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The Impact of International Trade on Firms and Workers
—
Empirical Evidence from Germany

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Introduction
When thinking about international trade theory, one might ask three simple questions: First, why do countries engage in trade? Second, why do some firms export and others do not? And third, how does trade affect these exporting firms and their workers?

As to the first question, a brief historic review of the three theories that had arguably the most impact on our thinking of international trade strives to show the reader that there is no simple answer at hand. It is rather a blend of these different theories and the forces embedded therein that is able to give a satisfying explanation of the features of today’s globalized trade.

The first theory of international trade goes back to David Ricardo’s *The Principles of Political Economy, and Taxation*, first published in 1817. In a world with technological differences across countries and labor as the sole factor of production, Ricardo’s remarks on foreign trade show that when countries specialize in the production of the good that their labor can produce relatively efficiently in comparison with other countries, i.e., the good in which the country has a so-called comparative advantage, overall output will increase and allocations can be found that are beneficial to all countries. It is these gains that create the incentive for countries to engage in trade.

Developed by Eli F. Heckscher (Heckscher 1919) and Bertil Ohlin (Ohlin 1933), a second theory, embodied in the so-called Heckscher-Ohlin model, later developed further by Stolper & Samuelson (1941) and Samuelson (1948), dispenses with the notion of differences in the labor force productivity and explains trade between countries through different factor endowments. Thereby allowing for trade in similar goods, a feature the classic Ricardo model cannot explain (Feenstra 2004, 1). According to the model, a country than exports those goods that are relatively intensive in the production of the input factors in which the country is relatively well endowed and that are therefore relatively cheaper in production.

However, when first put to the test, the empirical findings suggested that a capital abundant country like the US exports labor-intensive goods and imports capital-intensive goods. A results that was contradictory to the Heckscher-Ohlin model and became known as Leontief’s paradox (Leontief 1953). With new datasets becoming available, later works by Trefler (1993) and Davis & Weinstein (2001) have then shown that when measuring the effective endowments of labor and capital, the US were not only abundant in capital but also abundant in labor. Since the US both exported labor and capital intensive goods, Leontief’s findings were not paradoxal at all. In this way, these works reestablished the importance of factor proportions alongside technological differences as a cause of international trade.
In 1977 Avinash Dixit and Joseph Stiglitz (Dixit & Stiglitz 1977) mathematically formulated a model of monopolistic competition that dates back to an analytical framework of Chamberlin (1933). Their model is based on a single representative consumer with a love of variety of a differentiated good (Feenstra 2004, 137-138). By allowing for increasing returns to scale and endogenous product variety, it went to become the workhorse of international trade theory (Brakman & Heijdra 2011, 12).

Inspired by Dixit & Stiglitz (1977) and supported by empirical findings of intraindustry trade, see e.g., Grubel & Lloyd (1975), as well as findings of trade among similar countries — features neoclassical trade theory could not explain — Paul Krugman developed a trade model, Krugman (1979), in which trade is solely explained by economies of scale at the firm level. With the opening of trade between two economies, firms have the incentive to increase their production in order to serve the foreign market in addition to the home market. Thus, a larger firm can for example benefit from the use of more specialized and efficient machinery or a fuller use of its capacity. In addition, some overhead costs might be independent of the scale of production and will hence fall per unit alongside increasing production (Helpman & Krugman 1985, 32). Together with Krugman (1980, 1981), this new approach that no longer relies on technological differences or differences in factor endowments to explain trade, triggered the so-called new trade theory. Note, that all these models lay emphasis on the firm’s decision making process. However, they assume that firms are symmetrical within a sector, so that sectoral output is given as a multiple of a single firm’s output.

As new detailed plant-level datasets became available, empirical studies, see e.g., Bernard et al. (1995) and particularly for Germany Bernard & Wagner (1997), showed that exporting firms outperform non-exporting firms in many ways, among other things in the wages paid to their employees, leading to the perception that the symmetry assumption can no longer hold (Helpman 2013, 3-5).

Empirical findings that bring us back to the second of our initial questions: Why do some firms export and others do not? In order to explain the above mentioned findings Melitz (2003) developed a Krugman (1980) based trade model that allows for firms to be heterogeneous in their productivity. A firm can further only enter the export market and thus gain additional profits when its productivity surpasses a certain threshold. If its productivity is below the threshold, the firm has to confine itself to the domestic market. Ever since then, this framework has become the standard trade model, leading to tremendous changes in the field of international trade theory.
In its wake new theoretical models like Egger & Kreickemeier (2009) or Helpman et al. (2010a) arose that try to give answer to the third question: How does trade affect these exporting firms and their workers? It is this question that is the common ground of the three working papers, Hesse (2013a,b,c) that build the body of this dissertation. In the following, we present a brief summary of their motivation and findings.

By extending the Melitz (2003) model to heterogeneous workers as well as search and matching frictions with an ensuing Stole & Zwiebel (1996) bargaining game, where workers and firms bargain over the surplus from production, Helpman et al. (2010a) were able to formulate a framework that explains the above mentioned empirically observed wage premia exporters pay to their employees. Due to these wage premia, the framework allows for trade liberalization to affect sectoral wage inequality as shown by empirical findings of Verhoogen (2008). Thus, an autarkic industry will see its wage inequality first increase and eventually decrease to its original level with gradual trade liberalization. This hump-shaped relationship between the extensive margin of trade openness and wage inequality is the key theoretical result of Helpman et al. (2010a). A result that was incidentally also derived by Egger & Kreickemeier (2009).

By making use of the LIAB, a German linked employer-employee panel dataset, Hesse (2013a) provides empirical evidence in favor of this prediction. The paper runs pooled OLS as well as fixed effects regressions of wage inequality on the extensive margin of trade openness. Trade openness is thereby measured by the share of workers in exporting firms according to different definitions of exporting, i.e., a firm either exports if its share of total turnover exceeds 0%, 5%, or 20%. There are two further measures for wage inequality: overall wage inequality, measured by the Theil index, as well as between-firm wage inequality, measured by the standard deviation of the firm level wage component, obtained by Mincer regressions. While being robust to a set of firm specific controls, results for both measures do not only bear out to a large extent the predicted inverted U-shaped relationship between wage inequality and trade openness but are also suggestive of similar levels of wage inequality in industries with relatively low and high shares of workers employed by exporting firms.

While most of these new Melitz inspired models of heterogeneous firms only allow for firms with a binary export status, i.e., either a firm exports or not, Hesse (2013b) shows that a continuous share of exports is of additional value when assessing the impact of trade exposure on certain firm characteristics. The theoretical background of these findings is given by a link between an extended Melitz (2003) model that
allows for a firm’s export status to be continuous, due to the existence of various export thresholds, and the Helpman et al. (2010a) framework of heterogeneous firms in a global economy. The model then predicts that a change in a firm’s share of exports are caused by changes in the firm’s revenue, its average wage, as well as its measure of workers hired. The predictions are ultimately borne out empirically by the LIAB using fixed effects regressions. By including the firm’s binary export status as well as its continuous share of exports in the regressions’ specifications, results are perceptive to both changes in the extensive margin and intensive margin of exports. As for the impact on revenue, the findings suggest that a firm that increases its share of exports from 10% to 11% will experience a 0.916% increase in revenue. Similarly, the coefficient of trade’s impact on wages — both for the overall average firm wage and the firm level wage component, which is purged of worker observables — though smaller, is positive and in line with the model’s predicted magnitude. This also holds for the results for the measure of workers hired. All coefficients are further significant and robust to a set of firm specific controls.

While a huge body of literature examined the effects of trade on firm characteristics, using models of heterogeneous industries, firms, and workers, relatively little is known of the sorting and matching pattern of heterogeneous production factors in the open economy. This is of interest as the sorting and matching pattern can, as recently shown by Grossman et al. (2013), affect the firm’s average factor ability and ultimately the factor’s income dispersion.

By allowing for complementarities between two heterogeneous factors of production, namely workers and managers, in a simple neoclassical trade model of two countries, two sectors, and two factors, Grossman et al. (2013) showed that the sorting and matching of these heterogeneous factors can have an impact on the firm’s output and therefore on relative factor income. As trade liberalization is assumed to affect the ability of a manager with whom a worker is matched and vice versa, both managers’ salary dispersion and workers’ wage dispersion can either increase or decrease.

Since these complementarity effects can be blended with forces of a factor’s comparative advantage and forces that are beneficiary to the real returns of the factor used intensively in the production, it is not possible to make a valid prediction of the impact of trade liberalization on a factor’s income dispersion without specific knowledge of the industry’s factor intensities, its distribution of factor ability, its prevailing factor sorting and matching pattern as well as the relative factor endowments of both countries.

As an example, consider the case of a relatively manager abundant country that
shows positive assortative matching across its two sectors, i.e., the more able workers are matched with the more able managers. In this setting, trade liberalization will, according to the Heckscher-Ohlin theorem, lead to an expansion of the manager intensive sector and hence cause the average ability of both its workers and managers to increase. Depending on the relative proportions of these ability increases, a worker’s match can either deteriorate or improve. The same holds for managers. As for the case of a similar relative increase, a worker’s match tends to deteriorate, while a manager’s match is prone to improve.

By using the LIAB, Hesse (2013c) therefore aims to test if the predicted link between trade liberalization and factor ability as well as the ensuing impact on income dispersion can be underpinned by empirical evidence.

In accordance with the above presented example of a relatively manager abundant country, the results suggest a relatively low but proportionally similar impact of trade liberalization on average factor ability. The latter is thereby measured by a ranked variable of the worker’s and manager’s education. As predicted by Grossman et al. (2013), the estimated coefficient of managerial ability on the workers’ wage dispersion is negative, while the impact of an increase in overall worker ability on the managers’ salary dispersion tends to be positive. Thus, these findings suggest that if one of 10 workers were to get a degree of the next rank, the managers’ salary dispersion would rise by about 0.52%.

The plan of this dissertation is as follows. Chapter II represents Hesse (2013a), Chapter III contains Hesse (2013b), while Hesse (2013c) is presented in Chapter IV. Furthermore, an Appendix to the above mentioned works is provided in order to give insight into the most important derivations of the Helpman et al. (2010a) framework and the Grossman et al. (2013) model, respectively.
II

Inequality in a Global Economy
— Evidence from Germany
1. Introduction

Helpman et al. (2010a), henceforth HIR, recently proposed a new framework — an extension of the Melitz (2003) model to Diamond-Mortensen-Pissarides search and matching frictions — linking sectoral wage inequality and trade openness. We provide empirical evidence in support of their key theoretical prediction that gradual trade liberalization in an industry first increases and then decreases wage inequality.

In contrast to the predictions of neoclassical trade theory, empirical findings, see e.g., Verhoogen (2008), show that trade can lead to wage inequality within sectors. While other models in this line of research use workers’ fair wage preferences, see e.g., Egger & Kreickemeier (2009), or efficiency wages, see e.g., Davis & Harrigan (2011), as a source of labor market imperfections in order to explain these findings, HIR developed a new framework, where heterogeneous firms and workers bargain over the surplus from production in a Stole & Zwiebel (1996) setting, thereby allowing for workers with similar characteristics to be paid differently. Since only the most productive firms go into export, the induced search and matching frictions are not only able to explain sectoral wage inequality but are also able to link it to trade.

Our aim is to empirically test the model’s prediction that a rise in the extensive margin of trade openness first increases and then subsequently decreases wage inequality to its original level for a classic developed country like Germany. A hump-shaped relationship between trade openness and wage inequality that was incidentally also derived in Egger & Kreickemeier (2009). As for the case of Germany, Dustmann et al. (2009) have shown that it does not — contrary to common perception — have a stable wage distribution, but witnessed a similar rise in wage inequality as the US, the UK, or Canada. Furthermore, recent findings by Card et al. (2013) suggest that about 21% of the increase in German wage inequality from 2002 to 2009 can be explained by rising dispersion in wage premiums at the firm level, while another 16% can be accounted for by the rise in positive assortative matching between workers and firms. Against this backdrop, the role of international trade in this development comes to mind. While related works by Krishna et al. (2012), Klein et al. (2013), Felbermayr et al. (2013), and Baumgarten (2013) could already provide reduced-form evidence in support of the link between trade openness and wage inequality, we show that this relationship is — as predicted in HIR — of a hump-shaped form. For this purpose, we use the LIAB, a linked employer-employee panel dataset from Germany, to run pooled OLS and fixed effects regressions of different measures of wage inequality on the change in trade openness with and without industry specific controls.

Our results confirm to a large extent the postulated inverted U-shaped relation-
ship between wage inequality and trade as well as considerable similarity in wage inequality levels between the autarkic and perfectly open industry. Further empirical evidence in support of the model via structural estimation comes from work that has recently been conducted by Helpman et al. (2013).

The plan of this paper is as follows. In Section 2 we recite the link between sectoral wage inequality in an autarkic, in a perfectly open and in a partially open economy, as recently proposed in the HIR model. Section 3 describes the dataset used and gives insight into recent developments of German exports as well as the role of collective bargaining in Germany. Section 4 presents our empirical results. Section 5 concludes. An Appendix gives a review of the HIR framework as well as its most important derivations.

2. Sectoral Wage Inequality and Trade Openness

By introducing heterogeneous workers and labor market frictions into a Melitz (2003) model, HIR established a link between the extensive margin of trade openness and sectoral wage inequality. Their key theoretical result is that sectoral wage inequality in the autarkic and the perfectly open economy are equal, whereas they are both strictly smaller than the sectoral wage inequality in the partially open economy, where not all firms are exporting.

For a notion of this proposition, consider an economy that is completely autarkic due to very high trading costs. As trading costs decrease, more and more firms will start exporting. While according to Melitz (2003) these firms see their revenue rise, they can now afford to set a higher ability threshold and thereby hire workers of a higher average ability. The ensuing Stole & Zwiebel (1996) bargaining process between workers and firms will then lead to higher wages for the entire workforce of these new exporters. Wage inequality will rise accordingly, since there is now an increasing share of firms that pay higher wages to their employees.

Next consider the case of a perfectly open economy, where every firm is exporting. In this case, wage inequality is, in theory, exactly the same as in the autarkic economy. Once there is a sufficiently small increase in trading costs, some firms have to stop exporting and will limit themselves to the domestic market. Since thereby their revenue will go down, wages will go down as well. Because the wages paid by these firms are already on the lower bound of the wage distribution, a further decrease will ultimately

\footnote{A concise review of the HIR framework is provided in the Appendix}
lead to an increase in wage inequality within the sector. Therefore wage inequality first increases and then decreases to its original level with the opening of trade, see Figure I.

Empirically, the extensive margin of trade openness in a given sector can either be measured by the share of exporting firms, $\rho^z$, which is closely related to the ratio of the productivity cutoff levels, $\rho = \theta_d/\theta_x$, HIR use in their theoretical framework, or by the share of workers employed by exporting firms, $s \equiv 1 - s_d$.\(^2\) Inasmuch as $s$ is a far more precise measure than $\rho^z$ for it already weighs the contribution of an exporting firm to the extensive margin of trade openness in a particular sector, we will conduct the empirical part of our paper with $s$ as the measure of trade openness. Note the higher $s$, the higher the degree of trade openness.

Furthermore, $s$ is also highly correlated with a trade intensity index, obtained by the German trade share in EU-15 world trade.\(^3\)

3. Data and Background

For the empirical part of our study we use the ‘LIAB cross-sectional model 2’, a linked employer-employee dataset from the German Institute for Employment Research (IAB).

\(^2\)See the Appendix for a derivation of $s$.

\(^3\)The correlation coefficient between the obtained trade intensity index and $s$ is in all three cases (see Section 4.1 for a description of the different definitions of $s$) around 0.67. Note that $s$ only measures the extensive margin of trade openness, while the trade intensity index is an indicator of overall trade openness. Data obtained from Eurostat’s COMEXT database. Export data was available for the first 17 industries in Table I.
On the employer side, the LIAB consists of survey data from the annual waves of the IAB establishment panel. The panel’s sample is drawn from the population of all German establishments, henceforth referred to as firms, having at least one employee covered by social security. It is further stratified according to firm size, industry, and federal state and has a varying firm response rate of 63% to 73% through the years.

Each firm is then classified according to the IAB Establishment Panel Employer Survey into one of 41 industries that are again part of an industry category. Since our main focus lies on the impact of trade, we exclude industries with no primary interest in exports, leading to a panel that consists of firms that belong to the first 25 industries in the IAB classification. These are all industries in the primary and secondary sector as well as industries in the categories ‘Trade and Repair’ and ‘Transport and Communication’.

Following a suggestion of Helpman et al. (2013), we exclude observations of firms with less than five workers in a given year, thereby ensuring that our results are not distorted by idiosyncratic factors of these very small businesses. However, we obtain very similar results using the universe of all firms belonging to the above mentioned 25 industries. In order to allow for a better comparability between estimations with and without industry specific controls, we exclude all firms that do not report whether or not their workforce is subject to a collective bargaining agreement. In each year these are so few in number — all together 88 firm-years — that there missing is only noticeable at the fourth decimal place in the regressions’ coefficients. Table I reports firm and employment shares for each industry in the base year 2000.

The information on individual employees stems from the social security notifications and is matched through a common identifier with IAB establishment panel. Since the IAB establishment panel is based on annual voluntary surveys, over the years some firms and therefore workers drop out of the panel in order to be replaced by new ones, while others can be followed through the entire panel. We only use the years from 2000 to 2008 for a major shift in the IAB classification of establishments in 2000 resulted in such significant changes that a consistent extension to the years before 2000 is not possible (Fischer et al. 2007, 8). In addition, it is not until 1996 that the annual surveys contain information about East German firms and workers, which would reduce a second panel to only four observations per industry. In accordance with other literature, we only include full-time workers with an average daily gross wage exceeding twice the minimum wage$^4$ (based on the wages in minor employment), which

$^4$By imposing this threshold, we follow a suggestion of Klein et al. (2013). The threshold is also very close to the one imposed in Akerman et al. (2013). Note that the mentioned amount is considerably below the social security aid that a non-working person would receive.
ranges, depending on the year, from 10.56 to 13.15 Euros per day. Thus, workers during vocational training, interns, workers in minor employment or women during maternity leave will not distort our analysis. Since the social security notification do
not state any additional income above the upper earnings limit, ranging from 144.16 to 173.77 Euros per day, wages within a range of 2 Euros at the limit are estimated according to the imputation procedure of Gartner (2005). Wages are further deflated by the Consumer Price Index, with 2000 as the base year. See Table I for the relative log mean wage in each industry in the year 2000.

While wages are obtained from the social security notifications, the other variable of interest, the firm’s share of exports, is obtained from the firm’s statement of its share of total turnover that is due to exports.

In total, we are left with 8,364,979 worker-years, corresponding to 49,860 firm-years. These data are further aggregated to 25 different industries, which leads with a span of nine years to a total number of 225 observations for the ensuing empirical analysis. Table I reports summary statistics for all 25 industries from 2000 to 2008.

### 3.1. Exports

As can be seen in Table I, German exports experienced a continuous increase in the extensive margin through the years. When trying to explain this development, two reasons come to mind: First, the economic expansion in the aftermath of the dot-com bubble burst in 2000 up to the dawn of the financial crisis in 2007 is naturally sure to have promoted exports considerably. Second, the enlargement of the European Union in May 2004, along with previously established bilateral trade agreements, considerably facilitated German exports into Eastern European countries. Thereby enabling German exporters to increase their output destined to the 10 new members from 2004 to 2008 by about 70%, while overall exports to the rest of the world only increased by about 31% in the same time.

### 3.2. Collective Bargaining

Since recent research by Felbermayr et al. (2013) has underpinned the relative importance of collective bargaining in the wage setting mechanism of exporting firms,
<table>
<thead>
<tr>
<th>TABLE II.</th>
<th>Summary Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Theil index</td>
<td>0.063</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
</tr>
<tr>
<td>Share of export workers</td>
<td>0.524</td>
</tr>
<tr>
<td></td>
<td>(0.346)</td>
</tr>
<tr>
<td>Collective agreement</td>
<td>0.826</td>
</tr>
<tr>
<td></td>
<td>(0.133)</td>
</tr>
<tr>
<td>Share of unskilled workers</td>
<td>0.476</td>
</tr>
<tr>
<td></td>
<td>(0.145)</td>
</tr>
<tr>
<td>Age</td>
<td>40.744</td>
</tr>
<tr>
<td></td>
<td>(1.022)</td>
</tr>
<tr>
<td>Number of firms</td>
<td>5,733</td>
</tr>
<tr>
<td>Number of workers</td>
<td>977,473</td>
</tr>
</tbody>
</table>

*Notes.* Unweighted mean of all 25 industries by year. Standard deviation in brackets. One observation is one industry in one year. Each observation contains information about the worker’s wage (used to compute the Theil index as a measure of wage inequality in each industry), firm’s export status (0: non-exporting; 1: exporting; in this case a firm is exporting as soon as its export share of total turnover is higher or equal to 5%), firm’s participation in a collective agreement (0: no; 1: yes), a worker’s skill level (un- or semi-skilled; skilled; highly qualified; manager), and his or her age. Source: LIAB, Version 2, Years 2000-2008.
we use this section to give some understanding of the role of collective bargaining in the German labor market. While the conditions in Germany are not very peculiar in comparison to other OECD countries, they differ in various points from the US labor institutions. Thus, the collective bargaining coverage rate is of far greater magnitude than in the US. While according to Venn (2009) in 2009 a mere 13% of all employees worked under a collective agreement in the US, in Germany the coverage rate was 63%\(^8\). Though in recent years this figure is on its way down, the overall importance of collective bargaining appears to be still quite large.

