ISSN 2042-2695

CENTRE *for* ECONOMIC PERFORMANCE

CEP Discussion Paper No 1450

October 2016

Trade and the Size Distribution of Firms: Evidence from the German Empire

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ESRC ECONOMIC & SOCIAL RESEARCH COUNCIL

Abstract
What is the effect of trade on the size distribution of firms? We collect historical data between 1882 and 1907 from the German Empire to address this question. Our data allow us to match three data sets according to the same geographic boundaries: industry census data, railway and waterway trade data. The key findings are that trade integration impacts the firm size distribution heterogeneously across three size categories. We find evidence of a stark shift in employment and firm share from small and medium firms towards larger firms. A "Bartik" instrument is proposed to argue that the correlations described are indeed causal. We provide evidence for a fall in transport costs and technology adoption as mechanisms to explain the stylized facts observed in the data.

Keywords: Firm size distribution, firm heterogeneity, technology adoption, German Empire
JEL codes: F14; F15

This paper was produced as part of the Centre's Trade Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

Acknowledgements
I thank Facundo Albornoz, Swati Dhingra, Hanwei Huang, Stephan Maurer, Gianmarco Ottaviano, Frank Pisch, Steve Pischke, Thomas Sampson, Daniel Sturm, Jens Suedekum, Catherine Thomas as well as participants of the CEP International Economics Workshop, Frankfurt EGIT, 15th GEP Annual Postgraduate Conference Nottingham, 16th Trans-Atlantic Doctoral Conference LBS, the Urban Economics Association Summer School at the IEC in Barcelona, Annual congress VfS in Augsburg 2016 and 18th ETSG in Helsinki for helpful comments and discussions.

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Published by
Centre for Economic Performance
London School of Economics and Political Science
Houghton Street
London WC2A 2AE

1 Introduction

During the recent past firms have been in the focus of studies in international trade. It has been shown in multiple studies that exporters are higher-performing than non-exporters, which only serve the domestic market. Exporters are known to be more productive, larger in employment and sales, more skill- and capital intensive and pay higher wages (Bernard et al., 2007).

In light of these findings, Melitz (2003) shows in a seminal theoretical work, how trade liberalization leads to a reallocation of labor from less productive to more productive firms when firms are heterogeneous in productivity. When countries open up to trade, only the most productive firms can overcome the fixed costs of exporting to enter export markets, and unproductive firms are driven out of the market by competition from foreign exporters (selection channel). This gives rise to aggregate productivity and welfare gains through cross firm resource reallocation (Melitz and Redding, 2015).

Subsequently, a large body of research in the literature on firm heterogeneity and trade has shown that firms can be induced to adopt a technology by export opportunities (e.g. Constantini and Melitz, 2007; Bustos, 2011). As exporting expands the market size to which goods are sold, the fix cost of adopting a technology can be amortized and the productivity cutoff for technology adoption decreases.

The increasing availability of firm-level data sets has transformed empirical evidence in international trade. Perhaps surprisingly, to the best of our knowledge, the field has - with few exceptions - made rarely use of historical firm-level data. In this paper, we exploit historical firm data to shed light on firm heterogeneity and trade in the context of the first wave of globalization in the German Empire between 1882 and 1907. The historical context is particularly well-suited as international trade integration was driven by a fall in transport cost (Jacks et al., 2010). In addition to falling international transport cost, we provide evidence for a fall in domestic transport cost. The German Empire was a particularly relevant state in the period as it became the second largest economy in international trade by the end of the period. The degree of trade openness in 1913 of the German Empire was only reached again sixty years later.

In this paper, we address two research questions: What is the effect of trade integration on the size distribution of firms? In a second question, we investigate the underlying mechanism: Does closer trade integration lead to endogenous productivity upgrading through technology adoption?

To this end, we make use of three data sources: industry census data available at the administrative state level and trade data for transport modes railway and waterway. We harmonize the data sets according to seventeen districts within the German Empire. Industry census data provide rich information on firms' employment and technology (motor usage) at the district level.

Firms in the industry census data are classified according to their size as small (less than 6 employees), medium (between 6 and 50 employees) and large (more than 50 employees). We document a heterogeneous treatment effect of trade integration across different size categories in the firm size distribution. Our main finding is that trade induced a stark shift in firm and employment share from small and medium-sized firms to large firms. To address reverse causality, we propose a "Bartik-Instrument" (shift-share approach) to argue that the correlation described is indeed causal.

Empirical studies have proven ample evidence in support of the reallocation effects of trade liberalization and found substantial productivity growth from reallocation. Pavcnik (2002) investigates the effect of trade liberalization in Chile on productivity growth. She finds that aggregate productivity grew by 25.4% and 31.9% in the export and import sectors respectively. The author estimates that exiting firms are on average 8.1% less productive than firms staying in the market, and most of the productivity improvement can be explained by the reallocation of market shares and resources from fewer to more productive plants. Trefler (2004) studies the effect of the Canada-US free trade agreement on an industrialized economy (Canada) and reports that labor productivity increased by 6%. Axtell (2001) finds that the firm size distribution in the US is characterized by the Zipf distribution. Giovanni et al. (2011) present a model which shows that international trade systematically affects power law estimates and claim that power law estimates which do not take into account international trade could be misleading. They report power law estimates for two measures of firm size: employment and sales. Both measures of firm size are highly correlated (0.79) in the French firm level data set. The authors find a higher power law coefficient for French exporters than for non-exporters for both measures of firm size. Atack et al. (2008) use historical manufacturing census data from 1850-1870 and find that access to the railroad had a positive causal effect on the share of firms with factory status (establishments with 16 or more workers) at the US county level. However, their data do not allow them to study the distributional consequences of market integration on the size distribution as we contribute in this study.

Our first contribution to this literature is to provide evidence for the selection channel of Melitz (2003) in the historical context of the first wave of globalization, trade affects the allocation of resources across firms by shifting resources towards larger firms. In addition, we provide evidence for a productivity premium of larger firms.[1] This quantitative finding is corroborated by anecdotal evidence from exporters' address books send as promotion to foreign countries. We calculate the share of advertisements relevant to our sample of industries across districts and correlate this share with the share of small and large firms in industry census data which reveals a strong negative correlation for small firms and positive correlation for large firms, i.e. exporting firms are larger than firms which serve only the domestic market.

In a second step, we suggest technology upgrading as underlying mechanism how larger firms become endogenously more productive. Empirical evidence in several countries shows that there is a complementary between entry into export markets and the adoption of technology (e.g. Bustos (Argentina), 2011; Lileeva and Trefler (Canada), 2010; Verhoogen (Mexico), 2008). The period studied is not only known as first wave of globalization, but also as second industrial revolution. Increased usage of motorized machinery as a substitute for handwork led to substantial productivity gains in industry in this period. We provide anecdotal evidence that this investment constituted a substantial fixed cost. We investigate the effects of market integration on technology adoption of existing technologies as well as a newly available technology in this period: the electric motor. The electric motor became a substitute for steam engine towards the end of the nineteenth century. Our second contribution in line with the literature on trade and technology adoption is to describe a further channel through which trade triggered productivity gains: trade affected the endogenous adoption decision of existing technologies as well as contributed to the diffusion of a new technology.

The remainder of this paper is organized as follows: First we provide a brief overview of the historical setting and the related literature. Then, we describe the data in more detail and present the estimation results. Finally, we discuss the underlying mechanism for the empirical findings and conclude.

[1] In the canonical Melitz model firm size is perfectly correlated with productivity.

1.1 Historical context

Before 1871 German-speaking countries were organized in a loose association of 39 states, the German Confederation. The German Empire was unified politically in 1871 following the Franco-Prussian war. The period we are considering falls into the "first wave of globalization", a key period in the economic development of the German Empire.[2] Between 1882 and 1907, real GDP per capita grew at an annual rate of approximately 1.9%.[3] The German Empire became the second largest economy in terms of GDP in the world by 1908.

This impressive economic development coincided with a period of rapid trade integration. Most notably was the extension of transport infrastructure. The size of the railway network expanded from 32,797 km (approximately 20,380 miles) in 1882 to 56,191 km (approximately 34,915 miles) in 1907. By this time the network was the largest in Europe. Between 1882 and 1907 transportation on railways steadily rose from 105,000 tonnes to 295,000 tonnes which implies an annualized rate of 4.6%.[4] Investment in the waterway canal system was almost as high as for railways. According to Wehler (2007), more than 1,000 km of canals were newly constructed between 1880 and 1914. For example, the newly constructed Dortmund-Ems Canal (completed in 1899) could support ships with a capacity of more than 1,000 tonnes. Formerly constructed canals were reconstructed to support ships with higher capacity, which was a necessity for waterways to remain competitive to railways. Kunz (1999) documents that the length of water canals, which could support more than 100 tonnes, increased from 6,600 km (1874) to approximately 10,000 km (1914). The average capacity of ships surged between 1877 and 1912 by +429% (from 80 tonnes/ship to 285 tonnes/ship).[5] The share of trade on waterways in relation to all trade rose from 21% in 1875 to 25% in 1910, i.e. the trade volume on waterways grew quicker than the volume on railways.[5] The rapid growth in trade volume is even more remarkable in contrast to the fourth largest economy in the world in 1882: France. According to Sympher (1913) the shipment measured in trillion tonnes kilometer grew between 1880 and 1905 at an annualized growth rate of 5.9% on waterway in the German Empire whereas in France the annual growth rate was approximately 3.7%. Likewise, the annualized growth rate on railway was significantly larger in the German Empire (4.9%) than in France (2.1%).

In allusion to Germany's "economic miracle" in the 1950s, the German historian Hans Ulrich Wehler coined this period as Germany's "first economic miracle" and exports were its driving force. Torp (2014) presents data on international trade integration of the German Empire. Its export quota almost doubled from 8.5% (1874-78) to 15.8% (1909-13). Likewise, the import quota rose from 15.2% (1874-78) to 19.2% (1909-13).[6] The level of trade openness of the German Empire attained in 1913 was only reached again sixty years later in 1973.[7] Figure A.2 in the appendix puts the level of trade openness in the long run perspective. Simultaneously, the share of exports originating from the German Empire of total world exports increased steadily from 1874-78 (9.5%) to 1909-1913 (12.2%).

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[2] Chronological placements of the "first wave of globalization" vary in the literature. The end of the period is generally characterized by the year before the outbreak of World War I (1913). Jacks et al. (2010) define the period as 1870-1913, i.e. their chronological placement includes 1882 to 1907. Hereafter, we follow their chronological definition.

[3] Calculated from Maddison Historical GDP Database on 10/12/2015: www.worldeconomics.com/Data/MadisonHistoricalGDP/MadisonHistoricalGDPData.efp.

[4] One ton is equal to 1000 kilogramme.

[5] Information retrieved from Zentralblatt der Bauverwaltung. Issue 41. 1921, No.2. Prussian ministry for public work, Berlin.

[6] Torp (2014) calculates export and import quota as their share of gross national product in constant 1913 prices.

[7] Trade openness measured by the share of exports and imports as of GDP.

Tariffs in the German Empire on manufactured increased from 4-6% (1875) to 13% (1913).[8] Bismarck's tariff on iron and rye in 1879 was the start of an international tendency towards protection. However, the tariff level of the German Empire on manufactured goods was still lower than in France and Italy. Only the UK fully committed to free trade and maintained a zero tariff level, whereas in the USA the tariffs displayed a much more pronounced level of protection than in the German Empire. Estevadeordal et al. (2003) claim that international tariffs increased only modestly between 1870-1913 from 12% to 15%. While tariff protection may have restrained international competition and fostered cartel building in specific industries such as the steel industry (Webb, 1980), our analysis will consider both domestic and international trade across a wide range of industries and rules out that results are driven by protectionist tariffs in few industries.

At the same time, the German Empire transformed from an agrarian country into an industrial country. In the 1895 census, the population share employed in industry and craft (38.5%) passed the share employed in agriculture (35%), after coming second in the 1882 census. By 1907, the industrial sector had supplemented its role as the leading sector with 42.2% of the population employed, whereas the share employed in agriculture declined even further to 28.4%.

In terms of value added, the industrial sector took the lead position in the German Empire in the 1880s. The share of value added in the industry and craft sector was the largest for the first time in 1889, and held this position until 1913. Its share of value added increased by approximately 15% between 1870 and 1913, from 26.4% to 41.1%.[9] The industrial index increased in all but for two years in the period between 1882 and 1907.[10] It increased by an astonishing 91.90% in this period corresponding to an annualized growth rate of 2.64%. Similarly, the index of production for producers' goods grew by 122.8% or an annualized growth rate of 3.26%.

Several of Germany's nowadays global players were founded and expanded significantly in this time period. The chemistry sector is a good example in which closer trade integration coincided with concentration in employment. Employment at chemistry producer Bayer almost eight-fold between 1888 (1000 employees) and 1907 (7811 employees). Similarly, employment at chemistry manufacturer BASF more than tripled between 1885 (2377 employees) and 1907 (8877 employees). Both companies were among the 100 largest in terms of employment in the German Empire in 1907.[11] By 1913 Germany had the largest share of world exports in chemistry (28%) with Great Britain (16%) coming second.

Wolf (2009) studies economic integration within the German Empire and across borders. His study indicates that the German Empire before 1914 was poorly integrated in the sense that administrative borders and cultural heterogeneity across regions and states still mattered for trade flows across regions in the unified Empire.

[8] Estimates taken from O'Rourke (2002).

[9] Information retrieved from Federal Agency for Civic Education: www.bpb.de/system/files/dokument_pdf/BPB_Tabellen_WertschoepfungnachWirtschaftsbereichen.pdf on 31/03/2016.

[10] Published in special edition of quarterly economic research reports (Wagenfuehr, 1933).

[11] Information retrieved from Fiedler (1999).

2 Data

2.1 Industry census data

In this section we describe the data deployed in the empirical analysis. We collect data on firm size distribution and employment distribution. Data are available at the administrative level for the German Empire for 39 regions and states, which include among others Prussian provinces, Kingdoms such as Bavaria and Grand-Duchies such as Baden. The data stem from the industry census data in the German Empire for which consistent data are accessible in 1882, 1895 and 1907.[12] The data capture employment in the first half of June across all years, hence data comparisons across years are unaffected by seasonality. The time difference between the first and second censuses is thirteen years, while the time difference between the second and third is similar with twelve years.

