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Keywords: Firm heterogeneity, skill premiums, wage inequality, worker heterogeneity

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1. Introduction

Theoretical and empirical investigation into the effect of trade on wages and wage inequality has progressed to find that the presence of worker and firm heterogeneity within sectors could increase wage dispersion across workers and firms. The wage effect of trade with worker heterogeneity, usually reflected in their skill set, has its theoretical background in a wide trade theory base, and rich evidence about the change in skill premium has been obtained thus far from burgeoning firm- and worker-level studies during the 2010s. As for the effect of increasing imported intermediate inputs, Amiti and Cameron (2012) show that it reduces the skill premium in Indonesia. However, results from Hummels et al. (2014) for Denmark; Carluccio et al. (2015) for France; and Chen et al. (2017) for China, show that raising intermediate inputs increase the skill premium. Increasing export also leads to a higher skill premium, as shown by Verhoogen (2008) for Mexico and Hummels et al. (2014) for Denmark. Evidence for the effect of the strengthening of import competition in the domestic final goods market on skill premiums is mixed: insignificant in Amiti and Cameron (2012) for Indonesia, a decrease in Dix-Carneiro and Kovak (2015) for Brazil, and an increase in demand for skilled workers in Kasahara et al. (2016) for Indonesia.

The effect of trade on wage also depends on firm heterogeneity, which stems from firms' productivity and trade status; it produces different wage effects by firms mainly because of the worker–firm matching mechanism and labor market friction and the ability to upgrade technology. Amiti and Davis (2012) present a theoretical framework to explain that a decline in output tariffs lowers wages at import-competing firms, but boosts wages at exporting firms; this is supported empirically by Indonesian data. Structural estimation by Ritter (2015) for Canada and Helpman et al. (2017) for Brazil, incorporating both worker and firm heterogeneity, shows that trade increases wage inequality.

This study takes a different approach to the issue about the causality from international trade to wages and wage inequality from preceding studies: comparing annually the actual wage inequality with the hypothetical wage inequality predicted from international trade and estimates of wage regression. The benefit of this approach is that it enables researchers to evaluate how much the prediction from international trade explains the actual wage dynamics on a yearly basis, and it incorporates a higher frequency of comparison between predicted and actual figures than previous studies. Predicted wage disparities cover 15 years from 1998 to 2013, and they are calculated from annual changes in international trade. Parameters for calculating wage disparities are obtained from regression results of hourly wage by using worker–establishment panel data. I conduct this research by employing a dataset of Japanese manufacturing workers.

Two kinds of trade activities are considered in this study: imports into domestic final goods markets and exports, both by industry. In addition, firms' sizes and workers' skills are considered and can therefore explain the change in wage inequality between industry–size–skill groups. Different trade effects on workers' wages are observed with respect to firm sizes, skill groups, and import sources. The study's estimation on wage change is consistent with the prediction of trade theories that, by combining the effects of imports and exports, the estimated wage increase is larger for workers in industries where Japan has a comparative advantage. More specifically, they are the workers who gain higher wages and are presumably working for large, highly productive firms in industries where Japan exports more to the world and imports less from Asia than other industries. However, the estimated wage effects of trade differ largely depending on the choice of trade indexes. In the case of Japan, use of logarithmic real trade value predicts a positive wage effect of international trade larger than use of the trade exposure ratio. Relating to this point, I argue that log real trade value is an appropriate trade index in the context of my dataset. It is also shown that the change of wage inequality predicted from actual changes in Japanese trade does not succeed well in explaining the actual change of wage inequality between industry–size–skill groups in a hypothetical population of Japanese manufacturing workers. This result indicates that international trade has a marginal effect on actual wage inequality compared with other shocks, even though potentially international trade would widen wage inequality in Japan.

The rest of this paper is structured as follows. Section 2 describes wage panel data of Japanese manufacturing workers constructed for this study and the annual change in wage inequalities calculated from this set of data. Section 3 explains the Mincerian wage equation and the base results of estimation used for simulation in next section, while Section 4 calculates the estimated trade effects on wage disparity and discusses the results. Section 5 summarizes the findings and discusses the significance of this research.

2. Data

The study uses three surveys conducted by Japanese ministries to construct worker–establishment panel data and to obtain the reproduced population of Japanese manufacturing workers. Worker data, including wage and worker attributes, are from *The Basic Survey on Wage Structure* (hereafter, *The Wage Survey*) from 1998 to 2013 for worker–establishment–year data, whereas information from *The Establishment and Enterprise Census* in 1999, 2001, 2004, 2006 and *The Economic Census for Business Frame* in 2009 (hereafter, both referred to as *The Censuses*) are used to construct panel data of the establishment.

The Wage Survey aims to provide a picture of the wage structure for employees in Japan. The Ministry of Health, Labour, and Welfare conducts this survey annually, targeting private establishments with five or more regular employees and public establishments with 10 or more regular employees. The population for this survey comprises roughly 1.4 million establishments and approximately 37 million employees nationwide. The survey uses a two-stage stratified sampling method, with the establishments as the primary sampling unit and the workers as the secondary. Sampling ratios are recorded on each observation of *The Wage Survey*.[1] About 75,000 establishments and 1.6 million employees are sampled every year. The survey items include each employee's

[1] Sampling ratios were determined so as to let standard error rates of the average scheduled cash earnings of a regular employee be less than five percent for prefecture, industry, and size of enterprise in the national scale statistics.

monthly contractual cash earnings, annual special cash earnings, years of job tenure, age, gender, school career, and workplace information. This survey is carried out in July, and therefore the information for each item is essentially a reflection of the labor market conditions in June of the survey year, with the exception of annual special cash earnings, which record the value provided to each employee in the previous year. The observations in *The Wage Survey* also contain an industry classification for establishments and the employment size for establishments and firms.

The Censuses conducted by the Statistics Bureau, Ministry of Internal Affairs and Communications cover all establishments and firms in Japan. They record basic information on each establishment such as name, address, telephone number, and the number of workers, and they serve as the master sampling framework for statistical surveys including *The Wage Survey*. Until 2006, *The Establishment and Enterprise Census* was conducted every two to three years. Afterwards, it was incorporated into *The Economic Census for Business Frame* launched in 2009 and *The Economic Census for Business Activity* launched in 2012.

The practice of constructing worker–establishment panel data occurs as follows (see also Figure 1 of Endoh, 2018). Each wage observation in *The Wage Survey* contains an identification (ID) number for the establishment at which workers are employed. Establishment ID numbers in *The Wage Survey* were assigned by *The Censuses* conducted several years ago. Since establishment ID numbers change in every census, the establishment ID number for a particular establishment in *The Wage Survey* also changes every two to four years. However, I can trace back a series of ID numbers for each establishment because *The Censuses* of and after 1999 contain ID numbers for all establishments for both current and previous censuses. I construct panel data on establishment ID numbers by using the five censuses from 1999 to 2009, making it possible to trace the ID numbers of each establishment in *The Wage Surveys* from 1998 to 2013. The panel variable of this data is the establishment, not the worker, since *The Wage Survey* contains information on annual randomly selected establishments and workers from the population and does not include any identification information to enable workers to be considered as a panel variable.

Each observation of *The Wage Survey* conducted in year *t* includes attributes of that worker in year *t*, some figures concerning monthly wages and working hours in June of year *t*, and annual special cash earnings paid to that worker in year *t*-1. I obtain an hourly wage as follows. First, an annual income in year *t* is calculated to sum 12 times the monthly wage in June of that year and the annual special cash earnings paid in the previous year. Monthly wages and annual special cash earnings are deflated by the Japanese GDP deflator of the corresponding years. Then, an hourly wage in year *t* is obtained to divide the annual income in year *t* by 12 times the monthly working hours in June of year *t*. This hourly wage is considered as an index of workers' wage, and is used to estimate the effect of trade on wage.

The study assumes that the calculated hourly wage of workers in industry *k* in year *t* is affected by international trade of goods in the same industry in year *t*-1 based on the hypothesis that import competition in the domestic final goods market of and exports by industry *k* in year *t*-1 would affect performance of establishments classified in the same industry in the same year, and then would change workers' bonuses in year *t*-1 and their monthly wages in June of year *t*. An establishment's industry is fixed at the industry in which that establishment first appears in *The Wage Survey* conducted on and after 1998. The constructed Japanese manufacturing worker–establishment panel data cover the periods 1997 to 2012 for trade and 1998 to 2013 for hourly wage. After constructing the panel data, some observations that are considered as unsuitable for the analysis were deleted, such as observations of workers aged 60 years or older, those of part-time workers, and those of workers whose tenure year is zero. [2] The final sample contains about 4.2 million worker–establishment–year observations.

[2] The criteria for deleting observations are as follows. First, for the characteristics of an establishment, only observations for private establishments in the manufacturing industry were used. Second, for workers' status, observations for workers aged 60 years and older were removed, because the age–wage profile in Japan is discontinuous at 60 years of age, owing to the mandatory retirement system in Japanese firms. Observations for part-time workers were removed because they do not include school career information, which is used as one proxy for skilled workers. In addition, observations of workers whose tenure year is zero were removed, because most of them do not receive special cash earnings, a component of annual earned income, in the previous year. Third, observations that meet the following conditions were deleted, since the working schedules of these workers are considered not to match their employment contract, or their contracts are rather exceptional: workers with less

In this paper, both imports and exports are used as independent variables in a regression equation in order to grasp the trade effect on wage in a general equilibrium manner. Imports were divided into those from Asia and those from Europe and North America for possible difference of adjustment induced by imports from these regions. I assume that imported goods from Asia affect establishments' performance through three characteristics, which are different from imports from Europe and North America. First, imported goods from Asia have the characteristic of low-quality and low-price, therefore they would compete directly with Japanese goods produced by small or low-TFP establishments. Second, some goods from Asia are used as intermediate inputs in domestic production by Japanese firms that have developed production network among firms in Asian countries. These firms therefore could benefit from imports from Asia. Third, until 2007 of the analyzing period, imports from Asia had expanded so rapidly that some establishments had difficulties in coping with them and subsequently reduced operations. These establishments include those with a rigid corporate system, those with a poor managerial strategy, those unable to produce new and differentiated products, and so on. Imports from areas other than Asia, Europe, and North America are not considered explicitly, because manufacturing goods imports from these origins account for less than 10 percent of the total Japanese manufacturing imports; they are strongly biased toward items related to mineral resources, including fossil fuels.