There are two further different kinds of collective agreements in Germany: industry-wide company agreements and internal company agreements. The latter plays a minor role and is in most cases just a way for companies to participate in industry-wide company agreements without having to become a member of the industry’s employers’ association. Most importantly, note that collective bargaining agreements are always on the firm level such that all outcomes apply to all workers of the company, irrespective of whether they are a member of the union or not.

4. Empirical Results

Since the original HIR model is devoid of any observable worker characteristics and just focuses on the firm’s average wage, which is a constant fraction of its average revenue per worker, sectoral wage inequality in the original model only consists of between-firm wage inequality. However, an extension to observable worker heterogeneity in the Technical Appendix to HIR provides average wage functions for different types of workers and thereby allows for wage inequality between and within firms to be part of sectoral wage dispersion. In view of this extension, the predicted hump-shaped relationship between wage inequality and trade openness should be valid both for overall sectoral and between-firm sectoral wage inequality. Against this backdrop, we perform two analyses, one where we first use the Theil index\(^9\) of individual worker wages as a measure of overall wage inequality, while in a second one, we solely use the standard deviation of the firm-level wage component for different skill levels as our measure of between-firm wage inequality.

\(^8\)The difference to the data in Table I stems from the fact that our panel does not include service-oriented industries.

\(^9\)The Theil index of wage inequality is defined as 

\[ T = \frac{1}{N} \sum_{i=1}^{N} \left( \frac{w_i}{\bar{w}} \ln \frac{w_i}{\bar{w}} \right), \]

where \( w_i \) denotes the wage of an individual worker \( i \) and \( \bar{w} \) the average wage across the set of all \( N \) workers.
4.1. Overall Wage Inequality

As a measure of wage inequality, we compute the Theil index for every industry in the years from 2000 to 2008 using the daily gross wages of those workers who met our wage and working hours standards. The share of workers employed by exporting firms within an industry was computed according to three different definitions. While in the first definition, a firm is exporting as soon as its export share of total turnover exceeds 0%, in the remaining two definitions, a firm is exporting only when its export share of total turnover is higher or equal to 5% or 20%.

A first look at a scatter plot, see Figure II, of the relationship between trade openness (according to the 5% definition) and wage inequality for all 225 industry-years already confirms to a degree the postulated inverted U-shaped pattern. Furthermore, autarkic and perfectly open industries are apparently prone to present similar levels of wage inequality.

![scatter plot with LOWESS fit and quadratic fit]

**FIGURE II.**
Wage Inequality - Trade Openness Scatter Plot of 225 Industry-Years

A non-parametric LOWESS regression, weighted by the tri-cube function with a smoothing parameter of 0.5, confirms our eyeballing prediction. In addition, the smoothed values of the LOWESS regression suggest that a good approach for a parametric specification might be a quadratic functional form. We therefore run a simple pooled OLS regression using the following specification:

\[
T_{jt} = \beta_1 s_{jt} + \beta_2 s_{jt}^2 + u_{jt},
\]
where $j$ and $t$ index industries and years, respectively. $T$ is the Theil index; $s$ the employment share of exporting firms; and $u$ the stochastic error. To fit the model’s prediction, the coefficient of the linear term has to be positive, while the coefficient of the quadratic term has to be negative. Table III.A presents the estimates of $\beta$ for all definitions of $s$ (OLS 1, OLS 3, OLS 5). As can be seen, both the linear and the quadratic term have the predicted signs and are in all but one case significant. In addition, Figure II shows that the predicted values of the quadratic form — we use the coefficients of OLS 3 — are also in unison with the results of the non-parametric specification. The coefficients of OLS 1 and OLS 3 further suggest that wage inequality peaks at about 54% trade openness.

As these results could also be affected by other industry specific variables, additional controls are required. Since the collective bargaining coverage rate is close to 80% in the dataset used, we add the industry’s share of workers who are employed by a firm with either an industry-wide company agreement or an internal company agreement, $ca_{jt}$. In addition, we control for the share of unskilled workers in each industry, $\bar{\ell}_{jt}$, as well as time fixed effects, $\zeta_t$. This leads to an extension of our estimating equation to

$$T_{jt} = \beta_1 s_{jt} + \beta_2 s_{jt}^2 + \beta_3 ca_{jt} + \beta_4 \bar{\ell}_{jt} + \zeta_t + u_{jt}.$$ 

Results are again reported in Table III.A (OLS 2, OLS 4, OLS 6). As one might expect, a higher share of contracts under a collective agreement, i.e., more trade union influence, significantly drives down wage inequality within an industry. It can also be observed that wage inequality is smaller the higher the industry’s skill level. Although the coefficient of the unskilled worker share is not significant, its negativity is in line with the fact that wage dispersion between unskilled workers is typically smaller than wage dispersion between more qualified workers. Most importantly, however, results are robust to our set of controls.

While the data bear out the inverted U-shaped pattern, a two-sample mean comparison test is in order to check the second part of the prediction, which states that autarkic and perfectly open industries present the same level of wage inequality. To this end, we compare the subsample of industries having an exporter employment share of less than 10% to a subsample of industries with a share exceeding 90%. While for the 0% export definition, we have to reject the hypothesis of equal means at the 2.72% level, in the case of the 5% (20%) export definition, we fail to reject the hypothesis of equal means at the 18.67% (96.65%) level.
### TABLE III.
**Regression of Overall Wage Inequality on Trade Openness with and without Industry Specific Controls**

#### A. Pooled OLS regression
Dep. var.: Wage inequality measured by the Theil index

<table>
<thead>
<tr>
<th></th>
<th>Exports &gt; 0% of total turnover</th>
<th>Exports ≥ 5% of total turnover</th>
<th>Exports ≥ 20% of total turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLS 1</td>
<td>OLS 2</td>
<td>OLS 3</td>
</tr>
<tr>
<td>Share of export workers</td>
<td>0.0927**</td>
<td>0.0847**</td>
<td>0.0826**</td>
</tr>
<tr>
<td></td>
<td>(0.0382)</td>
<td>(0.0356)</td>
<td>(0.0368)</td>
</tr>
<tr>
<td>Share of export workers^2</td>
<td>−0.0858**</td>
<td>−0.0773**</td>
<td>−0.0788**</td>
</tr>
<tr>
<td></td>
<td>(0.0362)</td>
<td>(0.0339)</td>
<td>(0.0357)</td>
</tr>
<tr>
<td>Collective agreement</td>
<td>−0.0323***</td>
<td>−0.0327***</td>
<td>−0.0345***</td>
</tr>
<tr>
<td></td>
<td>(0.0101)</td>
<td>(0.0102)</td>
<td>(0.0108)</td>
</tr>
<tr>
<td>Unskilled worker share</td>
<td>−0.0094</td>
<td>−0.0103</td>
<td>−0.0145</td>
</tr>
<tr>
<td></td>
<td>(0.0130)</td>
<td>(0.0128)</td>
<td>(0.0124)</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>N.obs.</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>R^2</td>
<td>0.1296</td>
<td>0.3536</td>
<td>0.1196</td>
</tr>
</tbody>
</table>

#### B. Fixed effects regression
Dep. var.: Wage inequality measured by the Theil index

<table>
<thead>
<tr>
<th></th>
<th>Exports &gt; 0% of total turnover</th>
<th>Exports ≥ 5% of total turnover</th>
<th>Exports ≥ 20% of total turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FE 1</td>
<td>FE 2</td>
<td>FE 3</td>
</tr>
<tr>
<td>Share of export workers</td>
<td>0.1298**</td>
<td>0.0841*</td>
<td>0.1409***</td>
</tr>
<tr>
<td></td>
<td>(0.0494)</td>
<td>(0.0448)</td>
<td>(0.0351)</td>
</tr>
<tr>
<td>Share of export workers^2</td>
<td>−0.0579*</td>
<td>−0.0530*</td>
<td>−0.0646**</td>
</tr>
<tr>
<td></td>
<td>(0.0333)</td>
<td>(0.0290)</td>
<td>(0.0249)</td>
</tr>
<tr>
<td>Collective agreement</td>
<td>−0.0250**</td>
<td>−0.0244**</td>
<td>−0.0241**</td>
</tr>
<tr>
<td></td>
<td>(0.0065)</td>
<td>(0.0056)</td>
<td>(0.0069)</td>
</tr>
<tr>
<td>Unskilled worker share</td>
<td>−0.0570**</td>
<td>−0.0493**</td>
<td>−0.0417**</td>
</tr>
<tr>
<td></td>
<td>(0.0198)</td>
<td>(0.0187)</td>
<td>(0.0170)</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>N.obs.</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>R^2</td>
<td>0.3207</td>
<td>0.6109</td>
<td>0.3696</td>
</tr>
</tbody>
</table>

**Notes.** An observation in the regression is one industry in one year. We report clustered standard errors at the industry level in brackets. All regressions in Part B include 25 industry dummies. Source: LIAB, Version 2, Years 2000-2008.

*** indicates significance at 1% level, ** at 5% level, * at 10% level.
In order to assess the quantitative effect of our estimates, we compare the predicted wage inequality of a completely autarkic industry to one that has 54% (the above mentioned turning point) of its workers in exporting firms. According to our estimates of OLS 3, the difference in wage inequality of these two industries would be approximately 0.0216 in the Theil index, which is about one and a half standard deviations. For a basic idea of this difference, let us consider the following example: In an industry where half the workers earn 495 Euros and the other half 1000 Euros — this would correspond to the average autarkic wage inequality level of the 5% definition, i.e., the intercept in OLS 3 — an increase of 0.0216 in the Theil index would mean that those workers who had 1000 Euros before now earn 1145 Euros whereas the other half’s wages stay constant.

Since the shape of the observed pattern could be solely driven by the variation between industries, a fixed effects regression is in order to assess the contribution of the within industry variation. Table III.B reports results with and without industry specific controls. Though we observe a very similar pattern for the fixed effects regressions, with both export coefficients being significant and of the predicted sign, their ratio is not sufficient to drive down the wage inequality of a perfectly open industry to the confines of an autarkic industry.

In view of the overall results, it is, nevertheless, still fair to say, that the model’s prediction of a hump-shaped relationship between wage inequality and trade openness holds to a large extent, while autarkic and perfectly open industries appear to have at least similar levels of wage inequality.

4.2. Between-Firm Wage Inequality

In addition to the overall wage inequality analysis, we now want to assess if the model’s results still hold for a measure of wage inequality that is solely driven by the firm-level component.

Relying strongly on the methods presented in Helpman et al. (2013) and Akerman et al. (2013), we decompose the within-industry-skill wage into its components. In a first step, the following OLS Mincer regression is estimated separately for each industry-skill-year:

\[
\ln w_{ijlt} = z_{ijlt}' \lambda_{jlt} + \varphi_{mjlt} + \nu_{ijlt},
\]

where \(w_{ijlt}\) is a worker \(i\)'s wage, in industry \(j\), with a skill level\(^{10}\) of \(\ell\), in a given

\(^{10}\) We again use the above mentioned simplified skill level (un- or semi-skilled, skilled, and highly qualified). However, in order to have enough observations in each industry-skill-year, we do not consider managers separately and hence categorize them with highly qualified workers.
year $t$. The vector $z'_{ijlt}$ denotes individual observable worker characteristics, while $\lambda_{jlt}$ captures the returns to these characteristics. $\varphi_{mjt}$ is the fixed effect of firm $m$ and $\nu_{ijlt}$ the stochastic error. Our specification for observable worker characteristics is as follows: education (using categories for: no degree at all; vocational training or high school degree; vocational training and high school degree; technical college degree; university degree; as well as missing values), age (using the categories: 19-24; 25-29; 30-39; 40-49; 50-65), and gender. Due to possible idiosyncrasies of very small businesses, we only use those workers with at least four colleagues in the same firm-skill-year category. Since the regression is estimated separately for each industry-skill-year, the coefficients on worker characteristics as well as the firm fixed effect can vary over time and across skill levels. The firm fixed effects are further normalized to sum to zero for each industry-skill-year, whereby the regressions’ intercepts are absorbed by the observable worker characteristics components.

We then use our estimates to decompose the within industry-skill-year wage inequality into the following terms:

$$\text{Var} (\ln w_{ijlt}) = \text{Var} (z'_{ijlt} \hat{\lambda}_{jlt}) + \text{Var} (\hat{\varphi}_{mjt}) + 2 \text{Cov} (z'_{ijlt} \hat{\lambda}_{jlt}, \hat{\varphi}_{mjt}) + \text{Var} (\hat{\nu}_{ijlt})$$

Table IV reports the obtained between-firm wage inequality, $\text{Var} (\hat{\varphi}_{mjt})$, the within-firm wage inequality, $\text{Var} (\hat{\nu}_{ijlt})$, the wage inequality due to worker observables, $\text{Var} (z'_{ijlt} \hat{\lambda}_{jlt})$, as well as the component due to assortative matching between workers and firms, i.e., the covariance between worker observables and firm fixed effects, $\text{Cov} (z'_{ijlt} \hat{\lambda}_{jlt}, \hat{\varphi}_{mjt})$, for the years 2000 and 2008.

We can now use the firm fixed wage component to assess changes in between-firm wage inequality due to changing levels of trade openness. As before, we specify

<table>
<thead>
<tr>
<th>TABLE IV.</th>
<th>Decomposition of Wage Inequality Within Industry-Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Between-firm wage inequality</td>
<td>40.05%</td>
</tr>
<tr>
<td>Within-firm wage inequality</td>
<td>42.14%</td>
</tr>
<tr>
<td>Worker observables</td>
<td>16.63%</td>
</tr>
<tr>
<td>Covariance worker observables – firm effects</td>
<td>1.13%</td>
</tr>
</tbody>
</table>

*Notes.* Results are weighted by the employment share of each industry-skill group in each year. Due to rounding, figures may not sum exactly to 100%. Source: LIAB, Version 2, Year 2000 and 2008.
a simple pooled OLS regression, using the employment weighted standard deviation across all skill levels of the firm fixed wage component as dependent variable:

\[ \text{Sd}(\bar{\varphi}_{mjlt})_{jt} = \gamma_1 s_{jt} + \gamma_2 s^2_{jt} + u_{jt} \]

Table V.A reports the coefficients for all three export definitions (OLS 7, OLS 9, OLS 11). As can be seen, both coefficients have the predicted signs and are in all cases but for the 20% export definition significant. Results are again robust to our set of industry specific controls (OLS 8, OLS 10, OLS 12).

While we fail to reject the hypothesis of equal means at the 10.26% level for the 0% export definition, we have to reject the hypothesis for the 5% and 20% export definition.

Once more, we run fixed effects regressions — with and without industry specific controls — to measure the effect of the within industry variation on the observed pattern. Table V.B reports the corresponding coefficients (FE 7 - FE 12). As one can see when comparing Table V.A and V.B, apart from the 20% export definition, results do not appear to be driven by the within industry variation as in the overall wage inequality analysis but rather by the between industry variation.

In spite of these imperfections, the predictions of the HIR model are still largely borne out by the overall results. Thus, both analyses speak in favor of the hump-shaped relationship between wage inequality and the degree of trade openness. Although only in a few cases the data presents identical levels of wage inequality between the perfectly open and the autarkic industry, the coefficients of the pooled OLS regressions are largely suggestive of at least similar levels.

As a concluding remark, note that in the original HIR model firm productivity is assumed to be drawn from a Pareto distribution. As the firm’s average wage paid to its employees can be written as a function of its productivity, this assumption leads to a piecewise-defined function of sectoral wage distribution, consisting of a truncated and an untruncated Pareto distribution for non-exporting and exporting firms, respectively. While the observable overlap in the log wage as well as in the firm-level wage component distributions of exporting and non-exporting firms (according to the 5% export definition) in Figure III is more in favor of a log normal distribution, Helpman et al. (2013) have shown that the Pareto distribution of firm productivity is not a necessity for the hump-shaped relationship between trade openness and wage inequality nor for the outcome that both the autarkic and the completely open economy present the same level of wage inequality.
TABLE V.
Regression of Between-Firm Wage Inequality on Trade Openness with and without Industry Specific Controls

A. Pooled OLS regression
Dep. var.: Wage inequality measured by the employment weighted standard deviation of the firm fixed wage component

<table>
<thead>
<tr>
<th>Exports &gt; 0% of total turnover</th>
<th>Exports ≥ 5% of total turnover</th>
<th>Exports ≥ 20% of total turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS 7</td>
<td>OLS 8</td>
<td>OLS 9</td>
</tr>
<tr>
<td>Share of export workers</td>
<td>0.0999*</td>
<td>0.0945**</td>
</tr>
<tr>
<td></td>
<td>(0.0576)</td>
<td>(0.0452)</td>
</tr>
<tr>
<td>Share of export workers²</td>
<td>-0.1231**</td>
<td>-0.1075***</td>
</tr>
<tr>
<td></td>
<td>(0.0516)</td>
<td>(0.0408)</td>
</tr>
<tr>
<td>Collective agreement</td>
<td>-0.1377***</td>
<td>-0.1381***</td>
</tr>
<tr>
<td></td>
<td>(0.0130)</td>
<td>(0.0129)</td>
</tr>
<tr>
<td>Unskilled worker share</td>
<td>0.0455**</td>
<td>0.0446**</td>
</tr>
<tr>
<td></td>
<td>(0.0178)</td>
<td>(0.0178)</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>N.obs.</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>R²</td>
<td>0.0794</td>
<td>0.4968</td>
</tr>
</tbody>
</table>

B. Fixed effects regression
Dep. var.: Wage inequality measured by the employment weighted standard deviation of the firm fixed wage component

<table>
<thead>
<tr>
<th>Exports &gt; 0% of total turnover</th>
<th>Exports ≥ 5% of total turnover</th>
<th>Exports ≥ 20% of total turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE 7</td>
<td>FE 8</td>
<td>FE 9</td>
</tr>
<tr>
<td>Share of export workers</td>
<td>0.2170*</td>
<td>0.1496</td>
</tr>
<tr>
<td></td>
<td>(0.1137)</td>
<td>(0.1256)</td>
</tr>
<tr>
<td>Share of export workers²</td>
<td>-0.0754</td>
<td>-0.0799</td>
</tr>
<tr>
<td></td>
<td>(0.0760)</td>
<td>(0.0824)</td>
</tr>
<tr>
<td>Collective agreement</td>
<td>-0.0249</td>
<td>-0.0233</td>
</tr>
<tr>
<td></td>
<td>(0.0241)</td>
<td>(0.0219)</td>
</tr>
<tr>
<td>Unskilled worker share</td>
<td>-0.0575</td>
<td>-0.0427</td>
</tr>
<tr>
<td></td>
<td>(0.0723)</td>
<td>(0.0659)</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>N.obs.</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>R²</td>
<td>0.2092</td>
<td>0.4255</td>
</tr>
</tbody>
</table>

Notes. An observation in the regression is one industry in one year. We report clustered standard errors at the industry level in brackets. All regressions in Part B include 25 industry dummies. Source: LIAB, Version 2, Years 2000-2008.

* indicates significance at 1% level, ** at 5% level, * at 10% level.
5. Conclusion

While neoclassical trade theory is only able to explain wage dispersion between sectors, it fails to explain empirical findings of increasing wage dispersion within sectors. Based on the Melitz (2003) model, HIR developed a framework with heterogeneous firms and workers in a labor market with search and matching frictions that is able to link trade and sectoral wage inequality.

We use German linked employer-employee panel data in order to supply empirical evidence in support of the model’s central prediction that wage inequality first increases and then decreases to its original level with gradual trade liberalization. This inverted U-shaped pattern stems from the wage premium exporters are paying their workers. Thus, an increase in the extensive margin of trade openness in an autarkic economy would increase wage inequality as some firms start to sell their products on the foreign market. These firms will in return pay higher wages to their employees. By contrast, rising trade frictions in a perfectly open economy would give rise to wage inequality as well, since some firms will be forced to exit the export market and limit themselves to the domestic market and are therefore forced to lower their wages.

