

Multinational Production and Labor Share*

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October 18, 2020

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Abstract

We investigate the impact of multinational enterprises (MNEs) on the labor share in the source country. We propose an equilibrium model that features a production function with factor inputs in foreign countries. Each firm receives a shock that shifts the productivity of foreign factor inputs. We conduct comparative statics regarding the foreign factor productivity shock and show that the difference in factor demand elasticities with respect to foreign factor prices affects aggregate labor share. To identify these elasticities, we develop a method-of-moments estimator that leverages a foreign factor productivity shock. We then apply the estimator to a unique natural experiment: the 2011 Thailand Floods. The floods had a strong impact on manufacturing clusters in areas north of Bangkok city and affected Japanese MNEs by forcing them to halt operations of plants located in the cluster. We employ a uniquely combined Japanese firm- and plant-level dataset that tracks wages, employment, fixed assets in Japan, and employment in foreign subsidiary plants. The estimated factor demand elasticities indicate that foreign factor augmentation increased capital demand in Japan more than labor demand, suggesting that the foreign factor augmentation contributes to reducing the labor share in Japan.

Keywords: Multinational enterprise, Labor share, Bias in technological change, Elasticity of factor substitution, Natural experiment, The 2011 Thailand Flood.

JEL codes: F23, E25, J23, F21, F66

*We thank patient and invaluable support by advisors Costas Arkolakis, Lorenzo Caliendo, and Peter Schott. We appreciate helpful comments by Pol Antras, Dominick Bartelme, Kirill Borusyak, Bill Brainard, Cheng Chen, Rafael Dix-Carneiro, Michal Fabinger, Pablo Fajgelbaum, Ana Cecilia Fielser, Sharat Ganapati, Teresa Fort, Sam Kortum, Giovanni Maggi, Kentaro Nakajima, Guillermo Noguera, Nitya Pandalai-Nayar, Micheal Peters, and Yuta Takahashi. We also acknowledge insightful discussions with Kailin Gao, Jay Junsik Hyun, Daisy Sun, Lucas Zavala, Ray Zhang, and seminar participants at Colorado Boulder, Columbia, IU Bloomington, NYU, RIETI, SNU, and Yale. This study is conducted as a part of the Project “Dynamics of Inter-organizational Network and Firm Lifecycle” undertaken at the Research Institute of Economy, Trade and Industry (RIETI). This study utilizes the micro data of the questionnaire information based on “the Census of Manufacture”, “the Basic Survey on Japanese Business Structure and Activities” and “the Basic Survey on Overseas Business Activities” which are conducted by the Ministry of Economy, Trade and Industry (METI). The author is grateful for helpful comments and suggestions by Discussion Paper seminar participants at RIETI. We also thank Takashi Iino for outstanding research assistance. All remaining errors are solely responsible to us.

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1. Introduction

A growing body of evidence suggests that in recent decades, labor shares of national income have decreased in several developed countries (Karabarbounis and Neiman, 2013). The decline raised concerns both for policymakers and economists. For policymakers, the decrease might be interpreted as increased income inequality between capital holders and laborers. For economists, it challenges one of the stylized facts of growth models (Kaldor, 1961).

The broad question of the current paper is to ask what drove the decrease in the labor share. Past studies proposed several potential explanations. Among them, Oberfield and Raval (2014) emphasized the role of bias in technological changes. Namely, if changes in productivity augment capital more than they do labor, then the total payment to labor relatively decreases. Although it is a theoretically coherent and straightforward explanation, there are several potential mechanisms behind such factor-specific augmentation. For example, there may be a relative increase in capital demands relative to labor when international direct investment and employment of foreign labor by multinational enterprises (MNEs) complements capital in the source country.¹ In this paper, we formalize this idea and ask if and to what extent it may explain the labor share trend.

What brings the surge MNEs' international factor employments? There has been a wide range of changes in the economic environment such as technological changes, policy and institutional reforms, and growths of developing economies. For example, better global communication technologies, removal of political barriers of international direct investment and employment of foreign labor, and increasing demand by external economies may increase firms' availability and productivity of foreign factors. We take these events as exogenous augmentations of foreign factors to MNEs and study the effects on the labor share of the source country.

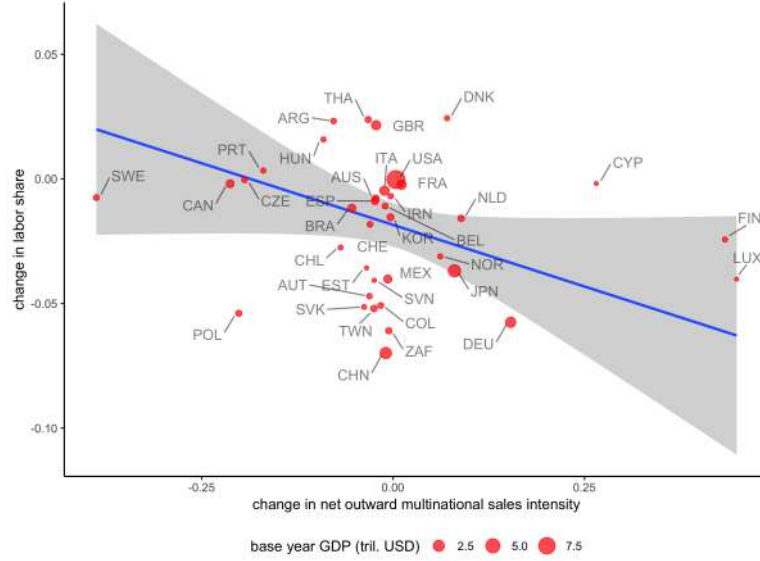
As first-pass evidence, we take the cross country variation in the change of net MNE sales and the change of labor shares in Figure 1.² There is a significant (at two-sided 95 percent) negative relationship. Although we do not conclude that the correlation is causal, the negative relationship is consistent with the idea that the outward MNE activities complement capital demand more than labor in the source country.

To formally answer the question if and how much foreign factor augmentation decreased the labor shares in the source country, we proceed with three steps. First, we develop a general equilibrium model that features heterogeneous and non-parametric production function that includes the employment of foreign factors and augmentations of the foreign factors. In the model, the factor market clearing wages are key endogenous variables to determine the labor shares. We show that to the first order, the elasticity structure of factor demands are critical to know the direction and size of the change in labor shares. This first order implication is robust across several existing models of multinational production and many factors. We show the equivalence results of our first order approximation to the one under the models of offshoring (Feenstra and Hanson, 1997) and

¹Other examples include other forms of globalization, such as global value chains and intermediate goods trade and technological growth represented by, for example, industrial robot penetration and computerization.

²Details of the construction of the data are discussed in Section B1..

Figure 1: Net Outward Multinational Sales and Labor Shares



Note: Authors' calculation by data from Karabarbounis Neiman (2014) and UNCTAD. The horizontal axis is the change in the sum of bilateral net outward multinational sales between 1991-1995 average and 1996-2000 average. The vertical axis is the change in labor share from 1991 to 2000. Singapore is dropped because it has an outlier value for the outward multinational sales measure.

multinational production with export platforms (e.g., [Arkolakis et al., 2017](#)). We then show how the key elasticities may be identified given the foreign augmentation shocks. We show the moment conditions and how to back out the structural errors that depend on our parameters of interest, the elasticity matrix.

Since our baseline model spans broad production technology, we give an example of homogeneous nested CES production. By doing so, we give the intuition behind the theoretical results and some guidance for the empirical application. Out of the specified model, our key theoretical results are twofold. First, the difference of elasticities of substitution between nests is key to the impact of foreign factor augmentation on home labor share. Namely, if home labor is more substitutable with foreign factor than home capital is, then the foreign factor augmentation implies a reduction in home labor share. Intuitively, if foreign factor augmentation occurs, both home labor and capital are substituted away given the output level. If the substitution is larger for labor, so is the *relative* decline in home labor demand. Thus, the labor share decreases. One of the challenges is to identify the novel parameter of our model, the foreign factor-home factor elasticity of substitution. To proceed, we assume the existence of an exogenous change in foreign factor productivity. Our second key theoretical result shows that the shock-induced derivative of home-foreign employment with respect to the shock is informative of the key parameter.

Armed with these theoretical results, we proceed to the empirical application to the *2011 Thailand Flood*. We argue that the flood may be interpreted as a unique negative foreign factor productivity shocks to Japanese MNEs operating in the flooded regions. To study this unique event, we employ and combine firm- and establishment-level microdata sourced from the *Basic Survey on Japanese Business Structure and Activities* (BSJBSA), the *Basic Survey on Overseas Business Activities* (BSOBA), and the

Orbis database from Bureau van Dijk (Orbis BvD). First, we calibrate the capital-labor substitutability by the first order condition and a shift-share-type instrumental variable (Raval, 2019). Consistent with the previous literature, we estimate that capital-labor are gross complements. Second, by regressing the log-home employment on the log-foreign employment (with the instrumental variable relating the intensity of the flood damage) and a firm-level fixed effect, we obtain a two-stage least square estimate, which indicates that the home labor and foreign labor are gross substitutes according to our theory. The result is based on our homogeneous nested CES specification.

Given the home labor-foreign labor substitutability implied by our estimate, we arrive at the result that foreign factor augmentation (from the perspective of Japan) did contribute to the decrease in labor share in Japan. We thus have shown that the foreign factor augmentation, if any, decreases the home labor share. To obtain the quantitative result, we exploit the nested CES specification to back out the aggregate evolution of foreign factor-augmenting productivities. Applying our implied elasticities of substitution, we derive that the foreign factor augmentation *solely* explains 59 percent of the decrease in Japan's labor share between 1995 and 2007.

We also show the elasticity estimate from a more general production function based on the method of moments. As is the nested CES case, the result shows that the foreign factor augmentation *relatively* increases the capital demand. This implies that the relative labor wage decreases and so does the labor share.

Our paper is structured as follows. Section 2. shows some of the motivating facts about labor shares and MNEs. Section 3. shows the model of labor shares and foreign factor augmentation. We show a general foreign factor demand model and a specified nested CES one. Section 4. discusses the empirical setting, data, specification and reduced-form estimates. Section 5. shows the derived structural parameters and estimation under a general model than nested CES. Section 6. concludes.

1.1. Related Literature

The existing literature falls into two categories—research concerning the recent decreases in labor shares (or increasing capital shares) and studies on MNEs and their impacts on the source country's labor market.

1.1.1. Changing Factor Shares

On the factor share studies, we must begin with some seminal research that empirically finds the decreasing labor shares. Elsbey et al. (2013) do this in the U.S., while Karabarounis and Neiman (2013) assemble comparable cross-country data and showed that it is the case in many countries, and in particular, developed countries. Piketty and Zucman (2014) emphasized the implication of decreasing labor shares on expanding within-country income inequalities. However, there are several qualifications in the concept and measurement of labor shares that nullify the empirical findings to some extent. For instance, Rognlie (2016, 2018); Bridgman (2018) stress the treatment of capital depreciation and self-employees' income allotment to each factor entails strong assumptions. Making a different argument, Koh et al. (2018) claim that "the capitalization of intellectual property prod-

ucts in the national income and product accounts” for the decline of the labor share in the U.S. in an accounting sense.³ We take a stand that after taking these reservations into account, Japan’s labor share between 1995 and 2007 is still decreasing. We detail the data in Section 2.2.2..

The research of the reasons why the labor is decreasing is ongoing. There are several candidate reasons. One of them is bias in technological changes. For instance, [Oberfield and Raval \(2014\)](#) emphasize the role of “technology, broadly defined, including automation and offshoring, rather than mechanisms that work solely through factor prices.” On the offshoring side, [Elsby et al. \(2013\)](#) conclude that the offshoring of labor-intensive activities among the supply chains are “the leading potential explanation of the decline in the U.S. labor share over the past 25 years.” On the technology side, among others, [Acemoglu and Restrepo \(2017\)](#) find that the U.S. commuting zones’ exposure to industrial robot reduced employment and wages. We take a stand that globalization explains a portion, in particular in our context of Japan in 1995-2007. Adding to the previous discussions, we offer evidence based on a particular mechanism that features the role of MNEs. We also give a novel identification strategy, and empirical application to the 2011 Thailand Flood.

Other potential explanations include decreased capital prices. For example, [Karabarbounis and Neiman \(2013\)](#); [Hubmer \(2018\)](#) explore if and how much the decrease in the capital good prices substitute labor demand with capital demand. In addition to such an explanation based on factor prices, the increase in market powers, and thus the profit, may have a direct implication on the decreased labor shares. Given large and dominant corporations, market powers can emerge both in the good market ([Autor et al., 2017a,b](#); [Barkai, 2017](#); [De Loecker and Eeckhout, 2017](#)) and in the labor market ([Gouin-Bonenfant et al., 2018](#); [Berger et al., 2019](#)).⁴ Although the market power is not the main driver we focus on, we explore its potential role to help validating our mechanism. We apply [De Loecker and Eeckhout](#)’s method to our data in Japan and find that in Japan the markup did not increase as much as in the U.S. The detailed discussion is given in Section 2.2.4.. Finally, since capital income is intrinsically related to the financial sector, some authors discuss the labor share may fall due to financial-market features, such as increasing risk premiums ([Caballero et al., 2017](#)) or equity values ([Greenwald et al., 2019](#)).

Our contribution to the literature is adding the MNE to the discussion of the reason behind the decreases in labor shares. Among this growing literature, we regard our work to be the closest to [Oberfield and Raval \(2014\)](#). As we mentioned above, they emphasized the role of biased technological change in production function by negating the factor-price-side story of decreases in labor shares such as [Karabarbounis and Neiman \(2013\)](#). For this purpose, they employ plant-level microdata in the U.S. and estimate the capital-labor substitution elasticity by estimating the first order condition for factor demand with a Bartik-type instrument. They found that since the 1970s, the aggregate capital-labor elasticity has been constant at around 0.7, which indicates that capital and labor are indeed gross complements. In this case, the capital cost decline like emphasized in [Karabarbounis and Neiman \(2013\)](#) would imply an increased labor share. We follow and extend their views and anal-

³Furthermore, [Cette et al. \(2019\)](#) discusses the role of real estate income.

⁴In fact, [Berger et al. \(2019\)](#) discuss that the labor market concentration contributed in the opposite direction, if any, since they observed that the U.S. local labor market concentration has been decreasing since the 1970s.

ysis. Namely, we apply their method of estimating capital-labor elasticity to firm- and plant-level data in Japan and confirm that the elasticity is below one. We depart from their analysis to the extent that we explicitly incorporate the foreign factor employment of home firms to consider the effect of foreign factor augmentation on the home labor share. In Section 3.1., we discuss how our production function nests the one in Oberfield and Raval (2014).

1.1.2. Labor Market Impacts of MNEs

There is a line of research that examines the impact of foreign production on the source country's labor market (Desai et al., 2009; Muendler and Becker, 2010; Harrison and McMillan, 2011; Ebenstein et al., 2014; Boehm et al., 2017; Kovak et al., 2017). Notably, these papers explicitly use exogenous variation that changes the firms' profitability from engaging in foreign production as the current paper does. For example, Desai et al. (2009) take the source country's economic indicators and construct a shift-share-style instrumental variable, whereas Kovak et al. (2017) use the change in bilateral tax treaties between the U.S. and other countries to construct the IVs. Bernard et al. (2018) study the effect on firms occupational organization using a shift-share-type instruments from a detailed set of firm-specific variables of change in import shares. Setzler and Tintelnot (2019) use MNEs' geographic clustering as the source of exogenous variation and find that when non-U.S.-owned MNEs enter the U.S., there are two effects on local wages—direct foreign MNE premiums on worker wages, and indirect wage-bidding-up effects on incumbent domestic firms. Our contribution to this line of research is twofold, empirical and theoretical. Empirically, our approach adds another piece of evidence to these studies in the sense that we use the unexpected natural disaster as a negative productivity shock that affects firms' foreign production decision and their domestic employment.⁵⁶

More importantly, unlike these studies, we are able to have a clear structural interpretation of the shock and the impact on employment by specifying the foreign production model in Section 3.. As will be clear, this is indeed the key to identifying the model parameters.⁷ Specifically, both Desai et al. (2009) and Kovak et al. (2017) statistically find positive causal effects of foreign employment on home employment. This is consistent with our finding that the flood-caused employment decrease in the foreign country is accompanied by a *decrease* in home employment. Our model further implies that such positive association caused by an exogenous shock to foreign productivity can be interpreted that home labor and foreign labor are *gross-substitutable*.

Other past studies rely on observational variation in factor costs rather than experimental or exogenous ones. Earlier studies include Brainard and Riker (1997); Slaughter (2000); Head and Ries (2002). These papers estimate the short-run cost function by regressing the domestic skill demand on

⁵Kato and Okubo (2017) study the same event to learn about the loss of vertical linkages in the destination country.

⁶Boehm et al. (2018) study another dimension about the impacts of a shock on multinational firms. They consider the 2011 Tohoku Earthquake in Japan as a shock on headquarters in Japan and its impact on foreign (U.S.) affiliates, whereas I am interested in the shock on foreign affiliates in Thailand and its impact on domestic headquarter in Japan.

⁷For example, Desai et al. (2009) use a Bartik shock with GDP growth rates as the 'shift' component. If we do not know the GDP growth is consumers' demand-sourced or firms' productivity-sourced in the short-run, then it is not clear how to interpret their coefficients. On the other hand, Kovak et al. (2017) employ arguably supply-side shock, the bilateral tax treaty enforcement. However, their approach does not allow to back out substitution parameters. They use a different sourcing model and therefore they do not estimate the 2SLS specification but only does the event-study regression.

foreign wages. The papers estimating short-run cost functions assume that foreign capital cannot be adjusted by investment. There are several papers that relax this assumption and estimate the long-run cost function by regressing the source-country labor demand on destination-country wage and rental rate (Harrison and McMillan, 2011). Regardless of whether the function estimated is short-run or long-run, these cost function approaches usually take local wages as a regressor. The identification assumption is that after controlling for a detailed set of control variables, variation in local wages is exogenous. Ebenstein et al. (2014) study the effect of trade and offshoring using worker-level data and find corroborating results as Harrison and McMillan (2011).⁸⁹

Although there is not a large literature on the relationship between MNEs and factor intensities, different factor intensities across firms may have quantitative implications for labor shares through the reallocation of factors across firms. Sun (2018) studies the differential capital intensities between MNEs and other firms, and the pattern by the source country's capital intensities. We also study the heterogeneous factor intensities by firm-level MNE data and show some evidence on the role of the heterogeneity. Furthermore, although Sun (2018) does not focus on estimating the elasticity between Home and Foreign factors but considers the free entry into foreign production sites. He calibrates the model of export platforms to global affiliate data using the cross-section variation. With the natural experiment, our focus is on formally identifying the elasticity between factors in MNE-source and destination country.

We finally discuss papers that argue automation is a mechanism that drives the trends of labor shares. As we discussed above, automation may displace the labor demand and thus works as a force that reduces labor shares. Our goal is to establish that instead of technological changes of automation, MNE activities played a substantial role in decreasing labor shares. However, it is hard to separate the effect of globalization from technological change, both conceptually and empirically (Fort et al., 2018). To partially address the concern, in Section 2.2.4., we provide a piece of evidence that in Japan the automation technology growth during the 1990s and the 2000s is not rapid relative to other countries.

2. Motivating Facts

In this section, we further provide suggestive evidence that behind the decrease in labor share was the surge in MNEs. For this purpose, we focus on our context, Japan, 1995-2007, as we overviewed

⁸Additionally, Boehm et al. (2017) studied the impact of outsourcing of multinational firms on domestic labor demand. Their mechanism specifically focuses on is outsourcing, whereby multinational firms import intermediate goods otherwise produced domestically. Therefore, a firm reduces its labor demand when it becomes a multinational firm. On the other hand, our study focuses mainly on offshoring. In our model, a firm reduces its labor when it becomes multinational firm and quits producing particular tasks domestically and exporting.

⁹Another strand of literature distinguishes the intensive and extensive margins of the impact of foreign production. Muendler and Becker (2010) establish two-stage estimators of the wage gradient of domestic input shares, where the first stage predicts the destination country the multinational firms, and the second stage estimates the wage gradient with correcting the selection by the control function approach. Although they focus on the multinational firms and consider the choice of location, we also take into account the purely domestic firms. In this sense, we add another layer of discussion to the extensive margin analysis of foreign production. Boehm et al. (2017) also study the effect of beginning outsourcing in foreign countries on the effect on domestic employment and establishments. We use an unexpected natural disaster to complement their observational findings.

in Section 1.. First, we discuss the major data source throughout our analysis in Section 2.1.. Using the data, we show relevant facts in Section 2.2..

2.1. Data

We combine four main datasets for studying our context. The first one is *Basic Survey on Japanese Business Structure and Activities* (BSJBSA). BSJBSA is an annual (surveyed as of every March 31) government survey to the universe of large firms in Japan, administered by the Ministry of Economy, Trade, and Industry (METI).¹⁰ BSJBSA has a detailed set of variables regarding Japanese firm-level information, such as firm's address, division-level distribution of employments, holding relationships, balance sheet components, sales by goods, costs by types, export and import by regions, outsourcing, research and development, technology and patent, among others. The data spans years 1995-2017.

In order to match the foreign production information to the BSJBSA, we employ the second set of the data, the *Basic Survey of Overseas Business Activities* (BSOBA). BSOBA is an annual government study of *all* (thus the coverage is both for private and public firms) Japanese MNEs that ask their domestic and foreign business information in March of each year, administered METI.¹¹ BSOBA constitutes of *Headquarter File* and *Subsidiary File*. Our study mostly relies on the Subsidiary File which asks questions for *all* child and grandchild foreign subsidiaries of the MNEs.¹² The questions consist of the destination country, local employment and sales, where the sales are broken up into the categories of destination such as Japan (home country), Asia, Europe, and America. We access the data from 1995 to 2016. To check the quality of employment and labor compensation of BSOBA data, Section B3.1. compare the variables to those obtained from PWT.

Finally, we take advantage of the address variable from *Orbis* dataset from Bureau van Dijk. Although variables from BSOBA contain the country of each subsidiary of the Japanese parent, it does not provide the detailed address in the destination country. As we saw in Section 4.1., only a subset of the regions in Thailand including Ayutthaya and Pathum Thani provinces were flooded. We define the flood-affected region as Ayutthaya and Pathum Thani (JETRO, 2012). Hence we pinpoint the location of the subsidiaries in Thailand to better assign the treatment status. For this purpose, we leverage the address variable from Orbis dataset.

Since these datasets do not share the firm IDs, we matched these by firms' names, locations, and phone numbers. For this purpose, we adopt a firm-level dataset that is collected by a private credit agency, *Tokyo Shoko Research* (TSR). The match rate is 93.0% from BSOBA. Since the TSR access is limited to date back to 2007, the BSJBSA-BSOBA match can be done only for years 2007-2016. The

¹⁰All firms with more than 50 employees and JPY 30 million (USD 0.3 million) initial fund are asked to fill and submit the questionnaire.

¹¹The definition of MNEs and foreign activities in BSOBA is the following. A firm is defined as a MNE if it has a foreign subsidiary. Foreign subsidiaries can be either of "child subsidiary" or "grandchild subsidiary". A child subsidiary firm is a foreign corporation whose Japanese ownership ratio is 10% or more. A grandchild subsidiary is a foreign corporation whose ownership ratio is 50% or more by the foreign subsidiaries whose Japanese ownership ratio is 50% or more. Therefore, the definition of foreign production is not limited to the greenfield investment but includes purchases of the foreign company such as M&A.

