouped together to achieve a sufficiently large number of observations for every estimation. Details on our industry aggregation can be found in the appendix.

positive in all cases. Second, material inputs are less likely to be subject to indivisibilities and we would hence expect them to follow more closely any unobserved changes in firm productivity. We estimate production functions at the 3-digit level employing the Levinsohn and Petrin procedure, and use the residuals from these estimations as our estimates for firm-level TFP. In order to compare TFP estimates resulting from different sector-wise estimations, and to focus our attention on firm heterogeneity within sectors, we divide our TFP measure by the average TFP in the respective industry and year, and refer to the measure thus obtained as relative productivity.<sup>10</sup>

In order to undertake these kinds of comparisons, we invoke the concept of first order stochastic dominance.<sup>11</sup> Suppose we have two independent random samples of productivity realizations. One sample  $\omega_1, \dots, \omega_n$  is drawn from a distribution function  $\Omega_1$  and the other sample,  $\omega_{n+1}, \dots, \omega_N$  is drawn from another distribution function  $\Omega_2$ . The hypothesis of interest is that  $\Omega_1(\omega) - \Omega_2(\omega) \leq 0 \quad \forall \omega \in \mathcal{R}$ . If this hypothesis holds, and the inequality is strict for at least some  $\omega \in \mathcal{R}$ , we say that  $\Omega_1$  dominates  $\Omega_2$  stochastically. More intuitively, this is to say that the cumulative distribution function of a variable in the first random sample lies entirely to the right the corresponding cumulative distribution function in the other random sample.

Girma et al. (2005) consider an interesting extension of the HMY model. They note that if one relaxes the assumption of deterministic and fixed productivity levels and assumes each period's productivity realization to be subject to a random shock, regions of uncertainty may arise around the threshold productivity levels. In these regions, firms with similar productivity levels may make different choices, creating some overlap between the productivities of firms from different categories that is not present in the original model. As long as the self-selection mechanism remains an essential determinant of a firm's participation in international markets, stochastic dominance would continue to hold in such a setting. The concept thus remains a valid means of examining the rank ordering

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<sup>10</sup> Hence an average-performing firm will have a relative TFP of exactly one.

<sup>11</sup> Although the concept of stochastic dominance dates from the 1930s, its first application in the context of international economics can be found in Delgado et al. (2002).

predicted by the model, even in the presence of some degree of uncertainty.

Stochastic dominance can be tested by evaluating two related null hypotheses. The first step is to reject the equality of distributions as in the null hypothesis

$$H_0: \Omega_1(\omega) - \Omega_2(\omega) = 0 \quad \forall \omega \in \mathfrak{R}.$$

This is the two-sided Kolmogorov-Smirnov test, for which the asymptotic distribution of the test statistic has been derived by Kolmogorov (1933) and Smirnov (1939) under the assumption of independently drawn samples. If equality of the distributions over samples can be rejected, and at the same time one cannot reject the corresponding one-sided test that

$$H_0': \Omega_1(\omega) - \Omega_2(\omega) \leq 0 \quad \forall \omega \in \mathfrak{R}.$$

then one can conclude that  $\Omega_1(\omega)$  stochastically dominates  $\Omega_2(\omega)$ . The asymptotic distribution of the corresponding test statistic is also known for the one-sided test under the condition that both samples are independent. Since we are using panel data which include repeated observations of the same firms, the independence assumption is likely to be violated if we pool observations from several years. For that reason, we run the KS-tests separately for each year from 1996 to 2002.

## 6 Results

The two- and one-sided KS-tests allow us to formalize two kinds of comparisons between subsets of firms. First, we compare the productivity outcomes between D and DX firms. As a second step, we compare DX and DI firms. If in both cases, the two-sided test is rejected while the one-sided test is not, then we can establish a clear ranking of the three samples by transitivity, and conclude that the productivity distribution of DX firms dominates D firms, while the distribution DI dominates both DX and D firms.