Census data capture the complete picture of employment in industry in the German Empire. We focus on the industries to which we can assign goods from trade classification. In so doing, we match descriptions of traded goods and industry classification as narrowly as possible to the finest hierarchy of industry classification.[13] The industry classification contains three hierarchies across all census years. In 1882, there were twenty industry groups, 96 industry classes and 248 industries at the finest level of aggregation. By 1907 the detail of aggregation changed to 23 industries, 129 industry classes and 396 industries. We can compare the industry classifications consistently over the years by tables provided in the statistics.

Industry census data were collected in conjunction with occupation census data. Different establishments of one firm in different locations were counted as different firms in the census, i.e. census data measure firm size at the establishment level. Each firm was assigned to an industry and in case its activity could fit into more than one category, the company was usually assigned to the industry which corresponded to its major business. In case a company was active in multiple industries, it was also possible to split it into subdivisions and count these as separate establishments. For the industries under consideration only 2.7% (1895) and 9.7% (1907) of the companies were active in multiple industries at the industry group level. Companies producing in the same industries with multiple locations accounted for only approximately 1% of all establishments. Hence, countries producing in multiple industries (either in the same place or in different places) or producing in the same industry in multiple locations were not the norm and we continue hereafter to refer to firm for counts in the census data instead of establishment.

Companies were located according to industry, trade, tax and other registers. In contrast to most modern data sets for firm size distributions, the historical data do not set any cutoff for counting (e.g. a minimum number of employees to be counted, i.e. all firms irrespective of size were counted), and we access industry census data, where participation was mandatory and not sampling is used.[14]

Industry surveys were conducted at the municipality level. Municipalities were divided into counting districts and one assistant was responsible for each counting district. Assistants distributed and collected the surveys and checked their consistency. Each assistant should not survey more than 50

[12] Industry census data are also available in 1875. However, the data do not contain as much information relevant to our analysis as census data from 1882 onward. In contrast to other census data, 1875 census data were collected in December and counted firms with more than five employees only.

[13] See page 38 in appendix for a list of industries and goods included in the analysis.

[14] Small firms with less than five employees were counted with the occupation census. All other firms, which employed more than five full time workers, were asked to answer a separate firm survey.

households/companies in a counting district such that distribution and collection of surveys was feasible within a time frame of one week.[15] Information about the counting was early distributed and no public events should take place two days prior, on the day of the counting and one day after the counting. Assistants filled out control lists passed to the head of the municipality. The head of the municipality had to confirm the consistency of the counting by signature before the results were transferred to the county and then to the statistical office. Not only summaries were transferred, but also raw data, i.e. surveys, were shipped to the responsible statistical office in the state in which the county was located. Companies were forced by law to participate in the survey and the director of each company had to confirm the truthfulness of their information with their signature. Misreporting was punished by 30 Mark in all census years which corresponds to a nominal value in 2015 of 213€ (1882) and 174€ (1907), hence measurement error stemming from untruthful reporting is unlikely to be an issue.[16] On the other hand, municipalities were offered an incentive to provide full coverage of occupation and industry census. For each inhabitant they received one Pfennig before the counting, one Pfennig three month and a half month after the counting day and one Pfennig on January 1st in 1896 for the 1895 census.[17]

To the best of our knowledge, the data availability of the German Empire provides an unparalleled opportunity to combine trade and industry census data in this historical context, particularly in contrast to the other two largest economies in terms of GDP in this time period - the United Kingdom and the United States of America. In the United Kingdom no industry census was conducted for the time period under consideration. In the United States of America, information on companies was collected early on incidentally to the collection of population data with a frequency of decennial census. However, only companies with a value of production of more than $500 were counted. According to Hesse (1914), a significant fraction of factories and small companies has not been counted arbitrarily. In addition, Hesse cites Francis Walker, who in 1869 was chief of the statistical office in Washington and census superintendent for the 1870 and 1880 censuses. According to Walker, respondents had no incentives to report truthfully due to fear of the use of census data by tax authorities or simply to escape counting. A comparison across years and regions before 1900 is hardly reasonable. Only from 1900 did the quality of data and did industry censuses comprise full coverage of all firms.[18]

By 1882 the twenty industries under consideration comprised 1.41 M. employees and 173820 firms and by 1907 2.94 M. employees and 203951 firms were counted. We focus on count of full-time employment as opposed to secondary employment. All firms with at least one person working full-time are taken into consideration.[19]

Comparing the average firm size in 1882 (8.12 employees) across all industries to the average firm size in 1907 (14.42 employees), we find evidence a striking concentration process - an increase in average firm size of approximately 77.5% within a 25-year period.

The distributions come in bins and for most of our analysis we limit ourselves to consideration of

[15] Information on counting procedure is exemplary presented for 1895, it is similar for other census years.

[16] Information retrieved from https://www.bundesbank.de/Redaktion/DE/Downloads/Statistiken/Unternehmen_Und_Private_Haushalte/Preise/kaufkraftaequivalente_historischer_betrage_in_deutschen_waehrungen.pdf?_blob=publicationFile. on 31/03/2016, values are purchasing power equivalent of the average value of one Euro in 2015.

[17] 100 Pfennig corresponded to one Mark, the currency of the German Empire. Payment for population before the counting based on the recent population census data. For 1895 the reference year was the population census in 1890.

[18] Francis Walkers concerns are also discussed in Atack and Bateman (1999). The quality of the US census data at the aggregate level is doubtful. Atack et al. (2008) use digitized original firm surveys. However, for the same industries their sample would contain 2567 establishments in 1880 compared to 173820 establishment in the 1882 census data deployed here.

[19] We exclude self-employment as data were not fully collected in 1882.

three bins: small (less than 6 employees), medium (between 6 and 50 employees) and large (more than 50 employees). Although these categories look quite small at first sight, a recent survey by Hsieh and Olken (2014) on the firm size distribution in developing countries uses similar categories.[20]

The data contain information regarding the number of firms in these three size categories (for all census years) and the number of employees.[21] Thus, we can calculate firm shares across size categories and employment shares across size categories.[22]

Figure 1: Evolution of firm shares across size categories.

Figure (1) shows the evolution of the firm share for each size category in the three census years. The share of small firms has fallen from 88.86% in 1882 to 77.56% in 1907, whereas the share of medium and large firm has increased within the 25-year period. In absolute terms, there is a slight increase in the number of small firms from 154456 (1882) to 157896 (1907), as industrial employment expanded and population was growing. On the other hand, the number of large firms increases steadily from 3861 (1882) to 8857 (1907).

Data for employment are not readily available at the finest industry aggregation. Based on the information available, we can calculate that the employment share of small firms declined from 27.6% to 19.6% between 1882 and 1895 for the finest level of industry aggregation.

Instead of presenting the incomplete picture of employment shares based on a finer level of industry aggregation, we take a look at the employment shares at the industry group level. The share of employment in small firms decreases markedly from well above 44.50% in 1882 to approximately 19.45% in 1907.[23] While there is only a modest increase in the share of employment in medium sized firms, there is a significant surge in the employment share of large firms from approximately 36.57% to 57.38% between 1882 and 1907.

[20] All category boundaries are the same as in this paper except the smallest size category has an upper bound of 10 employees.

[21] Employment data are available for small firms, for medium and large firms in 1882 and 1895 at the industry class aggregation for eight out of seventeen of districts. At the finest industry aggregation in 1882 and 1895 for all districts, but only for small firms and not distinguishing between medium and large firms. At the industry group aggregation, employment data are available for all districts in 1895 and 1907 and for eight out of seventeen districts in 1882.

[22] We calculate firm distributions according to the finest level of industry classification. For the graphical illustration, we calculate employment distributions at the level of the industry group, e.g. for cotton textile, in order to depict the evolution of employment across all three census years.

[23] As one can see, the industries considered in our analysis have a significantly smaller employment share of small firms. Their employment share as of total employment in the industry group grew from 47.3% to 56.9% between 1882 and 1907, i.e. the shift in employment share from small firms towards large firms is likely to be more pronounced than the shift presented in Figure (2) at the industry group level.

One reason for the more pronounced shifts in the employment share variable is the discontinuity of the number of firms in each bin. For example, we see only a firm shifting size category from medium to large if it grows above 50 employees, while a firm with 49 employees is still counted as medium sized firm. However, such a firm may have grown in employment by a factor of seven in case its initial employment in 1882 was seven.

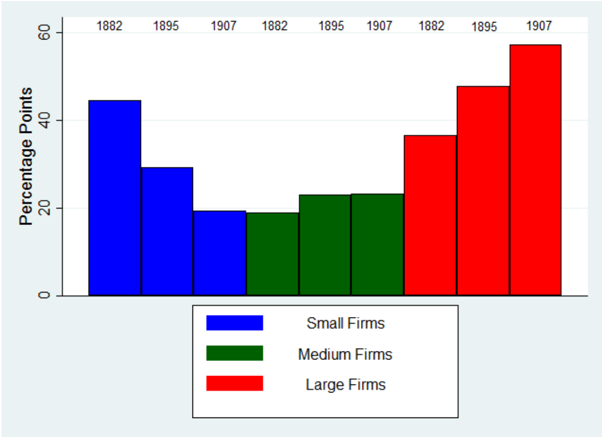

Figure 2: Evolution of employment shares across size categories.

2.2 Trade data

We collect data for twenty goods which are among the most significant in terms of trade volume and we can assign to an industry from official German Empire trade statistics.[24] Two examples of industries are iron ore and chemistry products.[25] Data are collected for two transport modes onto which goods were predominantly traded in the period under consideration: railways and waterways.[26] Our data comprise all inland railway and waterway transportation and bilateral trade on railroad.[27] Despite the fact that the railway network expanded by more than 60% between 1882 and 1907, we observe an upswing in trade volume per mile of 146% for the goods under consideration.

For seaports, the data allows us to capture trade of goods transferred to the most important seaports via railway. Hence, only trade by seaports is possibly not fully captured by our data. As a robustness check, we drop the districts which are seaport locations, i.e. we consider only landlocked districts. For this set of districts our data capture all trade flows, including transportation to sea ports at the maritime border, apart from local land transportation.

Data for trade on railway are only available from 1883, so we take these data as best proxy for railway trade in 1882 for which were not collected. For 1895 and 1907 railway data are readily available, likewise waterway data are available for all three years we are considering. All trade data are measured as quantities in tonnes. The list of goods collected for railway trade statistics was guided by the list of

[24]The share of total railway trade volume of the 24 goods considered out of 70 varies from 50.8% (1883) to 53.5% (1907).

[25]See page 38 in appendix material for full list of goods included.

[26]Statistics for land transportation were not collected, because land transportation (e.g. horse-drawn vehicles) was only locally important. The automobile industry was still in its infancy between 1882 and 1907. For example, the van with engine was invented only in 1896.

[27]Conservative estimates suggest a maximum of 1.1% in railway network length not covered in the statistics for 1907 and a smaller share for 1883 and 1895. The lines not covered were mostly short distance and relevant for local traffic. Waterway transport is measured for custom borders, important port stations and water gates.

goods collected for waterway trade statistics, hence we can collect the same good categories for both trade modes apart from two industries for which no trade on waterway is documented in the statistics.[28]

Trade data on railroads are divided according to 36 trade districts. These districts follow closely the administrative states and regions according to which the industry census data are classified. We merge districts states and regions in the industry census and railway data to construct seventeen districts for both types of data which contain exactly the same boundaries, which is a unique characteristic of the data and would not be feasible with modern data.[29] For the waterway ports (e.g. 117 ports in 1907), we can match the location of each waterway port, and hence waterway trade to the same seventeen districts.

3 Estimation and Discussion

We combine industry census data with the trade data using the constructed 17 districts in our regression analysis. Let "c" denote the size category under consideration, i.e. small, medium or large. Furthermore, "i" is the sub-index for industry, "j" for district and "t" for time. Finally, we distinguish among seven trade modes "m":

- export of district with the rest of the German Empire (railroad)
- import of district with the rest of the German Empire (railroad)
- international export of district with 17 regions/countries outside of the German Empire (railroad)[30]
- international import of district with 17 regions/countries outside of the German Empire (railroad)[30]
- internal trade within district itself (railroad)
- export of district within the German Empire (waterway)
- import of district within the German Empire (waterway)

Overall data for seven distinct trade modes are in the list. The trade mode "internal trade" is correlated with consumption within a district, however it captures transport of goods via railway for final consumption and not goods produced for consumption within a district that are not shipped by railway.[31] In appendix Figure A.3, the composition of trade across five distinct trade modes on railway is illustrated. The shares of each trade mode remain fairly stable across all three years. Exports and imports within the German Empire constitute about one third of trade on railway, while the share of internal trade is 25% by 1907. Exports abroad account for 6.37% and imports abroad for 3.70% of railway trade in 1907.

Bernard et al. (2009) document stylized facts about importing firms in modern US data (1993-2000). According to their analysis more than 50% of firms that import also export and these firms account for

[28] The industries are the chemistry industry and paper industry.

[29] Page 41 in appendix material shows a map and description of the constructed districts. Construction of districts is dictated by the spatial units of industry census data and trade statistics. What is more, we construct districts such that most industries are represented in all districts.

[30] Page 44 in appendix enumerates the 17 regions/countries outside of German Empire.

[31] Through the aggregation of districts in railway statistics we have to adjust domestic exports, domestic imports and internal trade. For example, we merge the railway districts "Kingdom of Bavaria" and "Bavarian Palatine" into one district. Hence, we subtract the trade flow between those two trade districts from domestic ex- and imports and add it to internal trade. We adjust trade flows for 1895 and 1907 precisely, for 1883 we access data in the third and fourth quarter and multiply them times two as an approximation as statistics for the first half of 1883 were published monthly. Results without this adjustment do not differ substantially from results presented in the appendix after this adjustment.

the majority of trade. While the early literature on firm heterogeneity has focused on exporters, we want to distinguish between effects of exports (selection) and imports (import competition) on the size distribution of firms and will examine them as distinct trade modes.