¹²We drop subsidiaries located in tax-haven countries. For this purpose, we follow the definition of such countries by Gravelle (2015). We thank Cheng Chen for kindly sharing the code for the sample selection.

detail in the match process can be found in Section B3.2.. Because BSOBA takes the universe of Japanese multinational firms as its scope of the study, for each firm in TSR, we interpret that the firm is multinational if and only if it appears in BSOBA as well in the year.

2.2. Stylized Facts from Japan, 1995-2007

Armed with the data, we overview some relevant aggregate trends of our case, Japan, 1995-2007. This will guide us to develop the model of labor shares and multinational activities in the following sections. In Section 2.2.1., we show the negative time-series correlation between labor share and multinational activities. In particular, the labor share decrease is robust to other measures discussed in the previous literature as shown in Section 2.2.2.. To give another angle of the role of MNEs, we compare trends of labor shares within MNEs and non-MNEs, and composition of MNEs in Section 2.2.3.. Finally, to provide partial evidence about other mechanisms, in Section 2.2.4., we show that (i) the increase in the stock of industrial robot is likely to have happened *before* the period of our analysis, and (ii) market power in Japan was low and relatively constant during 1995-2007.

2.2.1. Negative Time-series Correlation between Labor Share and Multinational Activities

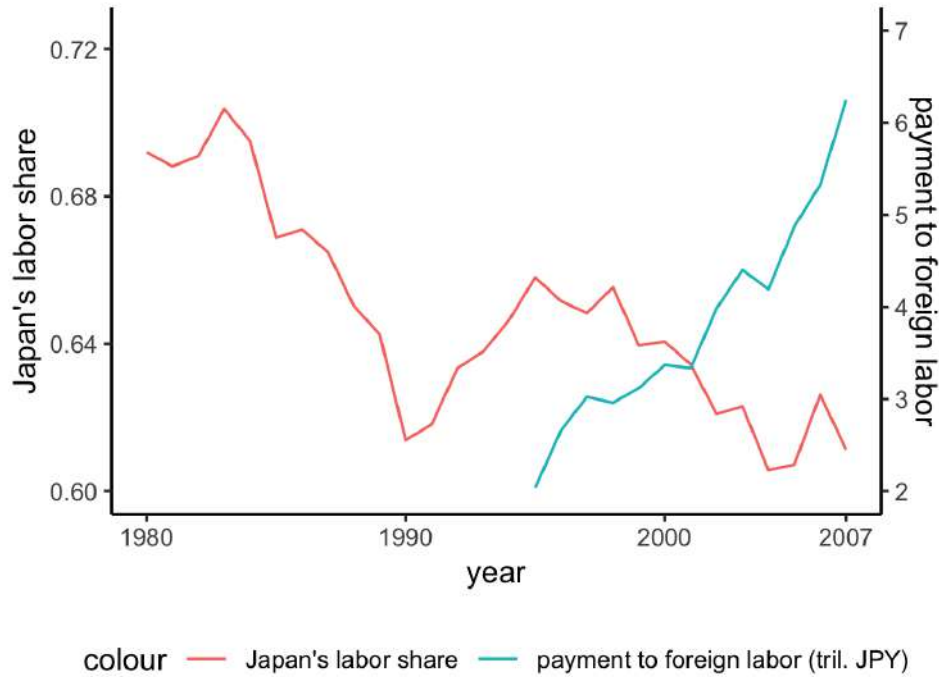
Figure 2 shows trends of Japan's labor share and aggregate payment to foreign employment. The red line shows the overall decreasing Japan's labor share since 1980.¹³ As hinted above, the current paper aims to explain such a decrease by foreign factor augmentation from the perspective of Japan. The factor augmentation potentially increases both factor prices and employment as our model section details. Therefore, one of the measures of augmentation is the aggregated payment of Japanese multinational enterprises (MNEs) to foreign workers. The blue line shows such a trend since 1995, which is the first year of our dataset. As can be seen, the trend increased rapidly, partly indicating the augmentation of the foreign factor. Given this finding as a motivation, the current paper asks if, how, and under which conditions there is a logical link between foreign factor augmentation and labor shares, and quantitatively how much portions of observed labor share decline can be attributed to the foreign factor augmentation.

Although Figure 2 is concerned about labor compensation payment, what happened to payment to capital, or net income, the foreign countries? To answer the question, Figure 3 shows the trend of both labor and capital earnings by Japanese MNEs from BSOBA data detailed in Section 2.1..

Note the capital income has been increasing since 1995, but the trend is more volatile than payment to labor. The increase can partly explain the faster increase in GNI in Japan than in GDP, because the income from the foreign capital is accounted under the positive net primary income from abroad. It will be a crucial step to explicitly allow the foreign capital in our model.

¹³Readers might notice a countercyclical component in the trend, which is observed in many countries. Schneider (2011) surveys the literature on the labor share and business cycles.

Figure 2: Labor Share and Payment to Foreign Employment, Japan

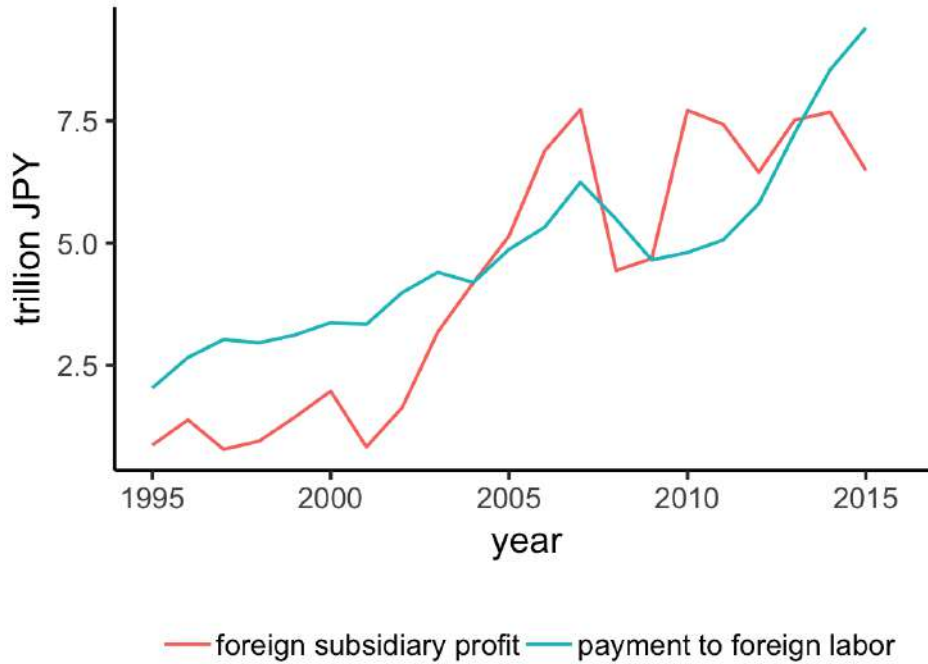


Source: Authors' calculation based on Japan Industrial Productivity (JIP) Database 2015 from Research Institute of Economy, Trade and Industry (RIETI) and Basic Survey on Overseas Business Activities (BSOBA) 1996-2008. The labor share is calculated by the share of nominal labor cost in nominal value added of JIP market economies. The payment to offshore labor is the sum of worker compensation to foreign subsidiaries of all Japanese multinational corporations in BSOBA.

2.2.2. Robust Labor Share Decrease

As we detailed in Section 1.1., neither the conceptual and operational measurement of the labor share is trivial. In this section, we overview several measures of the labor share in Japan between 1995 and 2007, the period of our analysis, to see that irrespective of the measurement we have robust evidence that the labor share has been decreasing. First, the green line in Figure 4 shows our preferred measure, the total labor cost divided by GDP. Since the GDP or value added contains the capital depreciation, it overstates the net capital income (Bridgman, 2018). To overcome the shortcoming, we take the SNA data from Japan's Cabinet Office Long-run Economic Statistics and calculate the trend of the share of nominal employee compensations over nominal national income, which excludes the capital depreciation (and excludes the indirect tax and includes the subsidy). The trend is drawn by the blue line. Another issue is the treatment of the mixed income of self-employees. Since self-employees typically own the production capital and labor by themselves, the allocation of the generated income to the labor and capital (e.g., Rognlie, 2018). To remove any biases due to the misallocation of such mixed income, we take the trend of domestic corporate factor income and their compensation payment to the labor. The trend is drawn by the red line. All of these trends are decreasing in Figure 4.

Figure 3: Earnings by Foreign Labor and Capital



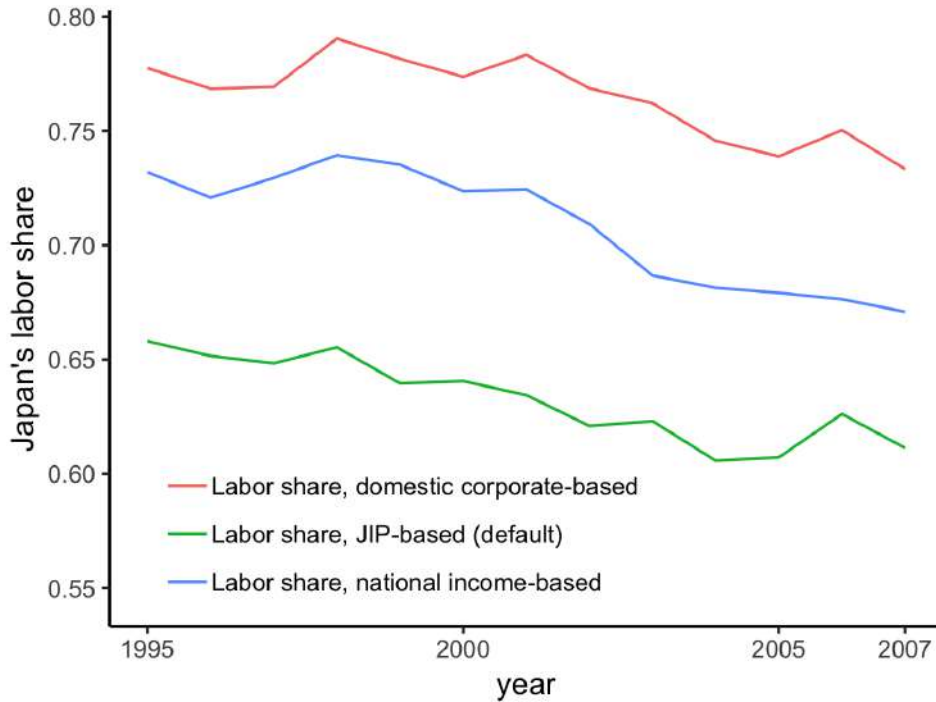
Source: Authors' calculation based on Basic Survey on Overseas Business Activities (BSOBA) 1996-2017. Foreign subsidiary profit is the sum of current net profit of all subsidiaries of Japanese multinational corporations in BSOBA. Payment to offshore labor is the sum of worker compensation to foreign subsidiaries of all Japanese multinational corporations in BSOBA.

2.2.3. Comparison of MNEs and Non-MNEs

To further analyze the role of MNEs in the decrease in labor shares, we conduct a simple decomposition analysis across MNEs and non-MNEs. We aggregate total sales, labor compensation and net income separately for MNEs and non-MNEs. We then calculate the labor share by the two groups. Figure 5 shows the trends of labor share and composition of MNEs. First, the blue line depicts the trends of the share of the sum of MNEs' sales (made by headquarters) relative to the sum of sales of all firms. In 1995, the share was roughly 12 percent, which rose to close to 15 percent in 2007. Therefore, the composition of sales became skewed toward MNEs over the period. In Figure 5, the red lines show the within-MNEs and within-non-MNEs labor share trends. Two things emerge. First, the labor share of MNEs decreases more rapidly than that of non-MNEs. Second, throughout the period of time, MNEs had lower labor share in levels. Since the composition of MNEs increased (as shown in the blue line), both of the two facts are the decreasing force of the aggregate labor shares.

One of the interpretations of these facts is as follows: within MNEs, the payment to labor relative to capital decreased over the period, *and* more firms become such MNEs. In the model section, we develop a framework in which *both* of these may be explained by the foreign factor augmentations.

Figure 4: Several Labor Share Measures, Japan, 1995-2007



Source: Authors' calculation based on Japan Industrial Productivity (JIP) Database 2015 from Research Institute of Economy, Trade and Industry (RIETI), Cabinet Office Long-run Economic Statistics (COLES, https://www5.cao.go.jp/j-j/wp/wp-je12/h10_data01.html, accessed on May 13, 2019), and Japan's SNA, Generation of Income Account, 2009. JIP-based labor share is calculated by the share of nominal labor cost in nominal value added of JIP market economies. National income-based labor share is the fraction of nominal employee compensations over nominal national income from COLES. Domestic corporate-based labor share is net labor share of domestic corporate factor income, calculated from the SNA, by the fraction of the item "Wages and salaries" over the sum of "Wages and salaries" and "Operating surplus, net."

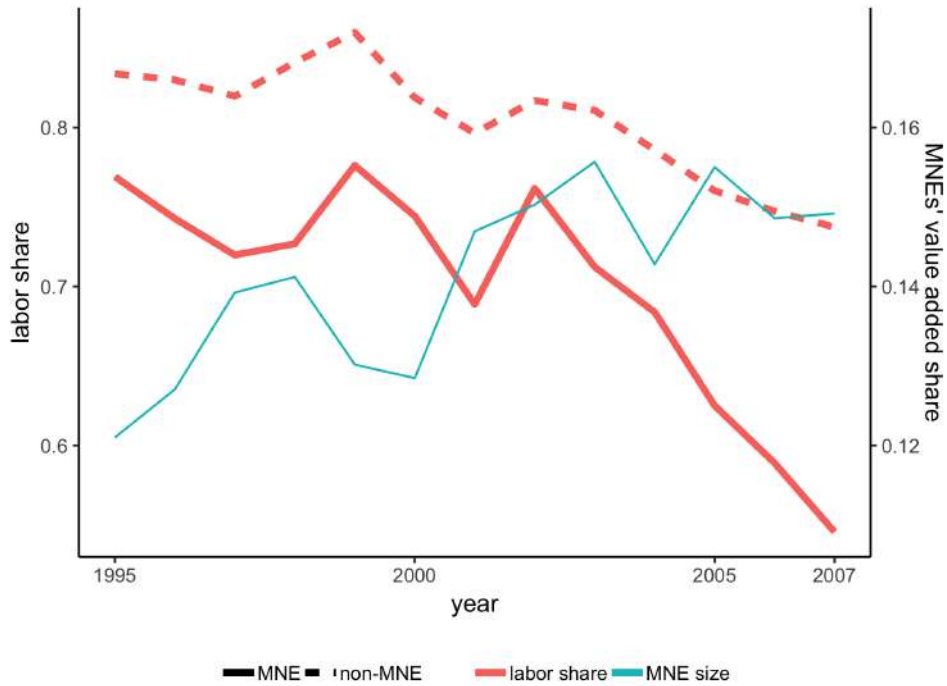
2.2.4. Other Potential Mechanisms

Automation in Japan? As we discussed in Section 1.1., bias in technological change can arise from at least two sources, automation or offshoring. Since the current paper focuses on the offshoring side, in particular, factor offshoring as opposed to good offshoring (Hummels et al., 2014), we do not delve into the evolution of automation technology in Japan. However, by examining the aggregate data used in the literature of automation (e.g., Acemoglu and Restrepo, 2017), we see suggestive evidence that during the period between the 1990s and 2010s, the automation acceleration was not observed in Japan at least as rapid as in other highly automating countries.

We employ data from the *International Federation of Robotics* (IFR). We obtain the operational stock of industrial robots in each country in each year. Figure 6 shows such trends of five most robot-adopting countries (China, Japan, United States, South Korea, Germany). All other countries than Japan have rapidly introduced industrial robots during the period between 1993 and 2016. In particular, China's absorption is extraordinarily fast since the mid 2000s, when it entered the international trade markets following the removal of a number of political, institutional barriers such as WTO accession. On the other hand, in the same period, Japan indeed saw the stagnant automation-capital stock.

Fort et al. (2018) also emphasized the existence of the role of globalization on the impact of

Figure 5: Labor Shares of MNEs and Non-MNEs



Source: Authors' calculation based on Basic Survey on Overseas Business Activities (BSOBA) 2007-2016, Basic Survey on Japanese Business Structure and Activities (BSJBSA) 1996-2017, and JIP 2015. Multinational is defined as the firms that appeared in BSOBA at least once during 2007-2016. For each firm, labor share is calculated as the fraction of total payroll over the sum of total payroll and current profit from BSJBSA. We then aggregate to multinational groups and non-multinationals. Share of MNE size is calculated as the fraction of aggregated sales of all multinational firms over the total nominal output from JIP 2015.

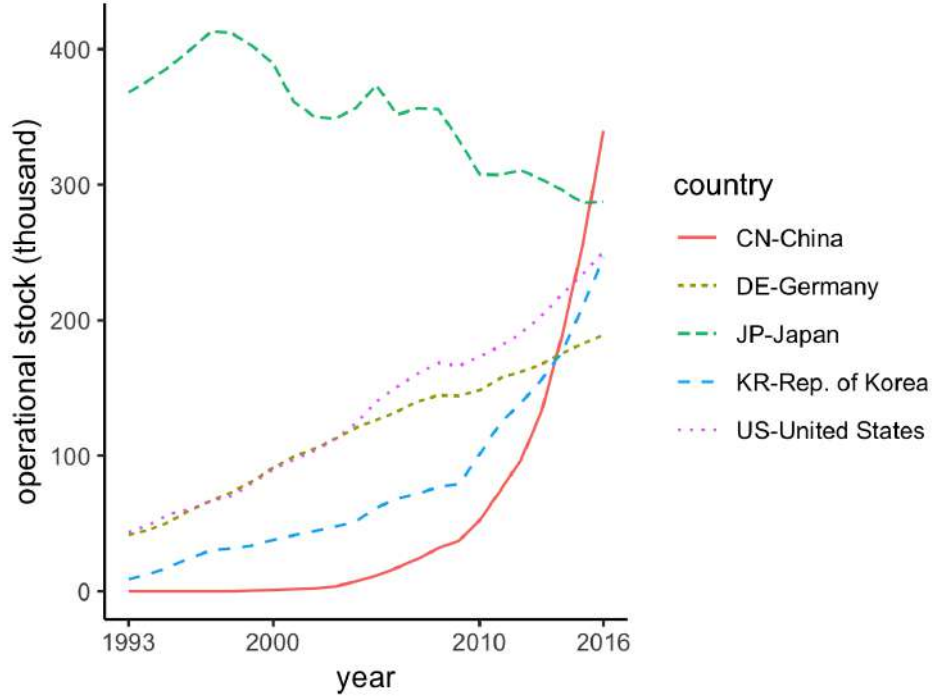
a country-level labor market, with the reservation that “providing a definitive accounting of the amount of employment change attributable to either factor is extraordinarily difficult.” Given the difficulty, we view that focusing Japan offers us a plausible case where the analysis is not contaminated by the concurrent technological growth to a large extent.

A Surge of Market Powers? As another explanation for the decrease in the labor share, [De Loecker and Eeckhout \(2017\)](#) argued that the surge in market power explains the labor share decline. They developed a parsimonious but versatile method to back out the markups from the firm- or plant-level data and concluded the markup in the U.S. has been increasing remarkably since around 1980. We apply their method to our Japanese firm-level data (BSJBSA). The result shows a smaller increase in markups relative to the U.S., which is in line with [De Loecker and Eeckhout \(2018\)](#).

3. Conceptual Framework

In this section, we set up our conceptual framework for the estimation and quantification that follow. First, in Section 3.1., we discuss a general framework that features foreign production. The framework has the same first order implications to labor shares as several offshoring ([Feenstra and Hanson, 1997](#)) and MNE models (among others, [Ramondo and Rodríguez-Clare 2013](#); [Arkolakis et](#)

Figure 6: Industrial Robot Stock, Top 5 Countries in 2016



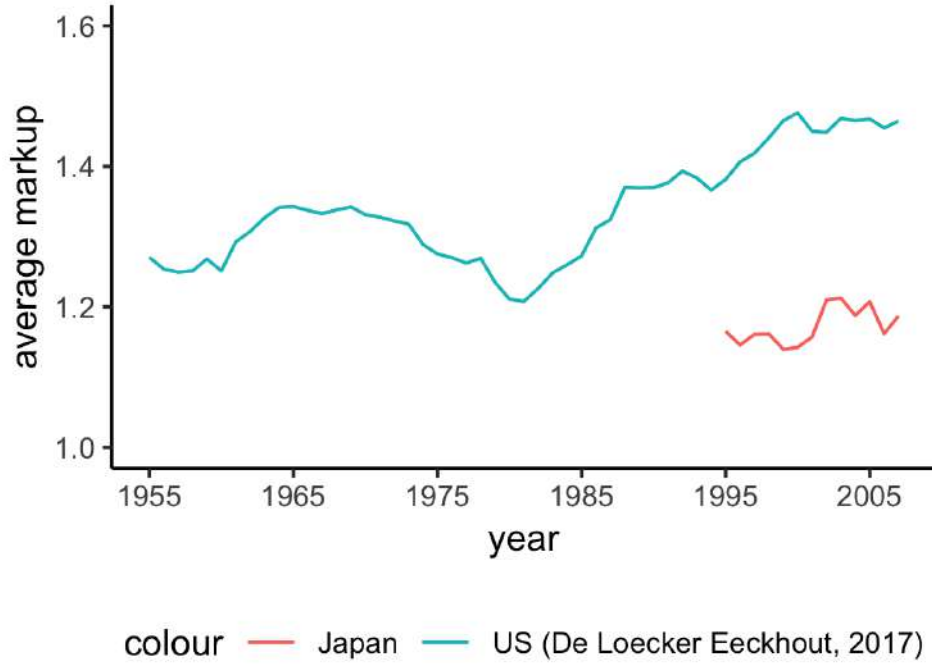
Source: International Federation of Robotics

al. 2017). It contains foreign factor augmentation that represents the reduction in the cost of multinational production, and factor market clearing conditions to discuss labor shares. The relationship with these models are relegated to Section A. In Section 3.2., we discuss the implications of the foreign factor augmentation on the labor share to the first order. Out of this section, readers will know what statistics out of the model are necessary to qualitatively and quantitatively understand the impact on labor shares. In Section 3.3., we discuss the methodology for identifying such statistics given the foreign factor augmentation shocks. In the estimation section, we apply the methodology to the 2011 Thailand Flood. In Section 3.4., we discuss a specific version of our general model, namely, a homogeneous nested CES production function. In this setup, we may discuss the solution to the labor share in a closed form, the necessary statistic in the form of constant parameters, and the identification in a simple linear regression. By doing so, we aim to offer simpler intuitions of the mechanisms of our model and guide ourselves to a setting for the estimation and quantification, as we will discuss in later sections.