Our empirical results do not only bear out the inverted U-shaped wage inequality pattern but also confirm to a large degree a similar level of wage inequality between the autarkic and the perfectly open industry.
While these results provide further insight into the forces that drive wage inequality within an industry, they also imply that the initial level of trade openness of an economy is crucial when trying to predict the impact of a change in trade frictions on wage dispersion.
III

The Impact of a Firm’s Share of Exports on Revenue, Wages, and Measure of Workers Hired — Theory and Evidence
1. Introduction

While recent models of heterogeneous firms in a global economy only allow for firms to have a binary export status (non-exporting or exporting), we argue that a firm’s precise share of exports is of large additional value when trying to assess the key drivers behind its revenue, its average wage, or the measure of its workers hired.

Our argumentation is borne out by an extended Melitz (2003) model in which we loosen the symmetry assumption in order to allow for countries with different aggregate expenditures and different aggregate prices. Thanks to this asymmetry, some firms will — after drawing their initial productivity — be able to export to a few countries, while other, more productive firms, are even able to export to more countries and will hence have a higher share of exports. We further link our extended model to the recently developed Helpman et al. (2010a) framework, henceforth HIR, so as to establish a connection between a firm’s share of exports and its revenue, its average wage rate as well as its measure of workers hired.

Ultimately, we use the LIAB, a linked employer-employee panel dataset from Germany, in order to empirically test our model’s reliability. For this purpose, we run fixed effects regressions of the firm specific variables mentioned above on the share of exports with and without controls for certain firm specific characteristics. While a dummy variable for the firm’s binary export status is perceptive to changes in the extensive export margin, taking into account the seminal findings of Bernard et al. (1995) and its ensuing body of literature, our results show that already very small changes in the intensive export margin can be accounted for relatively large changes in the variables of interest.

The plan of this paper is as follows. Section 2 presents the theoretical framework. In Section 3 we describe the dataset used. Section 4 contains our empirical results. Section 5 concludes. An Appendix provides the most important derivations.

2. Theoretical Framework

2.1. A Firm’s Productivity

Our model consists of a world with a home country and $n$ asymmetric countries, while the asymmetry stems from different distributions of firm productivity across countries. In this way, a country $c$’s firm productivity in a given sector $s$ is assumed

\footnote{For reasons of simplicity, we henceforth suppress the country, sector, and firm subscript whenever possible and consider just one firm $k$ in a given sector $s$ in country $c$.}
to be Pareto distributed with the continuous cumulative distribution

\[ G_c(\varphi) = 1 - \left( \frac{\varphi_{\min,c}}{\varphi} \right)^{z_c} \text{ for } \varphi > \varphi_{\min,c} \text{ and } z_c > 1 \text{ for all } c = 1, ..., n + 1, \]

where less productive countries have a higher \( z_c \) and/or a smaller \( \varphi_{\min,c} \).

As in the Melitz (2003) model, after entering the market, each firm draws its productivity parameter \( \varphi_{csk} \), henceforth \( \varphi \), from \( g_c(\varphi) \) with support over \( [\varphi_{\min,c}, \infty) \), where the draw of a productivity level that is not sufficient to serve the domestic market, i.e., \( \varphi \) is smaller than the domestic cutoff productivity level \( \varphi_{d,c}^* \), will force a firm to immediately exit the market. Though in contrast to Melitz (2003), from the point of view of the home country, there are now \( n \) different export cutoff productivity levels \( \varphi_{x,c}^* \) for each foreign country \( c = 1, ..., n \). Without loss of generality, we can arrange these cutoff levels in ascending order, where 1 corresponds to the country with the lowest export cutoff productivity level. Accordingly, a domestic firm with a productivity \( \varphi \), so that \( \varphi_{x,c}^* < \varphi < \varphi_{x,c}^* + 1 \), can export to the \( c' \) least productive countries, with \( 1 \leq c' \leq n \). However, since firms can only export if they produce for their domestic market, we get \( \varphi_{d,c}^* \leq \varphi_{x,1}^* \). We further assume no price discrimination and an equal elasticity of substitution \( \sigma = 1/(1-\rho) \), with \( 0 < \rho < 1 \), for each industry across countries.

### 2.2. Worker Ability

We assume worker ability to be independently distributed across countries and to be drawn from a Pareto distribution with the continuous cumulative distribution

\[ G_{a,c}(a) = 1 - \left( \frac{a_{\min,c}}{a} \right)^{\zeta_c} \text{ for } a > a_{\min,c} \text{ and } \zeta_c > 1 \text{ for all } c = 1, ..., n + 1. \]

As in HIR, before hiring, firms will pay search costs of \( bm \) in order to be randomly matched with \( m \) workers. Since worker ability is unobservable beforehand, firms have to pay screening costs of \( \varepsilon a_{\varepsilon}/\delta \), where \( \varepsilon > 0 \) and \( \delta > 0 \), to identify from those \( m \) workers the ones that have at least an ability of \( a_{\varepsilon} \). For more productive firms will set the screening threshold higher, \( a_{\varepsilon} \) is dependent of \( \varphi \), i.e., \( a_{\varepsilon}(\varphi) \).

### 2.3. A Firm’s Revenue and Export Decision

Following HIR, the production side is represented by a simple Cobb-Douglas function, so that output \( y \) is given by

\[ y(\varphi) = \varphi h^\gamma a, \quad (\text{III.1}) \]
where \( h = m(a_{\text{min},c} / a_c)^{\zeta_c} \) is the measure of workers hired, \( 0 < \gamma < 1 \), and \( \bar{a} = \zeta_c a_c / (\zeta_c - 1) \) the average ability of the firm’s workforce. This leads to

\[
y(\varphi) = \varphi \frac{\zeta_c}{\zeta_c - 1} a_{\text{min}}^{-\gamma} a_c^{1-\gamma}.
\]

The equilibrium revenue of a firm in the home country that is producing a variety \( \omega \) and is exclusively serving the domestic market can be written as

\[
r_d(\omega) = y_d(\omega) p_d(\omega) = y_d(\omega)^{\rho} I_d^{1-\rho} P_d^\rho = y_d(\omega)^{\rho} A_d,
\]

where \( I_d \) is domestic income, \( P_d \) the domestic aggregate price, and \( A_d = I_d^{-\rho} P_d^\rho \) a domestic demand shifter. \( A_d \) is linked to the total average productivity \( \bar{\varphi}_{t,d} \), which includes all domestic and foreign firms of the home country, via (A.III.1). The quantity \( y_d(\omega) \) is given by the Marshallian demand function

\[
y_d(\omega) = p(\omega)^{-\sigma} P_d^\sigma - I_d = \left( \frac{p(\omega)}{P_d} \right)^{-\sigma} I_d = \left( \frac{w}{P_d^\rho \varphi} \right)^{-\sigma} I_d.
\]

As can be seen, with increasing productivity, a firm’s output and thereby its domestic revenue will increase continuously, so as of now we can write (III.2) as

\[
r_d(\varphi) = y_d(\varphi)^{\rho} A_d.
\]

In an analogous way to HIR, a firm that has then drawn a productivity high enough to export to \( c' \) countries will allocate its domestic output and its exports to country \( c \), \( y_d \) and \( y_{x,c} \), respectively, to equate its marginal revenue for every market. From

\[
r(\varphi) = r_d(\varphi) + \sum_{c=1}^{c'} r_{x,c}(\varphi) = y_d(\varphi)^{\rho} A_d + \sum_{c=1}^{c'} \left( \frac{y_{x,c}(\varphi)}{\tau_c} \right)^{\rho} A_{x,c},
\]

with \( r(\varphi) \) being overall revenue, \( r_{x,c}(\varphi) \) the revenue from export to country \( c \), \( \tau_c \) iceberg trading costs to country \( c \), such that \( \tau_c > 1 \) units of a variety must be exported for one unit to arrive in country \( c \)’s market, and \( A_{x,c} \) the demand shifter for country \( c \), we obtain \( c' \) different first-order conditions

\[
\frac{\partial r_d(\varphi)}{\partial y_d(\varphi)} = \frac{\partial r_{x,c}(\varphi)}{\partial y_{x,c}(\varphi)} \iff \frac{y_{x,c}(\varphi)}{y_d(\varphi)} = \frac{\tau_c^{\rho \sigma - 1} \left( \frac{A_{x,c}}{A_d} \right)^{\frac{1}{1-\sigma}}}{\tau_c^{\rho \sigma - 1}} \quad \text{for all } c = 1, \ldots, c'.
\]

Using (III.3) and (III.4), we can write a firm’s total revenue as

\[
r(\varphi) = y(\varphi)^{\rho} A_d \left( 1 + \sum_{c=1}^{c'} \tau_c^{-\rho \sigma} \left( \frac{A_{x,c}}{A_d} \right)^{\frac{1}{1-\sigma}} \right)^{1-\rho}.
\]

\[ \text{ See the Appendix for a derivation.} \]

\[ \text{ See the Appendix for a derivation.} \]

\[ \text{ See the Appendix for a derivation.} \]

\[ \text{ See the Appendix for a derivation.} \]
Summing up the right-hand side of (III.4) over $c = 1, \ldots, c'$ and linking it to (III.5) along with the fact that $y(\varphi) = y_d(\varphi) + y_{x,1}(\varphi) + \ldots + y_{x,c'}(\varphi)$ which implies $y_d(\varphi) = y(\varphi)/\Upsilon$, where $\Upsilon = 1 + \tau_1^\frac{A_{x,1}}{A_d} \frac{\rho}{\rho - 1} + \ldots + \tau_{c'}^\frac{A_{x,c'}}{A_d} \frac{\rho}{\rho - 1}$, leads to

$$ r(\varphi) = y(\varphi)^\rho A_d \cdot \Upsilon^{\frac{1-\rho}{\rho}} $$

or equivalently

$$ r(\varphi) = r_d \cdot \left( \frac{\varphi}{\varphi_d} \right)^\frac{\rho}{1-\rho} \cdot \Upsilon^{\frac{1-\rho}{\rho}} $$

with $r_d$ being the revenue of a non-exporting firm that makes zero profits and $\Gamma = 1 - \rho \gamma - \rho(1 - \gamma \zeta)/\delta$. As can be seen, more productive firms are able to export to more countries and will hence have in general a higher revenue.

A firm’s profit function can then be written as a combination of its domestic and foreign profits

$$ \pi(\varphi) = \pi_d(\varphi) + \pi_{x,c}(\varphi) = r_d(\varphi) + \sum_{c=1}^{c'} r_{x,c}(\varphi) - bm - \varepsilon \delta a_c - f_d - \sum_{c=1}^{c'} f_{x,c} $$

By analogy with the Melitz (2003) model, in the end, a firm will only export to a certain country $c$, with $1 \leq c \leq c'$, if the profits are non-negative, i.e., $\pi_{x,c}(\varphi) > 0$. Therefore a firm’s export decision depends not only on its own productivity surpassing the export cutoff productivity level, which is a necessary condition, but also on the demand shifter and the trading costs. By taking this into account, the number of countries a firm is actually exporting to, denoted by $c^*$, can be smaller than $c'$, i.e., $c^* \leq c'$. However, since the Melitz (2003) model assumes constant productivity over time, changes in the share of exports can only occur through changes in the demand shifters or in trading costs.

Bringing trading costs into focus, this framework can explain two kinds of changes in a firm’s share of exports. In this way, a small decrease in trading costs to countries with a relatively low export cutoff productivity level as well as a considerable decrease in trading costs to high productivity countries can make it profitable for some firms to start exporting to these countries. While highly productive firms with a relatively large share of exports might increase their exports to these countries only slightly, this change in trading costs will mainly affect the extensive margin of exports. On the other hand, an overall decrease in trading costs to high productivity countries will especially affect the intensive margin of exports, for firms already exporting to these countries will find it profitable to increase their output allocated to these countries. Therefore $\Upsilon$ can either change through shifts in the intensive or extensive margin.

By bringing trading costs into focus, we state the following proposition:

$^6$See the Appendix for a derivation.
Proposition 1: A decrease in trading costs will weakly increase the firm’s share of exports and its revenue.

2.4. Wages

In the following, we again rely on HIR to establish a link between a firm’s average wage and its share of exports. The solution to the bargaining game between a firm and its workers\(^7\) yields that the total wage bill is \(\rho \gamma / (1 + \rho \gamma)\) of the average revenue while the firm keeps a share of \(1 / (1 + \rho \gamma)\). The resulting profit maximization problem for a firm in the home country is then defined by

\[
\pi(\varphi) \equiv \max_{m \geq m_{\text{min}}, a_{\varepsilon} \geq a_{\min}} \left\{ \frac{1}{1 + \rho \gamma} \left[ 1 + \sum_{c=1}^{c'} \tau_c \left( \frac{A_{x,c}}{A_d} \right)^{\frac{1}{1 + \rho}} \right]^{1 - \rho} \times A_d \left( \varphi \frac{c_d}{c_d - 1} m^\gamma a_{\varepsilon}^{1 - \gamma} \right)^\rho - bm - \frac{\varepsilon}{\delta} a_{\varepsilon} - f_d - \sum_{c=1}^{c'} f_{x,c} \right\},
\]

where \(f_d\) and \(f_{x,c}\) are fixed production costs for the domestic and foreign market, respectively. For the measure of workers sampled \(m\) and the ability threshold \(a_{\varepsilon}\) we derive the first-order conditions of the profit maximization problem:

\[
\frac{\rho \gamma}{1 + \rho \gamma} r(\varphi) = bm(\varphi) \quad (\text{III.7})
\]

and

\[
\frac{\rho(1 - \gamma c_d)}{1 + \rho \gamma} r(\varphi) = c a_{\varepsilon}(\varphi)^\delta \quad (\text{III.8})
\]

As one can see, firms with a higher revenue will not only sample more workers, but will also set a higher ability threshold. We can use these results along with \(h = m(a_{\min,d}/a_{\varepsilon})^{c_a}\) in order to define the firm’s average wage

\[
w(\varphi) = \frac{\rho \gamma}{1 + \rho \gamma} \frac{r(\varphi)}{h(\varphi)} = \frac{bm(\varphi)}{h(\varphi)} = b \left[ \frac{a_{\varepsilon}(\varphi)}{a_{\min,d}} \right]^{\frac{\delta}{c_a}}. \quad (\text{III.9})
\]

The relation we get from this last equation is in line with the general intuition that firms with a higher revenue will also employ workers with a higher ability level, who will correspondingly be better paid. Using again (III.4) and (III.5), we can derive\(^8\)

\[
w(\varphi) = w_d \cdot \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\delta}{2}} \cdot \gamma^{\frac{(1 - \rho)}{\alpha}}, \quad (\text{III.10})
\]

\(^7\)A derivation of the solution to the bargaining game can be found in Acemoglu et al. (2007) and in the Technical Appendix to HIR.

\(^8\)See the Appendix for a derivation.
where \( w_d \) denotes the lowest average firm wage. This leads to our second proposition:

**Proposition 2:** A decrease in trading costs will weakly increase the firm’s share of exports and the average wage paid to its employees.

### 2.5. Measure of Workers Hired

Making once again use of the first-order conditions (III.7) and (III.8) along with \( h = m(a_{\min,i}/a_e)^\zeta \), we can in a similar manner to the average wage rate derive the firm’s measure of workers hired, namely

\[
h(\varphi) = h_d \cdot \left( \frac{\varphi}{\varphi_d} \right)^{\rho(1-\zeta)} \cdot \frac{\Upsilon^{(1-\rho)(1-\zeta)/\delta}}{1},
\]

with \( h_d \) being the lowest measure of workers hired. We state our third proposition as follows:

**Proposition 3:** A decrease in trading costs will weakly increase the firm’s share of exports and its measure of workers hired.

### 3. Data

For the empirical part of our study we use the ‘LIAB cross-sectional model 2’, a linked employer-employee dataset from the German Institute for Employment Research (IAB). A detailed description of the dataset can be found in Jacobebbinghaus & Seth (2010) and chapter II. We furthermore rely on the same conditions used in the latter, which are mainly: only industries with a primary interest in exports are included in the panel, i.e., the first 25 industries in the IAB industry classification; only firms with five or more full-time workers whose wages exceed the twice the minimum wage (based on the wages in minor employment) are considered; years from 2000 to 2008. Chapter II reports firm and employment shares for each industry in the base year 2000.

Using the deflated wages obtained in chapter II, we then compute for each firm, each year, and each of the three skill levels (un- or semi-skilled; skilled; highly qualified) the average daily gross wage. The variables are then matched with the firm’s export statement in the annual IAB survey, which ultimately leads to a dataset of 49,860 observations, corresponding to 8,364,979 worker-years, while one observation is one firm in one year. Summary statistics for all firms in the dataset used can be found in Table I.

\(^9\)See the Appendix for a derivation.
<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary export status</td>
<td>0.360</td>
<td>0.375</td>
<td>0.382</td>
<td>0.375</td>
<td>0.381</td>
<td>0.396</td>
<td>0.396</td>
<td>0.396</td>
<td>0.409</td>
<td>0.385</td>
</tr>
<tr>
<td></td>
<td>(0.480)</td>
<td>(0.484)</td>
<td>(0.486)</td>
<td>(0.484)</td>
<td>(0.486)</td>
<td>(0.489)</td>
<td>(0.489)</td>
<td>(0.489)</td>
<td>(0.492)</td>
<td>(0.487)</td>
</tr>
<tr>
<td>Revenue (in million Euros)</td>
<td>43.774</td>
<td>46.166</td>
<td>47.166</td>
<td>49.193</td>
<td>55.087</td>
<td>71.177</td>
<td>61.341</td>
<td>65.478</td>
<td>69.773</td>
<td>55.858</td>
</tr>
<tr>
<td>Wage (all)</td>
<td>76.853</td>
<td>76.880</td>
<td>78.949</td>
<td>79.610</td>
<td>80.469</td>
<td>82.117</td>
<td>82.553</td>
<td>82.631</td>
<td>82.290</td>
<td>80.137</td>
</tr>
<tr>
<td>Wage (un- or semi-skilled)</td>
<td>70.543</td>
<td>70.569</td>
<td>72.316</td>
<td>72.757</td>
<td>73.497</td>
<td>75.211</td>
<td>75.371</td>
<td>75.505</td>
<td>75.307</td>
<td>73.347</td>
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<td>Wage (skilled)</td>
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<td>78.091</td>
<td>80.237</td>
<td>80.727</td>
<td>81.728</td>
<td>83.365</td>
<td>84.056</td>
<td>84.204</td>
<td>84.380</td>
<td>81.515</td>
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<tr>
<td>Wage (highly qualified)</td>
<td>115.658</td>
<td>116.108</td>
<td>120.385</td>
<td>122.379</td>
<td>123.288</td>
<td>126.151</td>
<td>127.358</td>
<td>128.647</td>
<td>128.374</td>
<td>122.812</td>
</tr>
<tr>
<td></td>
<td>(34.759)</td>
<td>(35.248)</td>
<td>(36.746)</td>
<td>(39.071)</td>
<td>(38.875)</td>
<td>(40.403)</td>
<td>(41.424)</td>
<td>(43.280)</td>
<td>(43.204)</td>
<td>(39.403)</td>
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<tr>
<td>All workers</td>
<td>170.499</td>
<td>170.236</td>
<td>164.268</td>
<td>159.480</td>
<td>170.484</td>
<td>181.060</td>
<td>165.914</td>
<td>158.389</td>
<td>169.197</td>
<td>167.769</td>
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<tr>
<td>Un- or semi-skilled workers</td>
<td>78.161</td>
<td>76.586</td>
<td>72.283</td>
<td>69.815</td>
<td>74.885</td>
<td>78.026</td>
<td>69.985</td>
<td>65.564</td>
<td>70.438</td>
<td>73.004</td>
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<tr>
<td>Skilled workers</td>
<td>62.257</td>
<td>62.888</td>
<td>60.080</td>
<td>58.963</td>
<td>62.420</td>
<td>67.006</td>
<td>63.458</td>
<td>59.762</td>
<td>63.508</td>
<td>62.235</td>
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<tr>
<td>Highly qualified workers</td>
<td>30.081</td>
<td>30.763</td>
<td>31.906</td>
<td>30.702</td>
<td>33.179</td>
<td>36.029</td>
<td>32.471</td>
<td>33.063</td>
<td>35.251</td>
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</tr>
<tr>
<td>Collective agreement</td>
<td>0.826</td>
<td>0.824</td>
<td>0.815</td>
<td>0.808</td>
<td>0.781</td>
<td>0.801</td>
<td>0.775</td>
<td>0.764</td>
<td>0.753</td>
<td>0.794</td>
</tr>
<tr>
<td></td>
<td>(0.133)</td>
<td>(0.134)</td>
<td>(0.158)</td>
<td>(0.145)</td>
<td>(0.186)</td>
<td>(0.136)</td>
<td>(0.141)</td>
<td>(0.143)</td>
<td>(0.145)</td>
<td>(0.147)</td>
</tr>
<tr>
<td>Age</td>
<td>40.744</td>
<td>40.655</td>
<td>41.185</td>
<td>41.549</td>
<td>41.821</td>
<td>42.045</td>
<td>42.276</td>
<td>42.486</td>
<td>42.604</td>
<td>41.730</td>
</tr>
<tr>
<td></td>
<td>(1.022)</td>
<td>(1.068)</td>
<td>(1.146)</td>
<td>(1.285)</td>
<td>(1.245)</td>
<td>(1.192)</td>
<td>(1.097)</td>
<td>(1.174)</td>
<td>(1.330)</td>
<td></td>
</tr>
<tr>
<td>Number of firms</td>
<td>5733</td>
<td>6205</td>
<td>5847</td>
<td>5650</td>
<td>5447</td>
<td>5438</td>
<td>5123</td>
<td>5201</td>
<td>5116</td>
<td>49860</td>
</tr>
<tr>
<td>Number of workers</td>
<td>977473</td>
<td>1056317</td>
<td>960475</td>
<td>901063</td>
<td>945675</td>
<td>984604</td>
<td>849977</td>
<td>823781</td>
<td>865614</td>
<td>8364979</td>
</tr>
</tbody>
</table>

4. Empirical Results

We now want to assess the model’s predictions that a higher share of exports leads to a higher revenue, a higher average wage, and a higher measure of workers hired.