We stack the trade data for all seven trade modes to run the following two regressions for each of the three size categories c= small, medium and large to quantify how trade on the seven modes has affected the firm- and employment-shares across size categories respectively.

$$\text{firmshare}^c_{ijt} = \sum_{m=1}^{7} \beta^c_m \cdot log(trade_{mijt}) \cdot \mathbb{1}(\text{trade mode m}) + \sum_{t=1}^{3}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{3}\sum_{j=1}^{17} district_{jt} + \varepsilon^c_{ijt} \quad (1)$$

$$\text{employmentshare}^c_{ijt} = \sum_{m=1}^{7} \beta^c_m \cdot log(trade_{mijt}) \cdot \mathbb{1}(\text{trade mode m}) + \sum_{t=1}^{2}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{2}\sum_{j=1}^{17} district_{jt} + \varepsilon^c_{ijt} \quad (2)$$

The left hand side in this regression firmshare^c_{ijt}($\text{employmentshare}^c_{ijt}$) is the share of firms (employees) in category c in industry i in district j at time t.[32] We include time varying industry-fixed effects to control for industry-specific heterogeneity and time varying district-fixed effect to control for heterogeneity at the district-level such as income, institutions, market size or population.

We decide to stack the data to isolate the different margins (distance, domestic and international trade) of trade modes on the size distribution of firms. Obviously, the trade flows across different trade modes are highly correlated and running the regression without stacking the data may produce insignificant estimates of some estimates due to high correlation between covariates. Alternatively, we can collapse all trade flows into a single measure of trade openness by taking the sum across trade modes as index for local trade exposure of an industry. The advantage of this measure over trade flows across different modes is fewer zero trade flows and hence fewer missing data points through the log transformation. We consider the following alternative specifications for equation (1) and (2):

$$\text{firmshare}^c_{ijt} = \beta^c \cdot log(\text{trade openness}_{ijt}) + \sum_{t=1}^{3}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{3}\sum_{j=1}^{17} district_{jt} + \varepsilon^c_{ijt} \quad (3)$$

$$\text{employmentshare}^c_{ijt} = \beta^c \cdot log(\text{trade openness}_{ijt}) + \sum_{t=1}^{2}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{2}\sum_{j=1}^{17} district_{jt} + \varepsilon^c_{ijt} \quad (4)$$

For ease of interpretation, we report estimates for equation (3)-(4) based on aggregate trade as single measure for trade openness in the main text and present similar tables for equation (1)-(2) in the appendix. Since we are using the natural logarithm of the trade volume as regressor, it allows us to interpret our estimate as semi-elasticity. The interpretation of β^c in equation (3)-(4) is as follows: a 1% increase in trade flow in industry “i” in district “j” leads to $\frac{\beta^c}{100}$ increase in category c in firm or employment share respectively. As the primary specification we report the regressions that match industry classifications and traded goods as narrow as possible. For the firm variable it is possible to collect data for all districts at the finest level of industry aggregation. At the finest level of industry aggregation employment data are available for all district in 1882 and 1895, but the data only allow us to capture

[32] As the left hand side is a share and the measures of trade are not bounded, some post-estimation predicted values may be smaller than zero or greater than one. One way to deal with this issue would consider the log of the odds ratio, i.e. $log(\frac{1-\text{firmshare}^c_{ijt}}{\text{firmshare}^c_{ijt}})$, as dependent variable and similarly for employment.

the share of employment in small firms and its residual. In a second step, we consider the employment variable data at the second finest level of industry aggregation (industry class) for eight out of seventeen districts in 1882 and 1895. Alternatively, we can estimate regression in equation (4) for all districts at the industry group.[33] Finally, we can investigate how the average firm size responds to trade integration at the finest level of industry aggregation.

We do not impose any restriction on the minimum number of firms within a district, i.e. we include observations with degenerate distributions, i.e. only one firm in a district. While such cases may lead to extreme shifts in the distribution, restrictions on the minimum number of firms within a district corroborate our estimates.[34] Standard errors are clustered at the district level. Serial correlation within districts might be less of a problem, since the census years are twelve and thirteen years apart. Estimated clustered standard errors turn out to be larger than robust standard errors, i.e. we report the more conservative estimates of conventional standard errors. We note, however, that the number of clusters is quite small - seventeen for equation (1)-(2).[35]

First of all, we estimate this reduced form regression and will later propose an instrumental variable approach to establish causality of our reduced form results.

We conclude that the share of small and medium-sized firms decreases as trade increases. In contrast, the share of large firm is positively correlated with trade volume. All estimates are highly significant. The shares of small and medium-sized firms are negatively affected by trade. The impact is slightly more pronounced for medium firms than for small firms. Subdividing the medium and large firm-size category into four finer categories illustrates that negative effects for medium-sized firms are driven by a decrease in share of firms with 6-10 employees, while the share of firms with 11-50 employees remains unaffected through trade integration (Table 2). Estimates for firms with 50-200 employees and more than 200 employees, which comprise only about 0.1% of our sample in all census years, are statistically highly significant and fairly similar.

For the employment shares, we observe more pronounced estimates compared to firm shares. One reason for the more pronounced shifts in the employment share variable is the previously mentioned

[33]The difference between industry group and industry class can be illustrated by considering the industry group "Industry of stone and earth". The industry group comprises five industry classes: 1. Stones, 2. Gravel, Sand, Lime, Cement, Tuff, Gypsum and Barite, 3. Clay extraction, Kaolin extraction and Glaze and Quartz mill, 4. Clay products, 5. Glass. For the main specifications we can match all products to their corresponding industry classification for the firm variable, i.e. 1. Stone, 2. Earth, Gravel and Sand, 3. Lime and Cement and 4. Glass. For the employment variable, we obtain a perfect match for Stone and Glass as industry classes. However, we do not have trade data for products Tuff, Gypsum and Barite in industry class two and trade is measured for earth, gravel and sand, lime and cement. Most likely their employment distributions are similar to the products for which we have trade data. Even if this is not the case, the induced measurement error in the *dependent variable* makes our estimates less efficient, but not inconsistent, in case the error is not systematic. See page 39 for a list of included industry classes in the sample and page 40 for a list of included industry groups in the sample.

[34]Results available on request. Alternatively, we weight observations in equation (3) by the firm share at the district level in each year and correspondingly for equation (4) by the employment share at the district level.

[35]In case, we estimate equation (2) with employment data at the industry class level the number of clusters decreases to eight. Employment data for 1882 and 1895 at the industry class level are available for districts 1,2,6,7,8,9,11 and 12 on page 42.

discontinuity of the size categories.[36] We observe negative and significant estimates for all trade modes for both employment shares of small firms and medium size firms (Table 3). On the other hand, the share in employment in large firms is positively correlated with aggregate trade (Table 3).[37]

Note that for all regressions there is a hierarchy in magnitude of coefficients across trade modes. Trade with foreign countries has higher marginal effects the firm size distribution than trade within the German Empire on railway. Furthermore, the marginal effect for waterway is higher than the corresponding railway coefficients (A.12-A.15).

3.1 Instrumental variable approach

Naturally, there are concerns of reverse causality - the firm size distribution affecting trade and not the other way around as implicitly assumed in the presentation of our reduced form regression analysis. For example, district-specific demand shocks can influence the shape of the firm size distribution which in turn can increase firm productivity and subsequently trade flows of a district. Alternatively, simultaneity may be a concern, i.e. trade flows and the size distribution are jointly influenced by a third *unobserved* factor.

To alleviate such concerns, we propose an instrumental variable approach, the shift-share approach, which was popularized by David Card in the context of migration (e.g. Card, 2001).[38] The idea is to decompose the growth in trade according to aggregate growth and to district specific components. The instruments absorb all district-specific shocks by holding the district share constant at a base year and assigning the aggregate growth component within an industry and trade mode to it.

The *identifying assumption* is that the initial distribution of trade volumes in the base year is uncorrelated with any district specific shocks that affect the firm size distribution in 1883, 1895 and 1907 respectively. We discuss two sources of relevant district specific shocks: *demand shocks* and *technology shocks*.

Technology shocks: A concern is that the firm size distribution shifts towards bigger firms due to technology shocks. Firms in districts exposed to positive technology shocks, could grow in size while at the same time exports grow independently. To control for this in the main specification, we include period-industry fixed effect, i.e. the industry specific intercept can vary within a year across industries and within an industry across years.

Demand shocks: Alternatively, the results could be driven by demand shocks within a district itself. We try to address this by including period-district fixed effects in all main specifications. We also control for some part of local demand shocks, by controlling for trade within a district itself.

We use trade in 1874 (for 1882) and 1882 (for 1895 and 1907) as base year to guarantee that the predicted trade flow is independent from any district specific shock until 1882, 1895 and 1907 respectively. To further clarify the construction of the instrument, we explain its calculation for the year 1895.[39] One

[36]A firm changes size categories only if it exceeds the upper threshold of its category. On the other hand, a firms' employment may grow within the boundaries of its category.

[37]Estimates for three cross sections at the industry group level are displayed in Table A.5. Note that estimates are similar to Table 3. The magnitude in Table A.5 is smaller as the employment share variable is constructed from industry census data at a higher level of aggregation in Table A.5.

[38]In the literature this approach is also known as "Bartik" instrument following Bartik (1991).

[39]The construction for 1907 follows the same method.

absorbs all district-specific shocks by creating the following predicted trade flow:

$$\text{trade } \widehat{\text{openness}}_{ij1895} = (1 + g_{i-j1882-1895}) \cdot \text{trade openness}_{ij1882} \quad (5)$$

In equation (5) trade $\widehat{\text{openness}}_{ij1895}$ denotes the predicted variable for 1895 data and $g_{i-j1882-1895}$ denotes the aggregate growth rate in industry "i" between the base year 1882 and 1895 *excluding* district j.[40]

We then calculate the variable which we use as an instrument for 1895: $log(\text{trade } \widehat{\text{openness}}_{ij1895})$. Note that this value is independent from any district-specific shock in 1895 provided our identifying assumption holds. For 1907 there are in principle two base years available, 1882 and 1895, and we decide to select 1882 as base year, since the time difference is longer for this choice.

For 1883 railway data and 1882 waterway data we construct the instrument based on waterway data in 1874. The data allow us to construct the instrument for eleven districts which increases count of observations by 135 and makes instrumental variable estimates more comparable to our reduced form regression analysis. Hence, for 1882 we construct the following predicted trade flow:

$$\text{trade } \widehat{\text{openness}}_{ij1882} = (1 + g_{i-j1874-1882}) \cdot \text{trade openness}_{\text{ij}1874} \quad (6)$$

For example, in order to predict aggregate trade in 1882, we calculate the aggregate growth rate between 1874 waterway trade and 1882 aggregate trade excluding district j and multiply it with the initial value of waterway trade. Hence, we run the following first stage regression:

$$log(\text{trade openness}_{ijt}) = \beta^{IV} \cdot log(\text{trade } \widehat{\text{openness}}_{ijt}) + \sum_{t=1}^{3}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{3}\sum_{j=1}^{17} district_{jt} + u_{ijt} \quad (7)$$

The scatter plot in Figure illustrates the constructed instrument plotted against observed trade flows. Obviously, there is a strong positive correlation of approximately 0.92 between the logarithm of observed and predicted trade flows.

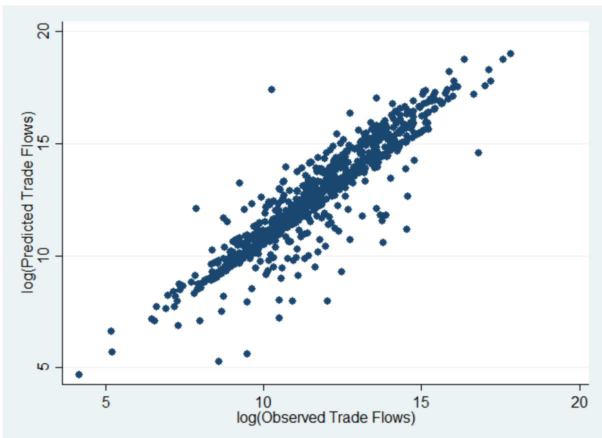

Figure 3: Scatter Plot illustrating observed and predicted trade flows.

Instrumental variable estimation results indicate that significance prevails for almost all significant co-

[40]For railway we have chosen - dictated by data availability - 1883 as base year.

efficients in the reduced form regressions.[41]

Significance prevails for all coefficients across size categories (Table 4). The magnitude of IV estimates is larger for the IV regressions compared to the reduced form regression, i.e. OLS estimates represent a lower bound for the causal effect.[42] Instrumental variable estimates for firms employing 6-10 employees turn insignificant, though the negative sign is prevailed and estimates are marginally insignificant. What is more, IV estimates for category 6-10 employees are significant with robust standard errors, thus the choice of standard errors matters in this estimation.[43] If we consider only landlocked districts IV estimates for 6-10 employees turn significant (Table A.10).

Instrumental variable estimates for employment shares are fairly similar to OLS estimates, except that estimates for small and medium firms' employment share change to marginally insignificant (Table 6).[44] Finally, we consider a third alternative to highlight the reallocation effects of trade across firms:

$$\text{log(average firm size)}_{ijt} = \beta \cdot log(\text{trade openness}_{ijt}) + \sum_{t=1}^{3}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{3}\sum_{j=1}^{17} district_{jt} + \varepsilon_{ijt} \quad (8)$$

In this regression we can interpret estimates for β as elasticity.

We obtain strongly significant estimates both for the reduced form and instrumental variable specification. The estimates are striking in magnitude: A 1% increase in trade integration implies ceteris paribus approximately an increase by 0.33% in average firm size with the IV estimation. This is in line with the effects described for both firm and employment shares across size categories.

We briefly sum up the stylized facts established in the empirical analysis:

- Estimates tend to be larger and positive for the large firm size category in contrast to smaller and negative estimates for the small firm size category.
- For medium size firms, we find a negative effect of trade on both the firm share and on the employment share. The effect is more pronounced than for small firms.
- Instrumental variable estimates tend to be larger, i.e. OLS estimates represent a lower bound.
- The elasticity of average firm size with respect to percentages in trade volumes is large. Its maximum is approximately 0.33.
- Table A.7-A.11 show results for restricting the sample to landlocked districts. In general, they display larger magnitudes and similar results in terms of significance.

[41] For brevity we do not report the first stage. Results display F-statistics that far exceed conventional thresholds of twelve.

[42] Note that instrumental variable estimates are not directly comparable to Table 1 as we can only instrument for eleven out of seventeen districts in 1882.