3.1. Setup

The environment is static. There are two countries H and F . There are no trade costs but factors cannot move between countries. Firms originate from both countries and produce firm-specific output $i \in I$. Each good i is contestable and so firms are perfectly competitive in the output market. Country H is small-open in the sense that the set I_H of firms from country H constitutes zero measure among all firms I and the total demand is determined by F demand. We detail the consumption setup, production setup, and equilibrium in turn. The representative consumer has a CES preference across all

Figure 7: Markup Estimates with the Method of De Loecker and Eeckhout (2017)



Note: Authors' calculation based on De Loecker and Eeckhout (2017) with Basic Survey on Japanese Business Structure and Activities (BSJBSA) 1995-2016. Variable input cost is the sum of labor compensation and intermediate purchase. Output elasticity is estimated by Olley and Pakes' (1996) method for each JSIC 3-digit industry. The average is taken with the weight of each firm's sales.

goods $i \in I$. Hence the demand function is

$$q_i = \left(\frac{p_i}{P} \right)^{-\varepsilon} Q, \quad (1)$$

where $P = \int_{i \in I} (p_i)^{1-\varepsilon} di$ is the ideal price index. Since H is small-open, P and Q are determined exogenously to country H . Firm i in H may hire intermediate inputs m_i . Note that foreign inputs are so general that it may entail the foreign-produced intermediate input (e.g., Feenstra and Hanson, 1997) or the foreign factor of production (e.g., Helpman et al., 2004; Ramondo and Rodríguez-Clare, 2013; Arkolakis et al., 2017). A firm i from H produces a firm-specific output with domestic factors k_i and l_i , and foreign inputs m_i according to the constant returns to scale production function:

$$F(\tilde{k}_i, \tilde{l}_i, \tilde{m}_i),$$

where $\tilde{k}_i \equiv a_i^K k_i$, $\tilde{l}_i \equiv a_i^L l_i$, and $\tilde{m}_i \equiv a_i^M m_i$ are the augmented factors. We assume F satisfies increasing, strictly concave, and twice continuously differentiable (so that Young's theorem applies in Section A7.). Note that there are factor augmentations (a_i^K, a_i^L, a_i^M) . Below, our theoretical interest is the effect of changes in foreign factor augmentation a_i^M . In particular, in our comparative statics, we are concerned about positive log-augmentation $d \ln a_i^M > 0$, whereas in our identification argument and empirical application, we consider a negative log-augmentation. One may interpret the foreign factor augmentation as policy or institutional changes that reduce the cost of firms' multinational

activities or technological and economic growth of country F that increases the productivity of the factors.¹⁴

Factors from country H are hired competitively at each factor market. As we will see, country H 's capital and labor markets clear at prices r and w respectively, but F 's factor prices are given to small-open country H . Firms solve the augmented factor demands by the standard cost-minimizing problem given the quantity q_i in terms of augmentation-controlled prices $\tilde{r}_i \equiv r/a_i^K$, $\tilde{w}_i \equiv w/a_i^L$, and $\tilde{p}_i^M \equiv p_i^M/a_i^M$. Write $\tilde{p}_i^f \equiv (\tilde{r}_i, \tilde{w}_i, \tilde{p}_i^M)'$ the vector of the augmentation-controlled factor prices. Given the CES world demand (1), we have the quantity q_i that depends on firm i 's price p_i . Given the perfect competition, p_i further depends on augmentation-controlled factor prices \tilde{p}_i^f . Substituting this relationship between q_i and \tilde{p}_i^f in the cost-minimizing factor demand, we have the *reduced* factor demand functions that only depend on augmentation-controlled factor prices:

$$\tilde{k}_i = \tilde{k}_i(\tilde{p}_i^f), \tilde{l}_i = \tilde{l}_i(\tilde{p}_i^f), \tilde{m}_i = \tilde{m}_i(\tilde{p}_i^f). \quad (2)$$

The factor prices are determined by market clearing. The small-open H assumption implies that the hiring of foreign input m_i by $i \in I_H$ does not affect the prices p_i^M , so that we write $p_i^M = \overline{p}_i^M$ and $\tilde{p}_i^M = \overline{p}_i^M/a_i^M$. In H , capital and labor are supplied inelastically at level K and L . The H factor markets are cleared at the factor market conditions

$$K = \int_{i \in I_H} \frac{\tilde{k}_i(\tilde{p}_i^f)}{a_i^K} di, \quad L = \int_{i \in I_H} \frac{\tilde{l}_i(\tilde{p}_i^f)}{a_i^L} di. \quad (3)$$

Hence the small-open equilibrium is $(\{k_i, l_i, m_i\}_{i \in I_H}, r, w)$ that satisfies (i) the factor demands given by (2) and (ii) the factor prices solve (3).

Under our continuous environment, it is routine to show the existence of the equilibrium. Furthermore, given the property that the firm consumer is homogeneous (since H is small-open), we may prove the uniqueness of the equilibrium. The proof is detailed in Section A1.. Given such a unique equilibrium, we will discuss the first-order properties of labor shares and identifications in the following subsections.

3.2. Labor Shares

We can then analyze the implication of the foreign productivity shock to labor share as follows. The definition of the labor share is given by

$$LS \equiv \frac{wL}{wL + rK}. \quad (4)$$

¹⁴Sun (2018) conducted the counterfactual analysis with respect to bilateral multinational production cost. However, his calibration strategy does not identify the bilateral productivity as he explicitly states. To this extent, his counterfactual analysis corresponds to ours in that either the decline in multinational production cost or productivity growths of foreign country may induce the change in equilibrium object including the labor shares.

Note that endogenous variables in expression (4) are w and r . Hence, the solution to the model should solve the endogenous expression to the exogenous one. By taking the log-first order approximation to the labor share definition, we may have

$$dLS = LS_0 (1 - LS_0) (d \ln w - d \ln r). \quad (5)$$

Thus, the labor share increases if and only if the Home wage grew more than the Home rental rate. To study this, we revisit the factor market clearing condition (3) and take the log-first order approximation to have:

$$\begin{aligned} 0 &= \int_{i \in I_H} s_i^K \left[\sigma_{\tilde{kr},i} d \ln r + \sigma_{\tilde{kw},i} d \ln w - \sigma_{\tilde{kp}^M,i} d \ln a_i^M \right] di, \\ 0 &= \int_{i \in I_H} s_i^L \left[\sigma_{\tilde{lr},i} d \ln r + \sigma_{\tilde{lw},i} d \ln w - \sigma_{\tilde{lp}^M,i} d \ln a_i^M \right] di, \end{aligned}$$

or

$$\overline{\Sigma}_H \times \begin{pmatrix} d \ln r \\ d \ln w \end{pmatrix} = \begin{pmatrix} \int_{i \in I_H} s_i^K \sigma_{\tilde{kp}^M,i} d \ln a_i^M di \\ \int_{i \in I_H} s_i^L \sigma_{\tilde{lp}^M,i} d \ln a_i^M di \end{pmatrix}, \quad (6)$$

where $s_i^K \equiv rk_i/rK$ (resp. $s_i^L \equiv wl_i/wL$) is the capital (resp. labor) employment share of firm i among all H -origin firms I_H .

$$\overline{\Sigma}_H \equiv \begin{pmatrix} \int_{i \in I_H} s_i^K \sigma_{\tilde{kr},i} di & \int_{i \in I_H} s_i^K \sigma_{\tilde{kw},i} di \\ \int_{i \in I_H} s_i^L \sigma_{\tilde{lr},i} di & \int_{i \in I_H} s_i^L \sigma_{\tilde{lw},i} di \end{pmatrix} \quad (7)$$

is the weighted Home factor elasticity matrix. If $\overline{\Sigma}_H$ is negative definite, we obtain

$$d \ln w - d \ln r = \begin{pmatrix} -1 & 1 \end{pmatrix} (\overline{\Sigma}_H)^{-1} \begin{pmatrix} \int_{i \in I_H} s_i^K \sigma_{\tilde{kp}^M,i} d \ln a_i^M di \\ \int_{i \in I_H} s_i^L \sigma_{\tilde{lp}^M,i} d \ln a_i^M di \end{pmatrix}. \quad (8)$$

It is worth noting that the relationship of our general equilibrium setup and offshoring and multinational production models in the literature. We claim that our general equilibrium model nests modified versions of models of offshoring (Feenstra and Hanson, 1997) and multinational productions (e.g., Arkolakis et al., 2017) in terms of the first order approximation to the factor prices (6). We formally show these equivalence results in Section A2.. Therefore, for our purpose, we may be away with the detailed models of international trade and multinational productions, and only focus on the sufficient statistics of the elasticity matrix given by equation (7). We discuss how to identify part of such elasticities in the following sections.

3.3. Identification

We introduce negative foreign factor-augmenting productivity shock to a measure-zero subset of firms.¹⁵ As such a shock we interpret the 2011 Thailand Flood in Section 4.1., as we will discuss in the

¹⁵This simplifying assumption is helpful because otherwise the equilibrium effect on factor prices (r, w^H, w^L) would emerge and complicate the analysis. We have this assumption because the set of Japanese firms hit by the flood is small relative to the population. Having said that, multinational firms are larger and comprise a significant portion of factor employment theoretically (Helpman et al., 2004; Arkolakis et al., 2017 among others) and empirically (Ramondo et al., 2015).

following sections. Formally, assume that there exists an instrumental variable Z_i that correlates with the Foreign productivity shock $d \ln a_i^M$ but not with Home productivity shocks $d \ln a_i^K$ and $d \ln a_i^L$. Then we may construct the moment conditions:

$$E \left[Z_i \begin{pmatrix} d \ln a_i^K \\ d \ln a_i^L \end{pmatrix} \right] = 0. \quad (9)$$

To obtain the structural productivity shocks $d \ln a_i^K$ and $d \ln a_i^L$, consider the following model inversion. By factor demand functions (2), we have

$$\begin{aligned} d \ln (rk_i) &= d \ln (\tilde{r}_i \tilde{k}_i) = (1 + \sigma_{\tilde{k}\tilde{r},i}) d \ln \tilde{r}_i + \sigma_{\tilde{k}\tilde{w},i} d \ln \tilde{w}_i + \sigma_{\tilde{k}\tilde{p}^M,i} d \ln \tilde{p}_i^M, \\ d \ln (wl_i) &= d \ln (\tilde{w}_i \tilde{l}_i) = \sigma_{\tilde{l}\tilde{r},i} d \ln \tilde{r}_i + (1 + \sigma_{\tilde{l}\tilde{w},i}) d \ln \tilde{w}_i + \sigma_{\tilde{l}\tilde{p}^M,i} d \ln \tilde{p}_i^M, \\ d \ln (p^M m_i) &= d \ln (\tilde{p}_i^M \tilde{m}_i) = \sigma_{\tilde{m}\tilde{r},i} d \ln \tilde{r}_i + \sigma_{\tilde{m}\tilde{w},i} d \ln \tilde{w}_i + (1 + \sigma_{\tilde{m}\tilde{p}^M,i}) d \ln \tilde{p}_i^M, \end{aligned}$$

or in matrix form

$$\begin{pmatrix} d \ln (rk_i) \\ d \ln (wl_i) \\ d \ln (p^M m_i) \end{pmatrix} = (I + \Sigma_i) \begin{pmatrix} d \ln (\tilde{r}_i) \\ d \ln (\tilde{w}_i) \\ d \ln (\tilde{p}_i^M) \end{pmatrix} = (I + \Sigma_i) \begin{pmatrix} d \ln r - d \ln (a_i^K) \\ d \ln w - d \ln (a_i^L) \\ d \ln p^M - d \ln (a_i^M) \end{pmatrix},$$

where

$$\Sigma_i \equiv \begin{pmatrix} \sigma_{\tilde{k}\tilde{r},i} & \sigma_{\tilde{k}\tilde{w},i} & \sigma_{\tilde{k}\tilde{p}^M,i} \\ \sigma_{\tilde{l}\tilde{r},i} & \sigma_{\tilde{l}\tilde{w},i} & \sigma_{\tilde{l}\tilde{p}^M,i} \\ \sigma_{\tilde{m}\tilde{r},i} & \sigma_{\tilde{m}\tilde{w},i} & \sigma_{\tilde{m}\tilde{p}^M,i} \end{pmatrix}. \quad (10)$$

Thus we have

$$\begin{pmatrix} d \ln (a_i^K) \\ d \ln (a_i^L) \\ d \ln (a_i^M) \end{pmatrix} = \begin{pmatrix} d \ln r \\ d \ln w \\ d \ln p^M \end{pmatrix} - (I + \Sigma_i)^{-1} \begin{pmatrix} d \ln (rk_i) \\ d \ln (wl_i) \\ d \ln (p^M m_i) \end{pmatrix}. \quad (11)$$

Therefore, conditional on parameter restrictions, we may identify two elasticity parameters from elasticity matrix (10) given moment condition (9). We will discuss the empirical detail in Section 4..

At this point, we discuss the nature of our identification strategy. A typical method for identifying the labor demand-side elasticity such as our Σ_i is to use the labor-supply side elasticity such as short-run surge in migration. In fact, the idea that labor supply shock can identify the supply elasticity is through the change in wages exogenous to producers (Ottaviano and Peri, 2012). The benefit of our approach is that we do not need to have such exogenous changes observed, since it does not rely on the factor price changes, but the change in *effective* factor prices, that are specific to firms. This implies our identification method is free of any assumptions about labor market delineation or competition structure within the labor market.

Therefore, it is a quantitatively relevant extension to allow the shock to positive-measured set of firms for identification.

3.4. Example: Nested CES

In this section, we discuss a special case of our non-parametric and heterogeneous framework formalized in Section 3.1.. By doing so, we give a clear intuition of our general setup and simpler identification strategy. We rely on this example to calibrate some of our model in later sections.

Setup We keep the same set up about the countries and consumer preferences. For firms, there are homogeneous set of firms. We keep denoting I as the set of firms in any country and I_H as that from country H . To have a different elasticity of substitution between the foreign factor and home factors, we assume a parsimonious nested CES production function. Namely, each firm produces output q with nested CES production function:

$$F(k, l, m) = \left((a^K k)^{\frac{\sigma-1}{\sigma}} + x^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

where $\sigma > 0$ is an upper substitution of elasticity and

$$x = \left((a^L l)^{\frac{\lambda-1}{\lambda}} + (a^M m)^{\frac{\lambda-1}{\lambda}} \right)^{\frac{\lambda}{\lambda-1}}, \quad (12)$$

where $\lambda > 0$ is a lower elasticity substitution. Note that the special case of $\lambda = \sigma$ implies the single-nest CES production function. Finally, suppose factor supplies (K, L, M) are fixed. Factor market clearing $k = K, l = L$, and $m = M$ gives the factor prices w^c and r . The labor share is given by equation (4).

Several discussions follow. To relate our production function choice with the one in Oberfield and Raval (2014), note that firms need not hire foreign factor m in reality. If this is the case, we can define the production function with $m = 0$, which would boil down to CES $q = \left((a^K k)^{\frac{\sigma-1}{\sigma}} + (a^L l)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$. On the other hand, Oberfield and Raval (2014) considered the CES production function with heterogeneous augmentation a^K and a^L at the firm level. Note also that firms need not hire foreign factor, which guides us to the restriction that the labor and foreign factor are gross substitutes, or $\lambda > 1$.

We further discuss potential parameter restrictions. To the extent that typical firms hold some form of capital to produce output, we have an educated guess that capital and aggregate labor are gross complements, or $\sigma < 1$. Because the parameter restrictions so far turn out useful for some of theoretical arguments, we formalize these as the following assumption.

Assumption 1. $\lambda > 1 > \sigma > 0$.

In what follows, we discuss that under Assumption 1, we show that the foreign labor (log-)augmentation $d \ln a_i^M > 0$ implies the reduction in labor share $dLS < 0$. As we detailed in Section 1.1., Oberfield and Raval (2014) indeed estimated that σ is well-below unity using the U.S. plant-level microdata. In our empirical and quantitative exercise, we apply the method modified to our nested CES assumption to Japanese firm- and plant-level data and confirm that $\sigma < 1$ is also the case in Japan. Moreover, our identification method applied to the natural-experiment based IV estimate

reveals in fact $\lambda > 1$. Therefore, we regard Assumption 1 holds empirically. On the other hand, notice that a number of results in the following section does not depend on a particular parameter restriction 1.

Labor Share We show this in Section A3. that under our setting the labor share expression may be solved analytically as

$$LS = \frac{(a^L L)^{1-\lambda^{-1}} X^{\lambda^{-1}-\sigma^{-1}}}{(a^L L)^{1-\lambda^{-1}} X^{\lambda^{-1}-\sigma^{-1}} + (a^K K)^{1-\sigma^{-1}}}, \quad (13)$$

where

$$X \equiv \left((a^L L)^{\frac{\lambda-1}{\lambda}} + (a^M M)^{\frac{\lambda-1}{\lambda}} \right)^{\frac{\lambda}{\lambda-1}}$$

is the aggregate value of the factor supplies to country H measured by function (12). Note that X is increasing in a^M . Hence, if $\lambda^{-1} - \sigma^{-1} < 0$ or $\lambda > \sigma$, LS is decreasing in a^M . Intuitively, if within the lower nest the factors are more substitutable, then the increase in the productivity of offshore worker relatively strongly substitutes away the domestic labor. More specifically, note that cost-minimizing factor demand (A.44) implies $d \ln L = WS_0^M d \ln A^M$ to the first order, where $WS^M \equiv p^M m / (wl + p^M m)$ is the aggregate share of payment to foreign labor in total payment to home and foreign labor. Throughout the paper, subscript 0 denotes the variable at the base year. Hence WS_0^M is the base-year value of the aggregate share of payment to foreign labor.

It is worthwhile to highlight the role of the simplifying assumptions, homogeneous nested CES and fixed foreign factor supplies, in deriving the closed form equation (13). Note that wage rate w and capital rental rate r are endogenous objects that may be solved according to factor market clearing conditions. With homogeneous and nested CES structures, we may solve the relative wages of these analytically. Furthermore, the assumption that the foreign factor market clears with the foreign factor supply is fixed at M plays crucial role in deriving the closed form in exogenous terms. Namely, without it, the lower aggregate term L contains the foreign factor supply M , which is endogenous and needs to be solved as other exogenous elements in the model.

With these assumptions, other exogenous variables being fixed, the first order approximation with respect to $d \ln a^M$ implies

$$\begin{aligned} dLS &= LS_0 (1 - LS_0) (\lambda^{-1} - \sigma^{-1}) d \ln L \\ &= LS_0 (1 - LS_0) (\lambda^{-1} - \sigma^{-1}) WS_0^M d \ln a^M, \end{aligned} \quad (14)$$

Therefore, again, it is crucial to know the relative values of λ and σ to learn the sign of the effects of foreign labor augmentation on the labor share. Thus, our informed guess in Section 3.1. establishes the following formal result.

Lemma 1. *Under assumption 1, foreign factor augmentation $d \ln a^M$ implies $dLS < 0$.*

Several discussions regarding Lemma 1 follows. In a special case, the single-nest CES production function $\lambda = \sigma$ would not be able to discuss the effect of foreign factor augmentation on home labor

share. In other words, this is one of the manifestations of the restrictive implication of *independence from irrelevant alternatives* (IIA) that CES function features. Namely, since the foreign factor is an irrelevant alternative to home capital and labor, the augmentation does not affect the *relative* factor demands of home capital and labor. To this extent, we need the nested structure in the production function in our simplest setting.

Quantitatively, identifying the value of $\lambda^{-1} - \sigma^{-1}$ is critical to understand the labor share implication. In what follows, we obtain an even stronger result for identification—we identify the absolute value of λ and σ . In short, the shift-share instrument is employed in identifying σ (Oberfield and Raval, 2014; Raval, 2019). In contrast, pure foreign negative productivity shock is leveraged for identification of λ as detailed below.

Since the homogeneous nested CES case is a special case of the general setup in Section 3.1., we may also relate the theoretical implications in terms of the general substitution elasticity matrix (10). We discuss this in Section A5..

Identification We then show the identification result given the foreign factor augmentation shocks as in Section 3.3.. In Section A4., we prove the following equations:

$$d \ln l = \left[(\lambda - \sigma) WS_0^M + (\sigma - \varepsilon) CS_0^M \right] d \ln a^M, \quad (15)$$

$$d \ln m = \left[-\lambda + (\lambda - \sigma) WS_0^M + (\sigma - \varepsilon) CS_0^M \right] d \ln a^M. \quad (16)$$

These equations mean that elasticities of pure foreign factor-augmenting productivity shock are summarized by three parameters $\lambda, \sigma, \varepsilon$ and constants WS_0^M and CS_0^M . The intuition follows. A negative foreign factor-augmenting productivity shock has *direct* and *indirect* effects on factor employments. The direct effect speaks to the *biasedness* of the factor-augmenting shock. Namely, consider the case where the shock is biased to foreign factor demand, or $\lambda > 1$ where the lower nest features gross substitutes, as formalized in Assumption 1.¹⁶ Then it has a force to decrease the foreign factor demand given the negative shock, by the elasticity of $\lambda - 1$. On the other hand, the indirect effect is as follows. To the first order, one percent decrease in the foreign factor-augmenting productivity shock increases the lower nest aggregate cost by WS_0^M percent and the marginal cost by CS_0^M percent. These increases have the effect on the total demand through the elasticities governed by the nested CES structure, $\lambda - \sigma$ and $\sigma - \varepsilon$, respectively. Due to the CRS production function, this effect applies to labor demand l and foreign factor demand m alike. Therefore, the direct effect matters for foreign labor employment, whereas the indirect one for all factor demands.

However, it is not trivial to observe the size of foreign factor-augmenting productivity shock $d \ln a^M$ empirically. Therefore, we consider the elasticity of foreign labor with respect to domestic

¹⁶On factor augmentation and biasedness, a detailed discussion given by, for example, Acemoglu (1998).

labor given the pure negative shock.¹⁷ Namely, write the elasticity as σ_{lm,a^M} . Formally,

$$\sigma_{lm,a^M} \equiv \frac{\frac{d \ln l}{d \ln a^M}}{\frac{d \ln m}{d \ln a^M}}. \quad (17)$$

Then by equations (15) and (16), we have

$$\sigma_{lm,a^M} = \frac{(\lambda - \sigma) WS_0^M + (\sigma - \varepsilon) CS_0^M}{-\lambda + (\lambda - \sigma) WS_0^M + (\sigma - \varepsilon) CS_0^M}. \quad (18)$$

In equation (18), readers might wonder why an increase in λ would result in the decrease in shock-induced elasticity σ_{lm,a^M} . To clarify, we discuss an extreme case when $\lambda < 1$, which means that the foreign factor augmentation is biased to *country-H* labor. In such a case, the negative foreign factor-augmenting productivity shock would imply the force to *increase* hire in foreign factor. This is because the home and foreign factors would be gross complements, which in turn means that the foreign factor compression would result in need of replenishing the physical foreign factor rather than substituting. Therefore, relative to the case $\lambda > 1$, the denominator of equation (18) would be small, which would result in a *large* value of σ_{lm,a^M} , so long as $-\lambda + (\lambda - \sigma) WS_0^M + (\sigma - \varepsilon) CS_0^M > 0$.

To summarize the discussion, by equation (18), we can identify λ given the knowledge of σ_{lm,a^M} , constants (WS_0^M, CS_0^M) , and other parameters (σ, ε) . We discuss how to obtain these constants and parameters in detail in the following sections. There we also discuss how to identify and estimate σ_{lm,a^M} . Finally, in the following sections, we use both the identification arguments based on equation (9) and (18).

4. Empirical Application—the 2011 Thailand Flood

Given our theoretical result of identification in Section 3., we discuss how we may obtain Σ_i in equation (10). In fact, it is not trivial to find a plausibly exogenous shock to multinational activities of MNEs. For example, there are challenges that emerge from the small number of MNEs relative to the population of firms. In particular, Boehm et al. (2017) mentioned “the notorious difficulty to construct convincing instruments with sufficient power at the firm level.”¹⁸ In this paper, our approach is to focus on a unique natural experiment, the 2011 Thailand Flood. We detail the event and the interpretation for our purpose in Section 4.1.. Then we discuss the firm- and plant-level data to capture the event in Section 2.1..

As our main empirical results, we rely on the homogeneous nested CES setting and identify parameters of interest based on the moment condition (18). Section 4.2. details the process. Section 5.3. discusses the alternative general approach based on the moment condition (9).

¹⁷ Although here we consider a pure shock, in estimation we conjecture it is possible to relax this assumption and consider more formal moment conditions. In this line of argument, Adao et al. (2018) offer an excellent rigorous derivation. This direction should be aimed in the future development of our research.