Two forms of trade indexes were used in this study, namely: the trade exposure ratio and the logarithmic real trade value, for expressing import competition from Asia for industry *k* in year *t* in Japan, J_{kt}^{imA}; import competition from Europe and North America, J_{kt}^{imEN}; and export from Japan, J_{kt}^{ex}. First, the trade exposure ratio of import and export was defined as:

than 15 or more than 26 working days in a month, workers with less than six or more than nine average scheduled working hours per day, and annual special cash earnings of more than eight times the following year's monthly wages.

$$J_{kt}^{imA}=\frac{IM_{kt}^{A}}{Y_{k96}+IM_{k96}-EX_{k96}},\quad J_{kt}^{imEN}=\frac{IM_{kt}^{EN}}{Y_{k96}+IM_{k96}-EX_{k96}},\quad J_{kt}^{ex}=\frac{EX_{kt}}{Y_{k96}+IM_{k96}-EX_{k96}}, \quad (1)$$

where IM_{kt}^{A}, IM_{kt}^{EN}, and EX_{kt} are real values of Japanese imports from Asia, Japanese imports from Europe and North America, and Japanese exports, respectively, of goods in industry *k* in year *t*, and $Y_{k96}+IM_{k96}-EX_{k96}$ is the total supply of goods in industry *k* to the Japanese market in 1996, one year before the initial year of the analysis, which is composed of domestic production Y_{k96}, the total imports IM_{k96}, and the total exports EX_{k96}. The following are deflated by trade goods price indexes: IM_{kt}^{A}, IM_{kt}^{EN}, and EX_{kt}. Studies that use varieties of these indexes as an independent variable include Bernard et al. (2006), Autor et al. (2014), and Bloom et al. (2016), for example, though they do not deflate their trade values. Second, the log real trade value is simply the logarithm of IM_{kt}^{A}, IM_{kt}^{EN}, and EX_{kt}:

$$J_{kt}^{imA}=\ln IM_{kt}^{A},\quad J_{kt}^{imEN}=\ln IM_{kt}^{EN},\quad J_{kt}^{ex}=\ln EX_{kt}. \quad (2)$$

This index is also interpretable as the log form of trade exposure ratio in equation (1), with the log of $Y_{k96}+IM_{k96}-EX_{k96}$ being a constant variable. Log trade value are used in Hummels et al. (2014) and Endoh (2018), for example; note that the former is in the context of firms' import of intermediate inputs and not deflated by price indexes. The Japanese import data were obtained from the Customs and Tariff Bureau, Ministry of Finance, Japan. Y_{k96} is obtained from *The Basic Survey of Japanese Business Structure and Activities* by the Ministry of Economy, Trade and Industry, Japan. Price indexes of exports and imports by trading partners (the base year is 2005) are obtained from *Trade Index Numbers for Unit Value, Value, Quantity, and Terms of Trade*, provided on the website of the Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO).[3] The

[3] The price index of imported goods from Asia is the average of that from China, newly industrializing economies (Hong Kong, Singapore, South Korea, and Taiwan), and four countries in the Association of Southeast Asian

manufacturing sector is broken down into 50 industries.

Figure 1 shows trade indexes by industry and by percentile of hourly wage in the first year of constructed panel data, that is, 1997 of trade and 1998 of income. The sample is the hypothetical population of manufacturing workers, constructed by multiplying the observations by the inverse of the sampling ratio, after trimming the observations which fall into categories explained in Footnote 2. The vertical axis of Panel A is the trade exposure ratio and that of Panel B is the log real trade value for 50 industries, whereas the horizontal axis of both figures is the averages of the log hourly wage by industry. We see the tendency in this panel that industries of higher average income record higher indexes for exports and lower indexes for imports from Asia.

However, trade exposure rations in Panel A contain some outliers, especially for exports. They include J_{k97}^{ex} = 1.989 in miscellaneous precision instruments, 1.540 in optical instruments and lenses, and 1.431 in metal working machinery. There are two views on these outliers. One is that they actually reflect real-life situations, and the other is that they result from the difference of defining industry for establishments and for trading goods. Elaborating the latter view, an establishment's industry is defined by its main business activity, whereas the industry classification of trading goods is based on their codes assigned by the Harmonized Commodity Description and Coding System. Outlier industries occur in situations where there are relatively few establishments operating their main business in these industries and therefore Y_{k96} for such outlier industries is small, while many other establishments in different industries produce and export products classified as these outlier industries. Later, I run the regression with and without three outlier industries as samples.

Instead of using averages by industry, Panels C and D use the percentile of hourly wage and show the relationships between two kinds of trade indexes and log hourly wage, both are the average values by percentile of hourly wage, in the hypothetical population of manufacturing workers in 1998. The relationships are shown

Nations (Indonesia, Malaysia, the Philippines, and Thailand), weighted by import values. The import price indexes of Europe and North America are that of the US and EU, respectively. As for exports to the world, the export price index to the world in the dataset of IDE-JETRO is directly used. The author employs the unit value index of the Fischer formula.

much clearer and smoother than Panels A and B: Higher-income workers tend to be working for industries with higher indexes for exports and lower indexes for imports from Asia. However, indexes for imports from Asia change little for workers with upper half of hourly wage in Panels C and D.

<< Insert Figure 1 here >>

The evolution of wage inequality and manufacturing trade in Japan is depicted in Figure 2. Panel A shows three figures: total wage inequality, wage inequality between industry–size–skill groups, and wage inequality between tenure groups, in a hypothetical population of Japanese manufacturing workers. Industry–size–skill groups comprise 50 industries, three categories of firm size, and eight groups of worker skills. The cut-off numbers of employees for classifying small, medium-sized, and large firms are 100 and 1,000. There are three dummies indicating skilled workers: college graduates, non-production workers, and supervisors (the definitions are explained later). The total number of combinations concerning dummies of the three skill categories is eight. These firm size and worker skill classifications are used as indexes of firm and worker heterogeneity in this study, and they determine wage inequality between industry–size–skill groups. Each year's sample is constructed in the same way as that for Figure 1: multiplying the observations of manufacturing workers in that year by the inverse of the sampling ratio, after trimming the observations. Total wage inequality in year *t*, T_t, and its within and between components, W_t and B_t, respectively, where $T_t = W_t + B_t$, was calculated using the following definition from Helpman et al. (2017).

$$T_t = \frac{1}{N_t}\sum_m \sum_{i \in m}\left(y_{it} - \overline{y}_t\right)^2, \; W_t = \frac{1}{N_t}\sum_m \sum_{i \in m}\left(y_{it} - \overline{y}_{mt}\right)^2, \; B_t = \frac{1}{N_t}\sum_m N_{mt}\left(\overline{y}_{mt} - \overline{y}_t\right)^2.$$

Here workers are indexed by *i*; *m* denotes industry–size–skill groups or tenure groups; N_t and N_{mt} denote the overall number of workers and the number of workers within group *m*; y_{it}, $\overline{y}_{mt}$, and $\overline{y}_t$ are the log hourly wage, the average log hourly wage within group *m*, and the overall average log hourly wage.

On Panel A, wage inequality between industry–size–skill groups shows an increasing trend from 0.092 in 1998 to 0.112 in 2007, after which it fluctuates toward 0.102 in 2013. On the other hand, between tenure wage inequality decreases from 0.081 in 1998 to 0.074 in 2004, then it exhibits a fluctuation between 0.084 in 2007 and 0.073 in 2011. Wage inequality between tenure groups strongly reflects demographic factors in labor force, and Kambayashi et al. (2008) explain that the decreasing period of between tenure wage inequality for a larger proportion of workers with longer years of tenure decreases the returns to tenure. Panel B shows $IM_{k\tau}^{A}$, $IM_{k\tau}^{EN}$, and $EX_{k\tau}$ deflated by trade price indices, from 1997 to 2012. An approximately 10-year period since the start of the period of analysis is characterized by the expansion of both Japanese trade and wage inequality between industry–size–skill groups. On the other hand, approximately the last five years are characterized by the fluctuation of wage inequality indexes and the drop and the stagnancy of Japanese trade because of the Great Recession and the 2011 Tohoku earthquake. This paper examines in Section 4 whether the change in wage inequality between industry–size–skill groups is explained by international trade.

<< Insert Figure 2 here >>

3. Estimation

The following Mincerian wage equation is used to estimate the effect of trade on wages:

$$y_{ijt} = \sum_{n=imA,imEN,ex} \left(\beta^n + \boldsymbol{\beta}^{\mathbf{n}}_{\mathbf{df}}\mathbf{d}_{\mathbf{fjt}} + \boldsymbol{\beta}^{\mathbf{n}}_{\mathbf{dw}}\mathbf{d}_{\mathbf{wit}}\right) J^n_{kt-1} + \mathbf{B}_{\mathbf{x}}\mathbf{x}_{\mathbf{wit}} + \mathbf{B}_{\boldsymbol{\phi}}\boldsymbol{\phi} + \varepsilon_{ijt} \tag{3}$$

where y_{ijt} is the log hourly wage for worker *i* working for establishment *j* in year *t*; J^n_{kt-1} is the trade index for the Japanese manufacturing industry *k* that establishment *j* belongs to in year *t*-1; $\mathbf{d}_{\mathbf{fjt}}$ and $\mathbf{d}_{\mathbf{wit}}$ are vectors of firm- and worker-level dummies, respectively, used as interaction terms with trade indexes; $\mathbf{x}_{\mathbf{wit}}$ and $\boldsymbol{\phi}$ are vectors of worker-level and fixed effect variables, respectively; and ε_{ijt} is the error term.