[43] The estimates are also significant, if we restrict observations to 1895 and 1907 for which the instrument is constructed with aggregate trade flows in 1882 as opposed to trade flows on waterway in 1874.

[44] Estimates for three cross sections at the industry group level are displayed in Table A.6. Note that estimates are similar to Table 6. The magnitude in Table A.6 is smaller as the employment share variable is constructed from industry census data at a higher unit of aggregation in Table A.6. Estimates for small and medium firms' employment share as dependent variable are negative and statistically highly significant.

- Table A.12-A.18 are similar to Table 1-7 and confirm their findings. The size of estimates is similar across trade modes. However, trade modes with longer distances of shipment tend to have a larger magnitude: international trade on railway and waterway.

4 Mechanism

4.1 Productivity

In this section, we provide evidence for the productivity premium of larger firms. Ultimately, this is the channel through which trade affects welfare, in our analysis, by reallocating resources towards more productive firms and raising productivity as outlined in Melitz (2003).

The resource allocation across firms can have profound effects for TFP: Hsieh and Klenow (2009) study to what extend misallocation of capital and labor can lower aggregate TFP. The authors study the counter-factual what would have been the percent TFP gains for China and India relative to those in US (in 1997), if moving to the US resource allocation? They find stunning gains in TFP: in China, between 50% (in 1998) and 30% (in 2005) and in India, between 40% (in 1987) and 59% (in 1994).

Production data are not readily available for all industries. For mines, metallurgy plants and saline production data do exist and we focus as an illustration on these industries in this section. More precisely, out of the twenty industries we consider six: brown coal, hard coal, iron as part of iron and steel, iron foundry as part of iron and steel products, iron ore and table salt as part of the salt industry. Data on production, the number of firms and employees at the administrative regional level allow us to consider the same seventeen districts as in our previous analysis.

Remarkably, all industries trade a significant share as of total production on railway (trade openness). This share increased over time. For example, trade openness for hard coal increased from 72.2% (1883) to 80.7% (1907), for brown coal from 36.2% (1883) to 47.7% (1907) and iron ore from 43.7% (1883) to 68.9% (1907).

As a reasonable approximation for productivity we consider output per worker (labor productivity). We then specify the following specification to quantify the impact of average firm size on labor productivity:

$$\text{log(average output)}_{ijt} = \beta \cdot \text{log(average firm size)}_{ijt} + \sum_{t=1}^{3}\sum_{i=1}^{6} industry_{it} + \sum_{t=1}^{3}\sum_{j=1}^{17} district_{jt} + \varepsilon_{ijt} \quad (9)$$

We include time varying industry-fixed effects to control for industry-specific changes in productivity in all specifications. First, we exclude district fixed effects as our main goal is to identify the cross sectional effect of average firm size on labor productivity. Estimates are statistically highly significant and the elasticity implies that a 1% increase in average firm size induces roughly a 0.26% increase in average labor productivity. This result is robust to the inclusion of time constant district fixed effects, though the magnitude of the elasticity falls to 0.16. Finally, if we include time varying district-fixed effects the estimates are still marginally significant.

Hence, we have identified the channel through which trade matters for welfare in line with Melitz (2003). Trade integration leads to a shift in resources from smaller to larger firms (Table 1-6) implying an increase in average firm size (Table 7). This increase in average firm size maps into a gain in average labor productivity (Table 8).

4.2 Technology

The question arises of why larger firms are more productive than smaller firms? Aside from the channel through increasing returns to scale and market integration, we now examine firms' technology. The period between 1870 and 1913 is not only known as "first wave of globalization" but also as "second industrial revolution" and is characterized by an increasing use of motorized machinery in the production process. Inventors from the German Empire were at the forefront of developing new types of motors, such as Otto (1877) and Diesel (1893).

The purchase of motorized machinery was expensive. For example, the cost for a small steam engine in Berlin in 1891 ranged from 1550 Mark (one horsepower) to 3530 Mark (six horsepower).[45] The operation costs for 300 ten hour working days amounted to 901.25 Mark (one horsepower) to 2689.10 Mark (six horsepower). By comparison, the wage of a male laborer in Berlin amounted to 2.7 Mark per day.[46] Hence, the expense for purchasing the machinery with one horse power corresponded to the annual wage of approximately two male laborers and the purchasing cost for the steam engine with six horsepower correspond to the annual wage of approximately four male laborers.

A cost-benefit analysis reveals the relative efficiency of lifting weight of one workmen, one horse and one physical horsepower in steam engines. The cost for one ton kilometer was 33.67 Pfennig for the steam engine, 185.76 Pfennig for the horse and 662.6 Pfennig for the workmen. Hence, one physical horsepower was as profitable as approximately five and a half horses or hiring almost twenty workmen.[47]

The adoption of steam technology as an example of transformed production in sectors such as the textile industry. According to Matschoss (1908), the adoption of steam technology in weaving mills, as part of the supply chain in the textile industry, increased productivity by a factor of 90 compared to manual work.

We access data on the motor use by different firm size categories from industry census data. Table 9 illustrates that the probability of adopting a motorized machinery increases as one moves upwards towards larger firm size categories, i.e. adopting firms are larger than the average firm. The probability of adoption of all firms increases from 14% in 1882 to 21.7% in 1907.[48] While almost all firms with more than 200 employees have adopted the technology in 1882 already the increase in adoption is driven by firm size categories 11-50 and 51-200 employees.

This finding is related to Bustos (2011) who finds that tariff cuts induced technology upgrading in the third quartile of firm size distribution. The probability of adoption is significantly smaller for firms

[45] Information retrieved from Matschoss (1908). The unit horsepower was adopted by James Watt in the late 18th century and is still used to measure the physical power of machinery. One horsepower corresponds to the power necessary to lift 75 kilogramme pond meter per second.

[46] Information on wage retrieved from Becker et al. (2014).

[47] Cost-benefit analysis published by Ernst Engel in Zeitschrift des Koeniglich Preussischen Statistischen Bureaus (1880, page 123 and following) based on information available at this time. The analysis compares a twelve horsepower steam engine running eleven hours a day, a workmen of 60 kilogramme (average power of working with hand gear, crank and treadwheel) and one horse moving 45 kilogramme at 0.9 meter per second for eight hours.

[48] The questionnaire in 1907 asks to report more types of motors than in 1882, e.g. due to technological progress in case of the electric motor.

between one and five and six and ten employees respectively. These findings suggest that the fix cost of adopting motorized machinery can only be overcome by larger firms.

It is also evident in the data that - conditional on adopting motorized machinery - larger firms have both a higher horsepower per firm and per employee. As can be seen the horsepower per company increases dramatically as firm size increases in 1907. More importantly, the power per employee is also monotonically rising in firm size. The horse power per employee in firms with more than 1,000 employees is almost ten times as large as the horse power per employee in firms with up to five employees. The data do not allow us to examine to what extend the differences in horse power per employee is driven by the intensive margin (higher horse power per machine) or extensive margin (more machinery) for the German Empire. However, Matschoss (1908) presents data for stationary steam engine in Prussia. From 1885 to 1904 their number more than doubled and their average horse power increased from 31.5 to 55.7 by 76.8%.

Data on technology adoption by firm size are not available at a spatial level. However, we have collected spatially disaggregated data on the probability of adopting the technology across all firms to quantify the impact of trade integration on this outcome. To this end, we run the following regression:

$$\text{motorshare}_{ijt} = \beta \cdot log(\text{trade openness}_{ijt}) + \sum_{t=1}^{3}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{3}\sum_{j=1}^{17} district_{jt} + \varepsilon_{ijt} \qquad (10)$$

$$\text{electricmotorshare}_{ijt} = \beta \cdot log(\text{trade openness}_{ijt}) + \sum_{t=1}^{2}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{2}\sum_{j=1}^{17} district_{jt} + \varepsilon_{ijt} \qquad (11)$$

The structure is similar to equation (3)-(4). The left-hand side is the share of adopting a technology as of all firms within a district.[49] The questionnaire changes over time. More types of motors are included in the 1895 and 1907 survey and the questionnaire is similar as opposed to the one in 1882. Therefore, we consider only 1895 and 1907 as robustness check. Alternatively, we consider in equation (11) the adoption of electric motors. A technology that became available for industrial use through the spread of electrification and a substitute to steam engine. Electrification and its wide-spread use was one of the main characteristics of the second industrial revolution.[50] In our sample, the number of firms using electric motors increased from 2259 (1895) to 79304 (1907) by a factor of 35.

We find robust statistical significant effects of market integration on technology adoption across all specifications (Table 11). Closer trade integration through a fall in trade costs can decrease the productivity cutoff for surviving firms to adopt the technology and increases probability of adoption over time.

We report statistically highly significant estimates for all coefficients on the probability of adopting electric motors (Table 12). Not only did market integration increase the probability of adopting existing technologies, but also contributed to the diffusion of newly available technologies.

[49] As data on technology adoption are not distinguishable by firm size, self-employment is included in the count. Therefore, the left-hand side represents a slightly different population of firms in comparison to the previous analysis. As self-employment is statistically not represented in 1882 data, we take this into consideration by considering only 1895 and 1907 as robustness check.

[50] Important inventions of electric motors fall between 1882 and 1895. For example, the three-phase induction motor was developed in 1889 by an inventor of AEG (English translation: General electricity company, founded in 1883).

4.3 Trade Costs

Trade costs comprise among others tariffs, transport costs and other factors such as exchange rate volatility. There is an extended literature examining the role of trade cost reduction as a cause for the first wave of globalization. Jacks et al. (2010) report that trade costs fell by 10-16% between 1870 and 1913 explaining approximately 44% of the rise in international trade in this period. Estevadeordal et al. (2003) claim that a fall in transport costs is the dominant explanation for the trade boom seen between 1870-1913. According to Pascali (2014) technological advance in shipping, namely the use of steam power, was the major reason for the reduction in trade costs and first wave of globalization. Due to steam power international maritime shipment became more reliable as opposed to wind dependent sail ships and shipping times were considerably reduced.

We access official railway freight rate statistics in 1881 and 1904. During this time the railway network was gradually nationalized such that the freight rate was the same across all regions within the German Empire. The nominal freight rate tariff remained fairly constant between 1881 and 1904 for most distances. Thus, the real freight cost declined for producers by the inflation rate of the producer price index. The corresponding inflation rate for the consumer price index was roughly 12%. Other tariffs such as unit load experienced a real decline of up to 43% (1,000 km distance). According to Lenschau (1907) nominal revenues per tonnes kilometer on railway declined by approximately 13% between 1882 and 1903 implying a real decline of 25% in freight cost per tonnes kilometer.

While railway freight rates were independent of any route characteristics apart from distance, waterway freight rates were determined in bargaining by demand and supply. Therefore, they were subject to more volatility over time. Even so, we can provide evidence for specific routes and goods[51]:

- Ruhrort-Mannheim (Coal, 1885-87 to 1908-1912) real decline of approximately 55%
- Ruhrort-Rotterdam (Coal, 1878 to 1908-1912) real decline of approximately 55%
- Hamburg-Dresden (Cotton, Fertilizer, Iron and Petroleum, 1876-1880 to 1905-1909) real decline of approximately 57%, 51%, 50% and 61%

Thus, in addition to the decline in international trade costs as described in the literature there is a downward trajectory in domestic trade costs at least through the margin of a fall in real transport costs. We provided evidence from official freight rates on railway and specific examples for route specific freight rates on waterway.

4.4 Agglomeration

Combes et al. (2012) study the relative importance of agglomeration and selection towards higher productivity in a larger city. Their structural approach allows them to empirically distinguish between the two mechanisms. While selection left truncates the productivity distribution of firms, agglomeration right shifts and dilates the productivity distribution. In the case of agglomeration, all firms enjoy the benefits of locating in a large city. The authors use French firm level data to test predictions of their

[51] Data for the listed freight rates taken from Teubert (1912). Inflation rate calculated based on purchasing power equivalent provided by information retrieved from https://www.bundesbank.de/Redaktion/DE/Downloads/Statistiken/Unternehmen_Und_Private_Haushalte/Preise/kaufkraftaequivalente_historischer_betrage_in_deutschen_waehrungen.pdf?_blob=publicationFile. on 31/03/2016

model. Estimation results find significant effects of agglomeration economies in contrast to mostly insignificant results for selection in areas with employment and population density above the median. The authors find only some evidence of selection for the smallest firms. On the other hand, they estimate consistent significant agglomeration forces and dilation effects, which also increase in magnitude as firm size increases.

In this section, we explore heterogeneity across districts to see whether we can find effects similar to Combes et al. (2012). To define a measure of agglomeration we keep with the literature and calculate two measures: the population density defined as $\frac{\text{Population}}{\text{Area in km}^2}$ and the employment density defined as $\frac{\text{Employment in industries}}{\text{Area in km}^2}$, where we take total employment count at the finest level of industry aggregation. We calculate these measures for all districts and rank them according to the densities with the largest density assigned a value of one and the lowest density assigned a value of seventeen. Then, we take the sum of ranks across all three years 1882, 1895 and 1907, calculate the rank of the sum and classify districts with rank one to nine as agglomerated districts.[52]

Classifications into agglomerated and non-agglomerated districts are the same for both measures employment and population density. In equation (12) below, these districts are defined as "Agglomeration District", whereas all other districts are defined as "Non-Agglomeration District". We investigate heterogeneity across agglomerated and non-agglomerated districts by estimating different coefficients for trade modes across both types of districts.

$$\begin{aligned} \text{firmshare}^{c}_{ijt} = \beta^{agglom,c} \cdot log(\text{trade openness}_{ijt}) \cdot \mathbb{1}(\text{Agglomeration District}) \\ + \beta^{non-agglom,c} \cdot log(\text{trade openness}_{ijt}) \cdot \mathbb{1}(\text{Non-Agglomeration District}) \\ + \sum_{t=1}^{3}\sum_{i=1}^{20} industry_{it} + \sum_{t=1}^{3}\sum_{j=1}^{17} district_{jt} + \varepsilon^{c}_{ijt} \end{aligned} \quad (12)$$

We focus on the analysis of firm shares as these are available at the finest level of industry aggregation and across all districts. Table 13 and 14 show the results for equation (12) similar to Table 1 and 4.