¹⁸ Such difficulty is reaffirmed in Section B7.1. by analyzing substitution parameter λ by means of shift-share instruments à la Desai et al. (2009) and Hummels et al. (2014).

4.1. Background

Between July 2011 and January 2012, massive flooding occurred along the Mekong and Chao Phraya river basins in Thailand, which caused sizable amount of plants in the area to halt operation. The magnitude of the shocks to the production economy is extraordinary. The estimate of economic damage is \$46.5 billion, which is then the fourth costliest disaster *in history* (World Bank, 2011).¹⁹ To the extent that the firms could not anticipate the flooding beforehand, we take this event as an exogenous shock. Section B3.5. further details the balancing test to confirm that there are not large systematic differences between the Japanese MNEs that had subsidiaries located in the flooded regions and not.

We then interpret that the flood can be interpreted as a *negative foreign productivity shock* for Japanese MNEs. First we detail that it can be seen as a productivity shock. To see this, it is worthwhile to confirm that the shock was local. Thailand is subdivided into several provinces. Among them, provinces of Ayutthaya and Pathum Thani along the flood-prone Chao Phraya river suffered from the flood severely. In these areas, the flood inundation reached its peak in October 2011. In fact, Adachi et al. (2016) showed by their survey results that to the local firms, the maximum days of inundation were 84 and 77 in Ayutthaya and Pathum Thani provinces, respectively. The corresponding values for maximal meter depth of inundation were 6 and 4, respectively. On the other hand, no firms from regions out of Ayutthaya or Pathum Thani provinces answered any days or height of inundation due to the 2011 flood.

In such severely damaged localities Ayutthaya province and Pathum Thani province, there were seven industrial clusters where roughly 800 plants resided (Tamada et al., 2013).²⁰ A large fraction of firms in the industry clusters engaged in automobile and electronics industries (Haraguchi and Lall, 2015). Therefore, the flood shook the local regions within Thailand, which are intensive in industrial production, in particular automobile and electronics.

To further give the economic background and suggestive evidence that the flood was shock on the production side of the economy, we observe that, after the Flood, Thailand experienced decrease in exports but not in imports. The observed pattern can be seen as a piece of evidence that the production side was hit by a shock rather than the demand side, as Benguria and Taylor (2019) argues to interpret the shock origin of the financial crisis. Section B2. discusses this in detail.

What makes the flood unique for our study is that although it hit local regions of Thailand, it can be considered to be a *sizable foreign productivity shock* from the perspective of Japanese MNEs. To see this, we detail the close relationship between the two countries as investment destination and source countries. Among the roughly 800 plants in the heavily flood-inundated industrial clusters, roughly

¹⁹To the extent that the economic damage includes the values of property damaged, natural disasters in developed countries are likely to be costlier. In fact, the three disasters whose economic damage surpassed the 2011 Thailand Floods are the 2011 Tohoku Earthquake and tsunami (Japan), the 1995 Great Hanshin Earthquake (Japan), and the 2005 Hurricane Katrina (U.S.). Therefore, given the economic damage, the physical shock to a developing country, like Thailand, should be regarded as even larger.

²⁰A reinsurance broker Aon Benfield summarized the flood area and the locations of the inundated industrial clusters in a report. The report is available at http://thoughtleadership.aonbenfield.com/Documents/20120314_impact_forecasting_thailand_flood_event_recap.pdf (accessed on July 7, 2019). In the Exhibit 16, the relevant map is available.

450 are Japanese subsidiaries.²¹ Section B3.3. overviews that the industrial patterns of plants that are subsidiaries of Japanese MNEs from our dataset. Indeed, the flood had a large negative shock to Japanese producers. In Section B3.4., we also show that Thailand is a major destination country of Japanese MNEs, using our dataset.

Recall that our dataset in Section 2.1. covers the information well to study the impact of the flooding shock on factor employment. BSJBSA data contains broad firm sample with domestic factor employments including employment, labor compensation, fixed asset and net income. BSOBA is a universe of Japanese MNEs with the universe of their plants worldwide. The plant-level variables contain the plant name, the parent firm name, employment, labor compensation, and net income. Orbis allows the exact address of these overseas plants. Finally, TSR data allows matching these datasets since it contains the universe of Japanese firms, which allows us to analyze the flood shock that hit a subset of firms in our dataset by methods of micro-econometrics.

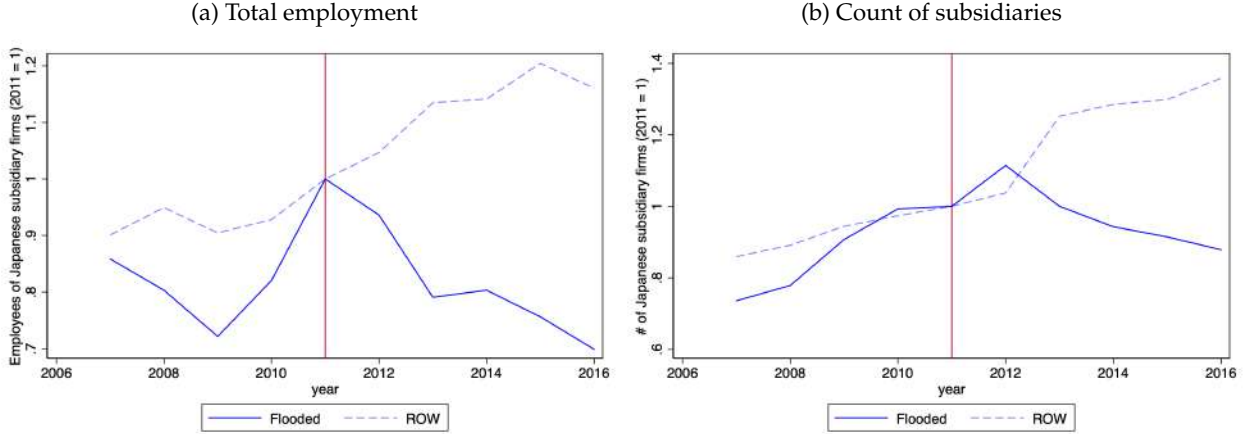
4.1.1. The Flood and Aggregate Trends

In this section, we overview the first-pass evidence of the effect of the flood on Japanese MNEs by our combined dataset detailed in Section 2.1.. Figure 8 shows relative trend of aggregate variables in flooded regions versus the rest of the world, excluding Japan. Panel 8a shows the trend of total employment, whereas Panel 8b the count of subsidiaries. In both panels, the solid line shows the trend for the flooded region and the dashed the other regions excluding Japan (labeled ROW). Both trends are normalized at one in 2011. One can see that, for both statistics, the ROW trend is increasing over the sample period. This is reflecting the fact that more firms are entering the pool of MNEs and invest in Thailand and hire local workers, or conditional on the firm being MNEs with Thailand subsidiaries, they expand and hire more local workers. Panel 8a reflects both of these possibilities, whereas Panel 8b the first. When we turn to the flooded regions, the pattern is sizably different. Indeed, such an increasing trend before the flood year 2011 is similarly rapid as ROW or even slightly faster if any, reflecting the fact that the flooded regions took some measures to attract foreign investors. However, the trend abruptly broke in the year or after the flood and began to decrease *in level*. What is further noteworthy is the *persistence* of such a decrease. Even though the flood itself was short-lived that largely went away by early 2012, the decreasing trend of both the total employment and count of subsidiaries continued at least up to 2016. A potential explanation to these behaviors can be found in news articles and academic discussions. Because the one-time event was large enough for firms to update their risk perception of the future flood, companies “move to avoid potential supply chain disruptions” (Nikkei Asian Review, 2014). The argument of this sort can be found in the discussion of negative effects of policy uncertainty on international trade and investment (Pierce and Schott, 2016; Handley and Limão, 2017; Steinberg et al., 2017).

Given the findings in Figure 8, we regard the elasticity findings below as the *long-run elasticities* as opposed to short-run. We come back to this issue when we set out our empirical specification.

²¹In the report in Footnote 20, Exhibit 15 shows the picture of inundated Honda Ayutthaya Plant, which is located in Rojana Industrial Park, one of the seven severely flooded industrial clusters.

Figure 8: Relative Trends of Aggregate Variables in Flooded Regions



Note: Authors' calculation from BSOBA 2007-2016. "Flooded" shows the evolution of total employment in plants located in the flooded area (*Ayutthaya* and *Pathum Thani* Province). "ROW" shows that out of the flooded area. Both trends are normalized to 1 in 2011.

Furthermore, section B3.6. details the other trends of investment and intermediate purchases.

4.2. Estimation

For our main empirical results, we apply the identification strategy based on linear regression (18). Specifically, we first calibrate the standard parameter values σ , ε and constants CS_0^F and WS_0^F . We discuss this in Section 4.2.1.. Given these values and the reduced-form parameter of σ_{lm,a^M} , we may back out λ from equation (18). Section 4.2.2. is devoted for discussing how we identify and estimate σ_{lm,a^M} .

4.2.1. Step 1: Calibration under Homogeneous Nested CES

To obtain λ , σ , and ε , first we discuss how we back out σ and ε from the data. Then we obtain λ from equation (18). As for the capital-aggregate labor elasticity σ , we employ the method developed in recent studies (Oberfield and Raval, 2014; Raval, 2019). Specifically, the cost-minimizing factor demands (A.41) and (A.42) imply $\ln(rk/p^X x) = (\sigma - 1) \ln(p^X/r) + \text{const}$. Furthermore, recall that for non MNEs we have $p^X = w$ and $p^X x = wl$. Therefore, for non MNEs we have

$$\ln \frac{rk}{p^X x} = (\sigma - 1) \ln \frac{p^X}{r} + \text{const}. \quad (19)$$

Based on this estimation equation, if we can obtain the coefficient on the log-relative factor price term, we can back out the substitution parameter σ . The idea to operationalize the first-order condition relationship (19) to the data is to use the location m -level variation of each plant i , or $m(i)$. Because local regions constitute labor markets due to commuting immobility, the wages vary across m 's. Moreover, such variations are empirically persistent. Thus, the coefficient obtained by such variation reveals the long-run elasticity of substitution. Note that the location-level variation in wage can be sourced from many shocks. Oberfield and Raval (2014); Raval (2019) let the location-level wage

Table 1: Estimates of $\sigma - 1$

	IV, CO	IV, BSWS, all	IV, BSWS, manuf.
$\log(w_{m(i)})$	-1.15*** (0.18)	-1.24*** (0.18)	-0.88*** (0.13)
Num. obs.	51477	51477	51477

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Notes: CO indicates that the wage data is from the Cabinet Office."BSWS, all" indicates that the wage variable is taken from all industries from Basic Survey on Wage Structures (BSWS), while "BSWS, manuf." indicates that the wage variable is taken from manufacturing industries from BSWS. All regressions include industry FE and multiunit status indicator. Standard errors are clustered at municipality level.

vary by a shift-share instrument. Therefore, the regression specification is

$$\ln\left(\frac{rk}{wl}\right)_i = b_0 + b_1 \ln(w_{m(i)}) + X_i b_2 + e_i, \quad (20)$$

with a shift-share instrument $z_m = \sum_{j \in \mathcal{J}^{NM}} \omega_{mj,-10} g_j$, where X_i is plant-level control variable, j is an industry, \mathcal{J}^{NM} is the set of non-manufacturing industries, $\omega_{mj,-10}$ is the employment share of industry j in location m in ten-year prior to the analysis period, and g_j is leave- m -out growth rate of national employment in industry j over the ten year that preceded the analysis year.

We apply this method to Japan's Census of Manufacture plant-level data. We select the firms that do not have plants internationally as the estimation equation (19) applies to non MNEs. We define the unit of location m as municipality.²² For municipality-level wage data, we have several the source. First, Japan's Cabinet Office (CO) offers the municipality-level average wage. Second, *Basic Survey on Wage Structures* (BSWS) administered by Japan's Ministry of Health, Labour and Welfare offers the national survey-based estimates of the municipality average wages for each industry. Therefore, we have three alternatives for w_m variable: CO wage, BSWS wage, and BSWS manufacturing-average wage. Details in the estimation procedure are discussed in Section B4.1. .

Table 1 shows the estimation result. Depending on the choice of regressors, our estimates imply lower substitution parameter $\sigma \leq 0.2$ than Oberfield and Raval (2014), which would imply a larger effect of $d \ln A^F$ on dLS according to equation (14).²³ To obtain the conservative result, in the following quantitative exercise we use the value of the upper bound $\sigma = 0.2$.

As for the demand elasticity ϵ , again we employ the 2011 survey of Japan's Census of Manufac-

²²The total number of municipalities is roughly 1700 as of 2005. This is fairly small definition of local labor market, resembling counties in the U.S., which counts roughly 3000. Another choice of local labor market in Japan is commuting zones recently used by Adachi et al. (2019), following the seminal method introduced and popularized by Tolbert and Sizer (1996). The commuting zones in Japan count 331 in 2005.

²³The central estimate of Oberfield and Raval (2014) was around 0.7. However, this value includes the industry-level heterogeneity in substitutability and the caused reallocation mechanism. Oberfield and Raval (2014) reported that plant-level elasticity estimates are within the range of 0.4-0.7 depending on industries, which is closer to our value. Incorporating heterogeneity into the model should be on our next research step with high priority.

Moreover, the capital-labor substitution parameters at micro and macro-level estimates sometimes disagree. In fact, although microdata-based finding of ours and Oberfield and Raval (2014) both point to gross-complementary capital and labor, the macro estimates often indicate that they are gross substitutes (Karabarbounis and Neiman, 2013; Hubmer, 2018). Note that these macro estimates typically rely on the U.S. data. In Japan, even at macro level, Hirakata and Koike (2018) showed that the capital-labor elasticity is below one, which is qualitatively consistent with our findings.

ture. Following [Oberfield and Raval \(2014\)](#) we back out ε by $\varepsilon = m / (m - 1)$, where $m \equiv \text{sales} / \text{cost}$ is the measured markup.²⁴ The distribution of measured markup is shown in Figure B.13. The implied average markup implies $\varepsilon \in [3.98, 4.88]$, depending on the treatment of extreme values. This lies well in the range of the demand elasticity estimate using firm-level markups. For conservative implication to the labor share, we choose low-end $\varepsilon = 4$. The value is within the range of demand elasticities of different industries in the U.S. reported in [Oberfield and Raval \(2014\)](#).

To have the value for the share of foreign labor cost in total cost $CS^M \equiv p^M m / (rk + wl + p^M m)$, we use the 2011 survey of BSOBA data. Since our purpose is to back out λ from our estimate of ε_{lm,a^M} , we focus on firms located in the flooded region. We then calculate, for each headquarter firm i ,

$$CS_{i,2011}^M = \frac{\sum_{l \in \text{flooded}} \text{total payroll}_{f,2011}^l}{\sum_{l \in \text{world}} \text{total cost}_{f,2011}^l},$$

where *flooded* is the set of locations that were hit by the Flood, the definition of total payroll and total cost are detailed in Section C1.. We then obtain the 2011 firm-level average value of $CS^M = 2.4\%$. The overall distribution of CS^M is drawn in Figure B.14. Similarly, we obtain the 2011 average value of $WS^M = 4.0\%$ by replacing the denominator of CS_i^M with the sum of payroll at all locations l in the world. Section B4.2. shows some detailed results in the estimation of ε and CS^M .

4.2.2. Step 2: Estimating λ by the Natural Experiment

For obtaining λ by Equation (18), our goal is to estimate the left-hand side parameter σ_{lm,a^M} . In our empirical application, specify $H = JPN$ and $F = ROW$. We measure the foreign factor employment m_{it} by the total foreign labor employment since in our data the quantity of factor employment is only available for labor. We thus specify the factor substitution between country H and F in the model as the substitution of labor across countries. Our result is robust to other choice of the measure of m_{it} , as is discussed below. Hence, we use the notation l^{JPN} as employment in Japan and l^{ROW} as the employment in the rest of the world, measuring the factor employment in the rest of the world.

We run the following regression

$$\ln(l_{it}^{JPN}) = a_i + a_t + b \ln(l_{it}^{ROW}) + e_{it}, \quad (21)$$

where $\ln(l_{it}^{JPN})$ is log of firm i in year t , $\ln(l_{it}^{ROW})$ is the log factor employment in the rest of the world, a_i and a_t are firm- and year-fixed effects, and e_{it} is the error term.

It is critical to control these rich fixed effects. In fact, controlling firm-fixed effects restrict ourselves to leverage within-firm variations, since high-productivity firms are likely to hire workers in ROW (or conducts FDI and become an MNE, as in [Helpman et al., 2004](#)). On the other hand, controlling for year-fixed effects enhances the validity of our analysis given the economic environment where more and more firms become MNEs and hire more local workers in foreign countries, as we

²⁴Note that we use the 2011 survey because equations (15) and (16) should be evaluated at the period of the shock, which is 2011 in our case.

saw in Figure 8.

In the data, the variation in the explanatory variable $\ln(l_{it}^{ROW})$ can emerge from any sources. One of such factors includes the firm-specific exchange rates that affect through the demand shocks or equivalently total factor productivity. Since we are concerned about pure foreign factor-augmenting productivity shock in equation (17), we construct an instrumental variable (IV) that leverages the 2011 Thailand Flood. For this purpose, note that the flood was local, happened in one period in time of the coverage of our dataset, and most importantly, was unexpected. We construct the IV that interacts the location at Thailand *before the flood* and the year after the flood. Because the shock was unexpected, the IV is exogenous to firms' foreign production decisions, after controlling for the firm and year fixed effect. To leverage the variation in $\ln(l_{it}^{ROW})$ caused by such pure foreign productivity shock, IV of a shock intensity measure is used:

$$Z_{it} \equiv \frac{l_{i,2011}^{flooded}}{l_{i,2011}^{IPN} + l_{i,2011}^{ROW}} \times \mathbf{1}\{t \geq 2012\}, \quad (22)$$

where $l_{i,2011}^{flooded}$ is firm- i 's total employment in the flooded regions in year 2011, right before the flooding. The measure captures the how much each MNEs i rely on the employment in the flooded region. Namely, if a firm hires relatively large amount of workers in the flooded region right before the flood, the firm is likely to be hit by the flood severely and receives a large negative (firm- i 's) foreign factor-augmenting productivity shock.

Given the instrument, the two-stage least square (2SLS) estimator is based on the following equations.

$$\ln(l_{it}^{ROW}) = \tilde{a}_i + \tilde{a}_t + \tilde{b}Z_{it} + \tilde{e}_{it}. \quad (23)$$

$$\ln(l_{it}^{IPN}) = a_i + a_t + bZ_{it} + e_{it}, \quad (24)$$

Therefore, we expect the first stage regression yields negative correlation between $\ln(l_{it}^{ROW})$ and Z_{it} conditional on the fixed effects. Given the validity of the first stage, we interpret

$$\widehat{b}_{IV} = \widehat{\sigma_{lm,a}^M}.$$

As we showed in Section 4.1.1., the flood had medium- to long-run effects as opposed to short-run effects on employments. Given this finding, we regard our coefficient \widehat{b}_{IV} , or in turn λ , as long-run elasticity rather than short-run. Namely, we relate the decline in employment found in aggregate in Panel 8a as an exogenous-sourced decline in ROW log-employment $\ln(l_{it}^{ROW})$, and relate that to the change in log-employment in Home $\ln(l_{it}^{IPN})$. This point is crucial when we move on to the quantitative exercise, because our concern is a relatively long-run event of the change in labor share. We conduct the robustness check to long-difference specification and extension exercise to the event-study regressions in the discussion below.

Table 2 shows the estimation result including 2SLS (23) and (24). The robust standard errors are

Table 2: Estimating σ_{lm,a^M}

VARIABLES	(1) $\ln l_{it}^{JPN}$	(2) $\ln l_{it}^{JPN}$	(3) $\ln l_{it}^{JPN}$	(4) $\ln l_{it}^{ROW}$	(5) $\ln l_{it}^{JPN}$
$\ln l_{it}^{ROW}$	0.446*** (0.00686)	0.0604*** (0.0106)	0.192*** (0.0502)		
Z_{it}				-0.728*** (0.108)	-0.140*** (0.0367)
Observations	5,563	5,563	5,563	5,563	5,563
Model	OLS	FE	2SLS	2SLS-1st	2SLS-reduced
Firm FE	-	YES	YES	YES	YES
Year FE	-	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

reported in the parentheses. All columns suggest the statistically significant coefficients at two-sided one-percent significance level.

Column 1 shows the result with OLS specification without any fixed effects, namely, under the restriction $a_i = a_t = 0$ for all i and t . Column 2 shows the result with the fixed effect specification. Column 1 and 2 compare that both coefficients are positive, but after controlling for fixed effects reflecting the firms' productivity heterogeneity, the coefficients get significantly small. Column 3 shows the result with the instrumental variable in equation (22).

Column 3 reads that for one-percent decrease in employment in the rest of the world caused by the 2011 Thailand Flood, Japanese MNEs *decrease* home employment by 0.192 percent. Although this coefficient is a composite of model parameters as shown in equation (18) without any meaningful interpretation by itself, it is produced by the 2SLS first stage and reduced-form regressions shown in columns 4 and 5. Column 4 shows that a firm that did not rely on the employment in the flooded region in 2011 would have reduced the employment in the rest of the world by 72.8 percent had it relied completely on the employment there.²⁵ Given the fact that after the flood a few firms resumed operation relatively quickly, it is reasonable that the reduction is less than 100 percent. As we detailed in Section 3.3., this number is proportional to the composite of direct and indirect effect of the flood shock, or related to equation (16). More interestingly, column 5 reveals that the same hypothetical increase in the reliance in Thailand employment would cause the firm to *reduce* the employment in Japan by 14.0 percent. Again, this cross effect of foreign factor-augmenting productivity shock on the home employment is indicative of the indirect effect described in equation (15). Thus, the fraction of these two coefficients, 0.192 in column 3, let us learn the direct effect of the flood, or implied elasticity of substitution between home and foreign labor inputs. Since the sign of the regression coefficient in column 5 is the key in the sign of the 2SLS estimate and thus the value of λ , we conduct a robustness exercise in Section B6.2..

²⁵The standard deviation of our IV is 0.157. Hence one standard deviation increase in our IV translates to 11.4% decrease in employment in foreign countries.

Before we move to back out our parameter of interest λ in the following sections, it is also worthwhile to note that column 3 estimates higher coefficients on the foreign employment than column 2. This is because of the difference in the source of identifying variation and is indicative of the benefit of our natural experiment approach. Namely, in the 2SLS specification, the source of variation is the pure offshore productivity shock. Therefore, we have the structural interpretation (or function of structural parameters) for the coefficient. On the other hand, the fixed effect specification does not identify any structural parameters. For example, if the underlying variation is the increase in wage (for example, caused by the TFP growth in the offshore country) in the offshore country relative to in Japan, then the substitution from offshore labor to Japanese labor (so called inshoring) would have negative correlation between offshore labor and Japanese labor. In this case, relative to the identified coefficient obtained by the 2SLS, the fixed effect coefficient is smaller in real number.

Armed with calibrations of σ and ε from Section 4.2.1., equation (17) implies that $\lambda = 1.4$. Since ε_{lm,a^M} has a valid standard error from the 2SLS estimation, we can obtain the standard error of λ by the Delta method as 0.13, indicating we reject the gross-complementary home and foreign labor $\lambda \leq 1$ at 0.1 percent significance level. Section B5. details this point. Therefore, our calibrations $\sigma = 0.2$ and $\lambda = 1.4$ imply that Assumption 1 is satisfied empirically. Applying Lemma 1, we conclude that given any positive foreign factor augmentation, the labor share decreases qualitatively. To proceed to quantitative implication, in what follows we back out the foreign factor augmentation from aggregate data.