The results from the two- and one-sided KS-tests are displayed in Table 2. Column 4 of Table 2 presents the results of the two-sided

tests for the equality of the distribution between D and DX firms. This null hypothesis can be easily rejected for all years. The one-sided test statistic in column 5, on the other hand, is not significant at conventional levels, meaning that we cannot reject  $H_0'$ . This is to say that we cannot reject the null that exporters are the higher productivity group. In other words, DX firms outperform D firms over the entire productivity distribution. The same kind of results for the comparison between DI and DX firms are displayed in the two rightmost columns of Table 3. Again, we can conclude stochastic dominance of the group of firms with the stronger foreign engagement.

**Table 2. Distributions of Productivity Levels.**

Kolmogorov-Smirnov tests for Non-Exporters (D) vs Exporters (DX).

| Year        | No. of D firms | No. of DX firms | Two-sided KS test<br>statistic ( $H_0$ )<br>Equality of<br>Distributions | One-sided KS test<br>statistic ( $H_0'$ )<br>DX larger group |
|-------------|----------------|-----------------|--|--|
| <i>1996</i> | 215            | 830             | 0.1562<br>(0.00)   | -0.0103<br>(0.96)  |
| <i>1997</i> | 345            | 747             | 0.2026<br>(0.00)   | -0.0094<br>(0.96)  |
| <i>1998</i> | 345            | 749             | 0.2133<br>(0.00)   | -0.0107<br>(0.95)  |
| <i>1999</i> | 145            | 434             | 0.2358<br>(0.00)   | -0.0116<br>(0.97)  |
| <i>2000</i> | 142            | 418             | 0.2202<br>(0.00)   | -0.0215<br>(0.91)  |
| <i>2001</i> | 145            | 453             | 0.1944<br>(0.00)   | -0.0099<br>(0.98)  |
| <i>2002</i> | 145            | 461             | 0.1904<br>(0.00)   | -0.0144<br>(0.96)  |

Asymptotic p-values in parentheses.

**Table 3. Distributions of Productivity Levels.**

Kolmogorov-Smirnov tests for Exporters (DX) vs Multinationals (DI).

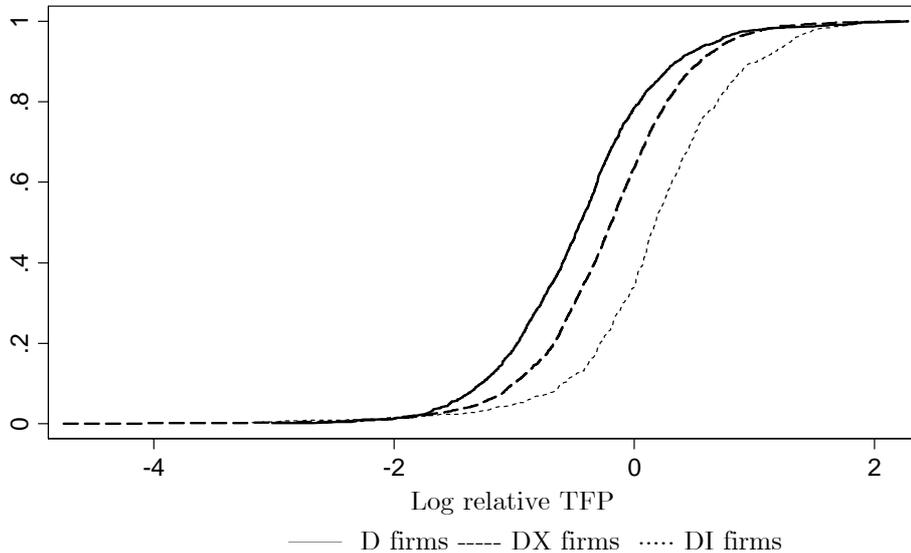
| Year        | No. of D firms | No. of DX firms | Two-sided KS test<br>statistic ( $H_0$ )<br>Equality of<br>Distributions | One-sided KS test<br>statistic ( $H_0$ )<br>DI larger group |
|-------------|----------------|-----------------|--|---|
| <i>1996</i> | 830            | 115             | 0.3817<br>(0.00)   | -0.0051<br>(0.99)   |
| <i>1997</i> | 747            | 142             | 0.3044<br>(0.00)   | -0.0161<br>(0.94)   |
| <i>1998</i> | 749            | 144             | 0.2797<br>(0.00)   | -0.0142<br>(0.95)   |
| <i>1999</i> | 434            | 61              | 0.2287<br>(0.01)   | -0.0195<br>(0.96)   |
| <i>2000</i> | 418            | 66              | 0.2257<br>(0.01)   | -0.0096<br>(0.99)   |
| <i>2001</i> | 453            | 72              | 0.3971<br>(0.00)   | -0.0212<br>(0.95)   |
| <i>2002</i> | 461            | 60              | 0.4260<br>(0.00)   | -0.0145<br>(0.98)   |

Asymptotic p-values in parentheses.