As in the Melitz (2003) model we assume constant firm productivity $\varphi$ over the years, which means in return that changes in the share of exports can only be caused by either changes in the foreign and domestic demand shifters $A_{x,c}$ and $A_d$, respectively, or in trading costs $\tau$. We claim that in the years from 2000 to 2008 especially the latter of the two events occurred. Thus, the enlargement of the European Union in May 2004, along with previously established bilateral trade agreements, considerably facilitated German exports into Eastern European countries, allowing German exports to the 10 new members to increase from 2004 to 2008 by about 70%, while overall exports to the rest of the world only increased by about 31%\(^{10}\) at the same time.

Since the model states that firm revenue, wages, and the measure of workers hired are driven by the firm’s share of exports, $\sum_{c=1}^{c'} y_{x,c}/y_d$, a variable not available in the dataset, we have to find a reliable proxy for the ensuing empirical analysis. For this purpose, we divide a firm’s total turnover by its domestic share of total turnover, which leads with (III.3) to

$$\frac{r}{r_d} = 1 + \sum_{c=1}^{c'} \frac{r_{x,c}}{r_d} = 1 + \sum_{c=1}^{c'} \tau_c - \rho \frac{A_{x,c}}{A_d} \left( \frac{y_{x,c}}{y_d} \right)^\rho \equiv \Upsilon_P.$$  

Note the close relation to

$$\Upsilon = 1 + \sum_{c=1}^{c'} \frac{y_{x,c}}{y_d} = 1 + \sum_{c=1}^{c'} \tau_c - \rho \left( \frac{A_{x,c}}{A_d} \right)^\frac{\tau_c}{\rho}.$$  

As can be seen, a decrease in trading costs $\tau_c$ as well as an increase in the foreign demand shifter $A_{x,c}$ will increase both $\Upsilon$ and $\Upsilon_P$. Though the proportions of the changes might be in both cases different and dependent on $\rho$, our proxy $\Upsilon_P$ nevertheless presents very similar features as the firm’s share of exports. While $\Upsilon_P$ is more suitable to capture any changes in the intensive margin of exports, an export indicator variable,

$$\mathbb{I} = \begin{cases} 1 & \text{if } \Upsilon_P > 1 \\ 0 & \text{if } \Upsilon_P = 1 \end{cases},$$

is perceptive to changes in the extensive margin. By allowing for both the commonly used binary export status of a firm as well as its share of total turnover due to

\(^{10}\)Data obtained from Destatis.
exports, we can in particular examine if the extension to a multiple country model is of any additional predictive value when trying to estimate certain characteristics of exporting firms. Since $\Upsilon$ as well as $\Upsilon_P$ are not defined for firms that do not produce for the domestic market — which is in accordance with one of the basic assumptions of the model — we include a dummy variable to represent those firms in the panel that export 100% of their total output and categorize them with firms that export 99%. Note that overall results would not change, if these 174 firm-years were dropped from the panel.

**TABLE II.**

**Regression of Revenue on Share of Exports with and without Firm Specific Controls**

<table>
<thead>
<tr>
<th></th>
<th>Dep. var.: Log revenue ($\ln r$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(FE 1)</td>
</tr>
<tr>
<td>Zero profit revenue ($\ln r_d$)</td>
<td>0.0535**</td>
</tr>
<tr>
<td></td>
<td>(0.0213)</td>
</tr>
<tr>
<td>Share of exports ($\ln \Upsilon_P$)</td>
<td>0.8155***</td>
</tr>
<tr>
<td></td>
<td>(0.0822)</td>
</tr>
<tr>
<td>Binary export status ($I$)</td>
<td>1.0704***</td>
</tr>
<tr>
<td></td>
<td>(0.1863)</td>
</tr>
<tr>
<td>Controls:</td>
<td></td>
</tr>
<tr>
<td>Collective agreement</td>
<td>1.0903***</td>
</tr>
<tr>
<td></td>
<td>(0.1176)</td>
</tr>
<tr>
<td>Share unskilled workers</td>
<td>0.1501</td>
</tr>
<tr>
<td></td>
<td>(0.2602)</td>
</tr>
<tr>
<td>Age</td>
<td>0.0031</td>
</tr>
<tr>
<td></td>
<td>(0.0147)</td>
</tr>
<tr>
<td>N.obs.</td>
<td>44 490</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.1512</td>
</tr>
</tbody>
</table>

*Notes. An observation in the regression is one firm in one year. All regressions include nine year and 25 industry dummies as well as a dummy variable for firms with an export share of 100% (not reported). We report clustered standard errors at the industry level in brackets. Since not all firms stated their annual revenue, the N.obs. are smaller than in the ensuing empirical analyses on wage and measure of workers hired. Nevertheless, the mean of the share of exports (12.5524) and its standard deviation (22.5751) of this subsample only differ slightly from the full sample. Source: LIAB, Version 2, Years 2000-2008.*** indicates significance at 1% level, ** at 5% level, * at 10% level.*
4.1. Revenue

In the following, we try to assess the relation between the share of exports — or to be more precise, the share of revenue due to exports — and firm revenue. By taking the logarithm of (III.6), we obtain the specification of our fixed effects estimating equation

\[ \ln r_{kst} = \beta_0 \ln r_{d,st} + \beta_1 \ln \left( \frac{\varphi_{kst}}{\varphi_{d,st}} \right) + \beta_2 \ln \Upsilon_{P,kst} + \beta_3 \bar{r}_{kst} + \psi_s + \xi_t + u_{kst}, \]

where \( t \) indexes years; \( \psi_s \) is an industry fixed effect, i.e., the intercept of each industry; \( \xi_t \) are time fixed effects; and \( u_{kst} \) denotes the stochastic error. Note that \( \beta_1 \) corresponds to \( \rho/\Gamma \) and \( \beta_2 \) to \( (1 - \rho)/\Gamma \). However, since we assume constant firm productivity \( \varphi \) over time, the coefficient for \( \beta_1 \) cannot be captured in our estimation.

Table II reports the coefficients for \( \beta_2 \) and \( \beta_3 \) (FE 1). First of all, the mere fact of becoming an exporting firm will, on average, increase the total revenue by 192%, a number consistent with other literature, see e.g. Verhoogen (2008). As predicted by the model, the share of exports — even while in the presence of the binary export status — does have a clear positive effect on revenue. For an idea of our results, we consider a firm that receives 10% of its total revenue from abroad, i.e., \( \sum c \rightleftharpoons c = 1 r_{x,c}/r = 0.1 \). Now an increase from 10% to 11% in this share — thereby reducing \( r_{d}/r \) from 90% to 89% — would lead to a 1.124% increase in \( \Upsilon_P \) and therefore to a 0.916% increase in total revenue. An effect of considerable magnitude, keeping the rather small increase in the export revenue ratio in mind. As far as the coefficient of the industry’s zero profit revenue, \( \beta_0 \), is concerned, we can see that though being significant it is nonetheless of very small importance.

Next, we include some firm specific controls into our analysis. We extend our main estimating equation to a dummy variable that is 1 if a firm is subject to collective bargaining\(^{11}\) and 0 if otherwise. As one can see, collective agreements tend to have a large positive effect on revenue, whereas the share of unskilled workers as well as the average age of its work force appear to be of no importance. Even though this extension to firm specific controls slightly decreases the effect of the share of exports (FE 2), the coefficient stays highly significant.

4.2. Wages

In order to measure the relationship of a firm’s share of exports and its average wage, we use two different kinds of wages for each year-skill category as dependent variable:

\(^{11}\)A detailed description of collective bargaining in Germany can be found in chapter II.
the overall average firm wage as well as the firm fixed wage component.

**Overall Average Firm Wage**

For the first part of the analysis, we take in analogy to the previous subsection the logarithm of (III.10) and obtain

\[
\ln w_{kst} = \beta_0 \ln w_{d,st} + \beta_1 \ln \left( \frac{\varphi_{kst}}{\varphi_{d,st}} \right) + \beta_2 \ln \Upsilon_{p,kst} + \beta_3 I_{kst} + \psi_s + \xi_t + u_{kst}.
\]

For each of the three different skill categories: un- or semi-skilled, skilled, and highly qualified\(^\text{12}\), denoted by \(\ell\), we then run fixed effects regressions using the overall average firm wage in each skill-year category as dependent variable. Since not all firms do employ workers with all three kinds of skill levels, the number of observations differs for each of these estimations. Due to possible idiosyncrasies of very small businesses, we only use those workers with at least four colleagues in the same firm-skill-year category.

Table III.A reports the coefficients \(\beta_2\) and \(\beta_3\) for all three different wage categories (FE 1, FE 3, FE 5). As can be seen, all three average wages are positively driven by the share of exports and the binary export status. To get an idea of the export share’s coefficient, we again consider a firm whose share of revenue due to exports increases from 10% to 11%, i.e., a 1.124% increase in \(\Upsilon_p\). According to our estimates of FE 1, this firm would then see the average wage paid to its un- or semi-skilled employees rise by 0.106%. While this effect is of a far smaller magnitude than the previously established rise in revenue, the outcome of the bargaining game — where workers will get \(\rho\gamma/(1+\rho\gamma)\) of the revenue, while the firm keeps a share of \(1/(1+\rho\gamma)\) — is in accordance with these figures. The coefficient of the industry’s lowest wage, \(\beta_0\), is again very small and only significant in the case of the average wage of skilled workers.

We further control for firm specific variables (FE 2, FE 4, FE 6). As expected, in all cases participation in a collective agreement appears to have a large positive effect on wages. In addition, a higher share of unskilled workers significantly drives down wages for un- or semi-skilled workers. As one might think, age, though not significant, positively drives wages. Though the coefficients of interest are robust to the controls, they all decrease in magnitude.

\(^{12}\text{In order to have enough observations in each industry-skill-year, we do not consider separately managers and hence categorize them with highly qualified workers.}\)
<table>
<thead>
<tr>
<th>regression of wage on share of exports with and without firm specific controls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Dep. var.: Average log wage (ln w)</strong>*</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Lowest wage (ln w_d)</td>
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<tr>
<td>(0.0188)</td>
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<tr>
<td>Share of exports (ln Υ_P)</td>
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<td>(0.0130)</td>
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<td>Controls:</td>
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<td>Collective agreement</td>
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<td>(0.0146)</td>
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<td>Share unskilled workers</td>
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<td>(0.0377)</td>
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<td>Age</td>
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<td>(0.0022)</td>
</tr>
<tr>
<td>N.obs.</td>
</tr>
<tr>
<td>R^2</td>
</tr>
<tr>
<td><strong>B. Dep. var.: Firm log wage component (η)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Lowest wage (ln η_d)</td>
</tr>
<tr>
<td>(0.0303)</td>
</tr>
<tr>
<td>Share of exports (ln Υ_P)</td>
</tr>
<tr>
<td>(0.0120)</td>
</tr>
<tr>
<td>Binary export status (I)</td>
</tr>
<tr>
<td>(0.0247)</td>
</tr>
<tr>
<td>Controls:</td>
</tr>
<tr>
<td>Collective agreement</td>
</tr>
<tr>
<td>(0.0151)</td>
</tr>
<tr>
<td>N.obs.</td>
</tr>
<tr>
<td>R^2</td>
</tr>
</tbody>
</table>

Notes. An observation in the regression is one firm in one year. All regressions include nine year and 25 industry dummies as well as a dummy variable for firms with an export share of 100% (not reported). We report clustered standard errors at the industry level in brackets. N.obs. differ for not every firm employs workers of all three kinds of skill levels. Source: LIAB, Version 2, Years 2000-2008.

*** indicates significance at 1% level, ** at 5% level, * at 10% level.
Firm Level Wage Component

As these results could be driven by worker specific characteristics as well as assortative matching between high-wage firms and high-wage workers, we decompose individual worker wages into its components and use the firm fixed wage component as dependent variable. We thereby rely strongly on the methods presented in Helpman et al. (2013) and Akerman et al. (2013).

To this end, we first estimate the following OLS Mincer regression separately for each industry-skill-year:

\[
\ln w_{is\ell t} = z'_{is\ell t} \lambda_{s\ell t} + \eta_{kstt} + \nu_{is\ell t},
\]

where \( w_{is\ell t} \) is a worker \( i \)'s wage, in industry \( s \), with a skill level of \( \ell \), in a given year \( t \). The vector \( z'_{is\ell t} \) denotes individual observable worker characteristics, while \( \lambda_{s\ell t} \) captures the returns to these characteristics. \( \eta_{kstt} \) is the fixed effect of firm \( k \) and \( \nu_{is\ell t} \) the stochastic error. Our specification for observable worker characteristics is as follows: education (using categories for: no degree at all; vocational training or high school degree; vocational training and high school degree; technical college degree; university degree; as well as missing values), age (using the categories: 19-24; 25-29; 30-39; 40-49; 50-65), and gender. As in the previous case, we only consider firms with at least five observations in a given firm-skill-year. Since the regression is estimated separately for each industry-skill-year, the coefficients on worker characteristics as well as the firm fixed effects can vary over time and across skill levels. The firm fixed effects are further normalized to sum to zero for each industry-skill-year, whereby the regressions' intercepts are absorbed by the observable worker characteristics components. We then estimate in analogy to the above specification the following fixed effects specification

\[
\hat{\eta}_{kstt} = \beta_0 \hat{\eta}_{d,\ell tt} + \beta_1 \ln \left( \frac{\varphi_{kst}}{\varphi_{d,\ell tt}} \right) + \beta_2 \ln \gamma_{P,kst} + \beta_3 \|_{kst} + \psi + \xi_t + u_{kstt},
\]

where \( \hat{\eta}_{d,\ell tt} \) denotes the industry’s lowest firm log wage component. Results are reported in Table III.B. As can be seen, all coefficients of interest are significant and of the same magnitude as in the overall average firm wage case, while being robust to controls for collective agreements. As the share of exports appears to be mainly driven by the firm level component of wages, the model’s predictions are borne out to a large degree.
4.3. Measure of Workers Hired

While we have seen that firms with a higher share of exports do not only have a higher revenue but also pay higher wages to their employees, we now try to give an answer to the question, if they — as the model suggests — also employ more workers. Using the logarithm on (III.11), we obtain the following estimating equation

$$\ln h_{kst} = \beta_0 \ln h_{d,st} + \beta_1 \ln \left( \frac{\varphi_{kst}}{\varphi_{d,st}} \right) + \beta_2 \ln \Upsilon_{P,kst} + \beta_3 I_{kst} + \psi_s + \xi_t + u_{kst}.$$  

| TABLE IV. |
| Regression of Measure of Workers Hired on Share of Exports with and without Firm Specific Controls |

<table>
<thead>
<tr>
<th>Dep. var.: Log measure of workers hired (ln $h$)</th>
<th>reported</th>
<th>matched</th>
</tr>
</thead>
<tbody>
<tr>
<td>(FE 1)</td>
<td>(FE 2)</td>
<td>(FE 3)</td>
</tr>
<tr>
<td>Lowest measure of workers hired (ln $h_d$)</td>
<td>0.0054</td>
<td>-0.0003</td>
</tr>
<tr>
<td></td>
<td>(0.0310)</td>
<td>(0.0312)</td>
</tr>
<tr>
<td>Share of exports (ln $\Upsilon_P$)</td>
<td>0.5329***</td>
<td>0.4367***</td>
</tr>
<tr>
<td></td>
<td>(0.0819)</td>
<td>(0.0671)</td>
</tr>
<tr>
<td>Binary export status ($I$)</td>
<td>0.7324***</td>
<td>0.6964***</td>
</tr>
<tr>
<td></td>
<td>(0.1259)</td>
<td>(0.1042)</td>
</tr>
</tbody>
</table>

Controls:

- Collective agreement: 0.8429***, 0.8314***
  - (0.0923) (0.0989)
- Share unskilled workers: 0.5251***, 0.4099**
  - (0.0858) (0.1564)
- Age: -0.0016, 0.0031
  - (0.0107) (0.0112)

N.obs. 49 860 49 847 49 860 49 860

$R^2$ 0.1112 0.2095 0.1182 0.2091

Notes. An observation in the regression is one firm in one year. All regressions include nine year and 25 industry dummies as well as a dummy variable for firms with an export share of 100% (not reported). N.obs. differ in FE 2 since not all companies reported their share of unskilled workers. We report clustered standard errors at the industry level in brackets. Source: LIAB, Version 2, Years 2000-2008.

*** indicates significance at 1% level, ** at 5% level, * at 10% level.
We then use two different kinds of observations for the measure of workers hired: the reported and the matched number of workers. Since the data stems from annual voluntary surveys of a sample of firms which is then matched with data from all workers liable to social security, there is on the one hand the stated number of workers in a firm (reported) while there is also the actual number of matched workers (matched). Now these two variables slightly differ in some cases for various reasons. For example the reported number of workers contains both workers in part-time employment and dormant employment relationships. These are workers we initially tried to exclude from our sample by introducing a wage threshold. However, since we cannot be perfectly sure that our sample reflects an accurate image of a firm’s actual full-time work force, for we might have excluded too few or too many workers, the use of the reported number of workers is not only a way to ensure more reliable results but also gives us an additional control for our previous estimations.

As predicted by the model, the measure of workers hired is in both cases positively driven by the share of exports. Now again, an increase from 10% to 11% in the firm’s share of revenue due to exports would go along with a 0.599% (FE 1) or a 0.621% (FE 3) increase in the measure of workers hired. With an average reported measure of workers of 167 this effect is quite large considering the relatively small increase in the share of exports.

While collective agreements have a positive influence, the average age of a firm appears to have no effect at all. In accordance with the reported measure of workers hired, we use the reported share of unskilled workers as a control in FE 2. Though this variable is better suited as a control than the observed share of unskilled workers for it also contains workers in part-time employment, we are suspicious that its accuracy has suffered due to the fact that firms had to decide by themselves if a worker’s task requires him or her to be skilled or not.

Nevertheless, both measures produce very similar results, a fact that assures us that the created dataset of full-time workers accurately represents each industry’s work force.

5. Conclusion

By expanding the Melitz (2003) model to a world with asymmetric countries and therefore to a world with different aggregate demand shifters, we can explain for firms to export to a varying number of countries, all depending on their initial productivity, trading costs, and the countries’ export thresholds. Since this setting enables firms
to have a continuum of export shares instead of the commonly used binary export status in the model, a link to the HIR framework, ultimately allows for a model that predicts a higher revenue, higher average wages as well as a higher measure of workers hired on account of an increasing share of exports. While assuming that the productivity drawn by a firm stays constant over time, its export status can still be subject to variation through changes in the countries’ demand shifters or in trading costs.

We further use the LIAB, a German linked employer-employee dataset, in order to empirically corroborate the predictions of our model. Since the LIAB doesn’t provide the share of products sold abroad as required in the model, we take the share of total turnover due to exports as a proxy variable. Using then fixed effects regressions, we are able to show that all three measures are positively driven by the share of revenue due to exports while being robust to a set of firm specific controls. The coefficients of the effects are in all cases of a considerable magnitude, while acting in accordance with the model’s parameter limitations. Our results do not only give further empirical support to a relatively new line of research of trade models with labor market frictions, but also show that allowing for a continuous export status gives valuable information when predicting the effects of trade liberalization or foreign demand shifts on domestic firms.
IV

The Impact of Complementarities between Workers and Managers on Income Inequality
1. Introduction

Grossman et al. (2013), henceforth GHK, recently presented a neoclassical trade model of two countries, two sectors, and two heterogeneous factors of production, namely workers and managers. Due to complementarities between these factors, production can be affected by their sorting and matching pattern into industries. According to the model, the opening of trade can cause a worker, depending on the country’s relative factor endowments and certain sector specific idiosyncrasies, to rematch with either a manager of a higher or lower ability. GHK further predict, that an overall increase in the manager’s ability with whom a worker is matched can cause the relative wage and therefore wage dispersion of the respective workers to increase. By the same token, the quality of a manager’s assigned team of workers can either improve or decrease, having a similar impact on managers’ salary dispersion.