The sign of estimates is negative for small firms in the OLS estimation and larger for non-agglomeration districts. Negative effects of trade on the share of medium-sized firms appear to be driven by agglomeration districts (Table 13). The IV estimates confirm this finding, though the coefficient estimate turns marginally insignificant for medium size firms. Finally, both agglomerated and non-agglomerated districts display significant estimates indicating a reallocation towards larger firms attributed to trade. However, the magnitude appears to be stronger for agglomerated districts. Though differences for the estimates between agglomerated and non-agglomerated districts are statistically insignificant.

4.5 Anecdotal evidence

In this section, we provide anecdotal evidence to corroborate our first key finding that trade integration is explanatory for differences in the size distribution. For this purpose, we refer to address books of German exporting firms. These were published from 1883 onward and we access the first four volumes in 1883-85 and a volume from 1897 as reference for 1895. The books were encouraged by the Prussian

[52] The nine districts defined as agglomerated districts are: 5, 6, 9, 10, 12, 13, 14, 15 and 17 on page 42.

department of commerce and the implementation was carried out by the German Central Association of Industry and the German Chambers of Commerce. One motivation underlying the publication of these books was "to show the most distant places in the world market that the German industry is fully competitive to the foreign."[53]

Selection of advertisements was delegated to industries and industrial unions. However, it is explicitly mentioned that the companies are represented as national and that local governments could intervene in case they felt their region was underrepresented to avoid any signs of partisanship. Most advertisements were translated into three further languages: English, French and Spanish. To ensure appropriate translation of technical language the patent office was consulted. Companies advertisements include information about their specialties and their location. Along their core competencies, some firms publish information on their size, output and machinery (e.g. efficiency measured as total horse power).

The volumes we consider from 1883-85 contain in total 3,200 advertisements. We consider advertisement which can be assigned to any of the twenty industries taken from the industry census data. The industry classification is very similar to the one used in industry census data. In total, we assign 1161, i.e. 36.3% of all advertisements, thus a substantial fraction of the advertising manufacturing industry is represented in our analysis.

We calculate the total number of firms advertising across all industries for each district.[54] Likewise, we compute in 1882 census data the number of establishments across all industries counted in each district and the share of small and large firms. The share of firms as of establishments advertising ranges from 0.13% in district one (Provinces of East- and West Prussia) up to 1.23% in district eleven (Province of Westphalia, Principalities of Lippe and Waldeck). The correlation between the share of advertisements and small firms is strongly negative with -0.88, whereas the correlation between the share of advertisements and large firms is positive with 0.59. If we take out Alsace-Loraine, which seems to be an outlier, the correlations magnify to -0.97 and 0.91 respectively.[55]

We use information on firm size published by some firms to provide additional descriptive evidence. To take into account the fact that firms may have multiple establishments, we divide employment by the number of establishments if multiple locations are advertised. Out of 140 companies that list their employment in the advertisements 135, i.e. 96.4%, employ more than 49 employees and belong to the large firm size category in the census data. Only five companies belong to medium-sized firms. Their employment is close to the upper bound of medium sized firms.[56] Though there may be selection into reporting of employment, this is additional compelling anecdotal evidence that the majority of exporters are large firms. As falling trade barriers enable more firms to start exporting the productivity cutoff falls and we observe a rise in the fraction of large firms over time.

Finally, we provide evidence on the location of exporters and relate this to agglomeration. The advertisements also reveal the exact location of the headquarters of each firm. We take a closer look at all locations with more than ten advertisements, which is approximately one percent of all advertisements considered.[57] Overall eighteen locations satisfy this requirement. Berlin, Leipzig and Dresden are the locations with most advertisements. Eight out of eighteen locations have more than 100,000 citizens

[53] Quote taken from preface "Adress-Buch Deutscher Export-Firmen", 1883 (Volume 1).

[54] Note that advertisements refer to the firm level as opposed to establishments. Some firms are assigned to more than one location, but most firms advertise themselves with their headquarters only.

[55] The under-representation of Alsace-Loraine may be related to the fact that it was annexed only in 1871.

[56] The sizes of these firms are 25,36,40,40 and 40-50.

[57] In this exercise, we exclude locations which advertise many firms within the same industry.

(large cities) and a further nine out of eighteen locations belong to the "medium-sized cities" with 20-100,000 citizens. This suggests that densely populated areas are more likely to be a location of exporting firms.

A new series of advertisements was published in 1897. The preface was written in 1895 and thus it appears reasonable to repeat this exercise for this new series of advertisements and the 1895 industry census data. This volume contains in total 1,299 advertisements. Again, we identify the advertisements relating to industries considered in our quantitative analysis. We can match 453, i.e. 34.9%, to those industries. The correlation between the share of advertisements and small firms is negative with -0.68, whereas the correlation between the share of advertisements and large firms is positive with 0.32. If we take out Alsace-Loraine, which again seems to be an outlier, the correlations magnify to -0.83 and 0.73 respectively.[55] All firms that reveal information about their firm size have a firm size larger than 50.[58] Reassuringly, the descriptive evidence established for 1882 is confirmed in 1895 data.

5 Conclusion

To the best of our knowledge this is the first study that uses district variation within one country to illustrate the importance of trade integration to explain observed changes in firm and employment distributions across different size categories. For this purpose, we used census data in the historical context of the first wave of globalization, a unique setting characterized by closer trade integration through the expansion of the transport infrastructure and falling transport costs as important component of trade costs. This paper emphasizes the role economic integration has played in shaping the industrial employment structure during industrialization in the German Empire.

Empirically, we find a relative shift in the employment and firm share from small and medium-sized firms to large firms. A shift-share instrumental variable estimation purges estimates from any district specific shocks and confirms our reduced form regression results. Anecdotal evidence from exporters' advertisement in representative address books corroborates our finding of a size premium of exporters in the cross section across districts.

We provide evidence for a premium in labor productivity of larger firms in line with the intuition of the Melitz model. We highlight technology adoption as mechanism through which firms upgrade their productivity in response to closer market integration.

Firm heterogeneity and international trade has been the center of attention in the literature in international trade over the past two decades. This paper is arguably the first to assess key implications of this literature in historical data. Our analysis confirms in an unparalleled historical setting that the effects theoretically described by Melitz (2003) have also been present during the first wave of globalization a century before the emergence of this pioneering literature.

[58] In total 37 firms publish information on their employment in this address book.

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Table 1: Results firm share OLS

Dependent variable		$\text{firmshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
log(Openness Measure)	–0.0271***	–0.0222**	0.0525***
	(0.0082)	(0.0079)	(0.0096)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.771	0.504	0.634
Observations	943	943	943

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (3).

Table 2: Results firm share OLS - Subcategories

Dependent variable	$\text{firmshare}^{c}_{ijt}$			
Sample	6-10	11-50	51-200	>200
log(Openness Measure)	–0.0183*	–0.0038	0.0299***	0.0226***
	(0.0093)	(0.0062)	(0.0078)	(0.0036)
Estimation Method	OLS	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.273	0.467	0.444	0.521
Observations	943	943	943	943

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (3) by subdividing medium and large firm size category into subcategories.

Table 3: Results employment share OLS

Dependent variable	$\text{employmentshare}^{c}_{ijt}$			
Sample	Small firms	Small firms	Medium firms	Large firms
log(Openness Measure)	–0.0317***	–0.0512*	–0.0822*	0.1334***
	(0.0100)	(0.0237)	(0.0376)	(0.0334)
Estimation Method	OLS	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.726	0.742	0.415	0.668
Observations	621	234	234	234

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (4). Sample in column 1 based on all districts at finest level of industry aggregation in 1882 and 1895. Employment data for 1882 and 1895 at the industry class level are available for districts 1,2,6,7,8,9,11 and 12 on page 42. Estimation in column 2-4 based on this sample in 1882 and 1895.

Table 4: Results firm share IV

Dependent variable		$\text{firmshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
log(Openness Measure)	–0.0331**	–0.0190	0.0521***
	(0.0137)	(0.0127)	(0.0119)
Estimation Method	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.769	0.493	0.631
Observations	758	758	758

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (3).

Table 5: Results firm share IV - Subcategories

Dependent variable	firmshare^c_{ijt}			
Sample	6-10	11-50	51-200	>200
log(Openness Measure)	–0.0168	–0.0028	0.0291***	0.0229***
	(0.0102)	(0.0098)	(0.0096)	(0.0050)
Estimation Method	IV	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.278	0.459	0.461	0.521
Observations	758	758	758	758

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (3) by subdividing medium and large firm size category into subcategories.

Table 6: Results employment share IV

Dependent variable	$\text{employmentshare}^{c}_{ijt}$			
Sample	Small firms	Small firms	Medium firms	Large firms
log(Openness Measure)	–0.0372*	–0.0922	–0.0665	0.1588***
	(0.0202)	(0.0548)	(0.0416)	(0.0338)
Estimation Method	IV	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.749	0.757	0.542	0.729
Observations	437	168	168	168

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (4). Sample in column 1 based on all districts at finest level of industry aggregation in 1882 and 1895. Employment data for 1882 and 1895 at the industry class level are available for districts 1,2,6,7,8,9,11 and 12 on page 42. Estimation in column 2-4 based on this sample in 1882 and 1895.

Table 7: Results average firm size OLS and IV

Dependent variable	log(average firm size)$_{ijt}$	
log(Openness Measure)	0.3226***	0.3280***
	(0.0364)	(0.0632)
Estimation Method	OLS	IV
Clustered Std. Errors	Yes	Yes
District-time fixed effects	Yes	Yes
Industry-time fixed effects	Yes	Yes
R^2	0.765	0.761
Observations	938	754

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (8).

Table 8: Results labor productivity OLS

Dependent variable	log(average output)$_{ijt}$		
log(average firm size)	0.2610***	0.1610*	0.1645*
	(0.0411)	(0.0785)	(0.0938)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District fixed effects	No	Yes	No
District-time fixed effects	No	No	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.846	0.867	0.892
Observations	183	183	183

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (9).

Table 9: Technology Adoption by Firm Size Category

	Firm Size Category					
	1-5	6-10	11-50	51-200	200-1000	>1000
Probability of Adoption in 1907 (%)	11.32	38.62	71.15	91.08	95.84	97.74
Probability of Adoption in 1882 (%)	8.41	36.59	63.27	87.67	97.45	100
Difference 1907-1882 (%)	2.91	2.03	7.88	3.41	–1.61	–2.26

Source: Authors' calculation based on Statistik des deutschen Reichs. Table 9 represents average adoption rates across twenty industries for the German Empire.

Table 10: Horse power per Firm and Employee by Firm Size Category

	Firm Size Category					
	1-5	6-10	11-50	51-200	200-1000	>1000
Horse power per Firm in 1907	0.65	4.43	21.77	119.39	634.88	5861.46
Horse power per Employee in 1907	0.26	0.60	0.95	1.19	1.47	2.41

Source: Authors' calculation based on Statistik des deutschen Reichs. Table 10 represents average horse power per firm and employee by firm size category across twenty industries for the German Empire.

Table 11: Results technology adoption motor OLS and IV

Dependent variable	$motorshare_{ijt}$			
Sample	1882-1907	1882-1907	1895-1907	1895-1907
log(Openness Measure)	0.0319***	0.0354**	0.0375***	0.0378***
	(0.0104)	(0.0137)	(0.0109)	(0.0109)
Estimation Method	OLS	IV	OLS	IV
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.782	0.794	0.787	0.787
Observations	934	750	625	625

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (10).

Table 12: Results technology adoption electric motor OLS and IV

Dependent variable	$\text{electricmotorshare}_{ijt}$	
Sample	1895-1907	1895-1907
log(Openness measure)	0.0229***	0.0225***
	(0.0061)	(0.0059)
Estimation Method	OLS	IV
Clustered Std. Errors	Yes	Yes
District-time fixed effects	Yes	Yes
Industry-time fixed effects	Yes	Yes
R^2	0.663	0.663
Observations	630	630

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (11).

Table 13: Results firm share agglomeration OLS

Dependent variable	$\text{firmshare}^{c}_{ijt}$		
Sample	Small firms	Medium firms	Large firms
log(Openness Measure)$^{\text{agglom}}$	–0.0256**	–0.0247**	0.0533***
	(0.0097)	(0.0089)	(0.0087)
log(Openness Measure)$^{\text{non-agglom}}$	–0.0301**	–0.0172*	0.0509***
	(0.0121)	(0.0097)	(0.0125)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.771	0.505	0.634
Observations	943	943	943

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (12).

Table 14: Results firm share agglomeration IV

Dependent variable		$\text{firmshare}_{ijt}^{c}$	
Sample	Small firms	Medium firms	Large firms
log(Openness Measure)$^{\text{agglom}}$	–0.0325**	–0.0195	0.0521***
	(0.0149)	(0.0133)	(0.0106)
log(Openness Measure)$^{\text{non-agglom}}$	–0.0342*	–0.0179	0.0520***
	(0.0163)	(0.0148)	(0.0160)
Estimation Method	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.769	0.493	0.631
Observations	758	758	758

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (12).