These results confirm the productivity ranking of firms postulated by theory. As predicted by the HMY model, exporting firms are better performers than firms that produce for the domestic market only, while firms with foreign subsidiaries are the most productive of the three groups. The patterns present in our dataset of German manufacturing firms are thus consistent with the self-selection hypothesis underlying the HMY model.

Figure 1 gives an illustration of the intuitive meaning of these test. It depicts the cumulative distribution functions (CDF) of TFP for the three subsamples D firms (domestic sales only), DX firms (exporters) and DI firms (firms with investment abroad). The productivity ordering suggested by theory becomes apparent in this graph: The CDF of DI firms lies entirely to the right of that of DX firms, whose CDF in turn lies entirely to the right of the one corresponding to firms of the D type. The difference between DI firms and DX firms is slightly larger than the one between DX and D firms.

Figure 1. Cumulative Distribution Functions of TFP for the three firm types.



Given the particular case of Germany with its different recent economic history between the western and the eastern part of the country, we want to make sure that our analysis is not influenced by differences between East and West. In particular, one might conjecture that East German firms suffer from a productivity disadvantage vis-à-vis their western counterparts, while at the same time being less involved in international markets. For this reason, we repeated the analysis after dropping all East German firms from our sample. All our previous results are qualitatively the same when using a reduced sample of West German firms only.<sup>12</sup>

## 7 Conclusion

In this paper, we have used a representative sample of German manufacturing firms to test a prediction of a recent theoretical paper in the theory of international trade with heterogeneous firms. Helpman, Melitz and Yeaple (2004) predict that it is the more productive firms that can afford to pay the fixed costs of serving

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<sup>12</sup> In fact, these results are so similar to the main results presented in tables 3 and 4 that we refrained from presenting them here. They are available from the authors upon request.

foreign customers via exports. Moreover, only the top performing firms find it profitable to pay a further fixed cost of setting up foreign establishments to be closer to their foreign customers.

To analyze this proposed pattern empirically, we estimate firm total productivity for 43 German manufacturing sectors using a semi-parametric estimator following Levinsohn and Petrin (2003) to control for a possible simultaneity bias of input choice. We then use a non-parametric testing technique to rank the distribution of total factor productivity across the three subsets of firms, as defined by their engagement in international markets. Rather than just comparing first moments, these Kolmogorov-Smirnov tests allow us to make statements about the entire distribution of productivity across groups, using the concept of stochastic dominance.

Our data display a significant amount of within-sector firm heterogeneity with respect to productivity. The predicted threefold ordering of firm productivity according to the firms' trade orientation is compatible with our German data. We show that German exporters outperform firms that serve only the domestic market over the entire productivity distribution. In a similar manner, German multinational firms, defined as firms with subsidiaries abroad, are more productive than both domestically focused and exporting firms in Germany. These findings hold true for each year from 1996 to 2002. Our results thus lend strong empirical support for one of the key predictions of the theoretical approach of Helpman, Melitz and Yeaple (2004) for the case of German manufacturing.