By using the LIAB, a linked employer-employee panel dataset from Germany, the aim of this paper is to provide empirical evidence of the above mentioned link between trade liberalization, factor ability, and income dispersion. In a first step, we therefore assess the effect of trade on the average within-firm ability of both workers and managers. Second, we show that changes in the workers’ and managers’ ability have a significant impact on the within-firm wage and salary distribution.

Related empirical evidence is provided by Krishna et al. (2012), who use a matched employer-employee dataset from Brazil to show that changes in trade openness will lead to greater increases in wage dispersion for high education workers relative to low education workers.

The plan of this paper is as follows. Section II briefly presents the theoretical framework of GHK. Section III describes the dataset used. Section IV contains the empirical results. Section V concludes. An Appendix provides the most important derivations of the GHK framework as well as additional empirical results.

2. Theoretical Framework

The GHK model consists of two countries, two sectors, and two factors. Countries can both differ in their relative factor endowments, giving rise to Stolper-Samuelson forces, and their distribution of factor endowments, allowing for technological differences and hence comparative advantages. Sectors can vary from one another in their factor intensities, in the strength of their factor complementarities, as well as in the contribution of their factor abilities.

The two factors of production are workers and managers. Though GHK also present
a framework where homogeneous managers are matched with heterogeneous workers, their ultimate interest lies in the case of two heterogeneous factors, as it gives much more insight into the distributional effects of international trade. Thus, they present two settings of this case, one with a Cobb-Douglas productivity function and one with a more general productivity function that allows for a determinate matching pattern. We shall focus on the latter, for a Cobb-Douglas productivity function due to its multiplicative separability does not allow for complementarities between workers.

All workers are further part of a mass of workers \( \bar{L} \) and managers part of a mass of managers \( \bar{H} \). The supply of workers with ability \( q_L \) is given by \( \bar{L} \phi_L(q_L) \), while \( \phi_L(q_L) \) is the density of workers with ability \( q_L \) with support over \( S_L = [q_{L,\text{min}}, q_{L,\text{max}}] \). Accordingly, the distribution of a manager’s ability \( q_H \) is given by \( \phi_H(q_H) \) with support over \( S_H = [q_{H,\text{min}}, q_{H,\text{max}}] \) and \( 0 < q_{H,\text{min}} < q_{H,\text{max}} < +\infty \).

2.1. Matching and Income Dispersion among Factors

Starting with the simple output function of a firm in sector \( i \):

\[
x_i = \psi_i(q_H, q_L)\ell^\gamma_i, \quad 0 < \gamma_i < 1,
\]

where \( \ell \) is the number of workers of type \( q_L \) with whom a manager is teamed, GHK derive a function for the relative salary of a connected set of managers \( [q_{H0}, q_H] \) that sorts to sector \( i \):

\[
\ln r_i(q_H) - \ln r_i(q_{H0}) = \int_{q_{H0}}^{q_H} \frac{\psi_{iH}[x, m(x)]}{(1 - \gamma_i)\psi_i[x, m(x)]} dx \quad (\text{IV.1})
\]

\( m(x) \) is thereby the solution to the firm’s profit maximization problem. Note that for a given managerial ability \( q_H \), \( m(q_H) \) indicates the common ability of the team of workers with whom the manager is teamed.

By the same token, GHK obtain a function for the relative wage of the set of workers \( [q_{L0}, q_L] \):

\[
\ln w_i(q_L) - \ln w_i(q_{L0}) = \int_{q_{L0}}^{q_L} \frac{\psi_{iL}[\mu(x), x]}{\gamma_i \psi_i[\mu(x), x]} dx, \quad (\text{IV.2})
\]

where \( \mu(x) \) is the inverse function of \( m(x) \). Since there is positive assortative matching within sectors, i.e., the better workers are always matched with the better managers, both \( m(x) \) and \( \mu(x) \) are strictly increasing in the set \( [q_{H0}, q_H] \) and \( [q_{L0}, q_L] \), respectively.

Based on the above results, we can state the following two hypotheses:
Hypothesis 1: Wage dispersion increases if all workers in \([q_{L0}, q_L]\) are re-matched with better managers.

Hypothesis 2: Salary dispersion increases if all managers in \([q_{H0}, q_H]\) are re-matched with better workers.

In other words, if a company replaces a manager with a better one, the productivity of the manager’s team of workers will increase, leading ultimately to a boost in the team’s relative wages, i.e., an increase in wage dispersion. The same holds true for managers who are teamed with workers of a higher ability.

2.2. The Impact of Trade on Income Dispersion

In the light of international trade theory these outcomes raises two empirical questions. First, how is the ability of the managerial and worker staff affected by an increase in exports? And second, motivated by the predictions of the GHK model, does an increase in this ability lead to more or less income dispersion?

Theoretically, these questions cannot be answered without further assumptions of the country’s factor endowments, the prevailing factor sorting pattern in each sector, the distribution of factor abilities, as well as the sector’s factor intensities. Thus, GHK provide different cases, where a manager’s and a worker’s match can either deteriorate or improve due to trade.

![Positive Assortative Matching within and across Sectors in Country A](image-url)
For an idea of how a sector’s factor ability can be affected by trade, we take a look at the following example. Consider two countries, $A$ and $B$, with a similar distribution of factor ability and hence no technological differences but with different relative factor endowments. Country $A$ is thereby to be taken as relatively abundant in managers, i.e., $\frac{\bar{H}^A}{\bar{L}^A} > \frac{\bar{H}^B}{\bar{L}^B}$. We further assume positive assortative matching across industries in both countries. In this way, the most able managers and workers will sort to sector 1, while the less able managers and workers sort to sector 2. In the case of sector 2 being manager intensive, i.e., $\gamma_2 < \gamma_1$, these assumptions depict the solid curve given in Figure I.

With the opening of trade, country $A$ will then, according to the Heckscher-Ohlin theorem, export the good that uses its abundant factor intensively, thereby increasing the relative price and hence the real return to the factor used intensively in the production of that good (Stolper-Samuelson theorem). As factors are fully mobile between industries, the manager intensive sector, i.e., sector 2 with low ability workers and low ability managers, will expand due to these increases in the real returns, causing a rise of the ability thresholds $q^*_L$ and $q^*_H$. In other words, the average ability of both workers and managers in the manager intensive sector will increase as a cause of trade liberalization.

We can now turn to our second initial question: How will this increase in factor ability affect income dispersion? Consider a case where $q^*_L$ and $q^*_H$ rise by similar proportions. The new matching pattern is then given by the dashed line in Figure I. As can be seen, managers who remain in sector 2 will see their matches improve, while those that move from sector 1 to 2 will see their matches deteriorate. Conversely, workers who were initially in sector 2 will realize worse matches, while those that switch from sector 1 to 2 will realize better matches. In the case of a relatively small expansion of the sector, on average, a worker’s match would hence decrease, while the ability of a manager’s team would increase, thus causing — according to (IV.1) — a rise in salary dispersion and — according to (IV.2) — a decrease in wage dispersion.

These theoretical thoughts also hold true at the firm-level where a trade induced extension of the manager intensive sector will cause firms to hire new workers and managers from the labor intensive sector. Depending on the relative increase of the firm’s skill-group abilities, the respective matches can then, as shown in Figure I, either improve or deteriorate.

Since we have shown how trade can theoretically affect factor ability and hence income dispersion, we now use firm-level data, provided by the LIAB, a German linked employer-employee dataset, to give an empirical answer to our initial questions.
3. Data

For the empirical part of our study we use the ‘LIAB cross-sectional model 2’, a linked employer-employee dataset from the German Institute for Employment Research (IAB). A detailed description of the dataset can be found in Jabobebbinghaus & Seth (2010) and chapter II. We further rely on the same conditions used in the latter, which are mainly: only industries with a primary interest in exports are included in the panel, i.e., the first 25 industries in the IAB industry classification; only establishments, referred to as firms, with five or more full-time workers whose wages exceed twice the minimum wage (based on the wages in minor employment).

<table>
<thead>
<tr>
<th>Industry</th>
<th>Employment share</th>
<th>Share skilled workers</th>
<th>Share managers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Hunting, Forestry &amp; Fishing</td>
<td>0.55%</td>
<td>16.19%</td>
<td>3.16%</td>
</tr>
<tr>
<td>Mining, Electricity, Gas &amp; Water Supply</td>
<td>5.55%</td>
<td>42.60%</td>
<td>3.01%</td>
</tr>
<tr>
<td>Manuf. of Food Prod.</td>
<td>3.89%</td>
<td>32.82%</td>
<td>2.35%</td>
</tr>
<tr>
<td>Manuf. of Textiles &amp; Apparel</td>
<td>1.18%</td>
<td>25.43%</td>
<td>2.25%</td>
</tr>
<tr>
<td>Manuf. of Paper Prod., Printing &amp; Publishing</td>
<td>2.40%</td>
<td>45.10%</td>
<td>3.77%</td>
</tr>
<tr>
<td>Manuf. of Wood Prod. (no Furniture)</td>
<td>1.02%</td>
<td>36.29%</td>
<td>1.61%</td>
</tr>
<tr>
<td>Manuf. of Chemicals, Coke &amp; Petroleum</td>
<td>10.11%</td>
<td>27.46%</td>
<td>3.98%</td>
</tr>
<tr>
<td>Manuf. of Rubber &amp; Plastic Prod.</td>
<td>3.34%</td>
<td>21.51%</td>
<td>2.48%</td>
</tr>
<tr>
<td>Manuf. of Other Non-Metallic Mineral Prod.</td>
<td>2.47%</td>
<td>23.05%</td>
<td>2.45%</td>
</tr>
<tr>
<td>Manuf. of Basic Metals</td>
<td>6.30%</td>
<td>35.80%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Manuf. of Fabricated &amp; Structural Metal Prod.</td>
<td>5.31%</td>
<td>35.77%</td>
<td>1.61%</td>
</tr>
<tr>
<td>Manuf. of Machinery &amp; Equipment</td>
<td>11.27%</td>
<td>41.26%</td>
<td>2.11%</td>
</tr>
<tr>
<td>Manuf. of Motor Vehicles &amp; Trailers</td>
<td>12.39%</td>
<td>31.18%</td>
<td>2.30%</td>
</tr>
<tr>
<td>Manuf. of Other Transport Equipment</td>
<td>4.28%</td>
<td>45.86%</td>
<td>2.09%</td>
</tr>
<tr>
<td>Manuf. of Electrical Equipment</td>
<td>6.45%</td>
<td>30.82%</td>
<td>2.55%</td>
</tr>
<tr>
<td>Manuf. of Precision &amp; Optical Equipment</td>
<td>1.75%</td>
<td>35.18%</td>
<td>4.73%</td>
</tr>
<tr>
<td>Manuf. of Furniture, Jewellery &amp; Other Prod.</td>
<td>1.46%</td>
<td>49.27%</td>
<td>1.53%</td>
</tr>
<tr>
<td>Recycling</td>
<td>0.20%</td>
<td>20.44%</td>
<td>1.93%</td>
</tr>
<tr>
<td>Building of Complete Constructions or Parts</td>
<td>3.73%</td>
<td>37.36%</td>
<td>1.52%</td>
</tr>
<tr>
<td>Building Installation &amp; Completion</td>
<td>1.64%</td>
<td>65.47%</td>
<td>1.70%</td>
</tr>
<tr>
<td>Sales, Maintenance &amp; Repair of Motor Vehicles</td>
<td>1.24%</td>
<td>62.75%</td>
<td>2.44%</td>
</tr>
<tr>
<td>Wholesale &amp; Commission Trade</td>
<td>3.11%</td>
<td>41.31%</td>
<td>4.62%</td>
</tr>
<tr>
<td>Retail Trade &amp; Repair of Household Goods</td>
<td>2.63%</td>
<td>36.10%</td>
<td>4.13%</td>
</tr>
<tr>
<td>Transport</td>
<td>7.14%</td>
<td>45.33%</td>
<td>2.12%</td>
</tr>
<tr>
<td>Communication</td>
<td>0.60%</td>
<td>42.95%</td>
<td>1.54%</td>
</tr>
</tbody>
</table>

All Industries                                100.00%          37.91%            2.47%

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary export status</td>
<td>0.360</td>
<td>0.375</td>
<td>0.382</td>
<td>0.375</td>
<td>0.381</td>
<td>0.396</td>
<td>0.396</td>
<td>0.396</td>
<td>0.409</td>
<td>0.385</td>
</tr>
<tr>
<td></td>
<td>(0.480)</td>
<td>(0.484)</td>
<td>(0.486)</td>
<td>(0.484)</td>
<td>(0.486)</td>
<td>(0.489)</td>
<td>(0.489)</td>
<td>(0.489)</td>
<td>(0.492)</td>
<td>(0.487)</td>
</tr>
<tr>
<td>Revenue (in million Euros)</td>
<td>43.774</td>
<td>46.166</td>
<td>47.166</td>
<td>49.193</td>
<td>55.087</td>
<td>71.177</td>
<td>61.341</td>
<td>65.478</td>
<td>69.773</td>
<td>55.858</td>
</tr>
<tr>
<td>Skilled workers</td>
<td>62.257</td>
<td>62.888</td>
<td>60.808</td>
<td>58.963</td>
<td>62.420</td>
<td>67.006</td>
<td>63.458</td>
<td>59.762</td>
<td>63.508</td>
<td>62.235</td>
</tr>
<tr>
<td></td>
<td>(23.363)</td>
<td>(54.272)</td>
<td>(65.407)</td>
<td>(67.647)</td>
<td>(56.394)</td>
<td>(58.323)</td>
<td>(47.796)</td>
<td>(76.535)</td>
<td>(94.56)</td>
<td>(62.746)</td>
</tr>
<tr>
<td>Wage (skilled workers)</td>
<td>78.170</td>
<td>78.091</td>
<td>80.237</td>
<td>80.727</td>
<td>81.728</td>
<td>83.365</td>
<td>84.056</td>
<td>84.204</td>
<td>84.380</td>
<td>81.515</td>
</tr>
<tr>
<td>Salary (managers)</td>
<td>140.492</td>
<td>141.484</td>
<td>146.796</td>
<td>154.600</td>
<td>152.903</td>
<td>157.562</td>
<td>158.761</td>
<td>159.447</td>
<td>158.201</td>
<td>151.683</td>
</tr>
<tr>
<td></td>
<td>(43.380)</td>
<td>(44.214)</td>
<td>(46.312)</td>
<td>(52.221)</td>
<td>(50.339)</td>
<td>(52.566)</td>
<td>(53.840)</td>
<td>(55.579)</td>
<td>(55.101)</td>
<td>(50.736)</td>
</tr>
<tr>
<td>Education (skilled workers)</td>
<td>2.113</td>
<td>2.110</td>
<td>2.194</td>
<td>2.109</td>
<td>2.115</td>
<td>2.126</td>
<td>2.131</td>
<td>2.135</td>
<td>2.137</td>
<td>2.119</td>
</tr>
<tr>
<td></td>
<td>(0.322)</td>
<td>(0.308)</td>
<td>(0.302)</td>
<td>(0.311)</td>
<td>(0.307)</td>
<td>(0.324)</td>
<td>(0.323)</td>
<td>(0.326)</td>
<td>(0.320)</td>
<td>(0.316)</td>
</tr>
<tr>
<td></td>
<td>(1.017)</td>
<td>(1.016)</td>
<td>(1.018)</td>
<td>(1.029)</td>
<td>(1.028)</td>
<td>(1.038)</td>
<td>(1.045)</td>
<td>(1.037)</td>
<td>(1.104)</td>
<td>(1.030)</td>
</tr>
<tr>
<td>Share university degree (skilled workers)</td>
<td>0.021</td>
<td>0.020</td>
<td>0.020</td>
<td>0.020</td>
<td>0.020</td>
<td>0.023</td>
<td>0.022</td>
<td>0.023</td>
<td>0.023</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.062)</td>
<td>(0.060)</td>
<td>(0.063)</td>
<td>(0.060)</td>
<td>(0.070)</td>
<td>(0.065)</td>
<td>(0.070)</td>
<td>(0.069)</td>
<td>(0.065)</td>
</tr>
<tr>
<td>Share university degree (managers)</td>
<td>0.233</td>
<td>0.233</td>
<td>0.237</td>
<td>0.246</td>
<td>0.243</td>
<td>0.250</td>
<td>0.254</td>
<td>0.254</td>
<td>0.254</td>
<td>0.244</td>
</tr>
<tr>
<td></td>
<td>(0.311)</td>
<td>(0.312)</td>
<td>(0.314)</td>
<td>(0.321)</td>
<td>(0.317)</td>
<td>(0.325)</td>
<td>(0.329)</td>
<td>(0.330)</td>
<td>(0.329)</td>
<td>(0.321)</td>
</tr>
<tr>
<td>Age (skilled workers)</td>
<td>40.265</td>
<td>40.502</td>
<td>40.627</td>
<td>41.027</td>
<td>41.246</td>
<td>41.529</td>
<td>41.846</td>
<td>42.062</td>
<td>42.364</td>
<td>41.232</td>
</tr>
<tr>
<td>Age (managers)</td>
<td>47.002</td>
<td>47.160</td>
<td>47.179</td>
<td>47.176</td>
<td>47.228</td>
<td>47.504</td>
<td>47.564</td>
<td>47.563</td>
<td>47.673</td>
<td>47.322</td>
</tr>
<tr>
<td>Number of firms with skilled workers</td>
<td>5490</td>
<td>5940</td>
<td>5561</td>
<td>5360</td>
<td>5263</td>
<td>5161</td>
<td>4861</td>
<td>4930</td>
<td>4806</td>
<td>47372</td>
</tr>
<tr>
<td>Number of firms with managers</td>
<td>3033</td>
<td>3283</td>
<td>2974</td>
<td>2297</td>
<td>2793</td>
<td>2758</td>
<td>2602</td>
<td>2520</td>
<td>2485</td>
<td>25245</td>
</tr>
</tbody>
</table>

*Notes.* Unweighted mean over all firms by year. Standard deviation in brackets. Number of firms includes only those firms that employ at least five or more skilled workers and managers, respectively. One observation is one firm in one year. Source: LIAB, Version 2, Years 2000-2008.
are considered; an employee’s income is deflated by the Consumer Price Index, with 2000 as the base year; years from 2000 to 2008. All employees are further categorized into four different skill levels (un- or semi-skilled; skilled; highly qualified; manager). The latter is built from the Blossfeld (1985) skill classification, which categorizes the employer’s stated occupational 3-digit code of each employee into 12 groups. Table I reports employment shares for each industry in the base year 2000.

As a proxy variable for an employee’s ability, we use the stated education information on the employer’s annual report to the social security system. In total, there are five educational categories (1 = no degree at all; 2 = vocational training or high school degree; 3 = vocational training and high school degree; 4 = technical college degree; 5 = university degree) which can be ranked in increasing order. The quality of the education variable has been improved by the Fitzenberger et al. (2006) routine which mainly relies on extrapolation of past and future information in order to cope with missing and presumable invalid observations. For each of the four skill levels, we then compute the average education level in a given firm-year.

These variables are then matched with the firm’s export statement in the annual IAB survey. We focus on the relation between managers and skilled workers, for according to the above mentioned Blossfeld (1985) skill classification, workers categorized as un- or semi-skilled, generally do not require managerial supervision.

In total, we are left with a dataset of 47,372 firms with five or more skilled workers and 25,245 firms with five or more managers. Summary statistics for firm characteristics as well as skilled workers and managers in the dataset used can be found in Table II.

4. Empirical Results

In the first part of our analysis, we examine the relationship between trade liberalization and average factor ability. We thereby use the firm’s share of total turnover due to exports to measure its exposure to trade. The average educational degree of the firm’s managerial and worker staff further serves as a proxy for factor ability. We estimate the following fixed effects specification separately for skilled workers,

\[ \tilde{q}_{L,ijt} = \beta_1 s + \psi_j + \xi_t + u_{ijt}, \]

and managers,

\[ \tilde{q}_{H,ijt} = \beta_1 s + \psi_j + \xi_t + u_{ijt}, \]

where \( \tilde{q}_L (\tilde{q}_H) \) denotes the average education of the skilled workers (managers) at
firm $i$ in industry $j$ at year $t$. $s$ is the firm’s share of total turnover due to exports; $\psi_j$ are industry fixed effects and $\xi_t$ time fixed effects; $u_{ijt}$ denotes the stochastic error. Table A.I presents results for both skilled workers and managers with and without firm specific controls.