Discussions Our results are robust to other specifications, sample selections, and variable choices. First, our IV is meant to capture the variation in foreign employment caused by the 2011 Thailand Flood. Section B6.1. shows that the two stage-least square estimate produced by different definitions of the IV also produces qualitatively similar results and the mechanism behind it. Second, note that our choice of IV does not explicitly separate firms that have subsidiaries in Thailand and others. Thus our estimation strategy does not depend on the comparison of “control” and “treatment” groups. In our main empirical results discussed in this section, we report the result from the sample of firms located in Thailand, to best control for the unobserved differences across plants of MNEs. We check the validity of such sample selection by considering the reduced form estimation (24) for different samples of firms. This point is discussed in detail in Section B6.2.. Third, readers may notice that the year of our natural experiment, 2011, there was another natural disaster that affected a large set of Japanese firms, *the 2011 Tohoku Earthquake*. We also conduct the robustness check regarding *the 2011 Tohoku Earthquake*. Our result is robust to the sample excluding the firms suffered by the earthquake severely, which indicates that our finding is not driven by the earthquake in Japan, but by the flooding in Thailand. The detail of the exercise is discussed in Section B6.3.. Fourth, we conduct the robustness checks regarding the choice of our foreign factor employment variable m_{it} and the instrumental variable Z_{it} . Specifically, instead of those based on foreign employment of labor, we checked that our results are qualitatively unchanged if we used the value added measures in the foreign subsidiaries. Section B6.4. details. Finally, since our goal is to identify the long-run elasticities, we expect that our fixed effect specification (23) and (24) may be replaced with the long-

difference specification relating the difference between before- and after-flood observations and the qualitative results are kept similar. We confirm that this hypothesis is correct in Section B6.5..

We also conduct extension exercises. First, a typical instrumental variable widely used in the literature is the shift-share instruments (Bartik, 1991; Card, 2001). We discuss that the use of the shift-share instrument does not well identify the reduced-form parameter of our interest. We regard this result as supporting evidence that our natural experiment-based identification strategy fits our purpose. Section B7.1. details the discussion. Second, we show in Table 2 a unique estimate that helps identify the parameter of our interest, λ . On the other hand, since we observe the firms' response to the flood for five years, we may conduct the event-study type regression to see how the effects evolve dynamically. The analysis reveals that the flood impacted the foreign employment in all years after the flood, which confirms that the flood effect was not short-run, but medium- to long-run, consistent with our preferred interpretation. We also conduct the flood impact on employment in Japan. Section B7.2. specifies the regression in detail and discusses the result that the Japanese employment-reducing effect of the flood continues at least five years after the flood. We also study the substitution between Thailand and third countries in Section B7.3.. We find that the flood did not necessarily induce firms to substitute the operation to third countries. Finally, some regression results that separate the sample into different industries are reported in Section B7.4..

5. Discussions

5.1. Quantitative Implication of Foreign Factor Augmentations

In Section 4., we discussed how we back out the *elasticity* of labor shares with respect to the foreign factor augmentation. To derive the implication quantitatively, we need to obtain how much foreign factor-augmenting productivity grew over the period of time of our interest. For this purpose, we invert the factor demand functions (A.43) and (A.44) in the aggregate. We proxy the quantity of employment of foreign factors M by the foreign employment L^{ROW} and accordingly the foreign factor prices by labor wage w^{ROW} . We apply $H = JPN$ and $F = ROW$ to obtain²⁶

$$\frac{a^M}{a^L} = \left(\frac{L^{ROW}}{L^{JPN}} \right)^{\frac{1}{\lambda-1}} \left(\frac{w^{ROW}}{w^{JPN}} \right)^{\frac{\lambda}{\lambda-1}}. \quad (25)$$

Therefore, given the aggregate employment and average wage measures in home and foreign countries, and the backed-out elasticity between home and foreign labor, we can obtain the implied relative productivity in the rest of the world. The intuitive behind the relationship is as follows. Suppose, as we calibrated, $\lambda > 1$, or factor augmentation is biased to that factor. Then given the wage structure in the rest of the world and Japan, relatively large employment in the rest of the world imply relatively augmentingly productive labor in the rest of the world. On the other hand, given the employment structure, relatively high wage in the rest of the world also reflect relatively augmentingly

²⁶It is an important extension to consider multi-country version of our model and empirical implementations. Section B3.1. overviews the country-level aggregate trends.

productivity labor in the rest of the world.²⁷ We measure (L^{ROW}, w^{ROW}) by BSOBA. In particular, we calculate L^{ROW} by aggregating all foreign employment in all countries except for Japan and w^{ROW} by dividing the aggregate total labor compensation by L^{ROW} . For (L^{JPN}, w^{JPN}) , we apply the JIP database, a Japanese project for assembling KLEMS database.

To obtain the absolute productivity a^M as opposed to the relative productivity a^M/a^L , we calibrate Japan's labor-augmenting productivity growth by JIP database's Quality of Labor measure. This measure reflects changes in the composition of the type of workers—gender, age, education, employment status, which is standard representation of the factor augmentation. We thus interpret this affects the efficiency units of labor, thereby Japan's labor-augmenting productivity. Given this trend, we can separate the trends of factor augmentation in Japan and the rest of the world. As a result, in Figure 10a, the left panel shows the trend of the evolution of $d \ln a_t^M \approx \ln a_t^M - \ln a_{1995}^M$, with our base year 1995. On the other hand, Figure C.1 shows the growth of Japan's labor augmentation.

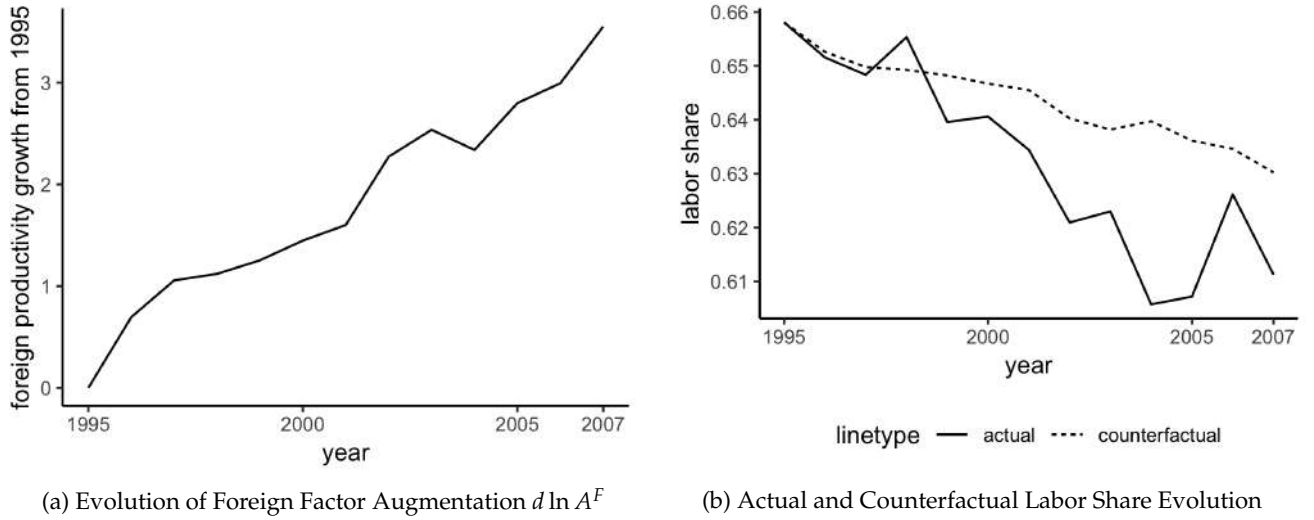
We emphasize the relative importance of $d \ln a_t^M$ and $d \ln a_t^L$. By comparing the unit in the y -axes, we confirm that the growth $d \ln a^L$ is relatively minor in the relative factor augmentation evolution $d \ln (a^M/a^L) = d \ln a^M - d \ln a^L$ in equation (25). This could be interpreted as due to at least two factors. First, the relative augmentation was fast in the rest of the world relative to in Japan. This is plausible given our BSOBA-based measure of L^{ROW} and w^{ROW} , the ingredients in equation (25), comes from employment data in many rapidly expanding economies including Thailand. Second and more importantly, another factor that may contribute to the relative importance of $d \ln a^M$ is globalization including the decreased transportation and communication costs, and removed political barriers for investments. These imply higher employment in the rest of the world by Japanese MNEs given the factor costs there. Given our calibration $\lambda = 1.4$, this implies foreign factor augmentation.

Given these calibrations, we may learn the effect evolution of the foreign factor augmentation on the labor share. We calculate WS_0^M as the fraction of total payment to foreign labor taken from BSOBA over the sum of it and the total payment to workers in Japan in the base year. This gives $WS_0^M = 0.8\%$. In Figure 10b, we show the counterfactual labor share had there been only the foreign augmentation, according to equation (14). Again, we set the base year in 1995, the first year of the BSOBA data. The solid line shows the actual evolution, whereas the dashed line shows the counterfactual one had it been only the foreign factor augmentation. The figure reveals that the foreign factor augmentation played a significant role in explaining the observed labor share decline during 1995-2007. Quantitatively, it explains 59 percent of the decline in the period.

Discussion Is our quantitatively large result an artifact of our choice of sample period? We choose the baseline final year of the analysis in 2007 both because the Great Recession would complicate the interpretation and SNA system changed drastically since 2008. In case readers wonder the implications on a more recent trend of labor share, Section C2. shows the corresponding diagram up to

²⁷Note our qualification $\lambda > 1$. In fact, if $\lambda < 1$, then the discussions in the main text reverses, which means observed increase in foreign employment and wages would imply *decreasing* relative foreign factor augmentation. To the extent that such decrease is implausible, this observation is another supporting evidence for $\lambda > 1$. Section C1.2. shows the implication to A^{ROW} nonetheless assumed $\lambda < 1$.

Figure 9: Quantitative Implications



2015.²⁸ There, we discuss that 58 percent of the decrease of labor share for roughly the 20 years may be attributed to our mechanism of the increased foreign productivity. Note also that the labor share has countercyclical components.

We also conduct the same quantitative analysis from peaks to peaks. In particular, we take the peak year data from Cabinet Office of Japan and set them as 1997, 2000, and 2008. When we conduct the quantitative analysis from 1997 to 2008 and 2000 to 2008, our mechanism could explain the decrease in the labor share by 77 percent and 112 percent.²⁹

Finally, how our quantitative results differ given the error in the estimate of our key parameter, λ ? We may address the issue given the standard error estimates $se(\hat{\lambda}) = 0.13$ that we derive in the Appendix B5.. In particular, we conduct the same quantitative analysis with one standard error smaller and larger value of λ . The results indicate that the quantitative magnitude relative to the observed decrease in the labor share varies between 48 percent to 83 percent depending on the value of λ . Although there is an uncertainty in the exact size of the impact, we conclude that there was a significant negative effect of foreign factor augmentation on the labor share in Japan.

5.2. Role of Firm Heterogeneity

Our estimation and quantitative implications relied on the homogeneous production function in Section 3.4.. An implication of such restriction is the coincidence of micro- and macro-elasticities (Oberfield and Raval, 2014). However, since we observe rich heterogeneity at firm level, the foreign factor augmentation may *reallocate* factor resources from a firm to another. Since factor prices clear the factor markets, such heterogeneity and reallocation may matter the implication to the relative wage, which through equation (5) affects the labor share. To consider the effect clearly, we consider

²⁸As a reservation, the quantitative result is sensitive to our parameter values, in particular the estimate of σ . Section C1.3. shows different results under several parameter values of λ and σ .

²⁹The reason we obtain large values for the recent waves of business cycle is that the actual decrease in the labor shares is small, in particular between 2000 and 2008. Thus the fraction our mechanism tells becomes large.

a modified version of the model in Section 3.4.—general equilibrium with the nested CES production function but with firm-level *heterogeneous* augmentations. To facilitate the comparison, we also consider a case with the same foreign factor augmentation across firms, $d \ln a_i^M = d \ln a^M$ for any i . This is consistent with the interpretation that the foreign factor augments because policy and institutional changes in country F or country F 's technological progress, which affects all firms in country H alike.

In Section A6., we prove that the change in the relative wage in this case may be solved as

$$d \ln w - d \ln r \propto \left[-(\lambda - \sigma) WS_l^M + (\sigma - \varepsilon) (CS_k^M - CS_l^M) \right] d \ln a^M, \quad (26)$$

where

$$WS_l^M \equiv \int \frac{wl_i}{wL} \frac{p^M m_i}{wl_i} di, CS_k^M \equiv \int \frac{rk_i}{rK} \frac{p^M m_i}{p_i q_i} di, CS_l^M \equiv \int \frac{wl_i}{wL} \frac{p^M m_i}{p_i q_i} di.$$

To interpret the terms in equation (26), note that the first term reflects the differences in the elasticities in the upper σ and lower nest λ . If $\lambda > \sigma$, then the increase in foreign productivity substitutes labor in country H relatively more than capital in country H , which results in a downward pressure to the wage relative to capital return, or in turn the labor share. This effect depends on the average wage payment share to the foreign factor WS_l^M . These arguments do not involve the firm heterogeneity and appear in the homogeneous model too. We call this term the *substitution effect*.

On the other hand, the second term involves the weighted averages of the cost share to the foreign factor CS_k^M and CS_l^M . More specifically, the difference between the differentially weighted averages $CS_k^M - CS_l^M$ matters. To understand this term, suppose (i) that demand elasticity ε is so elastic that $\varepsilon > \sigma$ and (ii) that the foreign factor share distribution is *more skewed* to capital intensive firms than it is to Home labor intensive firms, or $CS_k^M - CS_l^M > 0$.³⁰ Then the increase in the foreign factor productivity results in the reduction in the marginal cost of production. Such cost reduction turns into high demand if ε is large. Across firms, this is more so for firms that relatively use more foreign factors. If such firms are more capital intensive than Home labor intensive, the aggregate demand for capital increases more than that for Home labor. This results in the increase in the capital return more than that in Home wage, which results in the reduction in the labor share. We call this effect the *reallocation effect*. Note that the argument above crucially depends on the heterogeneity in firms' factor intensities. Indeed, if firms are homogeneous, the weight of the weighted average of cost shares does not matter, so that $CS_k^M - CS_l^M = CS^M - CS^M = 0$. Therefore, there does not exist the reallocation effect and the effect on the Home relative wage only emerges as the substitution effect.

To measure the size of the substitution effect and the reallocation effect, we employ our matched dataset. BSJBSA data contains the variable of cost of labor compensation in the domestic firms and net operating surplus. We take these measures as wl_i and rk_i , respectively. From BSOBA data, we can take the total compensation in each foreign plant of multinational firms. We aggregate these to form a measure of $p^M m_i$. We match these datasets and calculate CS_k^M , CS_l^M , and WS_l^M that are relevant in equation (26). The matched data is available for 2007-2016. With values $\lambda = 1.4, \sigma = 0.2, \varepsilon = 4$, we plot the size of the substitution effect and the reallocation effect according to data from each year in

³⁰Note that assumption (ii) is consistent with the finding by Sun (2018) that "multinational firms are on average larger firms and larger firms on average use more capital-intensive technologies."

Figure 10: Relative Size of the Effects

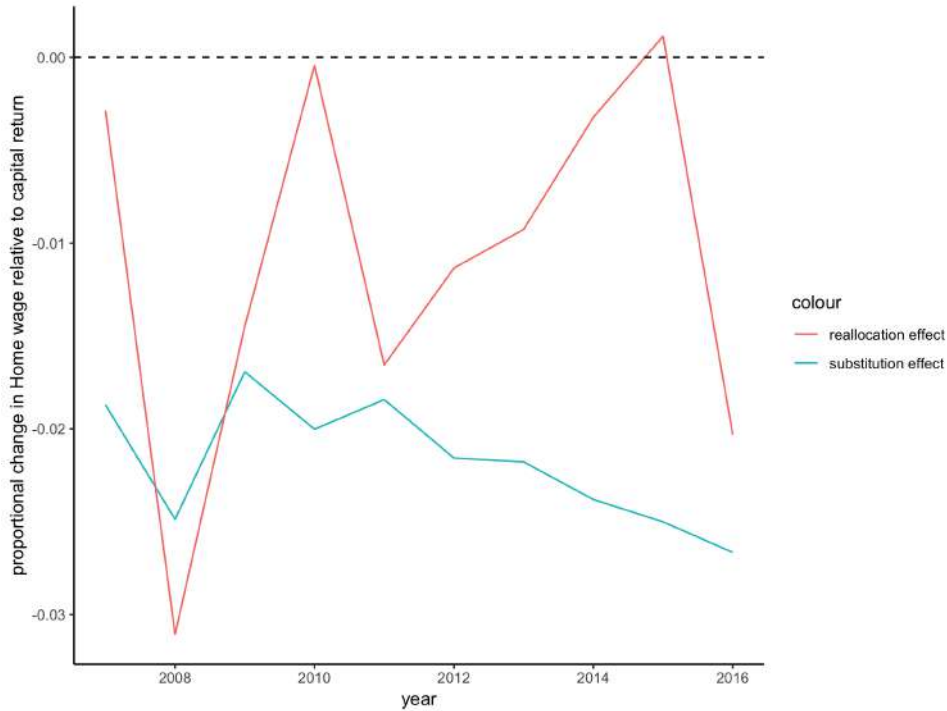


Figure 10.

Figure 10 gives us two takeaways. First, both substitution and reallocation effects are negative for most of the years. Indeed, except for the reallocation effect in 2015, all effects head to the negative side. These imply that when the foreign factor productivity increases, the relative Home wage decreases, which pushes down the Home labor share. Moreover, considering heterogeneity in the model *strengthens* the negative effect of given increase in the foreign productivity due to the reallocation effect. Note that the substitution effect is negative because $\lambda > \sigma$. The reallocation effect is mostly negative both because (i) $\varepsilon > \sigma$ and (ii) in most of the years $CS_k^M > CS_l^M$ in the data. Second, in many years, the reallocation effect is smaller than the substitution effect in an absolute value. Therefore, although the reallocation amplifies the negative substitution effect, it does not contribute to the overall effect in a dominant way.³¹ Combining these two observations, we conclude that considering the firm heterogeneity and reallocation effect does not alter our conclusion that the foreign factor augmentation worked as a decreasing force of labor share in Japan in 1995-2007.

5.3. Method of Moments Estimation

We may apply the estimation method based on the general moment conditions (9). For this purpose, we take a two-step approach. First, we separate the set of parameters estimated by equation (9) and other nuisance parameters. We then fix the nuisance parameters by the method based on the nested CES specification discussed so far. Second, given the parameters, we identify and estimate the parameters of our interest.

³¹One may see relatively high volatility of the reallocation effect. This is in part due to the fact that we measure the capital payment by accounting net operating surplus which is volatile.

In particular, given the elasticity matrix discussed in Section A5., for all i , we set $\sigma_{\tilde{k}r,i} = -\sigma + (\sigma - \varepsilon) CS_i^K$, $\sigma_{\tilde{k}\tilde{w},i} = (\sigma - \varepsilon) CS_i^L$, $\sigma_{\tilde{l}r,i} = (\sigma - \varepsilon) CS_i^K$, $\sigma_{\tilde{l}\tilde{w},i} = -\lambda + (\lambda - \sigma) WS_i^L + (\sigma - \varepsilon) CS_i^L$, $\sigma_{\tilde{m}p^M,i} = -\lambda + (\lambda - \sigma) WS_i^M + (\sigma - \varepsilon) CS_i^M$, where σ and λ are a constant reflecting the substitution parameters under nested CES, CS_i^f are firm i 's factor- f cost share for $f = K, L, M$, and WS_i^f are firm i 's factor- f payment share between L and M for $f = L, M$. We take CS_i^f and WS_i^f from our firm-level Japanese MNE data, and calibrate $\lambda = 1.4$, $\sigma = 0.2$, and $\varepsilon = 4$.

We then estimate the remaining parameters, elasticities of country- H capital and labor demand with respect to foreign factor prices. We employ the method of moments (9) and the flood-based instrumental variable. In particular, first, to have restrictions on $\sigma_{\tilde{m}r,i}$ and $\sigma_{\tilde{m}\tilde{w},i}$, note that by the symmetry of the Hessian matrix of the cost function, demand structure (1), and Shephard's lemma, we have

$$CS_i^M \sigma_{\tilde{m}r,i} = CS_i^K \sigma_{\tilde{k}p^M,i}, \quad (27)$$

$$CS_i^M \sigma_{\tilde{m}l,i} = CS_i^L \sigma_{\tilde{l}p^M,i}. \quad (28)$$

Proof of these equations is given in Section A7.. Finally, to implement the estimation, we assume the following constant parameter assumption.

Assumption 2. $\sigma_{\tilde{k}p^M,i} = \sigma_{\tilde{k}p^M}$ and $\sigma_{\tilde{l}p^M,i} = \sigma_{\tilde{l}p^M}$ for all $i \in I_H$.

Given these setups, we implement the method of moments estimation based on equation (9) as follows.

1. Set $n = 0$. Guess $(\sigma_{\tilde{k}p^M}, \sigma_{\tilde{l}p^M}) = (\sigma_{\tilde{k}p^M}^{(n)}, \sigma_{\tilde{l}p^M}^{(n)})$ and generate implied firm-level elasticity matrix $\Sigma^{(n)}$ based on equation (10) and our set of partial identification assumptions and the factor augmentation

$$\begin{pmatrix} d \ln \left(a_{it}^{K,(n)} \right) \\ d \ln \left(a_{it}^{L,(n)} \right) \\ d \ln \left(a_{it}^{M,(n)} \right) \end{pmatrix}$$

based on equation (11).

2. Remove the year-fixed effects from the factor augmentation and instrumental variables Z_{it} .
3. Evaluate the sample-analog of the moment condition (9).
4. If the solution is not close obtained, update n , go back to process 1 and iterate until convergence.

Out of the above algorithm, we obtain

$$\widehat{\sigma_{\tilde{k}p^M}} = -0.20 \text{ (std. err. 0.13)}, \quad (29)$$

$$\widehat{\sigma_{\tilde{l}p^M}} = -0.09 \text{ (std. err. 0.04)}. \quad (30)$$

Recall that our finding that the capital demand is more elastic, $\widehat{\sigma_{kp^M}} < \widehat{\sigma_{lp^M}}$, suggests that given the negative cost shock (or positive factor augmentation) increases the demand for Home capital *relatively more than* Home labor. Given that the capital demand is more negatively elastic to capital rental rate and labor demand is to wage, the capital rental rate must increase while the wage for labor must decrease to restore the factor market clearing conditions (3).

Note that the last part of this logic is reminiscent of the celebrated Stolper-Samuelson's theorem—Consider the two-factor economy. If the factor demand increases *differentially* for one factor, then the relative wage of the factor increases (more than the increase in the factor demands) while the wage of the other decreases. In the Stolper-Samuelson setup, the factor demand increase is caused by the exogenous change in the terms of trade. On the other hand, in our setup, what drives the changes in factor demands in H is the combination of foreign factor augmentations and (total) elasticity with respect to it of factors in H . If (same-sized) foreign factor augmentation elastically increases demand for a factor (in our empirical case, capital relative to labor), that means that the demand for the factor increases differentially, or the factor is complementary to the foreign factor that augmented.

We discuss the detail on the estimation of standard errors of estimator defined by equation (9) in Section C3..