Since trade indexes are consider to be endogenous with respect to wages, the method of instrumental variables (IV) is employed here to address this problem.[4] A recent strand of the literature shows IV can be constructed using demand and supply shocks from the rest of the world (Hummels et al., 2014; Carluccio et al., 2015). I follow this procedure and use three world export supply and import demand indexes as IV for J^{imA}_{kt}, J^{imEN}_{kt}, and J^{ex}_{kt}. In the form of both trade exposure ratio and log real trade value, IM^A_{kt}, IM^{EN}_{kt}, and EX_{kt} in equations (1) and (2) were replaced by WEX^A_{kt}, WEX^{EN}_{kt}, and WIM_{kt} to produce new indexes W^{exA}_{kt}, W^{exEN}_{kt}, and W^{im}_{kt} for IV where WEX^A_{kt} represents the total exports from Asia to the world except to Japan, WEX^{EN}_{kt} represents the total exports from Europe and North America to the world except to Japan, and WIM_{kt} represents the total imports by the world except by Japan, of goods classified in industry *k* in year *t*. Each of these world trade scenarios affects a corresponding Japanese trade. World trade data were obtained from the World Integrated Trade Solution, and deflated by trade goods price indexes that were constructed from the afore-mentioned data of IDE-JETRO.[5]

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[4] Other methods to address the endogeneity include using an appropriate natural experiment. However, this approach is not applicable to Japan as well as other countries which have had relatively smaller change of trade policy for decades. In the case of Japan, its tariff rates have already been at a low level (except for agricultural and marine products) over the past two or more decades, resulting in little variation in tariff rates. In addition, though Japan has concluded 15 free trade agreements (FTAs), effective as of 2017, the share of imports and exports with FTA partners represents only less than a quarter of the total Japanese trade, and their tariff variations are supposed to be endogenous to Japanese industries, firms, and workers.

[5] Eight kinds of world trade goods price indexes were constructed: exports and imports, by four regions. In each of the four regions, I choose two to three large sourcing countries to Japan from each region and calculate the weighted average of export and import Fischer indexes by goods category and year: China, South Korea, and Malaysia from Asia, the US and Canada from North America, France, Germany, and the UK from Europe, and Australia, Brazil, and Mexico for the rest of the world.

The estimation equation also includes column vectors of firm-level dummies $\mathbf{d_{fjt}}$ and worker-level dummies $\mathbf{d_{wit}}$ as interaction terms. $\mathbf{d_{fjt}}$. contains two dummies, d_{sm} and d_{sl}, about the size of a firm to which an establishment belongs: $d_{sm} = 1$ if the firm is medium-sized with between 100 and 999 employees, and $d_{sl} = 1$ if the firm is large, with 1,000 or more employees. $\mathbf{d_{fjt}}$ represents three aspects of Japanese firms with respect to international trade, which are documented in Wakasugi et al. (2014). First, larger firms tend to pay higher wages, and they attract talented workers who render the firms more immune to tougher competition. Second, larger firms tend to engage in exports and imports by themselves. While increased overall imports may decrease wages as a result of tougher final market competition, firms that import intermediate inputs may benefit from it. Further, exporting firms could reap additional benefits from foreign markets. Third, larger firms tend to have higher total factor productivity (TFP). Firms with high TFP are expected to be better able to cope with imported goods from foreign countries. International trade possibly affects domestic firms' size, but this study assumes that only the marginal number of firms change their size dummies according to international trade. [6]

Three dummies in $\mathbf{d_{wit}}$ are used to represent each definition of skilled labor, obtained from *The Wage Survey* and widely used in previous literature: college graduates d_{cg}, non-production workers d_{np}, and supervisors d_{sv}. Workers who graduated from higher-level vocational schools, junior colleges, colleges, and graduate schools are classified as college graduates; workers recorded as clerical and technical workers are classified as non-production workers; and workers in supervisory but not management positions are classified as supervisors. Note that the dummy for non-production workers is recorded in the establishment if its number of employees is 10 or more, and that the dummy for supervisors is recorded in the establishment if its firm has 100 or more employees. The coefficients on the interaction terms with respect to firm sizes and worker skills could

[6] Some firm variables possibly have endogeneity with their industries' import competition and export volumes. I assume the classification of firm size used in this study—small, medium-sized, and large firms—is affected little from international trade and therefore is able to be treated as exogenous, because it is safe to estimate that only a limited number of firms change their number of employees by trade shocks large enough to shift their firm-size status among three groups.

measure how establishment and worker heterogeneity affect the wage effect of trade. $\mathbf{x}_{wit}$ includes workers' attributes for explaining their wage profile, and $\boldsymbol{\phi}$ is a column vector of fixed effect variables to absorb the characteristics of the Japanese labor market and the transition of its structure.[7] Firm-level variables, such as output and capital, were not included in equation (3), since the study intends to observe the total wage effects of import competition after these firm-level variables were adjusted by firms.[8]

The descriptive statistics for some variables are summarized in Table 1. Three variables about trade exposure ratio all have the coefficient of variation (the ratio of the standard deviation to the mean) of more than one, and their distributions are heavily right-skewed. This is not an idiosyncrasy of this dataset: Autor et al. (2014) use trade exposure ratios as independent variables, and their Table 1 reports that these indexes are also heavily skewed. For three indexes of log real trade value, on the other hand, their coefficients of variation are very small, and their distributions are skewed only lightly.

[7] The complete list of worker-level variables is as follows. (1) Variables for wage profile: years of potential work experience and its square, and years of job tenure and its square. (2) Dummy variables for workers' characteristics: junior high school graduate, senior high school graduate, higher-level vocational school or junior college graduate, college or graduate school graduate, senior management level, middle management level, lower management level, crew leader or equivalent, other supervisory level, specialist, non-production worker, fixed-term employment, and female. (3) Differences in wage profiles reflect worker and industry characteristics: interaction terms with each variable in (1) and each variable in (2), and interaction terms with each variable in (1) and each dummy for the 50 industries. Establishment j's industry l is fixed at the industry in which establishment j first appears in the constructed panel data. Workers' years of potential work experience are calculated by subtracting the assumed age when workers graduated from school with their highest educational level from the present age. The assumed age of graduation is 15 years for a junior high school graduate, 18 years for a senior high school graduate, 20 years for a higher-level vocational school or junior college graduate, and 22 years for a college graduate. *The Wage Survey* does not distinguish between workers who have graduated from graduate schools versus colleges in the questionnaire and, thus, graduate school graduates are considered as college graduates in this calculation. The fixed effect variables comprise three types. The first set of dummies is to absorb fixed effects by age group, gender, and year. Here, workers were categorized by their age in years into 10s, 20s, 30s, 40s, and 50s, and were subdivided by gender and then by years. Second, manager–year dummies were incorporated. Senior and middle managers are regarded as employers, and their labor contract is different from that of employees. These dummies are used to consider the changing wage gap between management and other workers, which reflects the gradual shift of the basis of the wage system for management in Japanese firms from seniority to performance. Third, female–prefecture dummies absorb the wage gap between male and female workers in each prefecture.

[8] Other firm-level variables such as firms' volume of international trade and firms' TFP are also not incorporated in the worker–establishment panel data constructed in this study. Though these variables are available from other Japanese statistics, these statistics do not cover most of the small firms and therefore incorporating other firm-level variables from them obscures most of the observations belonging to small firms. This causes seriously biased results for income inequality.

<< Insert Table 1 here >>

Table A1 in Appendix and columns (1) and (2) of Table 2 summarize the first- and second-stage estimation results where all five firm size and worker skill variables are employed. Table A1(1) shows the first-stage results for column (1) of Table 2 (the trade index is trade exposure ratio) and Table A1(2) does so for column (2) of Table 2 (the trade index is log real trade value). I find that $W_{k\tau}^{exA}$, $W_{k\tau}^{exEN}$, and $W_{k\tau}^{im}$ all generally have high explanatory power for $J_{k\tau}^{imA}$, $J_{k\tau}^{imEN}$, and $J_{k\tau}^{ex}$, in both trade indexes. In addition, most of the estimates of the interaction terms of $W_{k\tau}^{exA}$, $W_{k\tau}^{exEN}$, and $W_{k\tau}^{im}$ with each firm or worker variable are statistically significant in the regression equations where the dependent variables are the interaction terms of $J_{k\tau}^{imA}$, $J_{k\tau}^{imEN}$, and $J_{k\tau}^{ex}$ with that variable.[9] These results show that Japanese trade variables by industry are well explained by IVs, which reflect the overall tendency of the international transaction in the same industry. Moreover, the null hypothesis of weak instruments was rejected, since the Cragg–Donald Wald F statistics for the weak identification in Table 2 were all sufficiently high.

Table 2 reports the second-stage results of the fixed effects (FE)-IV regression of equation (3). Column (1) represents the case in which the trade index is the trade exposure ratio. The coefficient of imports from Asia is – 0.1685, meaning that a 0.01 point increase in the import exposure ratio from Asian countries decreases base workers' wage by 0.17 percent. However, this negative effect disappears for medium-size firms and even becomes positive for large firms, with the coefficient of their interaction term being 0.1522 and 0.4458, respectively. This vividly shows the interaction between imported goods from Asia and Japanese firms. Smaller firms tend to have lower TFP in Japan, therefore their products, supposedly low-quality and low-price, are close substitute for imported goods from Asia. Also, low-TFP small firms struggle to innovate their products as well as themselves to

[9] For example, all three interaction terms with college graduates in column (4) of Table A1(1) (the dependent variable is the interaction term of Japanese imports from Asia and college graduates) have estimates that reach statistical significance at the one percent level. See Table A1 in Appendix.

cope with strengthening import competition from Asia. On the other hand, some large firms which have developed production networks among Asian countries use imports from Asia as intermediate inputs in domestic production in order to improve production efficiency. In addition, large firms with high TFP could use tougher import competition as the medium to innovate themselves. The skill premiums with respect to three skill definitions all grew with the increase of imports from Asia; this probably reflects the fact that unskilled labor is intensively embodied in imported goods from developing countries.

The coefficient of imports from Europe and North America for the base group is positive, but this positive effect disappears for workers in large firms. One interpretation is that imported goods from developed countries are a close substitute for products of large Japanese firms, whereas they bring new technologies to small Japanese firms. The other a subset of imports from Europe and North America is a substitute to those from Asia, and the increase of the former pushes down the latter, alleviating negative wage effect of imports from Asia for small firms. Exports do not have positive effects on wages for workers in small and medium-sized firms, because most Japanese exports are by large firms. In addition, the absolute values of estimates of exports and their interaction terms are smaller than those of the two sets of import variables. I argue that this is because the increase of exports is accompanied by longer working hours in Japan, with hourly wage changing only slightly. Most coefficients in column (1) are statistically highly significant.