As can be seen, the average education of both skilled workers and managers increases with a firm’s exposure to trade. All coefficients of interest are significant and robust to a set of firm specific controls. These comprise the employment share of the respective skill group, its average age, the firm’s revenue as well as a dummy that states whether a firm’s work force is subject to a collective bargaining agreement or not.\(^1\)

**TABLE III.**
**Regression of Average Education on Share of Exports with and without Firm Specific Controls**

<table>
<thead>
<tr>
<th></th>
<th>Dep. var.: Average education ($\bar{q}_{L}$)</th>
<th>Dep. var.: Average education ($\bar{q}_{H}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skilled workers (FE 1)</td>
<td>Managers (FE 2)</td>
</tr>
<tr>
<td></td>
<td>(FE 3)</td>
<td>(FE 4)</td>
</tr>
<tr>
<td>Share of exports ($s$)</td>
<td>0.0012***  (0.0003)</td>
<td>0.0005*  (0.0003)</td>
</tr>
<tr>
<td></td>
<td>0.0040***  (0.0011)</td>
<td>0.0022**  (0.0011)</td>
</tr>
<tr>
<td>Controls:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collective agreement</td>
<td>$-0.0343***  (0.0059)$</td>
<td>0.0197  (0.0463)</td>
</tr>
<tr>
<td>Employment share</td>
<td>$-0.1340***  (0.0365)$</td>
<td>$-0.1532  (0.2230)$</td>
</tr>
<tr>
<td>Age</td>
<td>$-0.0016***  (0.0005)$</td>
<td>$-0.0008  (0.0028)$</td>
</tr>
<tr>
<td>Log revenue</td>
<td>$0.0201***  (0.0032)$</td>
<td>$0.0839***  (0.0144)$</td>
</tr>
<tr>
<td>N.obs.</td>
<td>47 312</td>
<td>42 311</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0075</td>
<td>0.0340</td>
</tr>
</tbody>
</table>

**Notes.** An observation in the regression is one firm in one year. All regressions include nine year and 25 industry dummies. Since not all companies reported their revenue, N.obs. is smaller when controlling for revenue. We report clustered standard errors at the industry level in brackets. Source: LIAB, Version 2, Years 2000-2008.

\(***\) indicates significance at 1% level, \(**\) at 5% level, \(\ast\) at 10% level.

\(^1\)A detailed description of collective bargaining in Germany can be found in chapter II.
While the effects are moderate, the increase in average education due to trade appears to be absolutely larger for managers than for skilled workers. Considering the differences in the standard deviation between worker and manager education, given in Table II, both increases are however, in relative terms, of a similar magnitude. For an idea of these results, consider a firm with 25 managers who all have a technical college degree. A 10% increase in the firm’s share of exports would, according to the coefficient of FE 3, raise the average education level of the managerial staff by 0.04.

### TABLE IV.
**Regression of Wage and Salary Dispersion on Average Education with and without Firm Specific Controls**

<table>
<thead>
<tr>
<th></th>
<th>Dep. var.: Dispersion of log wage ((\ln w_{max} - \ln w_{min}))</th>
<th>Dep. var.: Dispersion of log salary ((\ln r_{max} - \ln r_{min}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skilled workers (FE 1)</td>
<td>Managers (FE 2)</td>
</tr>
<tr>
<td>Skilled worker education ((\tilde{q}_L))</td>
<td>0.0515*</td>
<td>0.1985***</td>
</tr>
<tr>
<td></td>
<td>(0.0253)</td>
<td>(0.0174)</td>
</tr>
<tr>
<td>Managerial education ((\tilde{q}_H))</td>
<td>0.0293**</td>
<td>-0.0164**</td>
</tr>
<tr>
<td></td>
<td>(0.0117)</td>
<td>(0.0071)</td>
</tr>
<tr>
<td>Share of exports (s)</td>
<td>0.0138***</td>
<td>0.0056***</td>
</tr>
<tr>
<td></td>
<td>(0.0012)</td>
<td>(0.0009)</td>
</tr>
<tr>
<td>Share of exports(^2) (s(^2))</td>
<td>-0.00011***</td>
<td>-0.00006***</td>
</tr>
<tr>
<td></td>
<td>(0.00002)</td>
<td>(0.00001)</td>
</tr>
<tr>
<td>Controls:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collective agreement</td>
<td>-0.0430***</td>
<td>-0.0180</td>
</tr>
<tr>
<td></td>
<td>(0.0131)</td>
<td>(0.0128)</td>
</tr>
<tr>
<td>Employment share</td>
<td>0.6067***</td>
<td>2.7346***</td>
</tr>
<tr>
<td></td>
<td>(0.0790)</td>
<td>0.3223</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0088***</td>
<td>-0.0043***</td>
</tr>
<tr>
<td></td>
<td>(0.0017)</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>Log revenue</td>
<td>0.2079***</td>
<td>0.1637***</td>
</tr>
<tr>
<td></td>
<td>(0.0074)</td>
<td>(0.0081)</td>
</tr>
<tr>
<td>N.obs.</td>
<td>24,800</td>
<td>22,199</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.0768</td>
<td>0.4799</td>
</tr>
</tbody>
</table>

**Notes.** An observation in the regression is one firm in one year. All regressions include nine year and 25 industry dummies. We report clustered standard errors at the industry level in brackets. Source: LIAB, Version 2, Years 2000-2008.

*** indicates significance at 1% level, ** at 5% level, * at 10% level.
In other words, one of these 25 managers were to be replaced by a manager with a university degree. In addition, the coefficients of the control variables are in line with the general intuition. Thus, as one might assume, collective bargaining is of no importance to managers. The negative coefficient of both collective agreements and the skilled employment share are further in accordance with the general view that both are on average higher in larger plants of an assembly line type where a work force of a lower average ability is more common, while both are usually smaller in more specialized manufacturing establishments. The negative coefficient of age underpins the fact that younger workers have on average a higher ranked educational degree. Last, the positive coefficient of log revenue is in line with the fact that firms with a higher revenue are generally prone to have a staff of a higher average ability. This holds for both skilled workers and managers.\footnote{As an additional robustness check, we reran the above analysis using the share of university degree holders per skill-group as an alternative proxy variable for the average ability of the firm’s respective skill-group. See the Appendix for a detailed description of the results.}

In a second step, we now want to assess the predicted effect of the changes in skilled worker and managerial ability on the income dispersion of the respective counterpart. We therefore estimate the following fixed effects specification, again separately for skilled workers,

\[ \ln w_{ijt,\text{max}} - \ln w_{ijt,\text{min}} = \beta_1 s + \beta_2 s^2 + \beta_3 \tilde{q}_{H,ijt} + \psi_j + \xi_t + u_{ijt}, \]

and managers,

\[ \ln r_{ijt,\text{max}} - \ln r_{ijt,\text{min}} = \beta_1 s + \beta_2 s^2 + \beta_3 \tilde{q}_{L,ijt} + \psi_j + \xi_t + u_{ijt}, \]

where \( w_{\text{max}} \) (\( w_{\text{min}} \)) denotes the firm’s maximum (minimum) wage paid to a skilled worker and \( r_{\text{max}} \) (\( r_{\text{min}} \)) its maximum (minimum) manager salary. Note the resemblance to the left-hand side of (IV.2) and (IV.1), respectively. Since the previous results show that the average ability of the firm’s work force is affected by trade, we include the firm’s export share into both specifications. A quadratic term of the share of exports takes recent findings that are suggestive of a hump-shaped relationship between wage inequality and trade openness by Hesse (2013a) and Helpman et al. (2013) into account. Results are reported in Table IV.

As predicted by the GHK model, the specification without firm specific controls (FE 1) states that the average wage dispersion of skilled workers significantly increases with the average education of the managerial staff. However, when including the previously used set of firm specific controls, the coefficient turns negative, implying that FE 1 overestimates the effect to a large extent. To get an idea of the
magnitude of the coefficient, consider an absolute increase of a firm’s managerial ability by 0.1, i.e., one of ten managers were to get a degree of the next rank. According to FE 2, this increase would go along with 0.16% decrease in wage dispersion.

Contrary to the above results, we find a positive relationship between the managers’ salary dispersion and the average education of the firm’s skilled workers that is robust to our set of firm specific controls. In this way, an increase in the skilled workers’ average education of 0.1 would according to FE 4 correspond to an increase of the managers’ salary dispersion by 0.52%.

Note that we obtain similar results when using the difference between the 80th and 20th income percentile as dependent variable in the above estimating equation.

In the end, our results are in line with the example given in section 2. Thus, trade liberalization leads to a moderate and proportionally similar increase of both worker and managerial ability. Although trade tends to benefit a firm’s overall factor ability level, in the case of a relatively manager abundant country — a legitimate assumption for a country like Germany — a worker’s match is prone to deteriorate, while a manager’s match generally improves. As predicted by the GHK model in this case, the empirical evidence suggests a decline in wage dispersion and an increase in salary dispersion.

As a concluding remark, note that the coefficients of both the linear and the quadratic export share are in accordance with the established inverted U-shaped relationship between wage inequality and trade liberalization.

5. Conclusion

By allowing for heterogeneous managers and workers in a simple neoclassical trade model of two countries, two sectors, and two factors, GHK were able to show that trade liberalization can affect the sorting and matching pattern of workers and managers and in the presence of factor complementarities their relative wages and salaries, respectively. In the light of different possible blends of these complementarity forces with Stolper-Samuelson and Ricardo-Viner forces, all depending on the initial assumptions of factor endowments, factor intensities, factor ability distributions, and the factor sorting and matching pattern, it is without specific knowledge of the industries’ idiosyncrasies not possible to give a general prediction of the impact of trade on factor ability and on relative factor return.

Against this backdrop, we use the LIAB to establish the empirical relationship between a firm’s exposure to trade and the average ability of its work force as well
as the ensuing changes in income dispersion.

Our empirical results are in line with the theoretical predictions of the impact of trade on a country that is relatively abundant in managers and is subject to positive assortative matching across industries. Thus, the opening to trade significantly increases the average education of the firm’s managers as well as its workers. Furthermore, our results suggest that an increase in managerial ability goes along with a decrease in skilled workers’ wage dispersion, while the managers’ salary dispersion appears to be positively affected by the average ability of the skilled work force.

In the aggregate, the empirical results underpin the Grossman et al. (2013) model and hence the importance of the effects of the sorting and matching pattern when trying to predict the impact of trade on skill-group income dispersion.
Appendix
Appendix to
Inequality in a Global Economy
— Evidence from Germany

The aim of this Appendix is to provide a basic understanding of the Helpman et al. (2010a) framework, henceforth HIR, and its most important derivations. The ensuing presentation naturally relies strongly on the original paper as well as its Technical Appendix (Helpman et al. 2010b).

Helpman et al. (2010a) Framework

In the HIR model, the real consumption index for the sector is given by

$$Q = \left[ \int_{j \in J} q(j)^\beta \, dj \right]^{\frac{1}{\beta}},$$

where $q(j)$ is consumption and hence also output of variety $j$, while $J$ represents the set of available varieties in the sector. These varieties are further assumed to be substitutes, so that $0 < \beta < 1$. The corresponding aggregated price index, i.e., an index of the true cost of living, is then denoted by

$$P = \left[ \int_{j \in J} p(j)^{\bar{\pi} \beta} \, dj \right]^{-(1-\beta)},$$

with $p(j)$ being the price of variety $j$. Accordingly, a firm that produces a variety $j$ and is confined to the domestic market, will bring in a revenue of

$$r(j) = p(j)q(j).$$

The production function is assumed to be represented by simple Cobb-Douglas function. A firm’s output for a given variety, $y = q(j)$, is given by

$$y = \theta h^\gamma \bar{a},$$

(A.II.1)
where $\theta$ is the productivity of the firm, $h$ the measure of workers hired with $0 < \gamma < 1$, and $\bar{a}$ the average ability of the firm’s workforce. Worker ability is assumed to be independently distributed and to be drawn from a Pareto distribution, $G_a(a) = 1 - (a_{\min}/a)^k$ for $a \geq a_{\min} > 0$ and $k > 1$. When hiring, the model assumes that a firm is willing to pay search costs of $b$ per worker. Afterwards, the firm has to pay screening costs of $ca_\delta/\delta$, where $c > 0$ and $\delta > 0$, in order to identify those workers of its total measure of matched workers $n$ with an ability above $a_c$. As can be seen, the higher the targeted ability threshold $a_c$, the higher the firm’s screening costs.

As in the Melitz (2003) model, firms first have to pay sunk costs $f_e$ in order to enter the sector. Then they are assumed to draw their productivity $\theta$ from a Pareto distribution $G_\theta(\theta) = 1 - (\theta_{\min}/\theta)^z$ for $\theta \geq \theta_{\min} > 0$. Afterwards, only the most productive firms with a productivity exceeding the export cutoff level, i.e., $\theta > \theta_x$, enter the export market, whereas the rest is confined to the domestic market, provided their productivity is larger than the domestic cutoff level, i.e., $\theta > \theta_d$, or has to exit.

Firms that are willing to pay screening costs face a trade-off. On the one hand, screening reduces their output for they employ fewer workers than they could (‘underhiring’), but on the other hand, screening increases their average productivity level $\bar{a}$ and thus their output. So for the firm to only hire workers above a certain productivity level, it must be the case that the increase in output caused by the raise of the productivity level is larger than the decrease caused by the underhiring. Since the ability of the workers is Pareto distributed, a firm with a screening threshold $a_c$ hires $h = n(a_{\min}/a_c)^k$. Accordingly, the average ability of the workforce is $\bar{a} = ka_c/(k-1)$. Inserting these results into (A.II.1) yields

$$y = \theta h^\gamma \bar{a} = \theta n^\gamma \left( \frac{a_{\min}}{a_c} \right)^{k\gamma} = \frac{k}{k-1} \frac{a_c^{\gamma k} \theta n^\gamma a_c^{1-\gamma k}}{a_{\min}^k}.$$  \hfill (A.II.2)

From (A.II.2) one can see that if $k$ is sufficiently low, so that $0 < \gamma k < 1$, the increase in output due to a higher productivity level $\bar{a}$ is stronger than the decrease due to the underhiring. The further development of the framework confines to this requirement.

Since exporting firms will always serve the domestic market as well, the firm’s total revenue consists of domestic and foreign revenue, i.e., $r(\theta) = r_d(\theta) + r_x(\theta)$.

As the firm will equate its marginal revenue in the domestic and the foreign market, where $y_d(\theta)$ is the output allocated to the domestic market and $y_x(\theta)/\tau$ the output allocated to the foreign market, with $y(\theta) = y_d(\theta) + y_x(\theta)$, revenue can, according to equation (5) and (7) from (Dixit & Stiglitz 1977, 298-299), be written as

$$r(\theta) = r_d(\theta) + r_x(\theta) = p y_d(\theta) + p \frac{y_x(\theta)}{\tau} = Ay_d(\theta)^\beta + A^* \left( \frac{y_x(\theta)}{\tau} \right)^\beta.$$
Note that $A$ and $A^*$ are defined according to the Dixit & Stiglitz (1977) notation as $I_s(q)^{1-\rho}q^\rho$ with $\rho \equiv \beta$ and $q \equiv y$.

Since firms allocate their output between the domestic and the foreign market so that marginal revenues are equal, i.e.,

$$\frac{\partial r_d(\theta)}{\partial y_d(\theta)} = \frac{\partial r_x(\theta)}{\partial y_x(\theta)} \iff \tau^{-\beta} \left( \frac{A^*}{A} \right)^{1-\beta} = \left( \frac{y_x(\theta)}{y_d(\theta)} \right)^{1-\beta},$$

with $y(\theta) = y_d(\theta) + y_x(\theta)$ the firm’s total revenue can be written as

$$r(\theta) = \left( 1 + I_x(\theta) \tau^{-\beta} \left( \frac{A^*}{A} \right)^{1-\beta} \right) A y(\theta)^{1-\beta} = \Upsilon(\theta)^{1-\beta} A y(\theta)^{1-\beta}, \quad (A.II.3)$$

where $A$ is the sector’s demand shifter. $\Upsilon(\theta)$ reflects the firm’s market access which is defined as

$$\Upsilon(\theta) = 1 + I_x(\theta) \tau^{\frac{-\beta}{1-\beta}} \left( \frac{A^*}{A} \right)^{\frac{1}{1-\beta}},$$

where $I_x(\theta)$ is an indicator variable that is 0 if the firm serves only the domestic market and 1 if otherwise. $\tau$ are standard iceberg trading costs as modeled in Samuelson (1954).

Since ex ante the firm does not know the exact ability of each worker, workers are treated all equal, as if they have an ability of $\bar{a}$. According to (A.II.1) and (A.II.3), the expected total revenue of a firm can therefore be written as

$$r(\theta) = \Upsilon(\theta)^{1-\beta} A(\theta \bar{a})^{\beta} \gamma. \quad (A.II.4)$$

Once a firm has observed its productivity and has made its decision on sampling, screening, production, and exporting, it engages with its workers in a Stole & Zwiebel (1996) bargaining game over the division of its revenue. The bargained wage rate, $w(\theta, h)$, has thereby to satisfy the first-order differential equation

$$w(\theta, h) = \frac{\partial (r(\theta, h) - w(\theta, h)h)}{\partial h}, \quad (A.II.5)$$

which equates the firm’s marginal surplus from employment to the worker’s surplus from employment.

**Proposition (HIR):** The solution to the above first-order differential equation yields

$$w(\theta, h) = \frac{\beta \gamma}{1 + \beta \gamma} \frac{r(\theta, h)}{h},$$

i.e., each worker receives $\beta \gamma/(1 + \beta \gamma)$ of the firm’s average revenue, while the firm receives the remaining share, $1/(1 + \beta \gamma)$, of its total revenue.
Proof.