6. Conclusion

What is the role of MNEs' increased employment of foreign factors on the labor share of the source country? To approach this question, we take three steps. First, we develop an equilibrium model that features production with the augmented employment of foreign factors with varying elasticities of substitution. From the theory, we pinpoint the key elasticities for the labor share implication, the relative size of labor and capital substitutions with foreign factors. To identify such elasticities, we show how a foreign factor-augmenting productivity shock to a small set of firms may help. Armed with these theoretical results, we apply to the 2011 Thailand Flood. We interpret it as the negative foreign factor productivity shock to Japanese MNEs. We leveraged the firm- and plant-level data from Japan. We estimate the reduced-form parameter with the instrumental variable related to the flood shock, with the result that indicates that the home and foreign labor are gross substitutes. With the estimates on capital-labor elasticity obtained by applying the existing method to our Japanese plant-level data, we conclude that the foreign factor augmentation *did* contribute to the decline in the labor share in Japan during 1995-2007. Our further quantitative counterfactual analyses show that out of the observed labor share decline in the period, 59 percent can be attributed to the foreign factor augmentation.

Several analyses are expected to be followed. First concerns model extension. We have at least three directions to which we extend our model. First, we may incorporate rich heterogeneity at firm level as discussed in Section A6. and at destination country level as we empirically hint in Section B3.1.. Second, we conjecture that our production model has the potential to nest some influential model of factor offshoring such as [Feenstra and Hanson \(1997\)](#). This tightens the connection with

the literature. For this purpose, we generalize the production function in Section A2.. Finally, our model also extends to a more complete general equilibrium with factor supplies and a large open economy. Note that all our results in identification, empirical application, and quantification depend on the specific model choice. These further theoretical developments are necessary.

We conclude by further counterfactual analyses including policy simulations. In several developed countries, academic researchers and policymakers are alike concerned about the rapid changes in demographic trends and their implications to overall economies. To our study on the role of multinational activities, we may interact basic economic conditions including demographic changes in our model. In particular in Japan, this has a tight connection with a political debate of whether to host foreign workers under the label of *Technical Intern Training Program*.

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Appendix

A Theory Appendix

This appendix details some proofs and extensions of the model in Section 3.

A1. Uniqueness of the Equilibrium

A desirable property of a general equilibrium is the uniqueness. Under the uniqueness, we may guarantee that our equilibrium is robust across the shocks and parameter values. Unfortunately, it is well-known by Sonnenschein-Mantel-Debreu results that in general the uniqueness result is hard to obtain (Sonnenschein, 1972; Mantel, 1974; Debreu, 1974). However, in our constant returns to scale, we may take a different approach—the *generic* uniqueness approach taken in Mas-Colell et al. (1995), Chapter 17. Below, the proposition numbers that begins with “17” are all taken from the chapter.

We begin by the following facts. (i) Under a regularity condition, any equilibrium factor price vector (r, w) is locally isolated (Proposition 17.D.1). Furthermore, the regularity condition holds generically (Proposition 17.D.5). (ii) If the weak axiom of revealed preference (WARP) is satisfied, under the constant returns to scale technology, the set of equilibrium price vectors (r, w) is convex. (Proposition 17.F.2). Note that our factor demand functions are obtained by solving the cost-minimization problem. Thus they satisfy WARP. Thus, the set of equilibrium factor price vectors is both the locally isolated convex and singleton. Thus, we may conclude the following.

Proposition 1. (*Generic Uniqueness*) *The general equilibrium defined in Section 3.1. is generically unique.*

A2. Equivalence Results

We consider a special case of our model in offshoring and multinational models. Specifically, below, we begin the equilibrium analysis from assumption of modified versions of Feenstra and Hanson (1997) and Arkolakis et al. (2017) and arrive at equation (6), respectively.

A2.1. Offshoring

We propose a modified version of Feenstra and Hanson (1997), where we do not distinguish the high-skill and low-skill workers, but we do distinguish the factor augmenting productivity shocks in each country. There are the Home country H and the Foreign country F . Each country $c = H, F$ is endowed with (L^c, K^c) . The factor prices are (w^c, r^c) , respectively. Competitive producers in H and F produce a numeraire single final good q by combining continuum intermediate inputs labeled by $z \in [0, 1]$. To produce the intermediate good, producers may use the factors in either H or F . In

production place c , the intermediate good z is produced by CES technology³²

$$x^c(z) = \left(\left(\frac{A^{c,L} l^c(z)}{a(z)} \right)^{\frac{\sigma-1}{\sigma}} + \left(A^{c,K} k^c(z) \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \quad (\text{A.1})$$

where $a(z)$ is increasing and $\sigma < 1$, namely, labor and capital are gross complements. The final good q is then costlessly assembled according to the Cobb-Douglas function³³

$$\ln q = \int_0^1 \alpha(z) \ln x^c(z) dz. \quad (\text{A.2})$$

There is no trade cost in output good. Consider for now that the world income $E = \bar{E}$ is fixed and spent on the output so that

$$q = \bar{E}. \quad (\text{A.3})$$

The equilibrium is characterized by factor prices (w^H, r^H, w^F, r^F) that solve the market clearing condition. To formally derive such conditions, suppose that the foreign labor L^F is abundant enough so that

$$\frac{w^H}{r^H} > \frac{w^F}{r^F},$$

or H has comparative advantage in producing capital-intensive intermediate good. Further assume L^F is large so that $\tilde{w}^H > \tilde{w}^F$ where $\tilde{w}^c \equiv w^c / A^{c,L}$ and $\tilde{r}^c \equiv r^c / A^{c,K}$ are augmented factor prices.³⁴ We consider our case of CES output demand and income effects after solving the current simple version.

To solve the model, consider the cost-minimizing factor demand given factor prices (w^H, r^H, w^F, r^F) . First, conditional on the country $c = H, F$, the unit cost function is

$$c^c(z) = \left(\left(a(z) \tilde{w}^c \right)^{1-\sigma} + \left(\tilde{r}^c \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \quad (\text{A.4})$$

Given the comparative advantage assumption, in equilibrium, there is $z^* \in [0, 1]$ that satisfies z is produced in the Home if and only if $z \leq z^*$. z^* satisfies $c^H(z^*) = c^F(z^*)$, or

$$\left(a(z^*) \tilde{w}^H \right)^{1-\sigma} + \left(\tilde{r}^H \right)^{1-\sigma} = \left(a(z^*) \tilde{w}^F \right)^{1-\sigma} + \left(\tilde{r}^F \right)^{1-\sigma}. \quad (\text{A.5})$$

The marginal cost is thus $c(z) \equiv \min_c \{c^c(z)\}$. Given such z^* , by Shepherd's lemma, the factor

³²Note that this formulation is more general than the nesting of Cobb-Douglas and Leontief production as in Feenstra and Hanson (1997).

³³Note that the same production function with costless intermediate good trade makes the trade in the final good irrelevant. Specifically, countries do not have an incentive to specialize (or not specialize) in the production of the final good. In this sense, the model is all about intermediate good trade. As we see in equation (A.5), H exports $z < z^*$ and imports $z > z^*$.

³⁴This assumption is not essential, but a technical one to proceed with unnecessary complications.

demands are characterized by,

$$\tilde{l}^c(z) = \left(\frac{a(z) \tilde{w}^c}{c^c(z)} \right)^{-\sigma} a(z) x^c(z), \quad (\text{A.6})$$

$$\tilde{k}^c(z) = \left(\frac{\tilde{r}^c}{c^c(z)} \right)^{-\sigma} x^c(z), \quad (\text{A.7})$$

for $c = H, F$, where $\tilde{l}^c(z) \equiv A^{c,L} l^c(z)$ and $\tilde{k}^c(z) \equiv A^{c,K} k^c(z)$ are the augmented factor demands for variety z in country c . Hence the market clearing conditions are

$$\tilde{L}^H = \int_0^{z^*} \tilde{l}^H(z) dz, \quad (\text{A.8})$$

$$\tilde{K}^H = \int_0^{z^*} \tilde{k}^H(z) dz, \quad (\text{A.9})$$

$$\tilde{L}^F = \int_{z^*}^1 \tilde{l}^F(z) dz, \quad (\text{A.10})$$

$$\tilde{K}^F = \int_{z^*}^1 \tilde{k}^F(z) dz, \quad (\text{A.11})$$

where $\tilde{L}^c \equiv A^{c,L} L^c$ and $\tilde{K}^c \equiv A^{c,K} K^c$ are the augmented endowment for $c = H, F$. To solve $x^c(z)$, by Cobb-Douglas assumption (A.2), we have $p(z) x^c(z) = \alpha(z) q$, where $p(z)$ is the price of the intermediate good z . Moreover, the perfect competition assumption implies that $p(z)$ is given by the (minimum) marginal cost $c(z)$. Thus, by good market clearing condition (A.3), we have

$$x^c(z) = \frac{\alpha(z)}{c(z)} \bar{E}. \quad (\text{A.12})$$

Thus, the equilibrium is $\left(z^*, \left(\tilde{w}^c, \tilde{r}^c \right)_{c \in (H,F)} \right)$ that solves equations (A.5), (A.8), (A.9), (A.10), and (A.11). To study the Home labor share, we still have $LS \equiv w^H L^H / (w^H L^H + r^H K^H)$ that is to the first order

$$dLS = LS_0 (1 - LS_0) (d \ln w^H - d \ln r^H).$$

Hence, it remains to study $d \ln w^H$ and $d \ln r^H$. For this purpose, we have log-first order approximations with respect to $d \ln A^{F,L}$ and $d \ln A^{F,K}$ to equations (A.5), (A.8), (A.9), (A.10), and (A.11) as follows:

$$\begin{aligned} CS^{H,L}(z^*) \left(\sigma_{az} d \ln z^* + d \ln \tilde{w}^H \right) + CS^{H,K}(z^*) d \ln \tilde{r}^H &= CS^{F,L}(z^*) \left(\sigma_{az} d \ln z^* + d \ln \tilde{w}^F \right) + CS^{F,K}(z^*) d \ln \tilde{r}^F, \\ 0 &= \frac{z^* \tilde{l}^H(z^*)}{\tilde{L}^H} d \ln z^* - \sigma d \ln \tilde{w}^H + \int_0^{z^*} \frac{\tilde{l}^H(z)}{\tilde{L}^H} \left(\sigma d \ln c^H(z) + d \ln x^H(z) \right) dz, \\ 0 &= \frac{z^* \tilde{k}^H(z^*)}{\tilde{K}^H} d \ln z^* - \sigma d \ln \tilde{r}^H + \int_0^{z^*} \frac{\tilde{k}^H(z)}{\tilde{K}^H} \left(\sigma d \ln c^H(z) + d \ln x^H(z) \right) dz, \end{aligned} \quad (\text{A.13})$$

$$d \ln A^{F,L} = -\frac{z^* \tilde{l}^F(z^*)}{\tilde{L}^F} d \ln z^* - \sigma d \ln \tilde{w}^F + \int_{z^*}^1 \frac{\tilde{l}^F(z)}{\tilde{L}^F} \left(\sigma d \ln c^F(z) + d \ln x^F(z) \right) dz,$$

$$d \ln A^{F,K} = -\frac{z^* \tilde{k}^F(z^*)}{\tilde{K}^F} d \ln z^* - \sigma d \ln \tilde{r}^F + \int_{z^*}^1 \frac{\tilde{k}^F(z)}{\tilde{K}^F} \left(\sigma d \ln c^F(z) + d \ln x^F(z) \right) dz.$$

Note that by equation (A.4) $d \ln c^c(z) = CS^{c,L}(z) d \ln \tilde{w}^c + CS^{c,K}(z) d \ln \tilde{r}^c$ and by equation (A.12), we have

$$d \ln x^c(z) = -d \ln c(z). \quad (\text{A.14})$$

Note also that z is produced in H if and only if $z < z^*$. Hence the conditions are further reduced to

$$0 = \frac{z^* \tilde{l}^H(z^*)}{\tilde{L}^H} d \ln z^* + \left(-\sigma + (\sigma - 1) ACS^{H,L}(z^*) \right) d \ln \tilde{w}^H + (\sigma - 1) ACS^{H,K}(z^*) d \ln \tilde{r}^H, \quad (\text{A.15})$$

$$0 = \frac{z^* \tilde{k}^H(z^*)}{\tilde{K}^H} d \ln z^* + (\sigma - 1) ACS^{H,L}(z^*) d \ln \tilde{w}^H + \left(-\sigma + (\sigma - 1) ACS^{H,K}(z^*) \right) d \ln \tilde{r}^H, \quad (\text{A.16})$$

$$d \ln A^{F,L} = -\frac{z^* \tilde{l}^F(z^*)}{\tilde{L}^H} d \ln z^* + \left(-\sigma + (\sigma - 1) ACS^{F,L}(z^*) \right) d \ln \tilde{w}^F + (\sigma - 1) ACS^{F,K}(z^*) d \ln \tilde{r}^F, \quad (\text{A.17})$$

$$d \ln A^{F,K} = -\frac{z^* \tilde{k}^F(z^*)}{\tilde{K}^F} d \ln z^* + (\sigma - 1) ACS^{F,L}(z^*) d \ln \tilde{w}^F + \left(-\sigma + (\sigma - 1) ACS^{F,K}(z^*) \right) d \ln \tilde{r}^F, \quad (\text{A.18})$$

where

$$ACS^{H,L}(z^*) \equiv \int_0^{z^*} \frac{\tilde{l}^H(z)}{\tilde{L}^H} CS^{H,L}(z) dz,$$

$$ACS^{H,K}(z^*) \equiv \int_0^{z^*} \frac{\tilde{k}^H(z)}{\tilde{K}^H} CS^{H,K}(z) dz,$$

$$ACS^{F,L}(z^*) \equiv \int_{z^*}^1 \frac{\tilde{l}^F(z)}{\tilde{L}^F} CS^{F,L}(z) dz,$$

$$ACS^{F,K}(z^*) \equiv \int_{z^*}^1 \frac{\tilde{k}^F(z)}{\tilde{K}^F} CS^{F,K}(z) dz,$$

are the average cost shares of each factor in each country. Assume for now $\tilde{w}^H > \tilde{w}^F$. Then we can show $CS^{H,L}(z^*) > CS^{F,L}(z^*)$.³⁵ We prove this below. Also, we will come back to the condition that guarantees $\tilde{w}^H > \tilde{w}^F$. By (A.13), we have

$$d \ln z^* = \frac{\left(CS^{F,L}(z^*) d \ln \tilde{w}^F + CS^{F,K}(z^*) d \ln \tilde{r}^F \right) - \left(CS^{H,L}(z^*) d \ln \tilde{w}^H + CS^{H,K}(z^*) d \ln \tilde{r}^H \right)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}. \quad (\text{A.19})$$

³⁵To see this, note that at $z = z^*$ we have $c^H(z^*) = c^F(z^*)$. Hence it remains to show $\tilde{w}^H \tilde{l}^H(z^*) > \tilde{w}^F \tilde{l}^F(z^*)$. By substituting the factor demand functions and noting that $c^H(z^*) = c^F(z^*)$ and thus $x^H(z^*) = x^F(z^*)$, the inequality is equivalent with $(\tilde{w}^H)^{1-\sigma} > (\tilde{w}^F)^{1-\sigma}$. Our assumption $\sigma < 1$ means that this is equivalent with $\tilde{w}^H > \tilde{w}^F$.

By substituting equation (A.19) to equations (A.15), (A.16), (A.17), and (A.18), we have

$$\begin{aligned}
0 &= \underbrace{\left[-\frac{z^* \tilde{l}^H(z^*)}{\tilde{L}^H} \frac{CS^{H,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + \left(-\sigma + (\sigma - 1) ACS^{H,L}(z^*) \right) \right]}_{\equiv \sigma_{\tilde{l}^H \tilde{w}^H}} d \ln \tilde{w}^H \\
&\quad + \underbrace{\left[-\frac{z^* \tilde{l}^H(z^*)}{\tilde{L}^H} \frac{z^* \tilde{l}^H(z^*) CS^{H,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + (\sigma - 1) ACS^{H,K}(z^*) \right]}_{\equiv \sigma_{\tilde{l}^H \tilde{r}^H}} d \ln \tilde{r}^H \\
&\quad + \underbrace{\frac{z^* \tilde{l}^H(z^*)}{\tilde{L}^H} \frac{CS^{F,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{l}^H \tilde{w}^F}} d \ln \tilde{w}^F + \underbrace{\frac{z^* \tilde{l}^H(z^*)}{\tilde{L}^H} \frac{CS^{F,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{l}^H \tilde{r}^F}} d \ln \tilde{r}^F, \\
0 &= \underbrace{\left[-\frac{z^* \tilde{k}^H(z^*)}{\tilde{K}^H} \frac{CS^{H,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + (\sigma - 1) ACS^{H,L}(z^*) \right]}_{\equiv \sigma_{\tilde{k}^H \tilde{w}^H}} d \ln \tilde{w}^H \\
&\quad + \underbrace{\left[-\frac{z^* \tilde{k}^H(z^*)}{\tilde{K}^H} \frac{CS^{H,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + \left(-\sigma + (\sigma - 1) ACS^{H,K}(z^*) \right) \right]}_{\equiv \sigma_{\tilde{k}^H \tilde{r}^H}} d \ln \tilde{r}^H \\
&\quad + \underbrace{\frac{z^* \tilde{k}^H(z^*)}{\tilde{K}^H} \frac{CS^{F,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{k}^H \tilde{w}^F}} d \ln \tilde{w}^F + \underbrace{\frac{z^* \tilde{k}^H(z^*)}{\tilde{K}^H} \frac{CS^{F,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{k}^H \tilde{r}^F}} d \ln \tilde{r}^F, \\
d \ln A^{F,L} &= \underbrace{\frac{z^* \tilde{l}^F(z^*)}{\tilde{L}^H} \frac{CS^{H,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{l}^F \tilde{w}^H}} d \ln \tilde{w}^H + \underbrace{\frac{z^* \tilde{l}^F(z^*)}{\tilde{L}^H} \frac{CS^{H,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{l}^F \tilde{r}^H}} d \ln \tilde{r}^H \\
&\quad + \underbrace{\left[-\frac{z^* \tilde{l}^F(z^*)}{\tilde{L}^H} \frac{CS^{F,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + \left(-\sigma + (\sigma - 1) ACS^{F,L}(z^*) \right) \right]}_{\equiv \sigma_{\tilde{l}^F \tilde{w}^F}} d \ln \tilde{w}^F \\
&\quad + \underbrace{\left[-\frac{z^* \tilde{l}^F(z^*)}{\tilde{L}^H} \frac{CS^{F,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + (\sigma - 1) ACS^{F,K}(z^*) \right]}_{\equiv \sigma_{\tilde{l}^F \tilde{r}^F}} d \ln \tilde{r}^F,
\end{aligned}$$

$$\begin{aligned}
d \ln A^{F,K} = & \underbrace{\frac{z^* \tilde{k}^F(z^*)}{\tilde{K}^F} \frac{CS^{H,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{k}^F \tilde{w}^H}} d \ln \tilde{w}^H + \underbrace{\frac{z^* \tilde{k}^F(z^*)}{\tilde{K}^F} \frac{CS^{H,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}}}_{\equiv \sigma_{\tilde{k}^F \tilde{r}^H}} d \ln \tilde{r}^H, \\
& \underbrace{\left[-\frac{z^* \tilde{k}^F(z^*)}{\tilde{K}^F} \frac{CS^{F,L}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + (\sigma - 1) ACS^{F,L}(z^*) \right]}_{\equiv \sigma_{\tilde{k}^F \tilde{w}^F}} d \ln \tilde{w}^F \\
& \underbrace{\left[-\frac{z^* \tilde{k}^F(z^*)}{\tilde{K}^F} \frac{CS^{F,K}(z^*)}{(CS^{H,L}(z^*) - CS^{F,L}(z^*)) \sigma_{az}} + (-\sigma + (\sigma - 1) ACS^{F,K}(z^*)) \right]}_{\equiv \sigma_{\tilde{k}^F \tilde{r}^F}} d \ln \tilde{r}^F.
\end{aligned}$$

Therefore, the elasticity matrix Σ is given as

$$\Sigma \equiv \begin{pmatrix} \sigma_{\tilde{l}^H \tilde{w}^H} & \sigma_{\tilde{l}^H \tilde{r}^H} & \sigma_{\tilde{l}^H \tilde{w}^F} & \sigma_{\tilde{l}^H \tilde{r}^F} \\ \sigma_{\tilde{k}^H \tilde{w}^H} & \sigma_{\tilde{k}^H \tilde{r}^H} & \sigma_{\tilde{k}^H \tilde{w}^F} & \sigma_{\tilde{k}^H \tilde{r}^F} \\ \sigma_{\tilde{l}^F \tilde{w}^H} & \sigma_{\tilde{l}^F \tilde{r}^H} & \sigma_{\tilde{l}^F \tilde{w}^F} & \sigma_{\tilde{l}^F \tilde{r}^F} \\ \sigma_{\tilde{k}^F \tilde{w}^H} & \sigma_{\tilde{k}^F \tilde{r}^H} & \sigma_{\tilde{k}^F \tilde{w}^F} & \sigma_{\tilde{k}^F \tilde{r}^F} \end{pmatrix}. \quad (\text{A.20})$$

Now we consider extension cases of non-homogeneous output and income effects. In particular, consideration of non-homogeneous output make the model more isomorphic to ours. Again, this helps us to think of heterogeneous firm case and identification given the productivity shocks. Suppose that the output is demanded by the following CES demand

$$q = \left(\frac{p}{P} \right)^{-\varepsilon} Q,$$

where P and Q are given exogenously (or H being small-open economy). Then the change in cost structure $d \ln p$ further has an feedback loop through the reduction in output demanded $d \ln q$ with elasticity ε . With this effect taken into consideration in the demand for the intermediate good, equation (A.12) becomes

$$d \ln x^c(z) = -d \ln c(z) - \varepsilon d \ln p.$$

And by the perfect competition assumption $d \ln p = \sum_c \left(ACS^{c,L}(z^*) d \ln \tilde{w}^c + ACS^{c,K}(z^*) d \ln \tilde{r}^c \right)$. With these considerations, we have our expression (6) with Σ defined in equation (A.20) and

$$\sigma_q = \begin{pmatrix} \varepsilon ACS^{H,L}(z^*) \\ \varepsilon ACS^{H,K}(z^*) \\ \varepsilon ACS^{F,L}(z^*) \\ \varepsilon ACS^{F,K}(z^*) \end{pmatrix}.$$

We then consider income effects. In other words, we relax the assumption of small open economy. This is desirable even when we are willing to assume that Japan is small-open. Namely, since the reduction in the cost of multinational production and offshoring were global phenomenon but not limited in a particular country such as Japan, it affects the world income even if Japan is small-

open. To put it differently, only in the case of Japan being small-open *and* an isolated country that experienced reduction in multinational production cost does the no-income-effect assumption hold. To put it simple, we come back to the homogeneous outcome case and consider the changes in income due to the productivity growth. Particularly, suppose instead of equation (A.3), the final demand is given by

$$q = \sum_c (w^c L^c + r^c K^c).$$

This implies that $d \ln q = \sum_c IS^c (LS^c d \ln w^c + (1 - LS^c) d \ln r^c)$, where $IS^c \equiv w^c L^c + r^c K^c / \sum_{c'} (w^{c'} L^{c'} + r^{c'} K^{c'})$ is the income share of country c . This again modifies equation (A.14) to

$$\begin{aligned} d \ln x^c(z) &= -d \ln c(z) + d \ln q \\ &= -d \ln c(z) + \sum_c IS^c (LS^c d \ln w^c + (1 - LS^c) d \ln r^c). \end{aligned}$$

Hence the relevant modification to the elasticity matrix (A.20) would accomodate.