Column (2) represents the case when the trade index is a log real trade value. Coefficients indicate the percentage wage change induced by one percent increase in imports and exports. Most coefficients have a generally high statistical significance, similar to the ones in column (1), with their positive or negative signs being the same as those of the correspondents in column (1). Coefficients of imports from Asia and those from Europe and North America in column (2) are about one tenth of those in column (1) (-0.0203 to -0.1685, and 0.0495 to 0.6265). This means that the trade exposure ratio and the log real trade value produce similar wage effects when the trade exposure ratio is around 0.1, because a 0.01 point increase in the trade exposure ratio from 0.1 to 0.11 implies a

10 percent increase in real trade value. The Cragg–Donald Wald F statistic is higher in column (2) than that in column (1), and coefficients of determination are similar in both columns.

Columns (3) and (4) are the case when three industries whose trade exposure ratio of export is more than one (that is, miscellaneous precision instruments, optical instruments and lenses, and metal working machinery) are deleted from the dataset as outliers. The absolute values of estimates regarding a set of imports from Europe and North America and a set of exports become remarkably larger in columns (3) than in column (1), comparing the cases of using trade exposure ratio as trade index. Whereas, comparing the cases of using log real trade value as trade index, coefficients in columns (4) are quite similar to those in column (2).

Columns (5) through (10) are the results of estimation using a full dataset of 50 industries but a part of independent variables in columns (1) and (2). Columns (5) and (6) represent the case in which all the interaction terms of firm size and worker skill with import index are eliminated; columns (7) and (8) represent the case when only firm sizes are considered as interaction terms; and columns (9) and (10) reflect the case when only worker skills are considered as interaction terms. These results are used to obtain the estimated change of wage dispersion in the next section, in the case that only a partial set of independent variables are considered in the regression equation.

<< Insert Table 2 here >>

4. Trade effects on wage inequality

The wage effect of trade on the population of Japanese manufacturing workers in 1998 is predicted by using the second-stage FE-IV estimates and the actual changes in Japanese exports and imports by industry. The total amount of predicted wage changes for worker *i* in establishment *j* from 1998 to 1998 + *T* was calculated from the following equation:

$$\widehat{\Delta y_{ij}} = \sum_{n=imA,imEN,ex} \left(\hat{\beta}^n + \sum_{g=sm,sl,cg,np,sv} \hat{\beta}_g^n d_g \right) \Delta J_k^n \, , \tag{4}$$

where $\hat{\beta}^n$ and $\hat{\beta}_g^n$ are estimates in equation (3), and ΔJ_k^n is the change of Japanese trade from 1997 to 1997 + *T*. Each observation was multiplied by the inverse of the sampling ratio to reproduce the population.

Panel A of Figure 3 shows pairs of the 1998 hourly wage and the average estimated changes in income for the following 15 years to 2013 for each percentile, for both the trade exposure ratio and the log real trade value as trade index. Estimates in equation (4) are from columns (1) and (2) of Table 2, therefore these estimated wage changes take firm- and worker-heterogeneity into account. This estimation was conducted on the hypothetical population of manufacturing workers in 1998, under the condition that workers in the manufacturing sector all belonged to the same establishment and had the same skill set, from 1998 until 2013. Pairs for both trade indexes are upwardly distributed and cross the $\widehat{\Delta y_{ij}} = 0$ line, meaning that lower income workers decrease their income more by ratio, while higher income workers increase theirs more by ratio, resulting in increased wage inequality by trade. Higher income workers on average export more to the world and import less from Asia, as depicted in Figure 2: this shows the fact that workers in Japanese comparative advantage industries gain more from trade. For workers whose hourly wage is more than the 25th percentile, pairs in the case of log real trade value as trade index distribute in higher place than those in the case of trade exposure ratio. Average changes in the log hourly wage in the cases of trade exposure ratio and log real trade value are – 0.0094 and 0.0095, respectively. That is, the hourly wage of Japanese manufacturing workers is estimated to decrease by one percentage on average for 15 years when the trade exposure ratio is used as a trade index, while increasing by one percentage when log real trade value is used, owing to Japanese international trade.

<< Insert Figure 3 here >>

Panel B represents how deleting three outlier industries changes the results of Panel A. It was calculated by the same method as for Panel A by using estimates in columns (3) and (4). Compared with Panel A, the distribution of symbols for the case of log real trade value shift upward, while those for the case of trade exposure ratio shift downward, and the change of the latter is larger than that of former. Average changes in the log hourly wage in the cases of trade exposure ratio and log real trade value are – 0.0277 and 0.0191, respectively: the former figure is lower than the correspondent in Panel A by 0.0183, and the latter figure is higher by 0.0096.

In this research, I choose log real trade value as a base trade index and use the results in column (2) of Table 2 as baseline results. This choice comes from the fact that trade exposure ratios have disadvantages of extremely large coefficients of variation and of heavily right-skewed distribution. Because of these disadvantages, a few extremely large trade indexes would influence regression results. Actually, excluding three industries with large exposure ratios of export produces remarkably different estimates in column (3) from those in column (1). One might think that trade exposure ratio has the advantage of considering the domestic market size of each industry in the denominator of equation (1). However, the log real trade value in equation (2) is the log form of the trade exposure ratio in equation (1), and its denominator is estimated as a fixed effect of each industry. Note here that I do not claim log real trade values are always better trade indexes than trade exposure ratios: it depends on their statistical characteristics and the theoretical foundation.

Panels C represents the estimated wage effect of exports and imports when the results of columns (6) (without any interaction terms), (8) (with firm-size interaction terms), and (10) (with worker-skill interaction terms) in Table 2 are used. The results without any interaction terms do not include any firm and worker heterogeneity, and therefore reflect only the differences in imports and exports by industry over the 15-year period. The distribution of dots are upward-sloping, but relatively flat compared with Panel A. This means that the differences among the industries in which firms are doing business per se is not a main driving force of trade-induced wage inequality. Also, they are above the $\widehat{\Delta y_{ij}} = 0$ line except the lowest three percentiles, indicating that we would come to conclude international trade benefits almost all workers, if we did not take firm and worker heterogeneity into account. The form of the distribution in the case when only worker-skill interaction terms are considered is almost identical with the case of no interactions, meaning worker heterogeneity produces little wage disparity. On the other hand, the form of the distribution in the case when only firm-size interaction terms are considered is similar to that when both firm-size and worker-skill interaction terms are considered. This distribution indicates that firm heterogeneity is a primary force of wage disparity by trade. The contrast between negligible effect of worker heterogeneity and large effect of firm heterogeneity is presumably peculiar to Japan where labor mobility between firms remains low.

Panel D depicts how firm sizes and worker skills differ between income percentiles. It is clearly shown that, as the wage percentile increases, so does the ratio of college graduates, non-production workers, and supervisors, as well as workers in large firms. Skilled workers are less vulnerable to Asian imports, and workers in large firms are able to increase wages from imports from Asia, as is clearly reflected in Table 2. A largely heterogeneous worker composition by wage percentile produces the stark contrast of the trade effect between high and low wage groups.

International trade also changes wage inequality between industry–size–skill groups, and the estimated change due to trade is calculated by using equation (4). Figure 4 depicts one example of the results. A solid line in the figure is the actual wage inequality between industry–size–skill groups, which is the same one as the long dash line in Panel A of Figure 2. Short and long dash arrows show the predicted annual change of inequality between industry–size–skill groups from a certain year, using the population of that year and the change of trade from that year to the next year, in the case of trade exposure ratio and log real trade value for trade index. For example, examining the left edge of the figure, actual wage inequality between industry–size–skill groups decreased from 0.0921 in 1998 to 0.0897 in 1999. At the same time, predicted inequality is 0.0939 in 1999 using worker population in 1998 and the actual annual change of Japanese trade from 1998 to 1999 when trade exposure ratio is used as trade index, and then is 0.0938 when log real trade value is used. That is, wage inequality is predicted to increase from 1998 to 1999, opposite to the actual change. In total for 15 years, this figure infers that predicted inequalities do not closely follow the actual inequalities. The directions of the annual change of predicted and actual inequalities are opposite in some years.

<< Insert Figure 4 here >>

I run the regression for actual annual change of wage inequality between industry–size–skill groups as a dependent variable to examine statistically whether predicted change can explain the actual change. I consider two independent variables: the annual change of wage inequality between industry–size–skill groups predicted by Japanese trade, and the actual annual change of wage inequality between tenure groups. The latter variable is used to exclude the effect of demographic shift in Japanese manufacturing labor market. Table 3 summarizes the results. There are four sets of regression results: two regressions use predicted change of wage inequality from estimates obtained in the case of trade exposure ratio, and one of them includes a single independent variable, while the other includes two. The remaining two are the cases of log real trade value. In each case, estimates of predicted annual change of wage inequality are not statistically significant. This result indicates that international trade has a marginal effect on actual wage inequality compared with other shocks such as the retirement of baby boomers and the burgeoning of new industries, wherein the trade effect becomes undetectable.

<< Insert Table 3 here >>

5. Conclusion

This study estimates the effect of import competition on the final goods market and export on workers' wage and its inequality, considering both worker and firm heterogeneity by using worker–establishment panel data from the Japanese manufacturing sector. Different trade effects on workers' wages are observed with respect to firm sizes, skill groups, and import sources. This study shows that, by combining the effects of imports and exports, the estimated wage change is positively larger for workers with higher wages who are employed by larger firms, while it is negatively larger for workers of lower wage, regardless of their industries. Firm heterogeneity dominates worker heterogeneity for the trade effect on wage dispersion. However, the estimated wage effects of trade differ largely depending on whether the trade index is in the form of the trade exposure ratio or the log real trade value. In the case of this study, I conclude that the log real trade value is a better index for international trade, and I found that the use of the log real trade value estimates the positive wage effect of trade larger than the use of the trade exposure ratio. One important finding is that the estimated wage dispersion induced by the change in Japanese trade does not fit well with its actual figure in a reconstructed population of Japanese manufacturing workers from 1998 to 2013, even after considering the demographic factors. This implies that international trade has a marginal effect on actual wage inequality compared with other economic and social shocks, though international trade has a potential to increase wage inequality in Japan.

This study is the first to estimate how the wage inequality of workers expands or shrinks with changes in international trade by using estimates of Mincerian wage function, and to observe how this function can explain the actual fluctuation of wage inequality in a population of workers. Significant scope exists for improvement of this study. One of the main limitations is that *establishment* rather than *worker* is used as the panel variable of the dataset featured in this study; therefore, we cannot follow a particular worker's wage and employment. The estimated wage changes depicted in Figure 3 represents the hypothetical changes that workers who had a job at the beginning of the analysis period would see if they continued their employment at the same establishment and with the same skill set. The dynamic aspect of the wage structure through entry and exit of workers induced by trade would be a meaningful future research topic.