By inserting the above solution as well as its derivative,

$$\frac{\partial w(\theta, h)}{\partial h} = \frac{\beta \gamma}{1 + \beta \gamma} \frac{\beta \gamma r(\theta, h) - r(\theta, h)}{h^2},$$

into (A.II.5), while revenue is given through (A.II.4), we obtain

$$w(\theta, h) = \frac{\partial r(\theta, h)}{\partial h} - w(\theta, h)h$$

$$\Leftrightarrow \frac{\beta \gamma}{1 + \beta \gamma} \frac{r(\theta, h)}{h} = \frac{\beta \gamma r(\theta, h)}{1 + \beta \gamma} - \frac{\beta \gamma}{1 + \beta \gamma} \frac{r(\theta, h)}{h}$$

$$\Leftrightarrow \frac{\beta \gamma}{1 + \beta \gamma} \frac{r(\theta, h)}{h} = \frac{\beta \gamma}{1 + \beta \gamma} \frac{r(\theta, h)}{h} (1 + \beta \gamma - \beta \gamma + 1 - 1).$$

$$\square$$

Given the firm’s share of total revenue, the firm’s profit maximization problem can be written as

$$\pi(\theta) \equiv \max_{n \geq 0, a_c \geq a_{c\min}} \left\{ \frac{1}{1 + \beta \gamma} \left[ 1 + I_x r^{\frac{\gamma}{1 - \gamma}} \left( \frac{A*}{A} \right)^{\frac{1}{1 - \gamma}} \right]^{1 - \beta} \right.$$ 

$$\times A \left( \frac{k}{k - 1} a_c^{k} \theta n a_c^{1 - \gamma k} \right)^{\beta} - bn - \frac{c}{\delta} a_c^{\delta} - f_d - I_x(\theta) f_x \}.$$ 

For the measure of workers sampled, $n$, and the ability threshold, $a_c$, we derive the first-order conditions

$$\frac{\beta \gamma}{1 + \beta \gamma} r(\theta) = bn(\theta),$$

$$\frac{\beta(1 - \gamma k)}{1 + \beta \gamma} r(\theta) = ca.c(\theta)^{\delta}.$$ 

As can be seen, firms with a higher revenue will not only sample more workers, but will also set a higher ability threshold. We can use these results in order to define the firm’s average wage as a function of its ability threshold, namely

$$w(\theta) = \frac{\beta \gamma}{1 + \beta \gamma} \frac{r(\theta)}{h(\theta)} = b \left[ \frac{a_c(\theta)}{a_{c\min}} \right]^{k}.$$ (A.II.6)

The relation we get from this last equation is in accordance with our intuition that firms with a higher revenue will employ workers with a higher ability level, who will correspondingly be paid better.
Using the earlier definition of $r(\theta)$ in (A.II.4), the production function, and the first-order conditions, we are now able to express revenue as a function of productivity ($\theta$), the demand shifter ($A$), the search cost ($b$), and parameters:

$$r(\theta) = \Upsilon(\theta)^{1-\beta} A^\beta = \Upsilon(\theta)^{1-\beta} A \left( \frac{k}{k-1} a_{\min}^k \theta \eta_{\max} a_c^{1-k} \right)^\beta$$

$$⇔ r(\theta) = \Upsilon(\theta)^{1-\beta} A \left( \frac{k}{k-1} a_{\min}^k \theta \left( \frac{\beta \gamma}{(1+\beta \gamma)} b \right) r(\theta) \right)^\gamma \left( \frac{\beta(1-\gamma \kappa)}{c(1+\beta \gamma)} r(\theta)^{\frac{1-k}{\beta}} \right)^\beta$$

$$⇔ r(\theta)^{1-\gamma \beta - \frac{\beta(1-\gamma \kappa)}{\beta}} = \Upsilon(\theta)^{1-\beta} A \left( \frac{k}{k-1} a_{\min}^k \theta \left( \frac{\beta \gamma}{(1+\beta \gamma)} b \right)^\gamma \left( \frac{\beta(1-\gamma \kappa)}{c(1+\beta \gamma)} \right)^{\frac{1-k}{\beta}} \right)^\beta$$

$$⇔ r(\theta) = \Upsilon(\theta)^{1-\beta} A r \left( \frac{k}{k-1} a_{\min}^k \theta \left( \frac{\beta \gamma}{(1+\beta \gamma)} b \right)^\gamma \left( \frac{\beta(1-\gamma \kappa)}{c(1+\beta \gamma)} \right)^{\frac{1-k}{\beta}} \right)^\beta$$

(A.II.7)

where $\Gamma = 1 - \gamma \beta - \frac{\beta(1-\gamma \kappa)}{\beta}$. In a next step, we compute the firm’s profits by making once more use of the first-order conditions

$$\pi(\theta) = \frac{1}{1+\beta \gamma} r(\theta) - b \eta(\theta) - \frac{c}{\delta} a_c(\theta)^\delta - f_d - I_x(\theta) f_x$$

$$= \frac{1}{1+\beta \gamma} r(\theta) - \frac{\beta \gamma}{1-\beta \gamma} r(\theta) - \frac{\beta(1-\gamma \kappa)}{(1+\beta \gamma) \delta} r(\theta) - f_d - I_x(\theta) f_x$$

$$= \frac{\Gamma}{1+\beta \gamma} r(\theta) - f_d - I_x(\theta) f_x. \quad (A.II.8)$$

Furthermore, we know that the firm with the lowest productivity $\theta_d$ brings in exactly zero profits (and is not exporting). Thence it follows that

$$\frac{\Gamma}{1+\beta \gamma} r(\theta_d) = f_d \quad ⇒ \quad r(\theta_d) = \frac{f_d}{\Gamma}.$$  \quad (A.II.9)

In the following, we use the expression for $r(\theta)$ from (A.II.7) and determine the relative revenue of a firm in comparison to the lowest productivity firm:

$$\frac{r(\theta)}{r_d} = \Upsilon(\theta)^{1-\beta} \left( \frac{\theta}{\theta_d} \right)^\beta ⇔ r(\theta) = \Upsilon(\theta)^{1-\beta} r_d \left( \frac{\theta}{\theta_d} \right)^\beta.$$

By the same token we are able to compute $a_c(\theta)$. We employ the first-order conditions and get

$$\frac{a_c(\theta)^\delta}{a_c(\theta_d)^\delta} = \Upsilon(\theta)^{-\frac{\beta}{\beta}} \left( \frac{\theta}{\theta_d} \right)^\beta \quad ⇒ \quad a_c(\theta) = \Upsilon(\theta)^{-\frac{\beta}{\beta}} a_c(\theta_d) \left( \frac{\theta}{\theta_d} \right)^\beta.$$
Using (A.II.9) with the first-order conditions, we can compute

\[ a_c(\theta_d) = \left( \frac{\beta(1 - \gamma k) 1 + \beta \gamma f_d}{(1 + \beta \gamma c \Gamma f_d)} \right)^{\frac{k}{c}} = \left( \frac{\beta(1 - \gamma k)}{c \Gamma a_{\min}} f_d \right)^{\frac{k}{c}}. \]

With the wage condition from (A.II.6), the lowest wage paid by a domestic firm is

\[ w(\theta_d) = b \left( \frac{a_c(\theta_d)}{a_{\min}} \right)^k = \left( \frac{\beta(1 - \gamma k)}{c \Gamma a_{\min}} f_d \right)^{\frac{k}{c}}. \]

This yields a wage relation that is solely dependent on \( \theta, \Psi(\theta), \theta_d, b, \) and parameters:

\[ \frac{w(\theta)}{w_d} = \left( \frac{a_c(\theta)}{a_c(\theta_d)} \right)^k = \Psi(\theta)^{k(1 - \beta)} \left( \frac{\theta}{\theta_d} \right)^{\frac{k}{c}} \Rightarrow w(\theta) = \Psi(\theta)^{k(1 - \beta)} w_d \left( \frac{\theta}{\theta_d} \right)^{\frac{k}{c}}. \] (A.II.10)

As can be seen from this last equation, wages increase with firm productivity and are always higher for exporting firms than for non-exporting firms.

We are now able to compute the wage distribution in the open economy. For this purpose, we first derive the share of workers being employed in the non-exporting sector

\[ s_d = 1 - \frac{\int_{\theta_d}^{\infty} h(\theta)G_d(\theta) d\theta}{\int_{\theta_d}^{\infty} h(\theta)G(\theta) d\theta} = 1 - \frac{\int_{\theta_d}^{\infty} h(\theta)g(\theta) d\theta}{\int_{\theta_d}^{\infty} h(\theta)g(\theta) d\theta + \int h(\theta)g(\theta) d\theta} \]

\[ = 1 - \frac{\int_{\theta_d}^{\Psi(\theta)} h_d\theta_d \frac{z}{c(1 - \beta)} \theta_{\min}^{-z} - z - 1 + \frac{1}{\Gamma} + \frac{z}{\beta} \Psi(\theta)^{k(1 - \beta)} \Psi(\theta)^{k(1 - \beta)} d\theta}{h_d\theta_d \frac{z}{c(1 - \beta)} \theta_{\min}^{-z} - z - 1 + \frac{1}{\Gamma} + \frac{z}{\beta} \Psi(\theta)^{k(1 - \beta)} \Psi(\theta)^{k(1 - \beta)} d\theta} \]

\[ = 1 - \frac{\Psi(\theta)^{(1 - \beta)(1 - k/d)} \left[ 0 - \theta_{\min}^{z - 1 + \frac{1}{\Gamma} + \frac{z}{\beta}} \right]}{h_d\theta_d \frac{z}{c(1 - \beta)} \theta_{\min}^{-z} - z - 1 + \frac{1}{\Gamma} + \frac{z}{\beta} \Psi(\theta)^{k(1 - \beta)} \Psi(\theta)^{k(1 - \beta)}} \]

\[ = 1 - \frac{\Psi(\theta)^{(1 - \beta)(1 - k/d)} \left[ 0 - \theta_{\min}^{z - 1 + \frac{1}{\Gamma} + \frac{z}{\beta}} \right]}{h_d\theta_d \frac{z}{c(1 - \beta)} \theta_{\min}^{-z} - z - 1 + \frac{1}{\Gamma} + \frac{z}{\beta} \Psi(\theta)^{k(1 - \beta)} \Psi(\theta)^{k(1 - \beta)}} \]

\[ = \frac{1 - \rho z - \frac{1}{\Gamma} \Psi(\theta)^{(1 - \beta)(1 - k/d)} \left[ 1 - \Psi(\theta)^{(1 - \beta)(1 - k/d)} \right]}{1 + \rho z - \frac{1}{\Gamma} \Psi(\theta)^{(1 - \beta)(1 - k/d)} \left[ 1 - \Psi(\theta)^{(1 - \beta)(1 - k/d)} \right]} - 1 = \frac{1 - \rho z - \frac{1}{\Gamma} \Psi(\theta)^{(1 - \beta)(1 - k/d)} \left[ 1 - \Psi(\theta)^{(1 - \beta)(1 - k/d)} \right]}{1 + \rho z - \frac{1}{\Gamma} \Psi(\theta)^{(1 - \beta)(1 - k/d)} \left[ 1 - \Psi(\theta)^{(1 - \beta)(1 - k/d)} \right]} - 1. \] (A.II.11)

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where \( \rho \) is defined as the ratio of the productivity cutoffs, i.e., \( \rho \equiv \theta_d / \theta_x \). The share of exporting firms is then given by \( [1 - G(\theta_x)]/[1 - G(\theta_d)] = \rho^z \). Accordingly, the share of workers employed by exporting firms is given by \( s \equiv 1 - s_d \).

If we solve the wage condition (A.II.10) for \( \theta_{w,d}(w) \), we can write the wage distribution across workers employed by domestic firms as follows

\[
G_{w,d}(w) = \frac{\theta_{w,d}(w)}{\int_{\theta_d}^{\theta_x} h(\theta) dG(\theta)} = \frac{\theta_{w,d}(w)}{\int_{\theta_d}^{\theta_x} h_d(1 - \beta(1-k/\delta)) \theta^{\mu} z(1 + \beta(1-k/\delta)) d\theta}
\]

\[
= \frac{\theta_{w,d}(w) - \theta_d}{\theta_x - \theta_d} - \frac{\theta_d - \theta_{w,d}(w)}{\theta_x - \theta_d} = \left( \frac{\theta_d}{\theta_{w,d}(w)} \right)^{z + \beta(1-k/\delta)} - 1, \quad \left( \frac{\theta_d}{\theta_x} \right)^{z + \beta(1-k/\delta)} - 1,
\]

with \( \theta_{w,d}(w) = \theta_d \left( \frac{w}{w_d} \right)^{\beta \Gamma / \beta k} \) and \( 1 + \frac{1}{\mu} = \frac{\beta \Gamma}{\beta k} - \frac{\delta - k}{k} \) we get

\[
G_{w,d}(w) = \frac{1 - (w_d/w)^{1+\frac{1}{\mu}}}{1 - \rho^z - \beta(1-k/\delta)}. \quad (A.II.12)
\]

By the same token, we compute the distribution of wages across workers employed by exporters

\[
G_{w,x}(w) = \frac{\theta_{w,x}(w)}{\int_{\theta_x}^{\theta_d} h(\theta) dG(\theta)} = \frac{\theta_{w,x}(w)}{\int_{\theta_x}^{\theta_d} \Gamma(\theta)^{1-\beta(1-k/\delta)} h_d(1 - \beta(1-k/\delta)) \theta^{\mu} z(1 + \beta(1-k/\delta)) d\theta}
\]

\[
= \frac{\theta_{w,x}(w) - \theta_d}{\theta_x - \theta_d} - \frac{\theta_d - \theta_{w,x}(w)}{\theta_x - \theta_d} = 1 - \left( \frac{\theta_{w,x}(w)}{\theta_x} \right)^{-z + \beta(1-k/\delta)},
\]

with \( \theta_{w,x}(w) = \theta_d \left( \frac{w}{w_d} \right)^{\beta \Gamma / \beta k} \) and \( 1 + \frac{1}{\mu} = \frac{\beta \Gamma}{\beta k} - \frac{\delta - k}{k} \) we get

\[
G_{w,x}(w) = 1 - \left( \frac{w_d}{w} \right) \Gamma(\theta)^{1-\beta(1-k/\delta)} \rho^z - \beta(1-k/\delta) \right)^{1+\frac{1}{\mu}} \right).
\]
Using (A.II.11), (A.II.12), and (A.II.13), the wage distribution of the open economy can be written as

\[ G_w(w) = \begin{cases} s_d G_{w,d}(w), & \text{for } w_d \leq w \leq w_d/\rho^{\beta k/(\delta \Gamma)}, \\ s_d, & \text{for } w_d/\rho^{\beta k/(\delta \Gamma)} \leq w \leq w_d Y_{x}^{k(1-\beta)/(\delta \Gamma)/\rho^{\beta k/(\delta \Gamma)}}, \\ s_d + (1-s_d) G_{w,x}(w), & \text{for } w \geq w_d Y_{x}^{k(1-\beta)/(\delta \Gamma)/\rho^{\beta k/(\delta \Gamma)}}, \end{cases} \]

(A.II.14)

whereas the autarkic economy wage distribution would be

\[ G_{w}^{a}(w) = 1 - \left( \frac{w_d}{w} \right)^{1+\frac{1}{\mu}}, \text{ for } w \geq w_d. \]

We are now able to compute a measure of wage inequality for the open and the autarkic economy. A widely used measure of inequality is for example the Theil index. One of the major advantages of the Theil index in comparison to other, more popular measures such as the Gini Coefficient is its decomposability. This means that even though (A.II.14) is a piecewise-defined function, the Theil index enables us to compare the wage inequality in the autarkic and in the open economy. The indices are defined as follows

\[ T_{w}^{a} = \int_{w_d}^{\infty} \frac{w}{w^a} \ln \left( \frac{w}{w^a} \right) dG^{a}_{w}(w), \quad T_{w} = s_d T_{w}^{d} + (1-s_d) T_{w}^{x} + s_d \ln \frac{\bar{w}_d}{w} + (1-s_d) \ln \frac{\bar{w}_x}{w}. \]

It can be shown that wage inequality in the open economy is higher than in the autarkic economy, i.e., \( T_{w}^{a} < T_{w} \).\(^1\) Note since the shape parameter, \( 1 + 1/\mu \), is the same for the wage distribution in the autarkic and the perfectly open economy, both economies have the same wage inequality, i.e., \( T_{w}^{a} = T_{w}^{x} \), where \( T_{w}^{x} \) denotes the Theil index of the perfectly open economy with \( \rho = 1 \). This ultimately leads to the key theoretical result of the HIR model, see Section 2.

\(^1\)For a proof see Helpman et al. (2010a)
Appendix to

The Impact of a Firm’s Share of Exports on Revenue, Wages, and Measure of Workers Hired — Theory and Evidence

This Appendix provides the most important derivations necessary to understand the framework of chapter III as well as the key theoretical propositions derived from it. The ensuing presentation borrows from Melitz (2003) and Helpman et al. (2010a).

Mathematical Derivations

Domestic demand $y_d$ and revenue $r_d$

A representative consumer’s preferences are given by a C.E.S. utility function over a continuum of varieties indexed by $\omega$:

$$U = \left[ \int_{\omega \in \Omega} y(\omega)^{\rho} d\omega \right]^{\frac{1}{\rho}},$$

where $\Omega$ represents the set of available varieties within the sector. These varieties are substitutes, implying $0 < \rho < 1$ and an elasticity of substitution between any two varieties of

$$\sigma = \frac{1}{1 - \rho} > 1 \iff \rho = 1 - \frac{1}{\sigma} = \frac{\sigma - 1}{\sigma}.$$

The consumer’s constrained maximization problem may be solved by the Lagrangian

$$\mathcal{L} = U^{\rho} - \lambda \left( \int_{\omega \in \Omega} p(\omega)y(\omega)d\omega - I \right),$$
where $U^ρ$ is a strictly increasing transformation of $U$ and $I$ the consumer’s income. Which yields the following first-order condition
\[
\frac{\partial L}{\partial y(\omega)} = \rho y(\omega)^{\rho - 1} - \lambda p(\omega) = 0.
\]
By dividing the first-order condition of one variety $\omega_1$ by the first-order condition of another variety $\omega_2$, we obtain the relative demand
\[
\frac{y(\omega_1)}{y(\omega_2)} = \left(\frac{p(\omega_1)}{p(\omega_2)}\right)^{\frac{1}{\rho - 1}}.
\]
Multiplying both sides with $y(\omega_2)$ yields
\[
y(\omega_1) = y(\omega_2) \left(\frac{p(\omega_1)}{p(\omega_2)}\right)^{-\sigma}.
\]
When multiplying both sides with $p(\omega_1)$ and taking the integral with respect to $\omega_1$, we get
\[
\int_{\omega \in \Omega} p(\omega_1)y(\omega_1)d\omega_1 = \int_{\omega \in \Omega} y(\omega_2)p(\omega_1)^{1 - \sigma}p(\omega_2)^\sigma d\omega_1.
\]
On the left-hand side we now have the consumer’s total expenditure on all varieties $R$, which is equal to his income $I$, i.e.,
\[
R = I = y(\omega_2)p(\omega_2)^\sigma \int_{\omega \in \Omega} p(\omega_1)^{1 - \sigma} d\omega_1.
\]
Solving for $y(\omega_2)$ yields the Marshallian demand for $\omega_2$
\[
y(\omega_2) = \frac{Ip(\omega_2)^{-\sigma}}{\int_{\omega \in \Omega} p(\omega_1)^{1 - \sigma} d\omega_1}.
\]
By defining an index of the overall price level, denoted by
\[
P = \left[\int_{\omega \in \Omega} p(\omega)^{1 - \sigma} d\omega\right]^{\frac{1}{1 - \sigma}},
\]
Marshallian demand simplifies to
\[
y(\omega) = p(\omega)^{-\sigma} P^{\sigma - 1} I = \left(\frac{p(\omega)}{P}\right)^{-\sigma} \frac{I}{P}.
\]
With domestic output, denoted by $y_d(\omega)$, being equal to $y(\omega)$ for non-exporting firms, domestic firm revenue can then be written as
\[
r_d(\omega) = y_d(\omega) \cdot p(\omega) = I_d \left(\frac{p(\omega)}{P_d}\right)^{1 - \sigma},
\]
where $I_d$ and $P_d$ indicate domestic income and the domestic aggregate price, respectively. Note that with $p_d(\omega) = y_d(\omega) \frac{1}{\sigma} I_d^{\frac{1}{\sigma}} P_d^{\frac{1}{\sigma}}$ domestic revenue can also be written as in HIR, i.e.,

$$r_d(\omega) = y_d(\omega) \frac{1}{\sigma} I_d^{\frac{1}{\sigma}} P_d^{\frac{1}{\sigma}} = y_d(\omega)^{\rho} I_d^{1-\rho} P_d^{\rho} = y_d(\omega)^{\rho} A_d,$$

where $A_d$ is called the domestic demand shifter, with $A_d = I_d^{1-\rho} P_d^{\rho}$.