List of industries and goods considered

- Fishery
- Iron ore
- Iron and steel
- Salt
- Hard coal
- Brown coal
- Stone
- Earth, gravel and sand
- Lime and cement
- Glass
- Iron and steel products
- Chemistry products
- Fertilizer
- Fat and oil
- Petroleum and other mineral oil
- Wool
- Cotton
- Paper
- Leather
- Timber

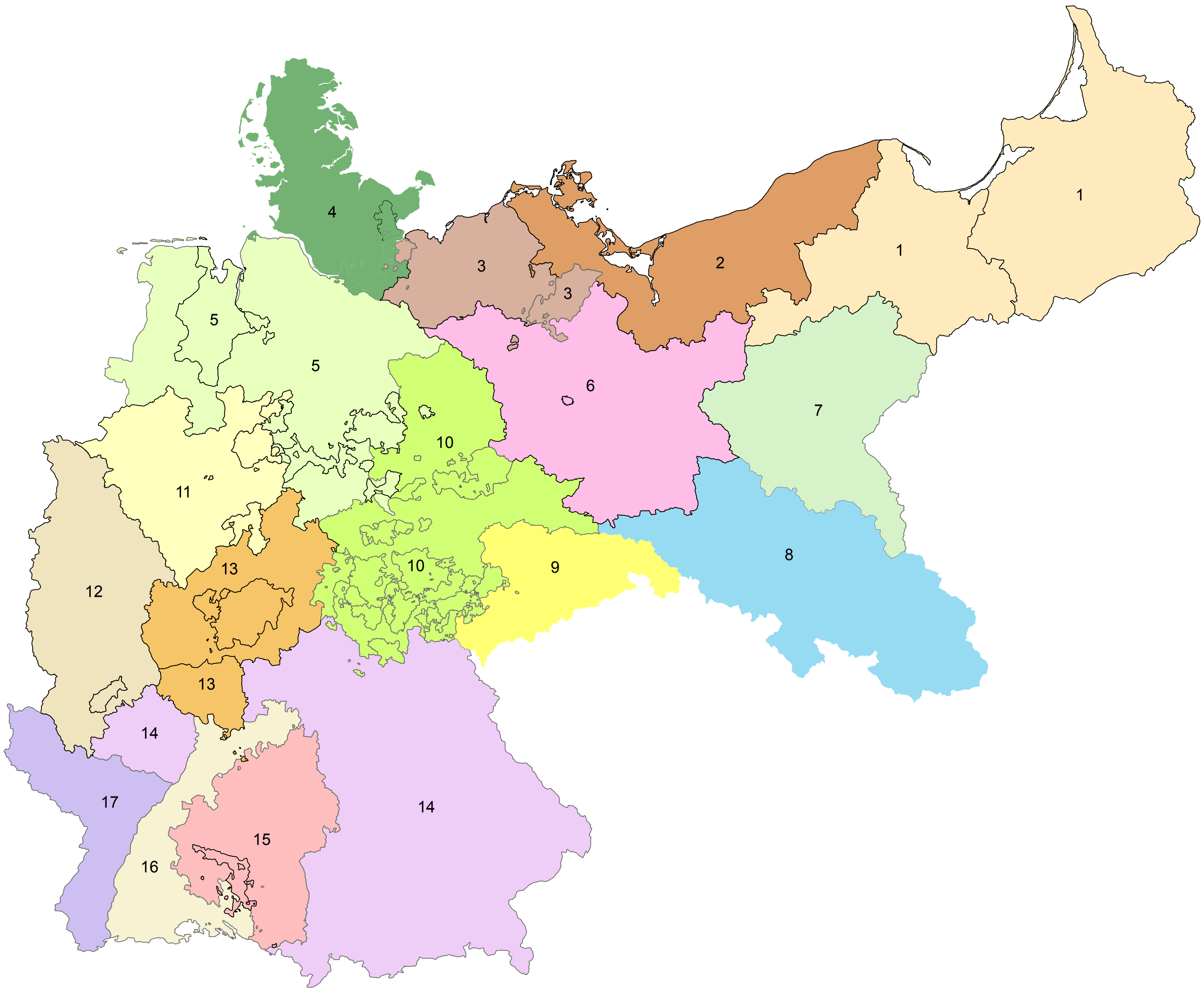
List of industry classes (goods) considered in Table 3, 6, reftab:TabA12 and reftab:TabA15

- Fishery
- Ore winning and processing of ore (Iron ore)
- Steel mill operation (Iron and steel)
- Salt
- Mining of hard coal and brown coal, coke, graphite, asphalt, petroleum, amber, briquette fabrication (Hard coal and brown coal)
- Stone
- Gravel and sand, lime, cement, tuff, gypsum, barite (Earth, gravel and sand, lime and cement)
- Glass
- Iron and steel products
- Chemistry products
- Waste products and synthetic fertilizer (fertilizer)
- Light and soap fabrication, Oil mills, Coal tar, Fabrication of mineral and etheral oil, fats and varnish (Fat and oil, Petroleum and other mineral oil)
- Textile (Wool, cotton)
- Paper and cardboard (Paper)
- Leather
- Timber conservation and finishing (Timber)

List of industry groups (goods) considered in Table A.5-A.6

- Animal husbandry and fishery (Fish)
- Coal mining, metallurgy and saline (Brown coal, Iron ore, Iron and steel, Hard coal, Salt)
- Stone and earth (Lime and cement, Stone, Glass, Earth, Gravel and sand)
- Iron processing (Iron and steel products)
- Chemistry (Chemistry products, Fertilizer)
- Forestry byproducts, Soaping, Fat, Oil, Varnish (Fat and oil, Petroleum and other mineral oil)
- Textile (Cotton, Wool)
- Paper (Paper)
- Leather (Leather dermis)
- Timber (Timber)

Figure A.1: Map of districts



List of districts

- 1: Province of East and West Prussia and sea ports Memel, Pillau, Koenigsberg, Elbing and Neufahrwasser
- 2: Province of Pomerania and sea ports Stolpmuende, Ruegenwalde, Colberg, Stettin, Swinemuende, Wolgast and Stralsund
- 3: Grand Duchies of Mecklenburg-Strelitz and Mecklenburg-Schwerin and sea ports Rostock, Warnemuende and Wismar[59]
- 4: Province of Schleswig-Holstein, City of Luebeck, City of Hamburg, Principality of Luebeck and sea ports Flensburg, Kiel, Luebeck, Hamburg, Altona, Glueckstadt[59] [60]
- 5: City of Bremen, Province of Hanover, Duchy of Oldenburg, Duchy of Braunschweig, Principality of Schamburg-Lippe, County Pyrmont, County Rinteln and sea ports Harburg, Stade, Cuxhafen, Bremen, Vegesack, Geestemuende, Bremerhafen, Nordenham, Brake, Elsfleth, Emden, Leer and Papenburg [59] [60]
- 6: Urban district of Berlin and Province of Brandenburg
- 7: Province of Posen
- 8: Province of Schlesien
- 9: Kingdom Saxony
- 10: Province of Saxony, Grand Duchy Sachsen-Weimar, Duchies of Sachsen Meiningen, Sachsen-Altenburg, Sachsen-Coburg-Gotha, Anhalt and Principalities of Schwarzburg-Sonderhausen, Schwarzburg-Rudolfstadt, Reuss-Greiz and Reuss-Gera, County Schmalkalden
- 11: Province of Westphalia, Principality of Lippe, Principality of Walbeck without county Pyrmont
- 12: Province of Rhineland and Principality of Birkenfeld[60] without county Wetzlar
- 13: Province of Hessia-Nassau and Grand Duchy of Hessia with county Wetzlar and without counties Rinteln and Schmalkalden
- 14: Kingdom of Bavaria and Bavarian Palatine[61]

[59] Two trade districts defined in the railway statistics include sea ports from two of the seventeen constructed districts: Railway district "Sea ports Rostock, Wismar, Flensburg, Kiel and Luebeck" contains sea ports from district three and four. Railway district "Sea ports Hamburg, Altona, Glueckstadt, Harburg, Stade and Cuxhafen" contains sea ports from district four and five. As allocation rule to proxy trade in each district, we assign the share of the trade flow to each district according to their share of the number of ships trading goods in each of these ports.

[60] The Grand Duchy Oldenburg consisted of separate territories Duchy of Oldenburg, Principality of Birkenfeld and Principality of Luebeck, which by construction of the seventeen districts belong to three different districts. For 1882 it is feasible to correctly allocate the firm number to each spatial unit. For years 1895 and 1907 we make use of census data and allocate firms according to the corresponding industry shares taking into account the differences in total employment within each industry.

[61] Mannheim belonged to Grand Duchy Baden and Ludwigshafen to Kingdom of Bavaria. Hence, railway district "Mannheim and Ludwigshafen" contains parts of two districts. We apportion trade flows of the railway district according to the share of employment of Mannheim (Grand Duchy Baden) and Ludwigshafen (Kingdom of Bavaria) as of total employment of Mannheim and Ludwigshafen in the corresponding two digit industry group.

- 15: Kingdom of Wuerttemberg and Province of Hohenzollern
- 16: Grand Duchy of Baden[61]
- 17: Alsace Lorraine

Districts in railway statistics assign the following counties different from census data which follow administrative boundaries:

- County Pyrmont in Waldeck of district eleven is assigned to district five
- County Rinteln of district thirteen is assigned to district five
- County Schmalkalden from district thirteen is assigned to district ten
- County Wetzlar from district twelve is assigned to district thirteen

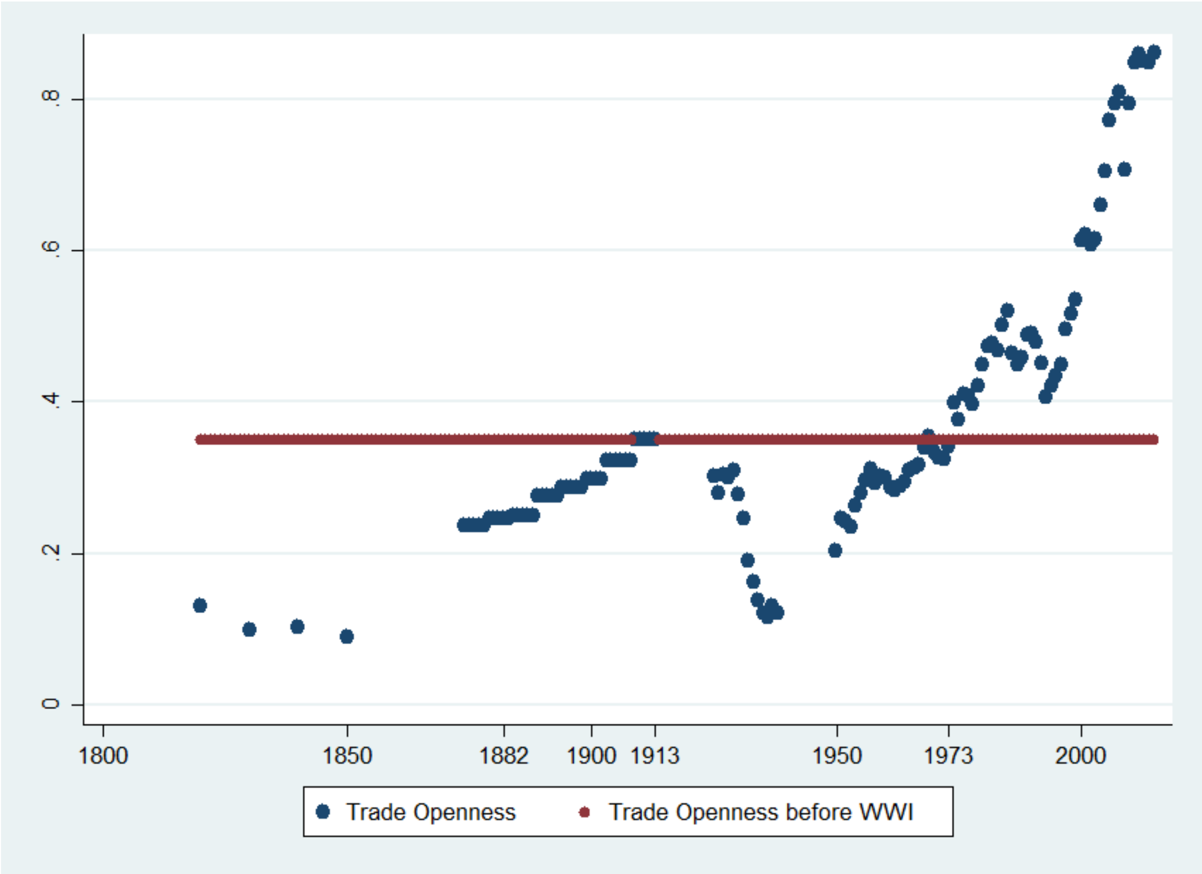
In 1900 there were 1049 counties. As distributional data are not available at the county level we cannot correct for this assignment. However, this departure from administrative boundaries should not induce any systematic measurement error.
In equation (2) we use industry census data from Prussia in 1882. The following differences arise:

- In 1882 district eleven is represented without Principality of Lippe and Principality of Walbeck without county Pyrmont, i.e. only Province of Westphalia
- In 1882 district twelve is represented without Principality of Birkenfeld[60] without county Wetzlar, i.e only Province of Rhineland

List of 17 regions/countries outside of German Empire included as trade partner in foreign railway export and import quantities

- Russia
- Poland
- Galicia and Bukovina
- Romania
- Hungary, Slavonia, Croatia, Transylvania, Bosnia and Herzegovina
- Serbia, Bulgaria, Turkey and Greece
- Bohemia
- Austria (without Bohemia and Galicia)
- Switzerland
- Italy
- France
- Luxemburg
- Belgium
- Netherlands
- Great Britain
- Sweden, Norway
- Denmark

Figure A.2: Trade Openness from 1870-1913 in the long run perspective



Trade Openness defined as share of exports and imports as of total GDP. The red line illustrates the level of openness reached in 1913 and the graph shows that this level was strongly passed only sixty years later. Data steam from different sources with possibly different price indices. GDP data for 1820, 1830, 1840 and 1850 interpolated from Fremdling (1995) and nominal trade data from Bondi (1958). Data for 1874-1913 are five-year averages taken from Torp (2014). Torp (2014) measures trade openness in terms of GNP. Data for 1925-1938 taken from Ritschl (2002). Observations from 1950-2015 calculated from statistics published by Federal Statistical Office of Germany (2016).
Federal Statistical Office of Germany (2016) online sources retrieved on 20/09/2016:
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Globalisierungsindikatoren/Tabellen/01_02_03_AH.html
https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/VGR/Inlandsprodukt/Tabellen/Volkseinkommen1925_pdf.pdf?__blob=publicationFile
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/LangeReihen/Aussenhandel/lrahl01.html

Figure A.3: Shares of trade modes on railway (in %)