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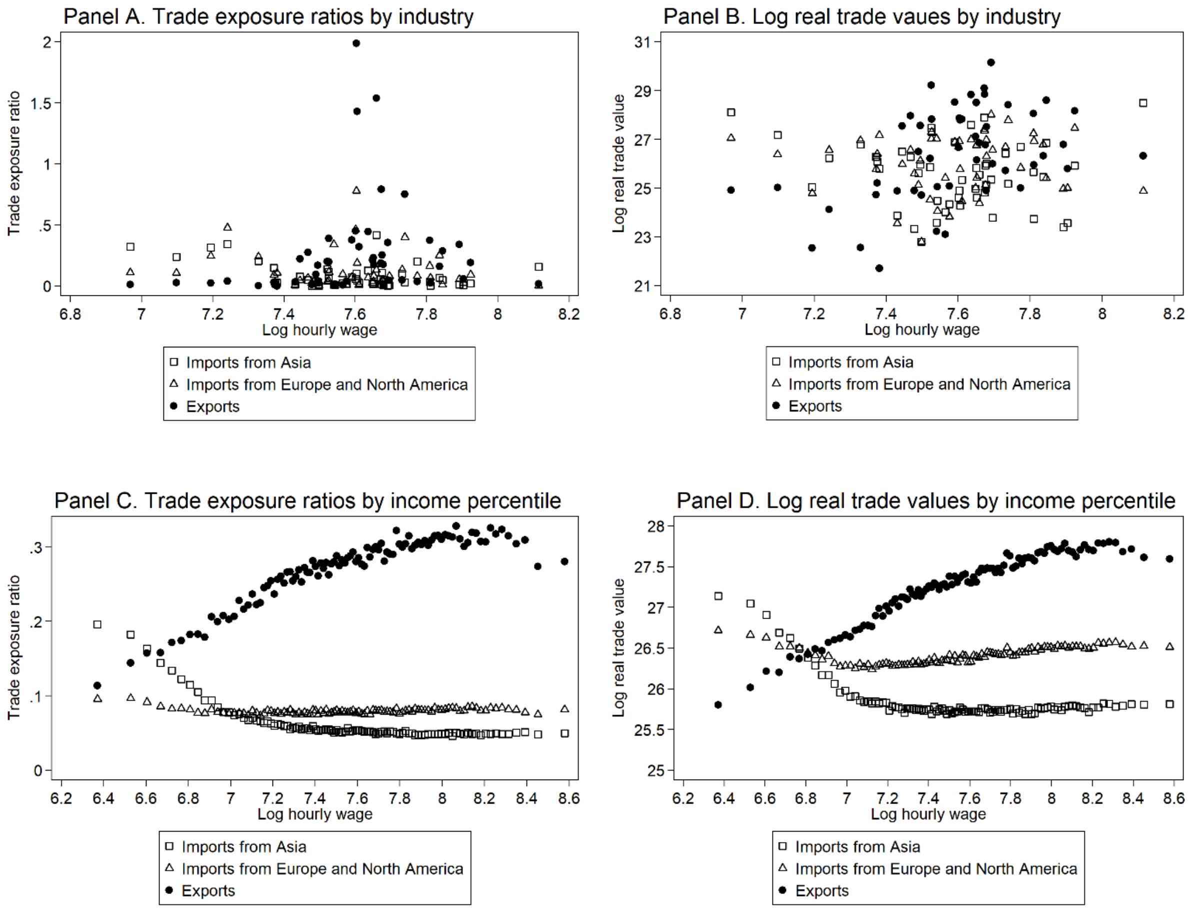
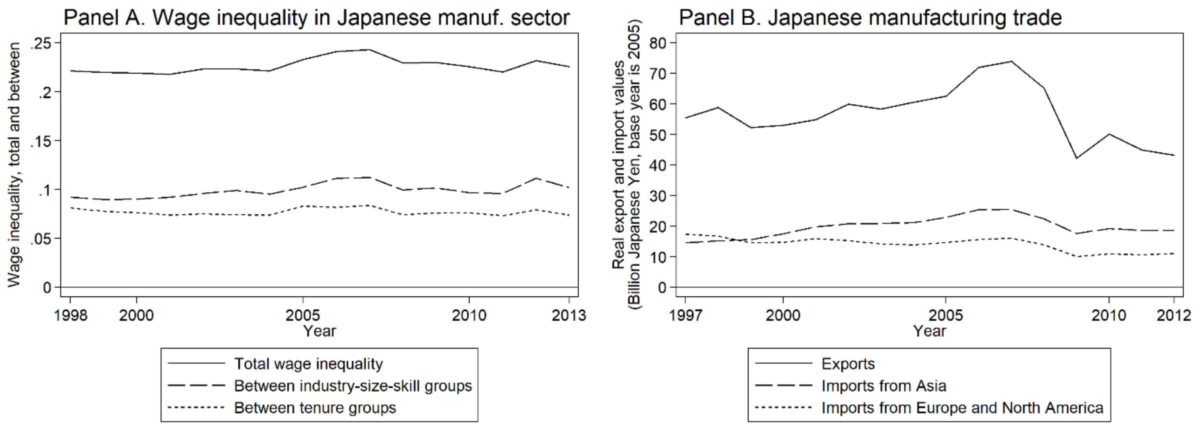
Figure 1. Two trade indexes: Trade exposure ratios and log quantities



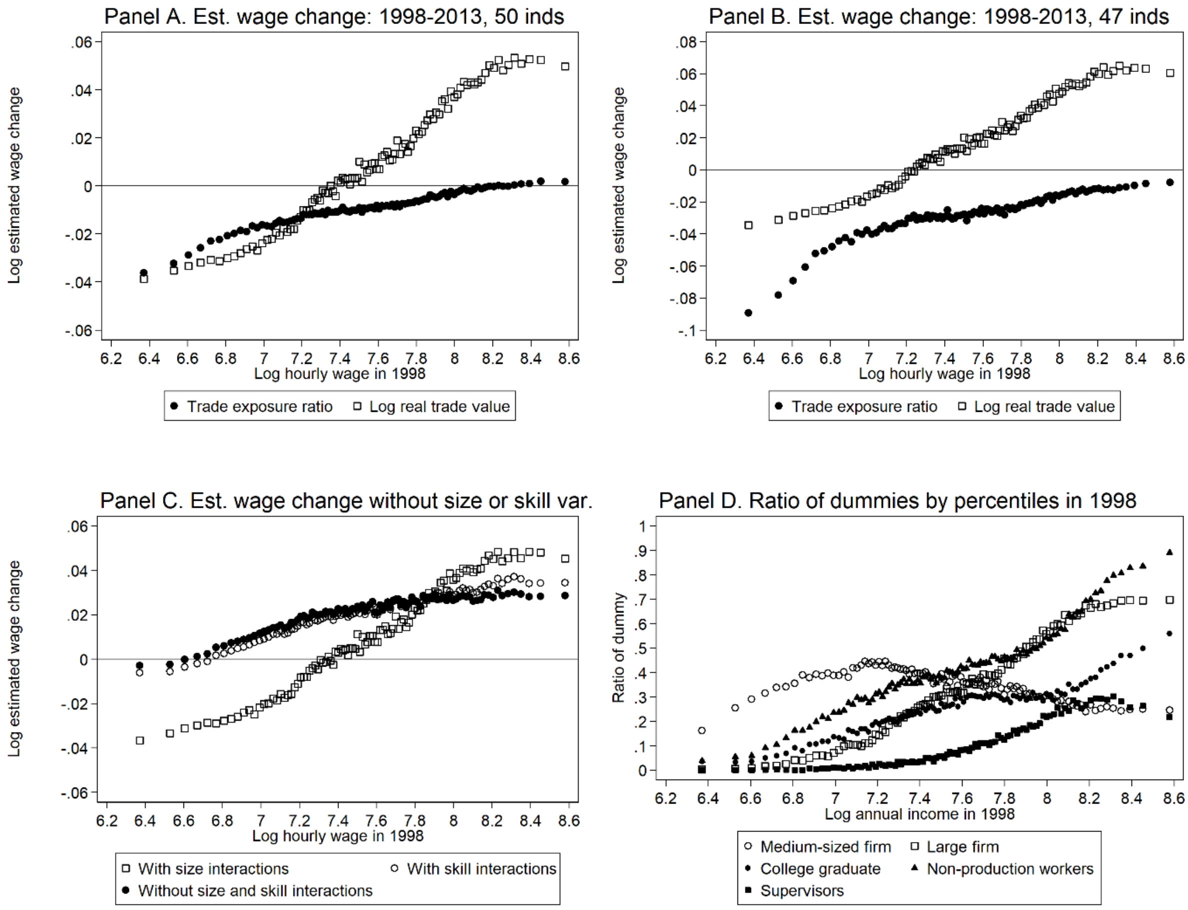
Source: Author's calculations.

Figure 2. Wage inequality and trade



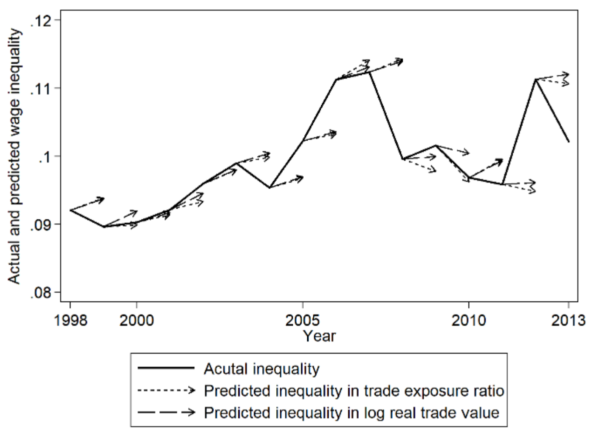
Source: Author's calculations.

Figure 3. Estimated income changes and ratio of dummies by percentiles



Source: Author's calculations.

Figure 4. Predicted wage inequality between industry–size–skill groups



Source: Author's calculations.