**Link between $A_d$ and $\tilde{\varphi}_{t,d}$**

With the aggregate productivity level defined as a function of each countries domestic cutoff productivity level, $\varphi^*_{d,c}$, i.e.,

$$\tilde{\varphi}_c(\varphi^*_{d,c}) = \left( \frac{1}{1-G_c(\varphi^*_{d,c})} \int_{\varphi^*_{d,c}}^{\infty} \varphi_c^{-1} g(\varphi_c) d\varphi_c \right)^{-\frac{1}{\sigma-1}}$$

for all $c = 1, \ldots, n + 1$ with $d \in c$,

we can link the domestic demand shifter $A_d$ to the total average productivity in the home country. In an analogous way to (Melitz 2003, 1710), the latter can be written as

$$\tilde{\varphi}_{t,d} = \left[ \frac{1}{M_{t,d}} \left( M_d \tilde{\varphi}_d^{\frac{1}{\sigma-1}} + \sum_{c \neq d} M_{x,c} (\tau_c^{\frac{1}{\sigma-1}} \tilde{\varphi}_c)^{\frac{1}{\sigma-1}} \right) \right]^{\frac{1}{\sigma-1}},$$

where $M_d$ denotes the equilibrium mass of all firms in the home country, $M_{x,c}$ the mass of all firms that export from country $c$ to the home country, and $M_{t,d} = M_d + \sum_{c \neq d} M_{x,c}$ the total mass of firms competing in the home country. By using equation (17) from (Melitz 2003, 1711),

$$I_d = M_{t,d} r_d(\tilde{\varphi}_{t,d}), \quad P_d = M_{t,d}^{\frac{1}{\sigma}} \frac{1}{\rho \tilde{\varphi}_{t,d}},$$

we obtain

$$A_d = I_d^{1-\rho} P_d^{\rho} = (M_{t,d} r_d(\tilde{\varphi}_{t,d}))^{1-\rho} \left( M_{t,d}^{\frac{1}{\sigma}} \frac{1}{\rho \tilde{\varphi}_{t,d}} \right)^{\rho} = r_d(\tilde{\varphi}_{t,d})^{1-\rho} \left( \frac{1}{\rho \tilde{\varphi}_{t,d}} \right)^{\rho}. \quad (A.III.1)$$

**$\Upsilon$ and a derivation of $y_d(\varphi) = y(\varphi) / \Upsilon$**

Using (III.4), we can write

$$y(\varphi) = y_d(\varphi) + y_{x,1}(\varphi) + \ldots + y_{x,c}(\varphi)$$
as
\[ y(\varphi) = y_d(\varphi) + \tau^\varphi_1 y_d(\varphi) \left( \frac{A_{x,1}}{A_d} \right)^{\varphi_1} + \ldots + \tau^\varphi_{c'} y_d(\varphi) \left( \frac{A_{x,c'}}{A_d} \right)^{\varphi_{c'}} \]
and
\[ = y_d(\varphi) \left( 1 + \tau^\varphi_1 \left( \frac{A_{x,1}}{A_d} \right)^{\varphi_1} + \ldots + \tau^\varphi_{c'} \left( \frac{A_{x,c'}}{A_d} \right)^{\varphi_{c'}} \right). \]

By defining \( \Upsilon = 1 + \tau^\varphi_1 \left( \frac{A_{x,1}}{A_d} \right)^{\varphi_1} + \ldots + \tau^\varphi_{c'} \left( \frac{A_{x,c'}}{A_d} \right)^{\varphi_{c'}} \), we obtain
\[ y_d(\varphi) = y(\varphi)/\Upsilon. \]

### Total revenue \( r \)

A firm’s total revenue is given by
\[ r(\varphi) = y_d(\varphi)^\rho A_d + \tau^\rho_1 y_{x,1}(\varphi)^\rho A_{x,1} + \ldots + \tau^\rho_{c'} y_{x,c'}(\varphi)^\rho A_{x,c'}. \]

Using the first-order conditions (III.4), this can be written as
\[ r(\varphi) = y_d(\varphi)^\rho A_d + \tau^\rho_1 y_d(\varphi)^\rho A_{x,1} \left( \frac{A_{x,1}}{A_d} \right)^{\rho_1} + \ldots + \tau^\rho_{c'} y_d(\varphi)^\rho A_{x,c'} \left( \frac{A_{x,c'}}{A_d} \right)^{\rho_{c'}} \]
\[ = y_d(\varphi)^\rho A_d \left( 1 + \tau^\rho_1 \left( \frac{A_{x,1}}{A_d} \right)^{\rho_1} + \ldots + \tau^\rho_{c'} \left( \frac{A_{x,c'}}{A_d} \right)^{\rho_{c'}} \right) \]
\[ = y(\varphi)^\rho A_d \left( 1 + \sum_{c=1}^{c'} \tau^\rho_c \left( \frac{A_{x,c}}{A_d} \right)^{\rho_c} \right)^{1-\rho}. \]

### Revenue as a function of a firm’s productivity

Using the earlier definition of \( r(\varphi) \) in (III.3), the production function, and the first-order conditions (III.7) and (III.8), we are now able to express revenue as
\[ r(\varphi) = \Upsilon(\varphi)^{1-\rho} A_d^\rho \left( \frac{\zeta}{\zeta - 1} \delta_{\min}^\varphi \left( \frac{\rho \gamma}{1 + \rho \gamma} \right)^\gamma \left( \rho (1 - \gamma \zeta) \right)^{\frac{1-\varphi}{\rho}} \right), \] (A.III.2)
where \( \Gamma = 1 - \rho \gamma - \rho(1 - \gamma \zeta)/\delta \). In a next step, we compute the firm’s profits by making once more use of the first-order conditions
\[ \pi(\varphi) = \Gamma \frac{r(\varphi)}{1 + \rho \gamma} - f_d - \sum_{c=1}^{c'} f_{x,c}. \]

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Furthermore, we know that the firm with the lowest productivity $\varphi_d$ makes exactly zero profits (and is not exporting). Thence it follows\footnote{Note that while $r_d(\varphi)$ is the domestic revenue for a firm with productivity $\varphi$, $r_d$ is the revenue of a non-exporting firm with zero profits.} \[ \frac{\Gamma}{1 + \rho \gamma} r(\varphi_d) = f_d \quad \Rightarrow \quad r(\varphi_d) \equiv r_d = \frac{1 + \rho \gamma}{\Gamma} f_d. \] (A.III.3)

In the following, we use the expression for $r(\varphi)$ from (A.III.2) and determine the relative revenue of a firm in comparison to the firm with the lowest productivity $\varphi_d$: \[ \frac{r(\varphi)}{r_d} = \Upsilon \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}} \Rightarrow r(\varphi) = r_d \cdot \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}} \cdot \Upsilon \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}}. \]

**Wage as a function of a firm’s productivity**

By the same token, we are able to compute $a_\varepsilon(\varphi)$. We again employ the first-order conditions (III.7) and (III.8) and get \[ \frac{a_\varepsilon(\varphi)}{a_\varepsilon(\varphi_d)} = \Upsilon \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}} \Rightarrow a_\varepsilon(\varphi) = a_\varepsilon(\varphi_d) \Upsilon \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}}. \] (A.III.4)

Using (A.III.3) with the first-order conditions and (III.8), we can compute \[ a_\varepsilon(\varphi_d) = \left( \frac{\rho(1 - \gamma k)}{(1 + \rho \gamma) \varepsilon} \right)^{\frac{1}{2}} \left( \frac{1 + \rho \gamma}{\varepsilon \Gamma} f_d \right)^{\frac{1}{2}} = \left( \frac{\rho(1 - \gamma k)}{(1 + \rho \gamma) \varepsilon} \right)^{\frac{1}{2}} \left( \frac{1 + \rho \gamma}{\varepsilon \Gamma} f_d \right)^{\frac{1}{2}}. \]

With the wage condition from (III.9), the lowest wage paid by a domestic firm is then \[ w(\varphi_d) \equiv w_d = b \left( \frac{a_\varepsilon(\varphi_d)}{a_{\min}} \right) \zeta_d \left( \frac{\rho(1 - \gamma k)}{(1 + \rho \gamma) \varepsilon} \right)^{\frac{1}{2}} \left( \frac{1 + \rho \gamma}{\varepsilon \Gamma} f_d \right)^{\frac{1}{2}}. \]

This yields a wage relation that is solely dependent on $\varphi$, $\Upsilon(\varphi)$, $\varphi_d$, $b$, and parameters: \[ \frac{w(\varphi)}{w_d} = \left( \frac{a_\varepsilon(\varphi)}{a_\varepsilon(\varphi_d)} \right) \zeta_d \Upsilon \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}} \Rightarrow w(\varphi) = w_d \cdot \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}} \cdot \Upsilon \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\rho \gamma}{\Gamma}}. \]

As can be seen from this last equation, wages increase with firm productivity and are always higher for exporting firms than for non-exporting firms.

**Measure of workers hired as a function of a firm’s productivity**

By the same token, we can derive the lowest measure of workers hired \[ h(\varphi_d) \equiv h_d = m(\varphi_d) \left( \frac{a_{\min d}}{a_\varepsilon(\varphi_d)} \right) \zeta_d = \frac{\rho \gamma}{1 + \rho \gamma} r_d \left( \frac{a_{\min d}}{a_\varepsilon(\varphi_d)} \right) \zeta_d. \]
Using (A.III.4) and (III.6), the relation to \( h(\varphi) \) is then given by

\[
\frac{h(\varphi)}{h_d} = \frac{r(\varphi)}{r_d} \left( \frac{a_e(\varphi_d)}{a_e(\varphi)} \right)^{\zeta_d} = \Gamma \left( \frac{\varphi}{\varphi_d} \right)^{\frac{\zeta_d}{\rho}} \left( \frac{\varphi}{\varphi_d} \right)^{-\frac{\zeta_d}{\delta}} \\
= \Gamma \left( 1 - \rho \right) \left( 1 - \frac{\zeta_d}{\delta} \right) \left( \frac{\varphi}{\varphi_d} \right)^{\rho \left( 1 - \frac{\zeta_d}{\rho} \right)},
\]

which ultimately leads to

\[
h(\varphi) = h_d \cdot \left( \frac{\varphi}{\varphi_d} \right)^{\rho \left( 1 - \frac{\zeta_d}{\rho} \right)} \cdot \Gamma \left( 1 - \rho \right) \left( 1 - \frac{\zeta_d}{\delta} \right).
\]
Appendix to

The Impact of Complementarities between Workers and Managers on Income Inequality

The aim of this Appendix is to provide the most important derivations of the Grossman et al. (2013) framework that are necessary to understand the functions of relative salary and wage, (IV.1) and (IV.2), presented in chapter IV. The ensuing presentation strongly relies on the original paper.


Starting with the simple output function

\[ x_i = \psi_i(q_H, q_L)\ell^{\gamma_i}, \quad 0 < \gamma_i < 1, \]

where \( \ell \) is the number of workers of type \( q_L \) a manager is teamed with, we obtain the firm’s profit function

\[ \pi_i(q_H, q_L, \ell) = p_i\psi_i(q_H, q_L)\ell^{\gamma_i} - w(q_L)\ell - r(q_H), \]

where \( p_i \) is the price of good \( i \), \( w(q_L) \) is the wage of a worker with ability \( q_L \), and \( r(q_H) \) the salary of a manager with ability \( q_H \). We calculate the first-order conditions
and obtain

\[ \frac{\partial \pi_i(q_H, q_L, \ell)}{\partial \ell} = \gamma_i p_i \psi_i(q_H, q_L) C^{\gamma_i} - w(q_L) = 0 \]

\[ \Leftrightarrow \ell_i(q_H, q_L) = \left( \frac{\gamma_i p_i \psi_i(q_H, q_L)}{w(q_L)} \right)^{\frac{1}{\gamma_i}}. \]

Substituting the optimal amount of labor into the profit function yields

\[ \tilde{\pi}_i(q_H, q_L) = p_i \psi_i(q_H, q_L) \left( \frac{\gamma_i p_i \psi_i(q_H, q_L)}{w(q_L)} \right)^{\frac{\gamma_i}{\gamma_i}} - w(q_L) \left( \frac{\gamma_i p_i \psi_i(q_H, q_L)}{w(q_L)} \right)^{\frac{1}{\gamma_i}} - r(q_H), \]

\[ = p_i \psi_i(q_H, q_L) \left( \frac{\gamma_i p_i \psi_i(q_H, q_L)}{w(q_L)} \right)^{\frac{\gamma_i}{\gamma_i}} \left( 1 - w(q_L) \frac{\gamma_i}{w(q_L)} \right) - r(q_H). \]

With \( \tilde{\gamma}_i = \gamma_i^{\frac{\gamma_i}{\gamma_i}} (1 - \gamma_i) \) profit can then be written as

\[ \tilde{\pi}_i(q_H, q_L) = \tilde{\gamma}_i p_i^{\frac{1}{\gamma_i}} \psi_i(q_H, q_L)^{\frac{1}{\gamma_i}} w(q_L)^{-\frac{\gamma_i}{\gamma_i}} - r(q_H). \]

The firm’s profit maximization problem is then solved in two stages. Given a certain managerial ability \( q_H \), the firm chooses the most suitable matches \( q_L \), in order to obtain the following profit function

\[ \Pi_i(q_H) = \max_{q_L \in S_L} \tilde{\pi}(q_H, q_L), \text{ for } q_H \in S_H, \ i = 1, 2, \]

with \( S_L = [q_{L_{\min}}, q_{L_{\max}}] \) and \( S_H = [q_{H_{\min}}, q_{H_{\max}}] \). The solution to this profit function is then given by

\[ q_L^* = m(q_H) = \begin{cases} 
  m_1(q_H) & \text{for } q_H \in Q_{H_1} \\
  m_2(q_H) & \text{for } q_H \in Q_{H_2}
\end{cases}, \]

where \( Q_{H_i} \) denotes the set of managers that sorts to industry \( i \). The firm then chooses \( q_H \) to maximize its profits \( \Pi_i(q_H) \).

Using \( q_L^* = m(q_H) \) the first-order condition to the profit maximization problem

\[ \frac{\partial \tilde{\pi}_i(q_H, q_L)}{\partial q_L} = \tilde{\gamma}_i p_i^{\frac{1}{\gamma_i}} \cdot \frac{1}{1 - \gamma_i} \psi_i(q_H, q_L')^{\frac{\gamma_i}{\gamma_i}} \cdot \psi_i(q_H, q_L') \cdot w(q_L')^{\frac{\gamma_i}{\gamma_i}} \]

\[ + \tilde{\gamma}_i p_i^{\frac{1}{\gamma_i}} \psi_i(q_L^*)^{\frac{1}{\gamma_i}} \cdot \frac{-\gamma_i}{1 - \gamma_i} w(q_L^*)^{\frac{1}{\gamma_i}} \cdot w'(q_L^*) = 0, \]

with \( \frac{\partial \psi(q_H, q_L)}{\partial q_L} = \psi_i(q_H, q_L) \), can then be written as
\[
\psi_i[q_H, m(q_H)]^{\frac{1}{\gamma_i}} \cdot \psi_{iL}[q_H, m(q_H)] \cdot w(q_L)^{\frac{1}{1-\gamma_i}} = \psi_i[q_H, m(q_H)]^{\frac{1}{\gamma_i}} \cdot \gamma_i w[m(q_H)]^{\frac{1}{1-\gamma_i}} w'[m(q_H)] .
\]

Dividing both sides by \( w[m(q_H)]^{\frac{1}{1-\gamma_i}} \) and \( \psi_i[q_H, m(q_H)]^{\frac{1}{\gamma_i}} \) leads to
\[
\frac{\psi_{iL}[q_H, m(q_H)]}{\gamma_i \psi_i[q_H, m(q_H)]} = \frac{w'[m(q_H)]}{w[m(q_H)]} .
\]

Multiplying both sides by \( m(q_H) \), ultimately yields the elasticity of the wage
\[
\frac{m(q_H) \psi_{iL}[q_H, m(q_H)]}{\gamma_i \psi_i[q_H, m(q_H)]} = \varepsilon_w(m(q_H)) .
\]

By the same token, i.e., forming the derivative of \( \tilde{\pi}_i(q_H, q_L) \) with respect to \( q_H \), we obtain the elasticity of the salary
\[
\frac{q_H \psi_{iH}[q_H, m(q_H)]}{(1-\gamma_i) \psi_i[q_H, m(q_H)]} = \varepsilon_r(q_H) .
\]

Note that the elasticities of productivity depend on the combinations of workers and managers. In other words, an increase in the managerial ability does not only affect the managerial output but also the workers’ output.

In order to have a look at the sorting at boundary points, consider a set of managers \( Q_{Hi}(q_H) \) and a set of workers \( Q_{Li}(q_L) \) that sort to sector \( i \) whose ability does not exceed \( q_H \) and \( q_L \), respectively. From the first-order conditions of the profit function and the above elasticities
\[
\frac{p_i \psi_{iL}(q_H, q_L) \ell^\gamma}{w(q_L) \ell} = \frac{w'(q_L)}{w(q_L)} = \frac{\psi_{iL}[q_H, m(q_H)]}{\gamma_i \psi_i[q_H, m(q_H)]} ,
\]
\[
\frac{p_i \psi_{iH}(q_H, q_L) \ell^\gamma}{r(q_H)} = \frac{r'(q_H)}{r(q_H)} = \frac{\psi_{iH}[q_H, m(q_H)]}{(1-\gamma_i) \psi_i[q_H, m(q_H)]} ,
\]
we obtain the demand for workers per manager
\[
\frac{r(q_H)}{(1-\gamma_i) \psi_i[q_H, m(q_H)]} = \frac{w(q_L) \ell}{\gamma_i \psi_i[q_H, m(q_H)]} ,
\]
\[
\Leftrightarrow \ell(q_H, q_L) = \frac{\gamma_i r(q_H)}{(1-\gamma_i) w(q_L)} .
\]
Now the firm’s demand of managers with an ability that does not exceed $q_H$ is equal to the demand of workers that are suitable to be matched with these workers, i.e.,

$$H \int_{q \in Q_H, (q_{Hi}^{min})} \frac{\gamma_i r(q)}{(1 - \gamma_i) w[m(q)]} \phi_H(q) dq + H \int_{q_{Hi}^{min}}^{q_{Hi}^{max}} \frac{\gamma_i r(q)}{(1 - \gamma_i) w[m(q)]} \phi_H(q) dq$$

$$= \bar{L} \int_{q \in Q_L, [m(q_{Li}^{min})]} \phi_L(q) dq + \bar{L} \int_{m(q_{Hi}^{min})}^{m(q_{Hi}^{max})} \phi_L(q) dq \quad \text{for all } q_H \in (q_{Hi}^{min}, q_{Hi}^{max}), \ i = 1, 2.$$

By differentiating both sides with respect to $q_H$, we obtain

$$H \frac{\gamma_i r(q_H)}{(1 - \gamma_i) w[m(q_H)]} \phi_H(q_H) = L \phi_L[m(q_H)] m'(q_H).$$

This last equation together with the elasticities, the zero-profit condition, and the boundary conditions characterize the equilibrium:

$$H \frac{\gamma_i r(q_H)}{(1 - \gamma_i) w[m(q_H)]} \phi_H(q_H) = L \phi_L[m(q_H)] m'(q_H)$$

$$= \frac{\bar{L} m(q_H)}{w[m(q_H)]} \left( \frac{\psi_{Li}[q_H, m(q_H)]}{\gamma_i \psi_i[q_H, m(q_H)]} \right)$$

$$r(q_H) = \bar{L} \int_{q_{Lo}}^{q_{Hi}} \left( \frac{\psi_{Li}[\mu(x), x]}{\gamma_i \psi_i[\mu(x), x]} \right) dx,$$  \hspace{1cm} \text{(A.IV.1)}

$$m(q_H) = q_L \quad \Leftrightarrow \quad q_H = \mu(q_L).$$

A simple sorting equilibrium, i.e., each sector only employs workers and managers from a single interval, can be characterized by two thresholds, $q_L^*$ and $q_H^*$. Using (A.IV.1) and (A.IV.2), we obtain

$$\frac{d}{dq_L} \ln w_i(q_L) - \frac{d}{dq_{Lo}} \ln w_i(q_{Lo}) = \frac{\psi_{Li}[\mu(q_L), q_L]}{\gamma_i \psi_i[\mu(q_L), q_L]} - \frac{\psi_{Li}[\mu(q_{Lo}), q_{Lo}]}{\gamma_i \psi_i[\mu(q_{Lo}), q_{Lo}]},$$

$$= \int_{q_{Lo}}^{q_L} \frac{\psi_{Li}[\mu(x), x]}{\gamma_i \psi_i[\mu(x), x]} dx,$$  \hspace{1cm} \text{for all } q_H, q_{H0} \in Q_{Hi},$$

which is

$$\ln w_i(q_L) - \ln w_i(q_{Lo}) = \int_{q_{Lo}}^{q_L} \frac{\psi_{Li}[\mu(x), x]}{\gamma_i \psi_i[\mu(x), x]} dx.$$  

Using the elasticity of the salary, we similarly obtain

$$\ln r_i(q_H) - \ln r_i(q_{H0}) = \int_{q_{H0}}^{q_H} \frac{\psi_{Hi}[x, m(x)]}{(1 - \gamma_i) \psi_i[x, m(x)]} dx.$$
Additional Empirical Results

As an additional robustness check for our analysis of the impact of trade liberalization on average factor ability, we use the share of university degree holders per skill-group within a firm as an alternative proxy variable of the average ability of the respective skill group. Results are reported in Table A.I.

As can be seen, the results are both in respect to magnitude and in respect to significance very similar to the results reported in Table III. It is only in the case of FE 2 that the coefficient is not significant. Note, however, that the share of university degree holders within skilled workers is relatively small, on average 2.14%, so that the results for skilled workers should not be overinterpreted.

<table>
<thead>
<tr>
<th>TABLE A.I.</th>
<th>Regression of Share of University Degrees on Share of Exports with and without Firm Specific Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dep. var.: Share of university degrees ($\bar{q}_L$)</td>
</tr>
<tr>
<td>Skilled workers</td>
<td>(FE 1)</td>
</tr>
<tr>
<td>Share of exports ($s$)</td>
<td>0.0002***</td>
</tr>
<tr>
<td>Controls:</td>
<td></td>
</tr>
<tr>
<td>Collective agreement</td>
<td>$-0.0054^{***}$</td>
</tr>
<tr>
<td>Employment share</td>
<td>$-0.0129^{**}$</td>
</tr>
<tr>
<td>Age</td>
<td>$0.0003^{***}$</td>
</tr>
<tr>
<td>Log revenue</td>
<td>$0.0044^{***}$</td>
</tr>
<tr>
<td>N.obs.</td>
<td>47 312</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0046</td>
</tr>
</tbody>
</table>

Notes. An observation in the regression is one firm in one year. All regressions include nine year and 25 industry dummies. Since not all companies reported their revenue, N.obs. is smaller when controlling for revenue. We report clustered standard errors at the industry level in brackets. Source: LIAB, Version 2, Years 2000-2008.

*** indicates significance at 1% level, ** at 5% level, * at 10% level.


Lebenslauf

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vollständig geöffneten Sektoren bestätigt werden.


Ich bin mir bewusst, dass eine unwahre Erklärung rechtliche Folgen haben wird.

Ulm, den 31. März 2014

Gregor Hesse