A2.2. Multinational Production and Export Platforms

Following Arkolakis et al. (2017), we consider a different type of offshoring, where firms from different source countries may produce a good in different production country, and sell to different destination countries. In particular, we take a special case of Arkolakis et al. (2017), which is the case with two distinct factors so that we interpret those as labor and capital. To simplify the matter, consider two country cases with H and F . There are no trade cost, where as there could be an iceberg-type cost for producing in different countries $\gamma^{il} > 1$ for $i \neq l$. In each country, there are two types of factors labor and capital with endowment (L^c, K^c) , where $c = H, F$.³⁶ Labor is used for production and capital for innovation. A potential firm in country i can enter the market and create a new variety by paying fixed entry cost $f^{e,i}$ unit of capital. When a firm enters, they draw a productivity vector $\mathbf{z} \equiv (z^H, z^F)$ from the multivariate Pareto distribution

$$\Pr(Z^H \leq z^H, Z^F \leq z^F) = G^i(z^H, z^F) \equiv 1 - \left(\sum_{l \in \{H, F\}} \left[A^{il} (z^l)^{-\theta} \right]^{\frac{1}{1-\rho}} \right)^{1-\rho},$$

with support $z^l \geq (\widetilde{A}^i)^{\theta^{-1}}$ for all l , where $\widetilde{A}^i \equiv \left[\sum_l (A^{il})^{(1-\rho)^{-1}} \right]^{1-\rho}$. $\rho \in [0, 1)$ is a parameter that governs the correlation between countries— $\rho = 0$ is the case of uncorrelated Z^H and Z^F , and $\rho \rightarrow 1$ is the perfect collinear extreme. We assume $A^{il} = A^{e,i} A^{p,l}$ so that $\widetilde{A}^i = \left[\sum_l (A^{p,l})^{(1-\rho)^{-1}} \right]^{1-\rho} A^{e,i}$.³⁷ We call $A^{e,i}$ the quality of innovation in country i and $A^{p,l}$ the productivity in production in country l .

$$\xi^{iln} \equiv \gamma^{il} w^l \tau^{ln}, \quad (\text{A.21})$$

³⁶This is a special case of the treatment in ?, namely, inelastic supply of production and innovation workers, by letting $\kappa \rightarrow 1$.

³⁷This is without loss of generality as γ^{il} may have the necessary variation as is clear.

$$\Psi^{in} \equiv \left[\sum_{l'} \left(A^{il'} (\xi^{il'n})^{-\theta} \right)^{(1-\rho)^{-1}} \right]^{1-\rho} \quad (\text{A.22})$$

$$\psi^{iln} \equiv \left(\frac{T^{il} (\xi^{iln})^{-\theta}}{\Psi^{in}} \right)^{(1-\rho)^{-1}} \quad (\text{A.23})$$

$$X^{iln} = \psi^{iln} \lambda^{E,in} X^n \quad (\text{A.24})$$

$$M^{iln} = \frac{\theta - \sigma + 1}{\sigma \theta} \frac{X^{iln}}{w^n F^n}, \quad (\text{A.25})$$

$$\lambda^{E,in} \equiv \frac{\sum_l X^{iln}}{X^n}. \quad (\text{A.26})$$

$$\lambda^{T,ln} \equiv \sum_i \frac{X^{iln}}{X^n} = \sum_i \psi^{iln} \lambda^{E,in}. \quad (\text{A.27})$$

We now characterize the equilibrium conditions that pin down (w^H, r^H, w^F, r^F) as follows. The labor market equilibrium is given by the payment to worker equals the sum of the value labor demand for production and marketing, as

$$\frac{1}{\bar{\sigma}} \sum_n \lambda^{T,ln} X^n + \left(1 - \eta - \frac{1}{\bar{\sigma}} \right) X^l = w^l L^l \quad (\text{A.28})$$

for each $l = H, F$. The capital market equilibrium condition is such that the payment to capital equals the value capital demand for innovation, as

$$\eta \sum_n \lambda^{E,in} X^n = r^i K^i \quad (\text{A.29})$$

for each $i = H, F$. Finally, the budget balance condition is

$$w^i L^i + r^i K^i + \Delta^i = X^i \quad (\text{A.30})$$

for each $i = H, F$, where Δ^i is the transfer to country i from the ROW.

Consider a multinational production shock to the economy $d \ln \gamma^{HF} < 0$. The log-first order approximations to the system (A.28), (A.29), and (A.30) give

$$LDS^l \sum_n PS^{ln} \left(d \ln \lambda^{T,ln} + d \ln X^n \right) + \left(1 - LDS^l \right) d \ln X^l = d \ln w^l, \quad (\text{A.31})$$

$$\sum_n IS^{in} \left(d \ln \lambda^{E,in} + d \ln X^n \right) = d \ln r^i, \quad (\text{A.32})$$

$$LS^i d \ln w^i + \left(1 - LS^i \right) d \ln r^i = d \ln X^i, \quad (\text{A.33})$$

where

$$LDS^l \equiv \frac{\frac{\sigma-1}{\sigma} \sum_n \lambda^{T,ln} X^n}{\frac{\sigma-1}{\sigma} \sum_n \lambda^{T,ln} X^n + (1-\eta - \frac{\sigma-1}{\sigma}) X^l}, \quad PS^{ln} \equiv \frac{\lambda^{T,ln} X^n}{\sum_{n'} \lambda^{T,ln'} X^{n'}}, \quad IS^{in} \equiv \frac{\lambda^{E,in} X^n}{\sum_{n'} \lambda^{E,in'} X^{n'}}$$

are the (value) labor demand share in production of each country, the production sales share to country n , and innovation sales share to country n . Substituting equation (A.33) to equations (A.31) and (A.32), we have

$$\sum_n PS^{ln} \left(d \ln \lambda^{T,ln} + LS^n d \ln w^n + (1 - LS^n) d \ln r^n \right) + LS^l d \ln w^l + (1 - LS^l) d \ln r^l = d \ln w^l, \quad (\text{A.34})$$

$$\sum_n IS^{in} \left(d \ln \lambda^{E,in} + LS^n d \ln w^n + (1 - LS^n) d \ln r^n \right) = d \ln r^i. \quad (\text{A.35})$$

To study $d \ln \lambda^{T,ln}$ and $d \ln \lambda^{E,in}$, first, by equation (A.27),

$$d \ln \lambda^{T,ln} = \sum_i \frac{\psi^{iln} \lambda^{E,in}}{\sum_{i'} \psi^{i'ln} \lambda^{E,i'n}} \left(d \ln \psi^{iln} + d \ln \lambda^{E,in} \right),$$

which, by equation (A.24), further simplifies to

$$d \ln \lambda^{T,ln} = \sum_i \frac{X^{iln}}{X^n} \left(d \ln \psi^{iln} + d \ln \lambda^{E,in} \right). \quad (\text{A.36})$$

On the other hand, by equation (A.26), we have

$$d \ln \lambda^{E,in} = \left(1 - \lambda^{E,in} \right) \left(d \ln M^i + d \ln \Psi^{in} \right) - \lambda^{E,\bar{i}n} \left(d \ln M^{\bar{i}} + d \ln \Psi^{\bar{i}n} \right). \quad (\text{A.37})$$

To further deduce, it remains to know $d \ln \psi^{iln}$, $d \ln M^i$, and $d \ln \Psi^{in}$. By equations (A.21), (A.22), (A.23), and (A.25), they are

$$\begin{aligned} d \ln \psi^{iln} &= \frac{1}{1-\rho} \left(-\theta d \ln \xi^{iln} - d \ln \Psi^{in} \right), \\ &= \frac{1}{1-\rho} \left(-\theta d \ln \left(d \ln w^l + d \ln \gamma^{il} \right) - d \ln \Psi^{in} \right), \end{aligned} \quad (\text{A.38})$$

$$\begin{aligned} d \ln \Psi^{in} &= \sum_{l'} \psi^{il'n} \left(-\theta d \ln \xi^{il'n} \right), \\ &= \sum_{l'} \psi^{il'n} \left(-\theta \left(d \ln w^{l'} + d \ln \gamma^{il'} \right) \right) \end{aligned} \quad (\text{A.39})$$

$$\begin{aligned} d \ln M^i &= \sum_{l',n'} \frac{M^{il'n'}}{M^i} \left(d \ln X^{il'n'} - d \ln w^{n'} \right) \\ &= \sum_{l',n'} \frac{M^{il'n'}}{M^i} \left(d \ln \psi^{il'n'} + d \ln \lambda^{E,in'} + d \ln X^{n'} - d \ln w^{n'} \right). \end{aligned} \quad (\text{A.40})$$

By substituting equations (A.36), (A.37), (A.38), (A.39), and (A.40), into equations (A.34) and (A.35) we will have an expression for

$$\Sigma \begin{pmatrix} d \ln w^H \\ d \ln r^H \\ d \ln w^F \\ d \ln r^F \end{pmatrix} = b,$$

for a reduced demand elasticity matrix Σ and shock vector b .

A3. Proof of Equation (13)

The cost minimization problem under the upper nest implies

$$k = (a^K)^{\sigma-1} \left(\frac{r}{p} \right)^{-\sigma} q, \quad (\text{A.41})$$

$$l = \left(\frac{w}{p} \right)^{-\sigma} q, \quad (\text{A.42})$$

where $p^X \equiv \left((w/a^L)^{1-\lambda} + (p^M/a^M)^{1-\lambda} \right)^{1/(1-\lambda)}$ is the aggregate wage index and $p \equiv \left((r/a^K)^{1-\sigma} + (p^X)^{1-\sigma} \right)^{1/}$ is the marginal cost index. Similarly,

$$l = a^L \left(\frac{w}{p^X} \right)^{-\lambda} l, \quad (\text{A.43})$$

$$m = a^M \left(\frac{p^M}{p^X} \right)^{-\lambda} l. \quad (\text{A.44})$$

By equating total demand to total supply, we have

$$\begin{aligned} K &= (a^K)^{\sigma-1} \left(\frac{r}{p} \right)^{-\sigma} q \Leftrightarrow r = p (a^K)^{\frac{\sigma-1}{\sigma}} \left(\frac{q}{K} \right)^{\frac{1}{\sigma}}, \\ X &= \left(\frac{p^X}{p} \right)^{-\sigma} q \Leftrightarrow p^X = p \left(\frac{q}{X} \right)^{\frac{1}{\sigma}}, \\ L &= (a^H)^{\lambda-1} \left(\frac{w}{p^X} \right)^{-\lambda} X \Leftrightarrow w = p^X (a^H)^{\frac{\lambda-1}{\lambda}} \left(\frac{X}{L^H} \right)^{\frac{1}{\lambda}}, \\ M &= (a^M)^{\lambda-1} \left(\frac{p^M}{p^X} \right)^{-\lambda} X \Leftrightarrow p^M = p^X (a^M)^{\frac{\lambda-1}{\lambda}} \left(\frac{X}{M} \right)^{\frac{1}{\lambda}}. \end{aligned}$$

By substituting these expressions,

$$\begin{aligned}
LS &\equiv \frac{wL}{wL + rK} \\
&= \frac{w (a^L)^{\frac{\lambda-1}{\lambda}} \left(\frac{X}{L}\right)^{\frac{1}{\lambda}} L}{w (a^L)^{\frac{\lambda-1}{\lambda}} \left(\frac{X}{L}\right)^{\frac{1}{\lambda}} L + c (a^K)^{\frac{\sigma-1}{\sigma}} \left(\frac{q}{K}\right)^{\frac{1}{\sigma}} K} \\
&= \frac{c \left(\frac{q}{K}\right)^{\frac{1}{\sigma}} (a^L)^{\frac{\lambda-1}{\lambda}} \left(\frac{X}{L}\right)^{\frac{1}{\lambda}} L}{c \left(\frac{q}{K}\right)^{\frac{1}{\sigma}} (a^L)^{\frac{\lambda-1}{\lambda}} \left(\frac{X}{L}\right)^{\frac{1}{\lambda}} L + c (a^K)^{\frac{\sigma-1}{\sigma}} \left(\frac{q}{K}\right)^{\frac{1}{\sigma}} K} \\
&= \frac{(a^L L)^{1-\lambda^{-1}} X^{\lambda^{-1}-\sigma^{-1}}}{(a^L L)^{1-\lambda^{-1}} X^{\lambda^{-1}-\sigma^{-1}} + (a^K K)^{1-\sigma^{-1}}}.
\end{aligned}$$

A4. Proof of Equations (15) and (16)

We prove the effect of the shock with the following property: The shock decreases only the foreign augmentation $d \ln a^M < 0$ but not capital and labor $d \ln a^K = d \ln a^L = 0$, and hits only an infinitesimal set of firms so the factor prices are not affected. Note that perfect competition implies the price is the marginal cost. Consider the following overall marginal cost function

$$\begin{aligned}
p &= \left(\left(\frac{r}{a^K} \right)^{1-\sigma} + \left(p^X \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \\
&= \left(\left(\frac{r}{a^K} \right)^{1-\sigma} + \left(\left(\frac{w}{a^L} \right)^{1-\lambda} + \left(\frac{p^M}{a^M} \right)^{1-\lambda} \right)^{\frac{1-\sigma}{1-\lambda}} \right)^{\frac{1}{1-\sigma}}.
\end{aligned}$$

Then the (first-order) elasticity of the cost with respect to log-foreign factor-augmenting productivity $d \ln A^F$ is

$$d \ln p = -CS_0^M d \ln a^M,$$

where $CS^M \equiv p^M m / (rk + wl + p^M m)$ is the share of foreign labor cost in the overall cost. In addition, by equation (1) we have $d \ln q = -\varepsilon d \ln p$. This in turn reduces the factor demand $d \ln x = d \ln q$ according to aggregate labor demand (A.42). Lower-nest labor demands (A.43) and (A.44) imply $d \ln l = d \ln x$ and $d \ln m = (\lambda - 1) d \ln a^M + d \ln x$. In a nutshell, we arrive at equations (15) and (16).

A5. Elasticity Matrix under Nested CES

Under the homogeneous nested CES, by factor demand functions (A.41), (A.42), (A.43), and (A.44), we may obtain that the reduced elasticity matrix

$$\Sigma \equiv \begin{pmatrix} -\sigma + (\sigma - \varepsilon) CS^K & (\sigma - \varepsilon) CS^L & (\sigma - \varepsilon) CS^M \\ (\sigma - \varepsilon) CS^K & -\lambda + (\lambda - \sigma) WS^L + (\sigma - \varepsilon) CS^L & (\lambda - \sigma) WS^M + (\sigma - \varepsilon) CS^M \\ (\sigma - \varepsilon) CS^K & (\lambda - \sigma) WS^L + (\sigma - \varepsilon) CS^L & -\lambda + (\lambda - \sigma) WS^M + (\sigma - \varepsilon) CS^M \end{pmatrix}.$$

A6. Proof of Equation (26)

We consider rich heterogeneity in factor augmenting productivities. The production function is

$$q_i = \left(\left(a_i^K k_i \right)^{1-\sigma^{-1}} + x_i^{1-\sigma^{-1}} \right)^{(1-\sigma^{-1})^{-1}},$$

$$x_i = \left(\left(a_i^L l_i \right)^{1-\lambda^{-1}} + \left(a_i^M m_i \right)^{1-\lambda^{-1}} \right)^{(1-\lambda^{-1})^{-1}}.$$

We assume that Assumption 1 is satisfied for the purpose of matrix inversion exercise below. For simplicity, assume additionally the competition environment features constant markups such as perfect competition or monopolistic competition. The factor supply (K, L, M) and total demand Q are fixed.³⁸ Thus, the following factor market clearing conditions determine the market wages (r, w, p^M) .

$$K = \int_0^1 k_i di, L = \int_0^1 l_i di, M = \int_0^1 m_i di. \quad (\text{A.45})$$

Unless otherwise noted, the integrals below are with respect to each firm and so from 0 to 1, which are omitted to keep the notation concise.

The cost-minimizing factor demands of firm i are

$$k_i = \left(a_i^K \right)^{\sigma-1} \left(\frac{r}{p_i} \right)^{-\sigma} q_i, x_i = \left(\frac{p_i^X}{p_i} \right)^{-\sigma} q_i, l_i = \left(a_i^L \right)^{\lambda-1} \left(\frac{w_i}{p_i^X} \right)^{-\lambda} x_i, m_i = \left(a_i^M \right)^{\lambda-1} \left(\frac{p_i^M}{p_i^X} \right)^{-\lambda} x_i,$$

where the marginal cost and aggregate labor-foreign input cost index are

$$p_i = \left(\left(\frac{r}{a_i^K} \right)^{1-\sigma} + \left(p_i^X \right)^{1-\sigma} \right)^{(1-\sigma)^{-1}}, p_i^X = \left(\left(\frac{w}{a_i^L} \right)^{1-\lambda} + \left(\frac{p_i^M}{a_i^M} \right)^{1-\lambda} \right)^{(1-\lambda)^{-1}}. \quad (\text{A.46})$$

Substituting these in conditions (A.45), we have

$$K = \int \left(a_i^K \right)^{\sigma-1} \left(\frac{r}{p_i} \right)^{-\sigma} \left(\frac{p_i}{P} \right)^{-\varepsilon} Q di, \quad (\text{A.47})$$

$$L = \int \left(a_i^L \right)^{\lambda-1} \left(\frac{w}{p_i^X} \right)^{-\lambda} \left(\frac{p_i^X}{p_i} \right)^{\sigma} \left(\frac{p_i}{P} \right)^{-\varepsilon} Q di, \quad (\text{A.48})$$

$$M = \int \left(a_i^M \right)^{\lambda-1} \left(\frac{p_i^M}{p_i^X} \right)^{-\lambda} \left(\frac{p_i^X}{p_i} \right)^{\sigma} \left(\frac{p_i}{P} \right)^{-\varepsilon} Q di. \quad (\text{A.49})$$

Since the system involves integrals of non-linear equations of unknowns (r, w, p^M) , the closed-form solution is hardly tractable. We thus rely on our first order approximation obtained in (6). Therefore,

³⁸Note that the fixed total demand Q means that Q is independent of the income of factors. This further implies that the treatment of economic profit of firms immaterial because so long as shares of them enter as incomes. An assumption that justifies this would be that the Home country is small-open *exporter* of the goods each Home firm produces. In this case the factor income of the Home country is negligible relative to the World income, which makes Q virtually fixed. We will come back to this issue when we analyze the general equilibrium.

it suffices to know the log-first order approximation on w and r . The log-first order approximations with respect to a^M to the system (A.47), (A.48), and (A.49) are

$$\begin{aligned} 0 &= \int \frac{rk_i}{rK} (-\sigma d \ln r + (\sigma - \varepsilon) d \ln p_i) di, \\ 0 &= \int \frac{wl_i}{wL} \left(-\lambda d \ln w + (\lambda - \sigma) d \ln p_i^X + (\sigma - \varepsilon) d \ln p_i \right) di, \\ 0 &= \int \frac{p_i^M m_i}{p^M M} \left((\lambda - 1) d \ln a^M - \lambda d \ln p^M + (\lambda - \sigma) d \ln p_i^X + (\sigma - \varepsilon) d \ln p_i \right) di, \end{aligned}$$

where, by equations (A.46) and cost-minimizing demand functions,

$$\begin{aligned} d \ln p_i &= \frac{rk_i}{p_i q_i} d \ln r + \frac{p_i^X x_i}{p_i q_i} d \ln w_i, \\ d \ln w_i &= \frac{wl_i}{p_i^X x_i} d \ln w^H + \frac{p_i^M m_i}{p_i^X x_i} d \ln w^F. \end{aligned}$$

With slight abuse of notation, for $Z = K, L, M$ and $y = k, l, m$, write CS_y^Z as the employment of factor y -weighted average of payment share to factor Z . For instance, with the home labor (l) employment as weight, the weighted average of capital (K) payment share is $CS_l^K \equiv \int \frac{wl_i}{wL} \frac{rk_i}{p_i q_i} di$. Accordingly, for $Z = L, M$ and $y = l, m$, write WS_y^Z as the employment of factor y -weighted average of wage payment share to factor Z .³⁹ With these notations, we can summarize the first order approximation as the linear algebraic problem $Az = b$, where

$$A \equiv \begin{pmatrix} (\sigma - \varepsilon) CS_k^K - \sigma & (\sigma - \varepsilon) CS_k^L & (\sigma - \varepsilon) CS_k^M \\ (\sigma - \varepsilon) CS_l^K & (\lambda - \sigma) WS_l^L + (\sigma - \varepsilon) CS_l^L - \lambda & (\lambda - \sigma) WS_l^M + (\sigma - \varepsilon) CS_l^M \\ (\sigma - \varepsilon) CS_m^K & (\lambda - \sigma) WS_m^L + (\sigma - \varepsilon) CS_m^L & (\lambda - \sigma) WS_m^M + (\sigma - \varepsilon) CS_m^M - \lambda \end{pmatrix}, \quad (\text{A.50})$$

$$\begin{aligned} z &\equiv \begin{pmatrix} d \ln r \\ d \ln w \\ d \ln p^M \end{pmatrix}, \\ b &\equiv \begin{pmatrix} (\sigma - \varepsilon) CS_k^M \\ (\lambda - \sigma) WS_l^M + (\sigma - \varepsilon) CS_l^M \\ (\lambda - \sigma) WS_l^M + (\sigma - \varepsilon) CS_l^M - \lambda - (\lambda - 1) \end{pmatrix} d \ln a^M. \end{aligned} \quad (\text{A.51})$$

Hence if A is nonsingular, z can be solved as $z = A^{-1}b$ and the log-first order approximation of labor share (6) can be solved accordingly. Indeed, equation (6) shows that only $x_2 - x_1$ is our variable of interest.

³⁹Note the similarity of the definition to the one used in the homogeneous case in equation (14). WS_y^X is the version that accomodates hegerogeneity and contains the homogeneous case as a special case—with homogeneous firms, $WS_y^X = WS^X$ for any y , and WS^F coincides with the one in equation (14).

To proceed, note that

$$z_2 - z_1 = \sum_{j=1}^3 \left(a_{2j}^{-1} - a_{1j}^{-1} \right) b_j,$$

where a_{ij}^{-1} is (i, j) -element of inverse matrix A^{-1} . According to the formula of inverting 3×3 matrices, we have

$$\begin{aligned} z_2 - z_1 &\propto \{ (a_{31} + a_{32}) a_{23} - (a_{21} + a_{22}) a_{33} \} b_1 \\ &\quad + \{ (a_{11} + a_{12}) a_{33} - (a_{31} + a_{32}) a_{13} \} b_2 \\ &\quad + \{ (a_{21} + a_{22}) a_{13} - (a_{11} + a_{12}) a_{23} \} b_3 \\ &= (a_{11} + a_{12}) (a_{33} b_2 - a_{23} b_3) + (a_{21} + a_{22}) (a_{13} b_3 - a_{33} b_1) \\ &\quad (a_{31} + a_{32}) (a_{23} b_1 - a_{13} b_2). \end{aligned}$$

Note that from equations (A.50) and (A.51), we have $a_{13} = b_1$, $a_{23} = b_2$, and $a_{33} = b_3 + (\lambda - 1)$. Therefore, $a_{33} b_2 - a_{23} b_3 = [b_3 + (\lambda - 1)] b_2 - b_2 b_3 = (\lambda - 1) b_2$, $a_{13} b_3 - a_{33} b_1 = b_1 b_3 - [b_3 + (\lambda - 1)] b_1 = -(\lambda - 1) b_1$, and $a_{23} b_1 - a_{13} b_2 = b_2 b_1 - b_1 b_2 = 0$. Using these facts, we further deduce

$$z_2 - z_1 \propto (a_{11} + a_{12}) b_2 + (a_{21} + a_{22}) b_1.$$

Substituting the elements in expressions (A.50) and (A.51), we finally have expression (26).