Table 1. Descriptive statistics

	Mean	Std. Dev.	Min	Max	P10	P50	P90
Worker-level variables (observations: 4,173,926)							
Log hourly wage	7.586	0.473	4.204	9.975	6.961	7.582	8.215
Medium-sized firms dummy	0.369	0.482	0.000	1.000	0.000	0.000	1.000
Large firms dummy	0.282	0.450	0.000	1.000	0.000	0.000	1.000
College graduates dummy	0.281	0.449	0.000	1.000	0.000	0.000	1.000
Non-production workers dummy	0.393	0.488	0.000	1.000	0.000	0.000	1.000
Supervisors dummy	0.097	0.296	0.000	1.000	0.000	0.000	0.000
Years of job tenure	14.237	10.564	1.000	44.000	2.000	12.000	31.000
Years of potential work experience	21.667	11.602	0.000	44.000	6.000	21.000	38.000
Industry-level trade variables (observations: 800)							
Ratio of imports from Asia	0.108	0.122	0.002	0.725	0.008	0.061	0.279
Ratio of imports from Europe and N. America	0.098	0.140	0.001	1.016	0.009	0.050	0.233
Ratio of exports from Japan	0.264	0.393	0.000	2.721	0.009	0.155	0.588
Log imports from Asia	25.928	1.286	22.722	28.802	24.100	25.975	27.588
Log imports from Europe and N. America	25.738	1.322	21.406	28.050	23.847	26.057	27.194
Log exports from Japan	26.375	1.961	21.413	30.613	23.338	26.511	28.695

Notes : The worker-level data have worker-year observations and the industry-level data have industry-year observations. Hourly wage is deflated by the GDP deflator. Trade variables are deflated by the trade price indexes explained in the text.
Source : Author's calculations.

Table 2. Results of second-stage FE-IV estimation

	Firm size & worker skill		Firm size & worker skill Drop three industries	
	(1)	(2)	(3)	(4)
Imports from Asia	-0.1685***	-0.0203***	-0.1549**	-0.0123*
	(0.0611)	(0.0076)	(0.0678)	(0.0073)
x medium-sized firms	0.1522***	0.0261***	0.1560***	0.0255***
	(0.0287)	(0.0039)	(0.0442)	(0.0038)
x large firms	0.4458***	0.0650***	0.3536***	0.0661***
	(0.0888)	(0.0092)	(0.1108)	(0.0092)
x college graduates	0.0284***	0.0027***	0.0318***	0.0028***
	(0.0102)	(0.0011)	(0.0106)	(0.0010)
x non-production workers	0.0795***	0.0064***	0.0768***	0.0065***
	(0.0114)	(0.0012)	(0.0122)	(0.0011)
x supervisors	0.0624***	0.0052***	0.0690***	0.0053***
	(0.0146)	(0.0013)	(0.0149)	(0.0013)
Imports from Europe and North America	0.6265***	0.0495***	1.7888***	0.0518***
	(0.1742)	(0.0088)	(0.4720)	(0.0090)
x medium-sized firms	-0.3859***	-0.0259***	-1.1543***	-0.0269***
	(0.1158)	(0.0053)	(0.3300)	(0.0055)
x large firms	-0.6760***	-0.0437***	-1.6202***	-0.0393***
	(0.1630)	(0.0110)	(0.4214)	(0.0118)
x college graduates	-0.0162	0.0031***	-0.0017	0.0036***
	(0.0147)	(0.0012)	(0.0167)	(0.0013)
x non-production workers	0.0178	-0.0026**	-0.0113	-0.0023*
	(0.0167)	(0.0013)	(0.0215)	(0.0013)
x supervisors	-0.1039***	-0.0079***	-0.1175***	-0.0077***
	(0.0183)	(0.0016)	(0.0210)	(0.0016)
Exports	-0.1204	0.0110	-0.7722***	0.0040
	(0.0773)	(0.0110)	(0.2847)	(0.0103)
x medium-sized firms	0.1305**	0.0055	0.6923***	0.0066
	(0.0541)	(0.0062)	(0.2188)	(0.0059)
x large firms	0.2240***	-0.0025	0.8655***	-0.0048
	(0.0766)	(0.0141)	(0.2593)	(0.0135)
x college graduates	0.0064	-0.0005	0.0133	-0.0008
	(0.0068)	(0.0013)	(0.0095)	(0.0012)
x non-production workers	-0.0067	-0.0064***	0.0062	-0.0062***
	(0.0075)	(0.0012)	(0.0113)	(0.0012)
x supervisors	0.0314***	0.0045***	0.0380***	0.0042***
	(0.0083)	(0.0015)	(0.0108)	(0.0015)
Trade index	Trade exposure ratio	Log real trade value	Trade exposure ratio	Log real trade value
CDF test	1853	4393	500.7	4749
R^2	0.7088	0.7098	0.7019	0.7092

Table 2. Results of second-stage FE-IV estimation (continued)

No firm and size var.		Firm size only		Worker skill only	
(5)	(6)	(7)	(8)	(9)	(10)
-0.0169	0.0244***	-0.1337**	-0.0170**	-0.0673	0.0192***
(0.0587)	(0.0067)	(0.0604)	(0.0076)	(0.0587)	(0.0068)
		0.1658***	0.0274***		
		(0.0285)	(0.0039)		
		0.4701***	0.0672***		
		(0.0879)	(0.0092)		
				0.0359***	0.0030***
				(0.0107)	(0.0011)
				0.0898***	0.0070***
				(0.0113)	(0.0012)
				0.0721***	0.0062***
				(0.0147)	(0.0013)
-0.0024	0.0174*	0.6259***	0.0501***	0.0273	0.0182**
(0.1017)	(0.0089)	(0.1708)	(0.0088)	(0.1017)	(0.0088)
		-0.4021***	-0.0271***		
		(0.1152)	(0.0053)		
		-0.6961***	-0.0444***		
		(0.1617)	(0.0111)		
				-0.0175	0.0031**
				(0.0151)	(0.0012)
				0.0134	-0.0032**
				(0.0165)	(0.0013)
				-0.1241***	-0.0096***
				(0.0187)	(0.0016)
0.1056***	0.0080	-0.1196	0.0073	0.0947**	0.0115
(0.0408)	(0.0114)	(0.0756)	(0.0109)	(0.0413)	(0.0113)
		0.1359**	0.0059		
		(0.0537)	(0.0062)		
		0.2307***	-0.0029		
		(0.0759)	(0.0141)		
				0.0055	-0.0005
				(0.0071)	(0.0013)
				-0.0050	-0.0063***
				(0.0075)	(0.0012)
				0.0399***	0.0055***
				(0.0085)	(0.0016)
Trade exposure ratio	Log real trade value	Trade exposure ratio	Log real trade value	Trade exposure ratio	Log real trade value
30331	65569	3834	8803	7271	16118
0.7089	0.7094	0.7087	0.7097	0.7091	0.7095

Notes: All specifications include establishment, age group-gender-year, manager-year, and female-prefecture dummies, as well as other worker controls; the table does not report their coefficients. Two import variables, an export variable, and their interaction terms are instrumented by corresponding world export supply indexes, a world import demand index, and their interactions. The numbers of industries, establishments, and observations are 50, 82,997, and 4,173,926 for columns (1), (2), and (5)-(10), whereas 47, 80,243, and 4,022,904 for columns (3) and (4). Standard errors in parentheses are clustered at the establishment level. *** p<0.01, ** p<0.05, * p<0.1.
Source : Author's calculations.

Table 3. Regression of wage inequality between industry–size–skill groups

	Trade exposure ratio		Log real trade value	
	(1)	(2)	(3)	(4)
Predicted annual change of wage inequality between industry–size–skill groups	0.1123	0.5530	0.1366	1.0418
	(0.9217)	(0.6001)	(1.9855)	(1.3013)
Actual annual change of wage inequality between tenure groups		1.2576***		1.2506***
		(0.2845)		(0.2865)
Constant	0.0006	0.0010	0.0005	-0.0002
	(0.0019)	(0.0012)	(0.0033)	(0.0021)
R^2	0.0011	0.6199	0.0004	0.6137

Notes : Number of observation is 15. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source : Author's calculations.