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## Appendix

**Table 4: The industry grouping used in our TFP estimations.**

| <b>Industry</b>   | <b>NACE 3</b>                                |
|---|--|
| Food Products and Beverages   | <i>151-159</i>                               |
| Other Food Products   | <i>158</i>                                   |
| Beverages, Tobacco Products   | <i>159-160, 171, 175, 180, 200, 211, 212</i> |
| Preparation and Spinning of Textile Fibres, Textile Weaving, Finishing of Textiles, Manufacture of Made-up Textile Articles, except Apparel   | <i>171-174</i>                               |
| Other Textiles, Knitted and Crocheted Fabrics and Articles  | <i>175-177</i>                               |
| Wearing Apparel; Dressing and Dyeing of Fur, Leather and Leather Products   | <i>180-193</i>                               |
| Wood and Wood Products  | <i>201-205</i>                               |
| Pulp, Paper and Paper Products  | <i>211</i>                                   |
| Articles of Paper and Paperboard, Reproduction of Recorded Media  | <i>212</i>                                   |
| Pulp, Paper and Paper Products, Publishing and Printing   | <i>221-223</i>                               |
| Coke, Refined Petroleum Products and Nuclear Fuel   | <i>231-233</i>                               |
| Basic Chemicals, Pesticides and Other Agro-chemical Products, Paints, Varnishes and Similar Coatings, Printing Ink and Mastics  | <i>241-243</i>                               |
| Pharmaceuticals, Medicinal Chemicals and Botanical Products, Soap and Detergents, Cleaning and Polishing Preparations, Perfumes and Toilet Preparations, Other Chemical Products, Man-made Fibres                                     | <i>244-247</i>                               |
| Rubber Products   | <i>251</i>                                   |
| Plastic Products  | <i>252</i>                                   |
| Glass and Glass Products  | <i>261</i>                                   |
| Non-refractory Ceramic Goods Other than for Construction Purposes; Refractory Ceramic Products, Ceramic Tiles and Flags, Bricks, Tiles and Construction Products, in Baked Clay   | <i>262-264</i>                               |
| Cement, Lime and Plaster, Articles of Concrete, Plaster and Cement  | <i>265-266</i>                               |
| Cutting, Shaping and Finishing of Ornamental and Building Stone, other Non-metallic Mineral Products  | <i>267-268</i>                               |
| Basic Iron and Steel and of Ferro-alloys, Tubes, Other First Processing of Iron and Steel   | <i>271-273</i>                               |
| Basic Precious and Non-ferrous Metals, Casting of Metals  | <i>274-275</i>                               |
| Structural Metal Products   | <i>281</i>                                   |
| Tanks, Reservoirs and Containers of Metal; Manufacture of Central Heating Radiators and Boilers, Steam Generators, except Central Heating Hot Water Boilers, Forging, Pressing, Stamping and Roll Forming of Metal; Powder Metallurgy | <i>282-284</i>                               |
| Treatment and Coating of Metals; General Mechanical Engineering   | <i>285</i>                                   |
| Cutlery, Tools and General Hardware   | <i>286</i>                                   |
| Other Fabricated Metal Products   | <i>287</i>                                   |
| Machinery for the Production and use of Mechanical Power, except Aircraft, Vehicle and Cycle Engines  | <i>290-291</i>                               |
| Other General Purpose Machinery, Weapons and Ammunition,  | <i>292, 296-297</i>                          |

|   |                 |
|---|-----------------|
| Dom. Appliances nec.  |                 |
| Agricultural and Forestry Machinery, Machinetools   | <i>293-294</i>  |
| Other Special Purpose Machinery   | <i>295</i>      |
| Office Machinery and Computers, Electric Motors, Generators and Transformers  | <i>300, 311</i> |
| Electricity Distribution and Control Apparatus, Insulated Wire and Cable, Accumulators, Primary Cells and Primary Batteries             | <i>312-314</i>  |
| Lighting Equipment and Electric Lamps   | <i>315</i>      |
| Electrical Equipment n.e.c.   | <i>316</i>      |
| Radio, Television and Communication Equipment and Apparatus   | <i>321-323</i>  |
| Medical and Surgical Equipment and Orthopaedic Appliances   | <i>331</i>      |
| Instruments and Appliances for Measuring, Checking, Testing, Navigating and Other Purposes, except Industrial Process Control Equipment | <i>332</i>      |
| Industrial Process Control Equipment, Optical Instruments and Photographic Equipment, Watches and Clocks                                | <i>333-335</i>  |
| Motor Vehicles, Bodies (Coachwork) for Motor Vehicles; Trailers and Semi-trailers   | <i>341-342</i>  |
| Parts and Accessories for Motor Vehicles and their Engines  | <i>343</i>      |
| Other Transport Equipment   | <i>351-355</i>  |
| Furniture, Jewellery and Related Articles   | <i>361-362</i>  |
| Games and Toys, Miscellaneous Manufacturing n.e.c.  | <i>365-366</i>  |

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