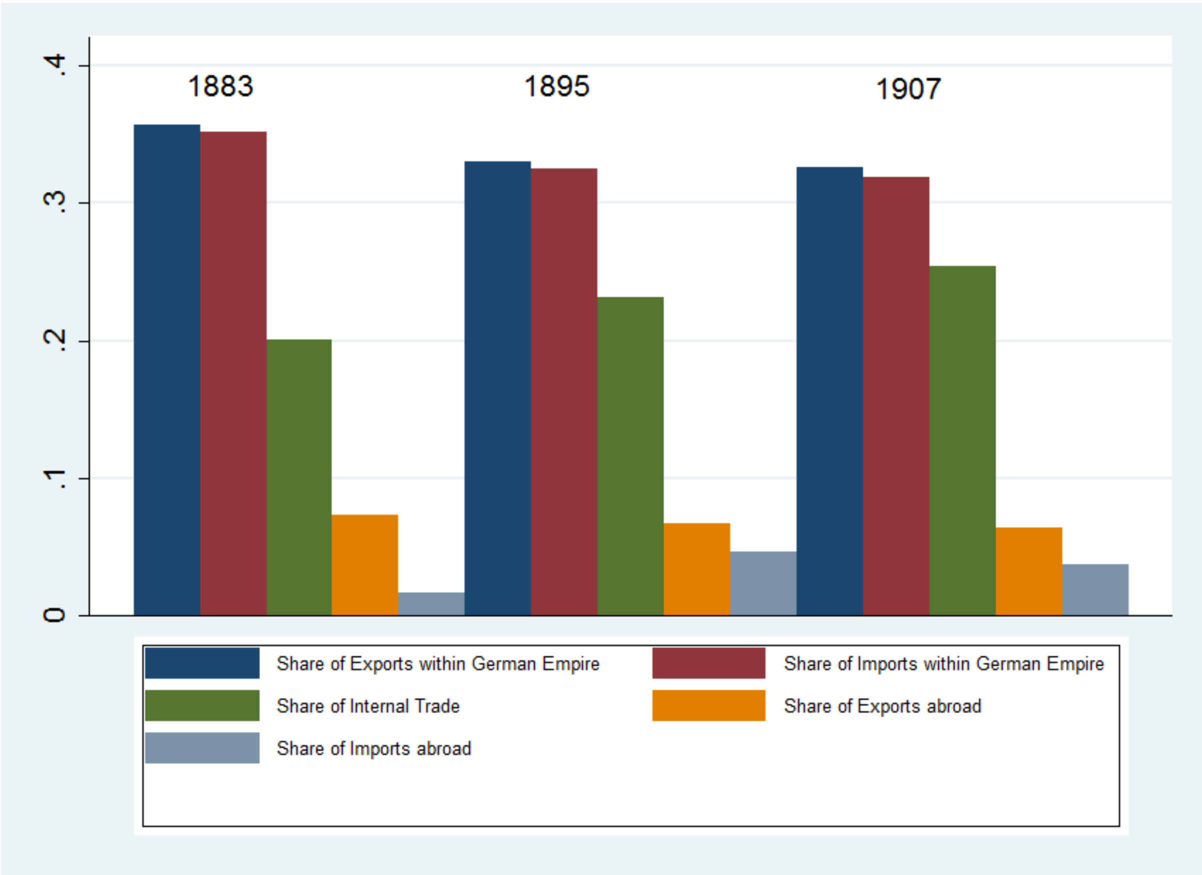


Table A.1: Evolution of firm number across size categories

	Firm Size Category		
	Small Firms	Medium Firms	Large Firms
1882	154456	15503	3861
1895	151198	28068	6310
1907	157896	36838	8857

Year	1882	1895	1907
Domestic Export	118793	210036	429761
	(786492)	(1181668)	(2071704)
Domestic Import	118777	210028	429762
	(553357)	(826381)	(1548399)
Internal Trade	64960	131571	286638
	(301064)	(471002)	(846833)
Foreign Exports	23646	40161	81399
	(198288)	(354418)	(661505)
Foreign Imports	6131	28141	47470
	(27473)	(182889)	(263972)
Waterway Export	14534	27901	43942
	(151293)	(290624)	(486831)
Waterway Import	16365	32343	75158
	(61189)	(125595)	(344025)
Trade Openness	320099	611333	1273435
	(1505580)	(2388757)	(4383565)

Table A.2: Mean of aggregated trade flows based on 340 observations for each year.[62] Trade Openness defined as sum of all trade within a district by industries. Standard deviation in parentheses.

[62] As mentioned before, railway statistics taken from year 1883 for column 1882 in the table.

Table A.3: Total employment in the twenty industries across districts.

District Number	1882	1895	1907
1	26723	34033	53543
2	99783	138675	204334
3	22482	25745	35561
4	10642	14975	20862
5	138682	198043	285086
6	118759	157110	224213
7	29916	40862	67442
8	62433	85096	133158
9	147924	224763	372262
10	254968	343814	547264
11	108318	182451	239881
12	148434	211691	300345
13	43788	66038	86432
14	35277	52055	81077
15	58002	92064	123162
16	8139	10565	13776
17	90803	99774	147339
Sum	1405073	1977754	2935737

Table A.4: Population across districts and time.

District Number	1882	1895	1907
1	3302528	3450746	3633579
2	3434972	4409244	5706576
3	1517712	1575052	1702286
4	1665617	1774046	1964806
5	3998782	4355477	4993098
6	3754116	4328073	4889295
7	1689621	2080890	2599051
8	2922288	3364889	3986105
9	2234514	2850951	3980652
10	4147917	5090825	6697844
11	5268761	5779176	6598168
12	3014822	3753262	4585500
13	2023843	2136572	2406659
14	1558598	1719238	2057561
15	2474327	2768928	3351508
16	674160	709836	747592
17	1539580	1623079	1820249
Sum	45222158	51770284	61720529

Source: Statistik des deutschen Reichs Volume 111 and Statistik des deutschen Reichs Volume 213.

Table A.5: Results employment share OLS – industry group

Dependent variable		$\text{employmentshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
log(Openness Measure)	–0.0519***	–0.0347***	0.0866***
	(0.0074)	(0.0079)	(0.0127)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.893	0.669	0.829
Observations	430	430	430

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation of equation (4), where employment shares are calculated by industry group aggregation. Observations in 1882 available for districts 1,2,6,7,8,9,11 (without Principalities of Lippe and Waldeck), 12 (without Principality of Birkenfeld) and 15. Grand Duchy of Oldenburg (Duchy of Oldenburg, Principalities of Birkenfeld and Luebeck) assigned to district 5.

Table A.6: Results employment share IV – industry group

Dependent variable	employmentshare$^{c}_{ijt}$		
Sample	Small firms	Medium firms	Large firms
log(Openness Measure)	–0.0388***	–0.0419***	0.0807***
	(0.0131)	(0.0104)	(0.0166)
Estimation Method	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.887	0.666	0.831
Observations	340	340	340

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimation of equation (4), where employment shares are calculated by industry group aggregation. Sample includes observations from 1895 and 1907 for seventeen districts. Grand Duchy of Oldenburg (Duchy of Oldenburg, Principalities of Birkenfeld and Luebeck) assigned to district 5.

Table A.7: Results firm share OLS

Dependent variable		$\text{firmshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
log(Openness measure)	–0.0311***	–0.0288***	0.0599***
	(0.0092)	(0.0088)	(0.0111)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.806	0.555	0.694
Observations	680	680	680

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (3). Sample includes observations from landlocked districts only.

Table A.8: Results firm share OLS - Subcategories

Dependent variable	$\text{firmshare}_{ijt}^{c}$			
Sample	6-10	11-50	51-200	>200
log(Openness measure)	–0.0230*	–0.0058	0.0337***	0.0263***
	(0.0111)	(0.0080)	(0.0081)	(0.0045)
Estimation Method	OLS	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.334	0.514	0.513	0.548
Observations	680	680	680	679

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (3) by subdividing medium and large firm size category into subcategories. Sample includes observations from landlocked districts only.

Table A.9: Results firm share IV

Dependent variable		$\text{firmshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
log(Openness measure)	–0.0410**	–0.0186	0.0596***
	(0.0154)	(0.0156)	(0.0130)
Estimation Method	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.810	0.542	0.688
Observations	542	542	542

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (3). Sample includes observations from landlocked districts only.

Table A.10: Results firm share IV - Subcategories

Dependent variable	$\text{firmshare}^{c}_{ijt}$			
Sample	6-10	11-50	51-200	>200
log(Openness measure)	–0.0240*	0.0054	0.0309***	0.0289***
	(0.0131)	(0.0093)	(0.0087)	(0.0065)
Estimation Method	IV	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.336	0.508	0.540	0.556
Observations	542	542	542	541

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (3) by subdividing medium and large firm size category into subcategories. Sample includes observations from landlocked districts only.

Table A.11: Results average firm size OLS and IV

Dependent variable	log(average firm size)$_{ijt}$	
log(Openness measure)	0.3495***	0.3698***
	(0.0430)	(0.0707)
Estimation Method	OLS	IV
Clustered Std. Errors	Yes	Yes
District-time fixed effects	Yes	Yes
Industry-time fixed effects	Yes	Yes
R^2	0.818	0.820
Observations	679	541

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (8). Sample includes observations from landlocked districts only.

Table A.12: Results firm share OLS

Dependent variable		firmshare^c_{ijt}	
Sample	Small firms	Medium firms	Large firms
log(Domestic Export)	–0.0035**	–0.0038**	0.0080***
	(0.0015)	(0.0014)	(0.0020)
log(Domestic Import)	–0.0032**	–0.0035**	0.0073***
	(0.0014)	(0.0013)	(0.0018)
log(Foreign Export)	–0.0044**	–0.0053**	0.0107***
	(0.0021)	(0.0019)	(0.0027)
log(Foreign Import)	–0.0046**	–0.0044**	0.0099***
	(0.0021)	(0.0018)	(0.0026)
log(Internal Trade)	–0.0033**	–0.0038**	0.0078***
	(0.0015)	(0.0014)	(0.0019)
log(Waterway Export)	–0.0042**	–0.0054**	0.0106***
	(0.0020)	(0.0019)	(0.0026)
log(Waterway Import)	–0.0039**	–0.0041**	0.0088***
	(0.0018)	(0.0015)	(0.0021)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.767	0.491	0.610
Observations	5867	5867	5867

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (1).

Table A.13: Results firm share OLS - Subcategories

Dependent variable	$\text{firmshare}^{c}_{ijt}$			
Sample	6-10	11-50	51-200	>200
log(Domestic Export)	–0.0029**	–0.0010	0.0045**	0.0035***
	(0.0013)	(0.0012)	(0.0018)	(0.0011)
log(Domestic Import)	–0.0026*	–0.0009	0.0042**	0.0031***
	(0.0012)	(0.0011)	(0.0017)	(0.0010)
log(Foreign Export)	–0.0037**	–0.0017	0.0058**	0.0049***
	(0.0017)	(0.0016)	(0.0025)	(0.0014)
log(Foreign Import)	–0.0036*	–0.0009	0.0058**	0.0042***
	(0.0017)	(0.0015)	(0.0025)	(0.0013)
log(Internal Trade)	–0.0028**	–0.0010	0.0044**	0.0034***
	(0.0013)	(0.0011)	(0.0018)	(0.0010)
log(Waterway Export)	–0.0038*	–0.0017	0.0058**	0.0048***
	(0.0018)	(0.0015)	(0.0025)	(0.0016)
log(Waterway Import)	–0.0032*	–0.0009	0.0055**	0.0033**
	(0.0016)	(0.0012)	(0.0022)	(0.0012)
Estimation Method	OLS	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.260	0.463	0.431	0.514
Observations	5867	5867	5867	5867

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (1) by subdividing medium and large firm size category into subcategories.

Table A.14: Results employment share OLS

Dependent variable	employmentshare$^{c}_{ijt}$			
Sample	Small firms	Small firms	Medium firms	Large firms
log(Domestic Export)	–0.0061***	–0.0076**	–0.0137***	0.0214***
	(0.0015)	(0.0028)	(0.0031)	(0.0033)
log(Domestic Import)	–0.0058***	–0.0075**	–0.0118***	0.0193***
	(0.0013)	(0.0029)	(0.0028)	(0.0028)
log(Foreign Export)	–0.0077***	–0.0095**	–0.0186***	0.0282***
	(0.0020)	(0.0039)	(0.0045)	(0.0053)
log(Foreign Import)	–0.0082***	–0.0107**	–0.0166***	0.0273***
	(0.0020)	(0.0042)	(0.0039)	(0.0051)
log(Internal Trade)	–0.0061***	–0.0074**	–0.0127***	0.0201***
	(0.0014)	(0.0030)	(0.0028)	(0.0032)
log(Waterway Export)	–0.0075***	–0.0106*	–0.0163***	0.0270***
	(0.0019)	(0.0047)	(0.0038)	(0.0050)
log(Waterway Import)	–0.0066***	–0.0088**	–0.0152***	0.0240***
	(0.0016)	(0.0036)	(0.0035)	(0.0040)
Estimation Method	OLS	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.726	0.728	0.390	0.613
Observations	3807	1380	1380	1380

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (2). Sample in column 1 based on all districts at the finest level of industry aggregation in 1882 and 1895. Employment data for 1882 and 1895 at the industry class level are available for districts 1,2,6,7,8,9,11 and 12 on page 42. Estimation in column 2-4 based on this sample in 1882 and 1895.

Table A.15: Results firm share IV

Dependent variable		$\text{firmshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
log(Domestic Export)	–0.0065**	–0.0081***	0.0144***
	(0.0027)	(0.0027)	(0.0039)
log(Domestic Import)	–0.0062**	–0.0077***	0.0135***
	(0.0027)	(0.0026)	(0.0037)
log(Foreign Export)	–0.0082**	–0.0111***	0.0191***
	(0.0038)	(0.0037)	(0.0054)
log(Foreign Import)	–0.0088**	–0.0101**	0.0183***
	(0.0037)	(0.0035)	(0.0051)
log(Internal Trade)	–0.0063**	–0.0081***	0.0142***
	(0.0027)	(0.0027)	(0.0038)
log(Waterway Export)	–0.0076**	–0.0114***	0.0188***
	(0.0035)	(0.0037)	(0.0051)
log(Waterway Import)	–0.0073**	–0.0091**	0.0159***
	(0.0032)	(0.0032)	(0.0043)
Estimation Method	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.768	0.491	0.610
Observations	4793	4793	4793

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (1).