Appendix. Results of first-stage FE-IV estimation

Table A1(1). First-stage results of column (1) in Table 2

	Japanese imports from Asia	x medium-sized firms	x large firms	x college graduates	x non-production workers	x supervisors	Japanese imports from Europe and North America	x medium-sized firms
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
World exports from Asia	0.0411***	-0.0206***	-0.0024***	-0.0100***	-0.0149***	-0.0025***	-0.0237***	0.0081***
	(0.0009)	(0.0014)	(0.0005)	(0.0005)	(0.0006)	(0.0002)	(0.0022)	(0.0011)
x medium-sized firms	0.0035***	0.0813***	-0.0055***	-0.0025***	-0.0032***	-0.0025***	-0.0066***	-0.0569***
	(0.0013)	(0.0022)	(0.0009)	(0.0006)	(0.0009)	(0.0004)	(0.0023)	(0.0025)
x large firms	0.0073***	0.0118***	0.0616***	-0.0063***	-0.0063***	-0.0031***	-0.0074**	0.0003
	(0.0022)	(0.0019)	(0.0023)	(0.0013)	(0.0018)	(0.0005)	(0.0033)	(0.0016)
x college graduates	-0.0005	-0.0004	-0.0007**	0.0887***	-0.0041***	-0.0006***	-0.0023***	-0.0009**
	(0.0003)	(0.0003)	(0.0003)	(0.0013)	(0.0005)	(0.0001)	(0.0004)	(0.0003)
x non-production workers	0.0018***	0.0013***	0.0001	-0.0009**	0.0926***	0.0004**	-0.0005	-0.0006**
	(0.0004)	(0.0003)	(0.0003)	(0.0004)	(0.0013)	(0.0002)	(0.0004)	(0.0003)
x supervisors	0.0001	0.0002	-0.0005	-0.0005	0.0001	0.0891***	-0.0004	-0.0007*
	(0.0004)	(0.0003)	(0.0004)	(0.0004)	(0.0006)	(0.0019)	(0.0005)	(0.0004)
World exports from Europe and North America	0.0101***	0.0055***	-0.0009***	0.0056***	0.0086***	0.0005***	0.0229***	-0.0025***
	(0.0007)	(0.0006)	(0.0003)	(0.0004)	(0.0005)	(0.0001)	(0.0012)	(0.0008)
x medium-sized firms	-0.0007	-0.0024**	0.0032***	0.0042***	0.0048***	0.0035***	-0.0080***	0.0229***
	(0.0010)	(0.0012)	(0.0004)	(0.0006)	(0.0007)	(0.0002)	(0.0015)	(0.0014)
x large firms	-0.0013	-0.0022***	0.0060***	0.0062***	0.0076***	0.0041***	-0.0123***	-0.0006
	(0.0017)	(0.0008)	(0.0018)	(0.0009)	(0.0012)	(0.0004)	(0.0016)	(0.0012)
x college graduates	0.0001	0.0001	0.0000	-0.0189***	0.0015***	-0.0001	-0.0009***	-0.0003
	(0.0003)	(0.0002)	(0.0003)	(0.0008)	(0.0004)	(0.0001)	(0.0003)	(0.0003)
x non-production workers	0.0008***	0.0007***	0.0006*	0.0008***	-0.0216***	0.0006***	-0.0002	-0.0002
	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0008)	(0.0001)	(0.0003)	(0.0003)
x supervisors	0.0003	0.0002	0.0001	-0.0002	0.0012***	-0.0212***	0.0003	-0.0000
	(0.0004)	(0.0002)	(0.0004)	(0.0003)	(0.0004)	(0.0012)	(0.0003)	(0.0003)
World imports	0.0052***	-0.0017***	-0.0012***	-0.0018***	-0.0030***	-0.0004***	-0.0009	-0.0072***
	(0.0004)	(0.0003)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0008)	(0.0005)
x medium-sized firms	-0.0020***	0.0074***	-0.0008***	-0.0023***	-0.0027***	-0.0011***	0.0064***	0.0232***
	(0.0006)	(0.0007)	(0.0002)	(0.0003)	(0.0004)	(0.0001)	(0.0010)	(0.0011)
x large firms	-0.0054***	0.0019***	0.0007	-0.0045***	-0.0058***	-0.0019***	0.0081***	0.0031***
	(0.0009)	(0.0004)	(0.0008)	(0.0005)	(0.0007)	(0.0002)	(0.0010)	(0.0008)
x college graduates	0.0002	0.0001	0.0002	0.0134***	-0.0005**	0.0002***	0.0004**	0.0001
	(0.0002)	(0.0001)	(0.0002)	(0.0005)	(0.0002)	(0.0001)	(0.0002)	(0.0002)
x non-production workers	-0.0008***	-0.0006***	-0.0004*	-0.0006***	0.0145***	-0.0004***	0.0003*	0.0002
	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0005)	(0.0001)	(0.0002)	(0.0002)
x supervisors	-0.0004	-0.0003*	-0.0001	0.0002	-0.0008***	0.0130***	-0.0000	0.0001
	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0007)	(0.0002)	(0.0002)

Appendix. Results of first-stage FE-IV estimation (continued)

				Japanese exports					
x large firms	x college graduates	x non-production workers	x supervisors		x medium-sized firms	x large firms	x college graduates	x non-production workers	x supervisors
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
0.0037***	0.0079***	0.0132***	0.0018***	0.0012	0.0285***	0.0065***	0.0026	0.0027	0.0044***
(0.0005)	(0.0006)	(0.0008)	(0.0002)	(0.0029)	(0.0045)	(0.0018)	(0.0019)	(0.0023)	(0.0009)
0.0043***	0.0007	0.0027**	0.0026***	0.0068**	-0.0367***	-0.0085***	-0.0015	0.0001	-0.0101***
(0.0009)	(0.0008)	(0.0011)	(0.0005)	(0.0033)	(0.0072)	(0.0032)	(0.0019)	(0.0025)	(0.0016)
-0.0516***	0.0023*	0.0060***	0.0034***	0.0053	-0.0425***	0.0041	-0.0071**	-0.0103***	-0.0079***
(0.0034)	(0.0014)	(0.0018)	(0.0008)	(0.0047)	(0.0074)	(0.0072)	(0.0032)	(0.0039)	(0.0019)
-0.0007*	-0.0799***	0.0008	-0.0004**	-0.0051***	0.0000	-0.0040***	0.0075	0.0037**	0.0008
(0.0004)	(0.0016)	(0.0005)	(0.0002)	(0.0008)	(0.0008)	(0.0009)	(0.0063)	(0.0018)	(0.0007)
0.0013***	0.0026***	-0.0753***	0.0014***	0.0021**	0.0033***	-0.0013	0.0036**	0.0010	-0.0001
(0.0004)	(0.0004)	(0.0015)	(0.0003)	(0.0008)	(0.0009)	(0.0009)	(0.0016)	(0.0062)	(0.0008)
-0.0003	0.0001	0.0021***	-0.0743***	0.0004	-0.0006	0.0011	0.0040***	0.0056***	0.0361***
(0.0005)	(0.0005)	(0.0007)	(0.0025)	(0.0010)	(0.0009)	(0.0010)	(0.0015)	(0.0021)	(0.0099)
-0.0021***	-0.0013***	-0.0024***	-0.0007***	0.0582***	-0.0218***	-0.0053***	-0.0208***	-0.0327***	-0.0035***
(0.0004)	(0.0004)	(0.0006)	(0.0002)	(0.0023)	(0.0027)	(0.0010)	(0.0012)	(0.0015)	(0.0005)
-0.0014**	-0.0008	-0.0003	0.0005	0.0154***	0.1222***	-0.0060***	-0.0037**	-0.0023	-0.0078***
(0.0006)	(0.0006)	(0.0008)	(0.0003)	(0.0031)	(0.0044)	(0.0017)	(0.0016)	(0.0019)	(0.0010)
0.0171***	-0.0019**	-0.0004	-0.0003	0.0109***	0.0089**	0.0928***	-0.0162***	-0.0124***	-0.0097***
(0.0013)	(0.0008)	(0.0010)	(0.0004)	(0.0042)	(0.0041)	(0.0042)	(0.0028)	(0.0030)	(0.0012)
-0.0004*	0.0167***	0.0002	-0.0002*	0.0017**	0.0009	0.0005	0.1602***	-0.0011	-0.0004
(0.0002)	(0.0008)	(0.0003)	(0.0001)	(0.0007)	(0.0006)	(0.0006)	(0.0028)	(0.0012)	(0.0005)
0.0008***	0.0006**	0.0173***	0.0005***	0.0003	-0.0001	-0.0004	-0.0018**	0.1605***	-0.0009*
(0.0002)	(0.0003)	(0.0008)	(0.0002)	(0.0008)	(0.0007)	(0.0007)	(0.0009)	(0.0029)	(0.0005)
-0.0001	0.0001	0.0008	0.0171***	-0.0002	0.0000	-0.0004	-0.0011	-0.0027**	0.1612***
(0.0003)	(0.0003)	(0.0005)	(0.0013)	(0.0009)	(0.0007)	(0.0007)	(0.0010)	(0.0013)	(0.0042)
-0.0021***	-0.0063***	-0.0098***	-0.0013***	-0.0028***	-0.0000	-0.0061***	-0.0050***	-0.0028***	-0.0015***
(0.0002)	(0.0003)	(0.0004)	(0.0001)	(0.0009)	(0.0019)	(0.0006)	(0.0007)	(0.0010)	(0.0003)
-0.0027***	-0.0009**	-0.0018***	-0.0021***	-0.0060***	0.0009	-0.0004	0.0016*	0.0009	0.0024***
(0.0004)	(0.0004)	(0.0005)	(0.0002)	(0.0015)	(0.0027)	(0.0010)	(0.0009)	(0.0012)	(0.0007)
0.0155***	-0.0025***	-0.0048***	-0.0025***	-0.0031*	-0.0015	0.0046*	0.0073***	0.0051***	0.0026***
(0.0012)	(0.0005)	(0.0007)	(0.0003)	(0.0018)	(0.0027)	(0.0024)	(0.0013)	(0.0018)	(0.0008)
0.0002	0.0357***	-0.0006**	0.0002*	-0.0005	-0.0006	0.0000	-0.0098***	0.0007	0.0001
(0.0002)	(0.0007)	(0.0002)	(0.0001)	(0.0004)	(0.0004)	(0.0004)	(0.0020)	(0.0008)	(0.0003)
-0.0007***	-0.0007***	0.0350***	-0.0006***	-0.0004	-0.0003	0.0003	0.0007	-0.0106***	-0.0001
(0.0002)	(0.0002)	(0.0007)	(0.0001)	(0.0004)	(0.0004)	(0.0004)	(0.0006)	(0.0021)	(0.0003)
0.0001	-0.0000	-0.0010**	0.0346***	0.0003	0.0002	0.0002	-0.0002	-0.0003	-0.0122***
(0.0002)	(0.0002)	(0.0004)	(0.0012)	(0.0005)	(0.0004)	(0.0004)	(0.0006)	(0.0008)	(0.0032)

Appendix. Results of first-stage FE-IV estimation (continued)

Table A1(2). First-stage results of column (2) in Table 2

	Japanese imports from Asia	x medium-sized firms	x large firms	x college graduates	x non-production workers	x supervisors	Japanese imports from Europe and North America	x medium-sized firms
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
World exports from Asia	0.3837***	-0.0404***	-0.0286***	-0.1058***	-0.1118***	-0.0059***	-0.0425***	0.1628***
	(0.0081)	(0.0073)	(0.0059)	(0.0041)	(0.0051)	(0.0019)	(0.0062)	(0.0079)
x medium-sized firms	0.0543***	0.5945***	-0.0521***	0.0014	0.0087**	-0.0354***	0.0122**	-0.3921***
	(0.0068)	(0.0097)	(0.0051)	(0.0031)	(0.0039)	(0.0021)	(0.0055)	(0.0095)
x large firms	0.1152***	-0.0421***	0.6295***	0.0149***	0.0263***	-0.0270***	0.0118	-0.0545***
	(0.0102)	(0.0085)	(0.0113)	(0.0046)	(0.0061)	(0.0026)	(0.0072)	(0.0085)
x college graduates	-0.0054***	-0.0037***	-0.0018*	0.7147***	0.0104***	-0.0004	-0.0079***	-0.0022**
	(0.0011)	(0.0009)	(0.0010)	(0.0073)	(0.0021)	(0.0009)	(0.0010)	(0.0010)
x non-production workers	0.0067***	0.0059***	0.0018	0.0117***	0.7117***	0.0032***	0.0074***	0.0033***
	(0.0013)	(0.0010)	(0.0013)	(0.0018)	(0.0070)	(0.0012)	(0.0013)	(0.0011)
x supervisors	-0.0006	0.0007	-0.0039**	0.0045***	0.0125***	0.7515***	0.0020	-0.0008
	(0.0016)	(0.0012)	(0.0015)	(0.0017)	(0.0028)	(0.0101)	(0.0014)	(0.0013)
World exports from Europe and North America	0.1981***	0.2765***	-0.0002	0.2315***	0.3051***	0.0282***	0.5334***	0.0742***
	(0.0113)	(0.0156)	(0.0074)	(0.0073)	(0.0091)	(0.0032)	(0.0125)	(0.0177)
x medium-sized firms	-0.0172	-0.3556***	0.1076***	0.0603***	0.0933***	0.0868***	-0.0512***	0.4896***
	(0.0125)	(0.0218)	(0.0096)	(0.0081)	(0.0099)	(0.0050)	(0.0127)	(0.0237)
x large firms	-0.0309**	-0.1186***	-0.0300	0.1163***	0.1954***	0.1057***	-0.0617***	-0.2115***
	(0.0156)	(0.0208)	(0.0199)	(0.0118)	(0.0148)	(0.0060)	(0.0168)	(0.0221)
x college graduates	0.0213***	0.0059***	0.0164***	-0.7500***	0.0547***	0.0028	0.0041	0.0047
	(0.0023)	(0.0022)	(0.0026)	(0.0165)	(0.0049)	(0.0019)	(0.0030)	(0.0029)
x non-production workers	-0.0033	-0.0007	0.0067*	0.0075	-0.8458***	0.0153***	0.0117***	0.0006
	(0.0029)	(0.0025)	(0.0035)	(0.0051)	(0.0160)	(0.0023)	(0.0032)	(0.0033)
x supervisors	-0.0008	0.0026	0.0002	0.0105**	0.0429***	-0.7937***	0.0069*	0.0068**
	(0.0033)	(0.0029)	(0.0037)	(0.0044)	(0.0063)	(0.0228)	(0.0039)	(0.0034)
World imports	0.1867***	-0.2665***	-0.0590***	-0.1722***	-0.2413***	-0.0385***	0.1169***	-0.3878***
	(0.0122)	(0.0179)	(0.0075)	(0.0084)	(0.0109)	(0.0035)	(0.0127)	(0.0209)
x medium-sized firms	-0.0383***	0.5880***	-0.0292***	-0.0540***	-0.0901***	-0.0346***	0.0278*	0.8458***
	(0.0139)	(0.0238)	(0.0100)	(0.0087)	(0.0112)	(0.0058)	(0.0152)	(0.0283)
x large firms	-0.0726***	0.2225***	0.2213***	-0.1194***	-0.2050***	-0.0573***	0.0356*	0.3257***
	(0.0160)	(0.0210)	(0.0169)	(0.0122)	(0.0164)	(0.0066)	(0.0195)	(0.0255)
x college graduates	-0.0103***	0.0008	-0.0134***	0.8131***	-0.0717***	-0.0006	0.0082**	-0.0003
	(0.0029)	(0.0027)	(0.0032)	(0.0214)	(0.0062)	(0.0025)	(0.0038)	(0.0037)
x non-production workers	-0.0073**	-0.0065**	-0.0093**	-0.0289***	0.9050***	-0.0209***	-0.0218***	-0.0054
	(0.0037)	(0.0031)	(0.0043)	(0.0063)	(0.0208)	(0.0031)	(0.0041)	(0.0040)
x supervisors	-0.0015	-0.0033	0.0022	-0.0155***	-0.0620***	0.7909***	-0.0105**	-0.0058
	(0.0041)	(0.0035)	(0.0046)	(0.0056)	(0.0081)	(0.0294)	(0.0049)	(0.0043)

Appendix. Results of first-stage FE-IV estimation (continued)

				Japanese exports					
x large firms	x college graduates	x non-production workers	x supervisors		x medium-sized firms	x large firms	x college graduates	x non-production workers	x supervisors
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
0.1024***	0.0763***	0.1270***	0.0438***	0.2380***	0.0405***	0.0280***	-0.0168***	-0.0610***	0.0082**
(0.0062)	(0.0040)	(0.0053)	(0.0021)	(0.0092)	(0.0152)	(0.0104)	(0.0064)	(0.0087)	(0.0040)
-0.0152***	0.0071**	0.0187***	-0.0074***	0.0108*	0.2317***	-0.0858***	-0.0182***	-0.0315***	-0.0674***
(0.0046)	(0.0030)	(0.0036)	(0.0022)	(0.0063)	(0.0196)	(0.0100)	(0.0044)	(0.0059)	(0.0042)
-0.3476***	0.0131***	0.0335***	-0.0041	-0.0103	-0.0898***	0.1907***	-0.0407***	-0.0870***	-0.0703***
(0.0086)	(0.0043)	(0.0052)	(0.0027)	(0.0071)	(0.0189)	(0.0163)	(0.0058)	(0.0077)	(0.0045)
-0.0046***	-0.4450***	0.0283***	-0.0036***	-0.0045***	-0.0006	-0.0034**	0.5690***	-0.0278***	0.0090***
(0.0011)	(0.0079)	(0.0021)	(0.0008)	(0.0013)	(0.0016)	(0.0016)	(0.0145)	(0.0040)	(0.0017)
0.0071***	0.0334***	-0.4356***	0.0072***	0.0102***	0.0077***	-0.0003	-0.0292***	0.5401***	-0.0161***
(0.0013)	(0.0020)	(0.0074)	(0.0012)	(0.0019)	(0.0019)	(0.0022)	(0.0036)	(0.0143)	(0.0024)
0.0005	0.0005	0.0192***	-0.3926***	-0.0023	-0.0026	-0.0003	0.0107***	-0.0197***	0.5760***
(0.0015)	(0.0020)	(0.0028)	(0.0104)	(0.0021)	(0.0020)	(0.0025)	(0.0031)	(0.0052)	(0.0203)
-0.0675***	0.0306***	0.0871***	0.0004	0.5609***	-0.3092***	-0.0627***	-0.1238***	-0.2762***	-0.0447***
(0.0105)	(0.0090)	(0.0110)	(0.0040)	(0.0182)	(0.0292)	(0.0130)	(0.0122)	(0.0149)	(0.0055)
0.0217*	0.0335***	0.0454***	0.0387***	0.0230	1.1913***	-0.0538***	-0.0796***	-0.0600***	-0.0562***
(0.0121)	(0.0090)	(0.0111)	(0.0055)	(0.0205)	(0.0412)	(0.0169)	(0.0119)	(0.0147)	(0.0081)
0.7948***	0.0988***	0.1627***	0.0497***	0.0627**	0.1613***	0.9538***	-0.1182***	-0.0766***	-0.0577***
(0.0198)	(0.0138)	(0.0170)	(0.0064)	(0.0290)	(0.0411)	(0.0389)	(0.0171)	(0.0217)	(0.0091)
0.0004	0.2218***	0.0680***	-0.0060***	0.0154***	0.0016	0.0119**	1.4570***	-0.0555***	0.0018
(0.0030)	(0.0184)	(0.0050)	(0.0021)	(0.0046)	(0.0042)	(0.0048)	(0.0292)	(0.0088)	(0.0029)
0.0198***	0.0328***	0.1498***	0.0137***	0.0238***	0.0060	0.0136**	-0.0499***	1.4587***	-0.0026
(0.0036)	(0.0051)	(0.0177)	(0.0026)	(0.0057)	(0.0047)	(0.0057)	(0.0072)	(0.0291)	(0.0039)
-0.0004	-0.0035	0.0376***	0.2556***	-0.0095	-0.0060	-0.0102	0.0002	-0.0136	1.4065***
(0.0043)	(0.0050)	(0.0070)	(0.0255)	(0.0069)	(0.0047)	(0.0071)	(0.0071)	(0.0104)	(0.0409)
-0.1205***	-0.2459***	-0.3893***	-0.0768***	-0.1643***	0.0791***	-0.1586***	-0.0447***	0.0478***	-0.0288***
(0.0111)	(0.0100)	(0.0125)	(0.0045)	(0.0176)	(0.0301)	(0.0142)	(0.0131)	(0.0164)	(0.0058)
-0.0548***	-0.0584***	-0.0929***	-0.0428***	-0.0504**	-0.2301***	0.0756***	0.0793***	0.0647***	0.0928***
(0.0150)	(0.0110)	(0.0136)	(0.0066)	(0.0239)	(0.0414)	(0.0181)	(0.0139)	(0.0173)	(0.0089)
0.3405***	-0.1471***	-0.2500***	-0.0665***	-0.0649**	-0.0762**	-0.0544	0.1241***	0.1119***	0.0900***
(0.0231)	(0.0167)	(0.0206)	(0.0078)	(0.0312)	(0.0345)	(0.0346)	(0.0192)	(0.0252)	(0.0101)
0.0036	1.2246***	-0.0984***	0.0109***	-0.0145**	-0.0009	-0.0133**	-0.6967***	0.0934***	-0.0132***
(0.0039)	(0.0236)	(0.0062)	(0.0026)	(0.0058)	(0.0052)	(0.0060)	(0.0316)	(0.0105)	(0.0038)
-0.0290***	-0.0655***	1.2974***	-0.0230***	-0.0346***	-0.0149**	-0.0138*	0.0916***	-0.6650***	0.0178***
(0.0047)	(0.0065)	(0.0225)	(0.0033)	(0.0074)	(0.0059)	(0.0075)	(0.0085)	(0.0328)	(0.0048)
-0.0005	0.0021	-0.0640***	1.1276***	0.0124	0.0085	0.0111	-0.0166*	0.0282**	-0.6401***
(0.0054)	(0.0065)	(0.0089)	(0.0318)	(0.0089)	(0.0059)	(0.0090)	(0.0088)	(0.0128)	(0.0444)

Notes: All specifications include establishment, age group-gender-year, manager-year, and female-prefecture dummies, as well as other worker controls; the table does not report their coefficients. Numbers of observations and establishments are 4,173,926 and 82,997, respectively. Standard errors in parentheses are clustered at the establishment level. *** p<0.01, ** p<0.05, * p<0.1.
Source: Author's calculations.