Table A.16: Results firm share IV - Subcategories

Dependent variable	firmshare^c_{ijt}			
Sample	6-10	11-50	51-200	>200
log(Domestic Export)	–0.0042	–0.0039*	0.0070*	0.0073***
	(0.0028)	(0.0022)	(0.0035)	(0.0021)
log(Domestic Import)	–0.0040	–0.0038*	0.0067*	0.0068***
	(0.0027)	(0.0021)	(0.0033)	(0.0020)
log(Foreign Export)	–0.0056	–0.0056*	0.0093*	0.0098***
	(0.0037)	(0.0029)	(0.0047)	(0.0029)
log(Foreign Import)	–0.0057	–0.0045	0.0091*	0.0093***
	(0.0037)	(0.0029)	(0.0047)	(0.0025)
log(Internal Trade)	–0.0041	–0.0041*	0.0070*	0.0072***
	(0.0028)	(0.0021)	(0.0034)	(0.0020)
log(Waterway Export)	–0.0056	–0.0059*	0.0089*	0.0099***
	(0.0037)	(0.0028)	(0.0046)	(0.0031)
log(Waterway Import)	–0.0047	–0.0045*	0.0082*	0.0078***
	(0.0032)	(0.0025)	(0.0039)	(0.0024)
Estimation Method	IV	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.268	0.461	0.451	0.512
Observations	4793	4793	4793	4793

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (1) by subdividing medium and large firm size category into subcategories.

Table A.17: Results employment share IV

Dependent variable	$\text{employmentshare}^{c}_{ijt}$			
Sample	Small firms	Small firms	Medium firms	Large firms
log(Domestic Export)	–0.0082**	–0.0085	–0.0116***	0.0202**
	(0.0037)	(0.0059)	(0.0033)	(0.0065)
log(Domestic Import)	–0.0080**	–0.0085	–0.0111***	0.0195**
	(0.0035)	(0.0059)	(0.0028)	(0.0065)
log(Foreign Export)	–0.0102*	–0.0100	–0.0164***	0.0263**
	(0.0050)	(0.0075)	(0.0046)	(0.0089)
log(Foreign Import)	–0.0117**	–0.0129	–0.0150**	0.0279**
	(0.0049)	(0.0087)	(0.0044)	(0.0100)
log(Internal Trade)	–0.0081**	–0.0083	–0.0107**	0.0190**
	(0.0037)	(0.0060)	(0.0031)	(0.0067)
log(Waterway Export)	–0.0094*	–0.0111	–0.0136***	0.0248**
	(0.0048)	(0.0085)	(0.0037)	(0.0098)
log(Waterway Import)	–0.0089**	–0.0100	–0.0128***	0.0229**
	(0.0041)	(0.0070)	(0.0035)	(0.0081)
Estimation Method	IV	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.753	0.759	0.562	0.716
Observations	2866	954	954	954

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (2). Sample in column 1 based on all districts at the finest level of industry aggregation in 1882 and 1895. Employment data for 1882 and 1895 at the industry class level are available for districts 1,2,6,7,8,9,11 and 12 on page 42. Estimation in column 2-4 based on this sample in 1882 and 1895.

Table A.18: Results average firm size OLS and IV

Dependent variable	log(average firm size)$_{ijt}$	
log(Domestic Export)	0.0472***	0.0767***
	(0.0084)	(0.0204)
log(Domestic Import)	0.0435***	0.0727***
	(0.0080)	(0.0195)
log(Foreign Export)	0.0618***	0.1009***
	(0.0115)	(0.0283)
log(Foreign Import)	0.0605***	0.0997***
	(0.0113)	(0.0264)
log(Internal Trade)	0.0463***	0.0753***
	(0.0081)	(0.0199)
log(Waterway Export)	0.0621***	0.0995***
	(0.0118)	(0.0269)
log(Waterway Import)	0.0522***	0.0844***
	(0.0095)	(0.0224)
Estimation Method	OLS	IV
Clustered Std. Errors	Yes	Yes
District-time fixed effects	Yes	Yes
Industry-time fixed effects	Yes	Yes
R^2	0.738	0.737
Observations	5845	4776

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (8), where we distinguish among seven trade modes similar to equation (1)-(2).

Table A.19: Results technology adoption motor OLS and IV

Dependent variable	$motorshare_{ijt}$			
Sample	1882-1907	1882-1907	1895-1907	1895-1907
log(Domestic Export)	0.0051**	0.0074*	0.0052**	0.0092**
	(0.0021)	(0.0035)	(0.0024)	(0.0036)
log(Domestic Import)	0.0046**	0.0070*	0.0047*	0.0087**
	(0.0020)	(0.0034)	(0.0023)	(0.0034)
log(Foreign Export)	0.0071**	0.0103**	0.0073**	0.0126**
	(0.0027)	(0.0047)	(0.0032)	(0.0049)
log(Foreign Import)	0.0065**	0.0100**	0.0066*	0.0122**
	(0.0029)	(0.0045)	(0.0033)	(0.0045)
log(Internal Trade)	0.0049**	0.0071*	0.0050*	0.0087**
	(0.0021)	(0.0034)	(0.0024)	(0.0035)
log(Waterway Export)	0.0063*	0.0096*	0.0064*	0.0123**
	(0.0030)	(0.0048)	(0.0034)	(0.0049)
log(Waterway Import)	0.0051*	0.0079*	0.0052	0.0098**
	(0.0026)	(0.0041)	(0.0030)	(0.0041)
Estimation Method	OLS	IV	OLS	IV
Clustered Std. Errors	Yes	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes	Yes
R^2	0.789	0.796	0.793	0.793
Observations	5818	4751	3942	3745

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (10), where we distinguish among seven trade modes similar to equation (1)-(2).

Table A.20: Results technology adoption electric motor OLS and IV

Dependent variable	$electricmotorshare_{ijt}$	
Sample	1895-1907	1895-1907
log(Domestic Export)	0.0032***	0.0051***
	(0.0009)	(0.0016)
log(Domestic Import)	0.0029***	0.0049***
	(0.0009)	(0.0016)
log(Foreign Export)	0.0044***	0.0069***
	(0.0013)	(0.0022)
log(Foreign Import)	0.0040***	0.0068***
	(0.0013)	(0.0022)
log(Internal Trade)	0.0031***	0.0050***
	(0.0009)	(0.0016)
log(Waterway Export)	0.0043***	0.0072***
	(0.0012)	(0.0022)
log(Waterway Import)	0.0035***	0.0056***
	(0.0010)	(0.0018)
Estimation Method	OLS	IV
Clustered Std. Errors	Yes	Yes
District-time fixed effects	Yes	Yes
Industry-time fixed effects	Yes	Yes
R^2	0.664	0.664
Observations	3976	3776

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (11), where we distinguish among seven trade modes similar to equation (1)-(2).

Table A.21: Results firm share agglomeration OLS

Dependent variable		$\text{firmshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
$\log(\text{Domestic Export})^{\text{agglom}}$	–0.0030	–0.0054*	0.0088***
	(0.0030)	(0.0028)	(0.0021)
$\log(\text{Domestic Import})^{\text{agglom}}$	–0.0028	–0.0051*	0.0082***
	(0.0029)	(0.0027)	(0.0020)
$\log(\text{Foreign Export})^{\text{agglom}}$	–0.0038	–0.0073**	0.0115***
	(0.0039)	(0.0034)	(0.0028)
$\log(\text{Foreign Import})^{\text{agglom}}$	–0.0038	–0.0064*	0.0107***
	(0.0038)	(0.0034)	(0.0026)
$\log(\text{Internal Trade})^{\text{agglom}}$	–0.0029	–0.0053*	0.0086***
	(0.0030)	(0.0027)	(0.0020)
$\log(\text{Waterway Export})^{\text{agglom}}$	–0.0039	–0.0080*	0.0123***
	(0.0042)	(0.0038)	(0.0030)
$\log(\text{Waterway Import})^{\text{agglom}}$	–0.0036	–0.0053*	0.0092***
	(0.0036)	(0.0030)	(0.0024)
$\log(\text{Domestic Export})^{\text{non-agglom}}$	–0.0042	–0.0020	0.0072**
	(0.0028)	(0.0018)	(0.0027)
$\log(\text{Domestic Import})^{\text{non-agglom}}$	–0.0037	–0.0016	0.0065**
	(0.0026)	(0.0017)	(0.0025)
$\log(\text{Foreign Export})^{\text{non-agglom}}$	–0.0055	–0.0028	0.0100**
	(0.0038)	(0.0026)	(0.0041)
$\log(\text{Foreign Import})^{\text{non-agglom}}$	–0.0058	–0.0020	0.0095**
	(0.0040)	(0.0025)	(0.0040)
$\log(\text{Internal Trade})^{\text{non-agglom}}$	–0.0039	–0.0020	0.0071**
	(0.0027)	(0.0018)	(0.0026)
$\log(\text{Waterway Export})^{\text{non-agglom}}$	–0.0046	–0.0025	0.0088**
	(0.0038)	(0.0025)	(0.0034)
$\log(\text{Waterway Import})^{\text{non-agglom}}$	–0.0043	–0.0030	0.0087**
	(0.0036)	(0.0028)	(0.0030)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.767	0.492	0.610
Observations	5867	5867	5867

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates of equation (12), where we distinguish among seven trade modes similar to equation (1)-(2).

Table A.22: Results firm share agglomeration IV

Dependent variable		$\text{firmshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
$\log(\text{Domestic Export})^{\text{agglom}}$	–0.0064	–0.0088*	0.0156***
	(0.0042)	(0.0047)	(0.0036)
$\log(\text{Domestic Import})^{\text{agglom}}$	–0.0062	–0.0080*	0.0144***
	(0.0040)	(0.0045)	(0.0035)
$\log(\text{Foreign Export})^{\text{agglom}}$	–0.0085	–0.0113*	0.0203***
	(0.0056)	(0.0061)	(0.0049)
$\log(\text{Foreign Import})^{\text{agglom}}$	–0.0082	–0.0104*	0.0190***
	(0.0052)	(0.0057)	(0.0046)
$\log(\text{Internal Trade})^{\text{agglom}}$	–0.0064	–0.0085*	0.0152***
	(0.0041)	(0.0046)	(0.0036)
$\log(\text{Waterway Export})^{\text{agglom}}$	–0.0079	–0.0121*	0.0206***
	(0.0057)	(0.0062)	(0.0050)
$\log(\text{Waterway Import})^{\text{agglom}}$	–0.0076	–0.0082	0.0160***
	(0.0047)	(0.0050)	(0.0039)
$\log(\text{Domestic Export})^{\text{non-agglom}}$	–0.0065	–0.0060*	0.0122**
	(0.0046)	(0.0031)	(0.0053)
$\log(\text{Domestic Import})^{\text{non-agglom}}$	–0.0066	–0.0052*	0.0112**
	(0.0042)	(0.0029)	(0.0048)
$\log(\text{Foreign Export})^{\text{non-agglom}}$	–0.0080	–0.0089*	0.0165**
	(0.0062)	(0.0044)	(0.0077)
$\log(\text{Foreign Import})^{\text{non-agglom}}$	–0.0102	–0.0073	0.0164*
	(0.0066)	(0.0046)	(0.0078)
$\log(\text{Internal Trade})^{\text{non-agglom}}$	–0.0060	–0.0061*	0.0118**
	(0.0045)	(0.0031)	(0.0052)
$\log(\text{Waterway Export})^{\text{non-agglom}}$	–0.0073	–0.0085*	0.0156**
	(0.0059)	(0.0044)	(0.0067)
$\log(\text{Waterway Import})^{\text{non-agglom}}$	–0.0071	–0.0085*	0.0149**
	(0.0055)	(0.0041)	(0.0063)
Estimation Method	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.769	0.489	0.611
Observations	4720	4720	4720

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimates of equation (12), where we distinguish among seven trade modes similar to equation (1)-(2).

Table A.23: Results employment share OLS – industry group

Dependent variable		$\text{employmentshare}^{c}_{ijt}$	
Sample	Small firms	Medium firms	Large firms
log(Domestic Export)	–0.0064***	–0.0045***	0.0109***
	(0.0011)	(0.0013)	(0.0019)
log(Domestic Import)	–0.0061***	–0.0042***	0.0102***
	(0.0011)	(0.0012)	(0.0019)
log(Foreign Export)	–0.0082***	–0.0057***	0.0139***
	(0.0015)	(0.0016)	(0.0023)
log(Foreign Import)	–0.0083***	–0.0057***	0.0140***
	(0.0016)	(0.0016)	(0.0024)
log(Internal Trade)	–0.0063***	–0.0044***	0.0107***
	(0.0012)	(0.0012)	(0.0019)
log(Waterway Export)	–0.0086***	–0.0057***	0.0144***
	(0.0016)	(0.0017)	(0.0025)
log(Waterway Import)	–0.0074***	–0.0048***	0.0122***
	(0.0014)	(0.0014)	(0.0022)
Estimation Method	OLS	OLS	OLS
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.884	0.650	0.798
Observations	2756	2756	2756

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation of equation (2), where we calculate employment shares by industry group aggregation. Observations in 1882 available for districts 1,2,6,7,8,9,11 (without Principalities of Lippe and Waldeck), 12 (without Principality of Birkenfeld), and 15. Grand Duchy of Oldenburg (Duchy of Oldenburg, Principalities of Birkenfeld and Luebeck) assigned to district 5.

Table A.24: Results employment share IV – industry group

Dependent variable	employmentshare$^{c}_{ijt}$		
Sample	Small firms	Medium firms	Large firms
log(Domestic Export)	–0.0059**	–0.0067***	0.0126***
	(0.0025)	(0.0019)	(0.0031)
log(Domestic Import)	–0.0057**	–0.0063***	0.0119***
	(0.0024)	(0.0018)	(0.0030)
log(Foreign Export)	–0.0074**	–0.0087***	0.0161***
	(0.0032)	(0.0024)	(0.0039)
log(Foreign Import)	–0.0076**	–0.0086***	0.0162***
	(0.0033)	(0.0024)	(0.0041)
log(Internal Trade)	–0.0058**	–0.0066***	0.0124***
	(0.0025)	(0.0019)	(0.0031)
log(Waterway Export)	–0.0081**	–0.0085***	0.0166***
	(0.0031)	(0.0025)	(0.0039)
log(Waterway Import)	–0.0070**	–0.0073***	0.0143***
	(0.0028)	(0.0021)	(0.0036)
Estimation Method	IV	IV	IV
Clustered Std. Errors	Yes	Yes	Yes
District-time fixed effects	Yes	Yes	Yes
Industry-time fixed effects	Yes	Yes	Yes
R^2	0.874	0.642	0.794
Observations	2117	2117	2117

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV estimation of equation (2), where we calculate employment shares by industry group aggregation. Sample includes observations from 1895 and 1907 for seventeen districts. Grand Duchy of Oldenburg (Duchy of Oldenburg, Principalities of Birkenfeld and Luebeck) assigned to district 5.

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