A7. Proof of Equations (27) and (28)

We only prove equation (27) as the other one follows the same logic. First, recall that the quantity-conditional factor demand cross derivatives $\partial \tilde{k}_i / \partial \tilde{p}_i^M|_{q_i}$ and $\partial \tilde{m}_i / \partial \tilde{r}_i|_{q_i}$ are equal because (i) due to Shephard's lemma, factor demands are partial derivative of (quantity-conditional) cost function and (ii) Hessian matrix is symmetric due to Young's theorem. Thus we have

$$\sigma_{\tilde{m}\tilde{r},i}|_{q_i} \equiv \frac{\tilde{r}_i}{\tilde{m}_i} \frac{\partial \tilde{m}_i}{\partial \tilde{r}_i}|_{q_i} = \frac{\tilde{r}_i}{\tilde{m}_i} \frac{\partial \tilde{k}_i}{\partial \tilde{p}_i^M}|_{q_i} = \frac{rk_i}{p^M m_i} \sigma_{\tilde{k}p^M,i}|_{q_i},$$

where the last equality follows by definition $\sigma_{\tilde{k}p^M,i}|_{q_i} \equiv \left(\tilde{p}_i^M / \tilde{k}_i \right) \left(\partial \tilde{k}_i / \partial \tilde{p}_i^M|_{q_i} \right)$ and the definitions of factor augmentation notations (tilde). By rearranging, we have

$$CS_i^M \sigma_{\tilde{m}\tilde{r},i}|_{q_i} = CS_i^K \sigma_{\tilde{k}p^M,i}|_{q_i}. \quad (\text{A.52})$$

Finally, we have

$$\begin{aligned} \sigma_{\tilde{m}\tilde{r},i} &\equiv \sigma_{\tilde{m}\tilde{r},i}|_{q_i} + \sigma_{qp} \frac{\partial \ln \tilde{p}_i}{\partial \ln \tilde{r}_i} \\ &= \sigma_{\tilde{m}\tilde{r},i}|_{q_i} + \sigma_{qp} CS_i^K, \end{aligned}$$

where the last equality again follows by Shepard's lemma. Similarly we have $\sigma_{\widetilde{k}p^M,i} = \sigma_{\widetilde{k}p^M,i}|_{q_i} + \sigma_{qp}CS_i^M$. Hence we have

$$CS_i^M \sigma_{\widetilde{m}\widetilde{r},i} = CS_i^M \sigma_{\widetilde{m}\widetilde{r},i}|_{q_i} + CS_i^M \sigma_{qp}CS_i^K = CS_i^K \sigma_{\widetilde{k}p^M,i}|_{q_i} + CS_i^K \sigma_{qp}CS_i^M = CS_i^K \sigma_{\widetilde{k}p^M,i},$$

where the second equality holds by equation (A.52).

A8. Properties of Factor Demand Elasticity Matrix

Generalizing the results in Section A7., we may establish the following result regarding off-diagonal elements of (quantity-controlled and -uncontrolled) elasticity matrix. We further establish additional results below.

Proposition 2. (i) (Off-diagonal elements) For any $f, g \in \{k, l, m\}$ with $f \neq g$,

$$CS_i^f \sigma_{\widetilde{f}\widetilde{g},i}|_{q_i} = CS_i^g \sigma_{\widetilde{g}\widetilde{f},i}|_{q_i},$$

$$CS_i^f \sigma_{\widetilde{f}\widetilde{g},i} = CS_i^g \sigma_{\widetilde{g}\widetilde{f},i}.$$

(ii) (Singularity) $\Sigma_i|_{q_i}$ is singular.

Proof. (i) is generalization to other factor-factor price pairs of the arguments in Section A7.. To show (ii), recall that by zero-th order homogeneity of cost-minimizing factor demand functions, Euler's theorem implies

$$\frac{\partial \widetilde{k}_i}{\partial \widetilde{r}_i}|_{q_i} \widetilde{r}_i + \frac{\partial \widetilde{k}_i}{\partial \widetilde{w}_i}|_{q_i} \widetilde{w}_i + \frac{\partial \widetilde{k}_i}{\partial \widetilde{p}_i^M}|_{q_i} \widetilde{p}_i^M = 0.$$

Hence we have

$$\sigma_{\widetilde{k}\widetilde{r},i}|_{q_i} + \sigma_{\widetilde{k}\widetilde{w},i}|_{q_i} + \sigma_{\widetilde{k}p^M,i}|_{q_i} = \frac{1}{\widetilde{k}_i} \left(\frac{\partial \widetilde{k}_i}{\partial \widetilde{r}_i}|_{q_i} \widetilde{r}_i + \frac{\partial \widetilde{k}_i}{\partial \widetilde{w}_i}|_{q_i} \widetilde{w}_i + \frac{\partial \widetilde{k}_i}{\partial \widetilde{p}_i^M}|_{q_i} \widetilde{p}_i^M \right) = 0.$$

Similar arguments apply for augmented-factor demand functions \widetilde{l}_i and \widetilde{m}_i . Hence we have

$$(\Sigma_i|_{q_i}) \mathbf{1} = 0.$$

Hence $\Sigma_i|_{q_i}$ is singular. □

B Empirical Appendix

B1. MNEs and Labor Share, Cross Country

This section details the construction of Figure 1 and some further results out of it. To see the first pass evidence that the multinational activities have an implication to labor shares, we take the cross country variation in the change of outward multinational activities and the change in labor shares.

To see this, we take the labor share data from [Karabarbounis and Neiman \(2013\)](#). We also assemble the data on multinational activities from UNCTAD. We calculate the level and change in outward multinational activities as follows. For the level, we take a snap-shot (1996-2000 average) net outward multinational sales. We take five-year average to control the noise in the raw data. For the change we obtain the change in net outward multinational sales between 1991-1995 average and 1996-2000 average.

We show the results of correlation plot in Figure 1. To allow the lagged response in the labor share to the multinational intensity changes, we take the change in the labor share between 1995 and 2007. The left panel shows the result with the level of outward multinational sales, and the right the change. We fit the correlation by the weighted regression by country size measured by the base-year GDP. The numbers of countries in the plots are 36 in the both plots. Even with such a small number of samples, both in the level of multinational intensity and the change, we see a remarkably significant negative relationship. Both regression slope coefficients are negatively significant at two-sided 95 percent.

An interpretation of this negative relationship is that the outward multinational activities substitute labor in home country more than capital there. Hence the demand for the labor in the home country decreases more than proportionately to the decrease in the capital demand. Theory in Section 3. details.

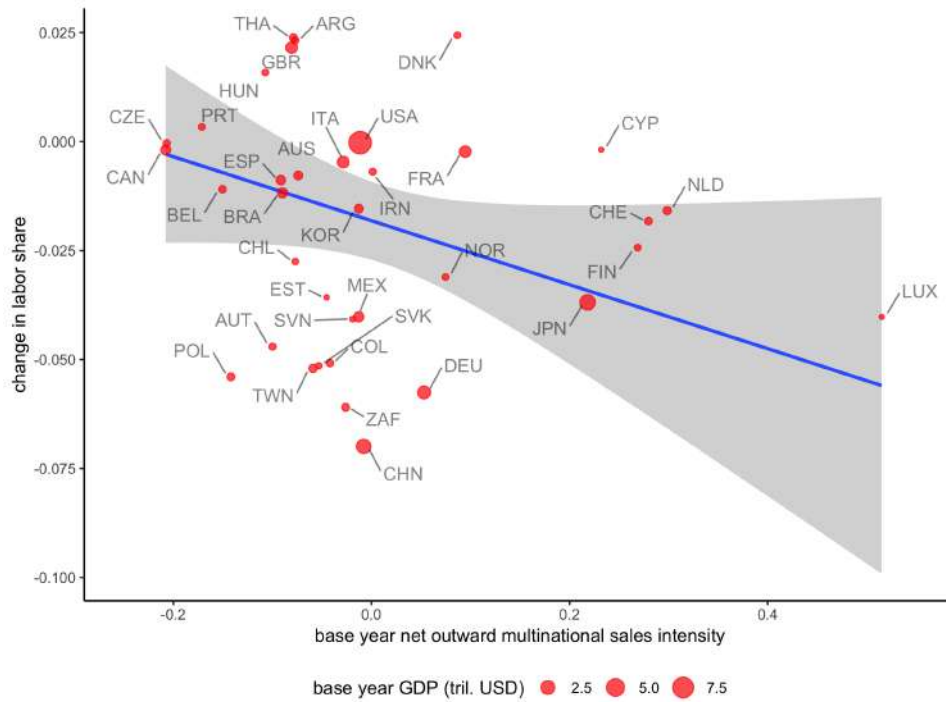
Figure B.1 shows the plot between the levels of net multinational sales (1991-1995) and the changes of labor shares (1991-2000). Again, the countries that have higher multinational sales have relatively larger decreases in labor shares in the next 10 years.

B2. Thailand Gross Export and Import Trend

Figure B.2 shows the trend of Thailand's export and import. The data source is Comtrade. Recall that 2011 was the year of the flood. Before the flood year, the export and import shows roughly a parallel trend, while after the export trend breaks and halted to increase relative to the trend of import. This finding is consistent with our interpretation of the shock that the flooding hit heavily the supply-side of the economy, given that several large-scale manufacturing industrial parks were inundated. [Benguria and Taylor \(2019\)](#) discuss the method to tell demand and supply shocks from the gross export and import data, in the context of financial crises and claim that the "firm deleveraging shocks are mainly supply shocks and contract exports," while leaving imports largely unchanged.

We also overview Thailand's economic policies. For international liberalization, Thailand went ahead other Southeastern countries. It is one of the original member countries of *Association of South-east Asian Nations* (ASEAN) and entered GATT in 1982. In early 2000's, it made FTAs with several large economies (India in 2003, the U.S. in 2004, Australia and Japan in 2005). ASEAN as an association also made some major internal and external FTAs. The internal FTA went effective in 1993. By 2003, the internal tariffs were driven down to below five percent. The external FTA with other large economies include the one with China in 2003. Given these history, over the period of our data be-

Figure B.1: Net Outward Multinational Sales and Labor Shares



Source: Karabarbounis Neiman (2014) and UNCTAD.

Note: The horizontal axis is the level of the sum of bilateral net outward multinational sales between 1991-1995 average. The vertical axis is the change in labor share from 1991 to 2000. Singapore is dropped because it has an outlier value for the outward multinational sales measure.

tween 2007 and 2016, we do not see a large number and scale of institutional internationalization.⁴⁰ The gross trade trends in Figure B.2 show the consistent pattern with this fact—the drivers behind the changes of trade trends are external business cycles (e.g., the global great recession since 2008) or political upheaval (e.g., coup d'état in 2014) rather than large trade policy changes.

B3. Details of Data Source

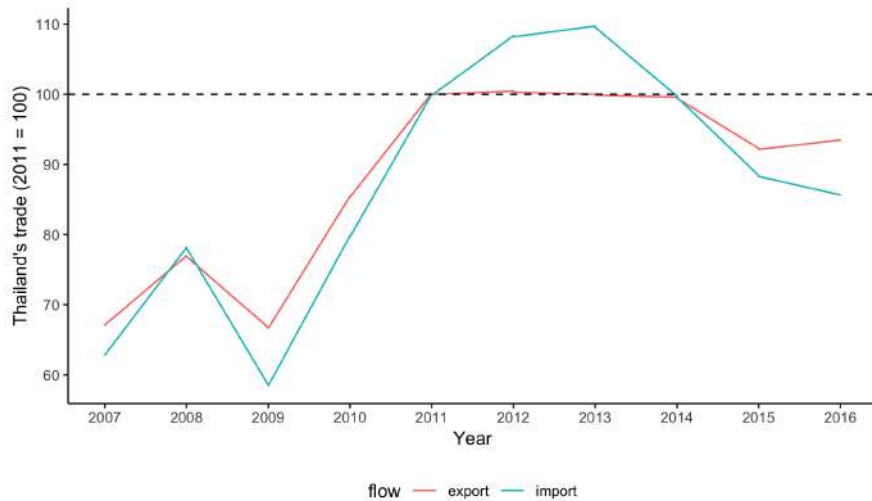
B3.1. Some Country-level Analysis from BSOBA

Throughout the main sections, we maintained assumption of the aggregated rest of the world. Although this simplify the analysis greatly, there are at least two reasons why we believe this may not be consistent with empirical findings. First, ample empirical evidence suggests that the motivations of MNEs investment are different between high-income and low-income countries (see, e.g., [Harrison and McMillan, 2011](#)). Second, to the extent that our natural experiment is a local natural disaster, a model in which the factors in the suffered area and others can be separated is more appealing and gain reality. To approach in this direction, this section discusses several country-level data. By doing so, we give the motivations for future development of multi-country analyses.

Recall that our major data source for MNE is BSOBA. As detailed in Section 2.1., BSOBA contains the universe of plants owned by headquarter firms located and registered in Japan. The coverage is

⁴⁰Several exceptions include the ASEAN-South Korea FTA that reduced the tariff between South Korea and Thailand in 2010 and Chile-Thailand FTA that went effective in 2015.

Figure B.2: Trend of Thailand's Trade



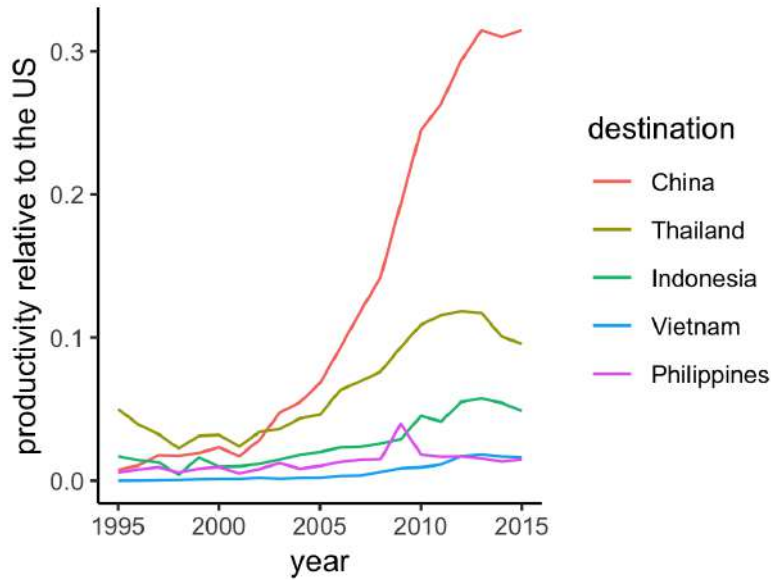
Source: Comtrade

both for private and public firms. Each plant-level observation has the country-level location, total employment and total labor compensation. Therefore, we may aggregate the country-level average wage or labor productivity measure. These variables are analyzed in detail below.

Productivity Growth in Each Destination Country We can apply the model inversion (25) for each destination country. Figure B.3 shows the results for Japan's five-most intensive MNEs' destination countries (measured by size of total employment). We take the base country in equation (25) as the U.S.. Therefore, observed productivity growth relative to the base country shows the relative augmentation of factors in these developing economies.

Broader Country-level Wage Trends—Evidence from PWT Figure B.4 shows the country-level wage by countries generated from the *Penn World Table* (PWT) data. Each line indicates the country-level average wage, where wage is calculated by per-capita average labor compensation. To signify the differences between developed and developing countries, the colors are separated—Blue lines indicate OECD countries, whereas red lines non-OECD. Since a key country of our empirical application is Thailand as in Section 4.1., we highlight it by bright color. Several points can be taken from the figure. First, there are significant wage variation across countries. In particular, OECD countries on average paid higher wages than non-OECD counterparts historically. These observation might indicate that the reasons of multinational activities might differ, which makes the theory based on multiple countries more realistic. For example, Harrison and McMillan (2011) pointed out that the cost changes in high-income and low-income countries result in different effects in home-country employment. Taking this into consideration should be aimed in the future research. Second, average wages grow in many countries. Indeed the growth occurs in OECD and non-OECD countries alike. This may make hard to derive the conclusions about the evolution of desirability for multinational firms to hire foreign workers based on the differences in labor costs. Our approach is therefore in-

Figure B.3: Country-level Measured Productivity



vert the factor demand to obtain the implied factor-augmenting productivity shocks, as detailed in Section 5.1.. Third, our natural experimental shock in Thailand in 2011 did not change the average wage drastically. This might be due to the fact that the flood shock was local and short-lived, which might not be well-captured in coarse country-year aggregate data. We employ microdata set out in Section 2.1. to study the still exogenous negative foreign factor productivity shock.

Comparison of BSOBA and PWT We then check the differences in the aggregate (average) wage measures from PWT and our primary source of data about multinational production, BSOBA. Note that PWT aggregate wage is calculated from the total labor cost and total employment in each country. Thus, the wage difference emerges if Japanese parented subsidiaries hire a different type of workers than more general firms in each country. Figure B.5 shows the comparison of BSOBA and PWT for a selected set of countries. We select these nine countries by the order of the number of total employment by Japanese subsidiaries as of the end of FY2015. From the Figure, one can see that overall the BSOBA and PWT shows a similar trend for each country. To this extent, we interpret that Japanese subsidiary firms hire workers from the similar labor market as other firms in each country. There are several interesting deviation from this pattern, particularly in high-income countries such as the UK and the U.S.. This might reflect the fact that the subsidiaries in these countries focus on high-value added activities such as finance, and therefore the hiring structure of Japanese subsidiaries is different from the rest of the firms. We also show the results of the regression of the PWT wage on BSOBA wage with or without fixed effects to show that the fit is remarkably high for a cross-section-cross-year data in Table B.1.

Figure B.4: Offshore Labor Cost in Thailand and Other Countries

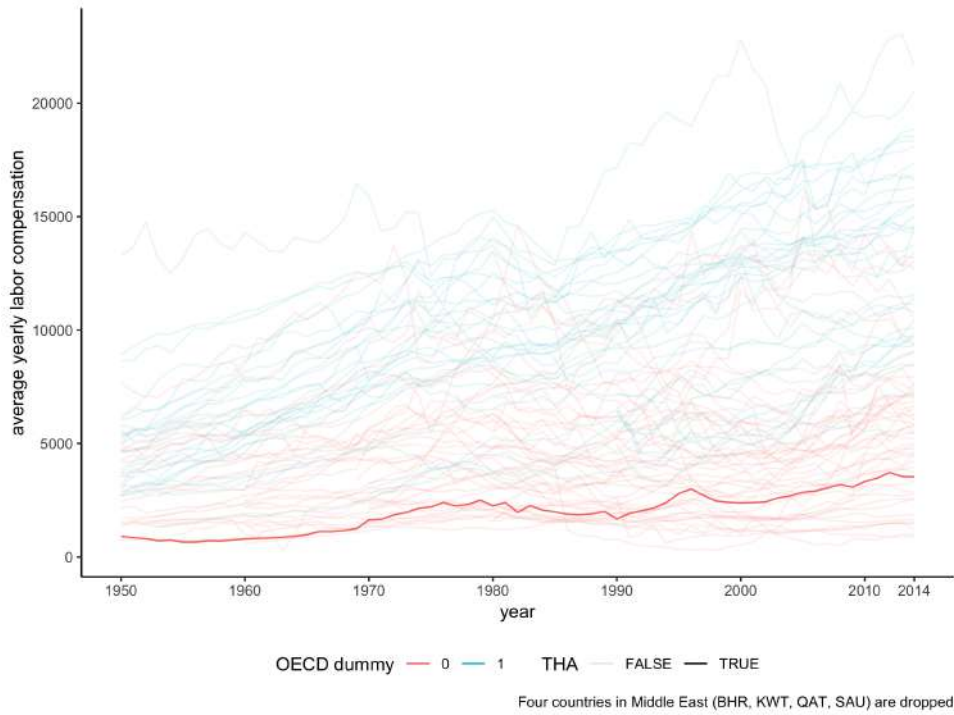


Table B.1: Discrepancies between SOBA and PWT

	All	All	Top 9	Top 9
	(1)	(2)	(3)	(4)
PR	0.332*** (0.014)	0.038*** (0.007)	0.772*** (0.028)	0.409*** (0.045)
Country FE		YES		YES
Year FE		YES		YES
Observations	1,350	1,350	180	180
R ²	0.300	0.950	0.805	0.983

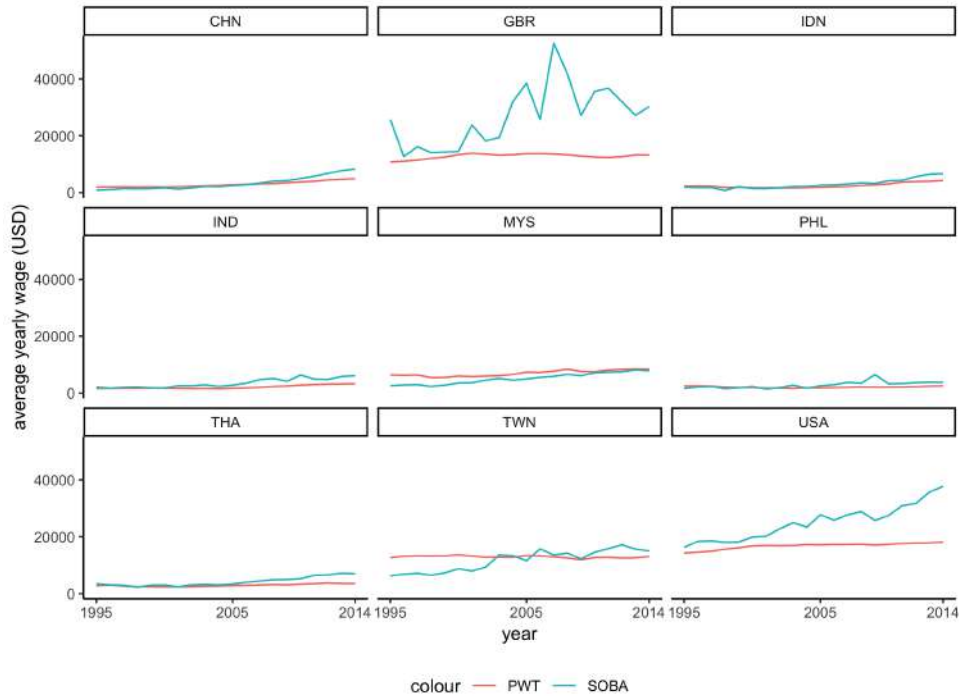
Notes: *** p<0.01, ** p<0.05, * p<0.1

B3.2. Data-linking strategy

We match BSJBSA and BSOBA datasets in the following way. First, we pick up from both BSOBA and TSR the firm name, the headquarter address and phone number for each year. To match the datasets by these information, we first need to deal with the spelling variation problem. Because of the language property, there are potential spelling variations meaning the same company or address. Therefore, we prepare the spelling variation table and applied it to the data to obtain the variation-proof dataset.⁴¹ In addition, to further improve the precision of addresses, we geocode the written address to the layered system of all Japanese addresses by applying CSV Geocoding Service

⁴¹The spelling variation table is available upon request.

Figure B.5: Comparison of BSOBA and PWT



offered by the University of Tokyo, Center for Spatial Information Science.⁴² The layers are defined as follows. 1: “todofuken” (prefecture), 2 and 3: city, 4: district in large cities, 5 and 6: coarse street address, and 7: fine street address.

Using the obtained datasets for each year, we conduct the following matching. To break the potential multiple matches within and across years, for each match in each year we assign a match score that measures the quality of match. The match score is defined as follows: firm name match receives the score of 1,000, firm phone number match receives 100, firm address match before geocoding receives 10, and firm address match after geocoding at the layer of $l = 2, \dots, 7$ receives l .⁴³ We consider the match successful if the match score is strictly larger than 1,000. In other words, this means that we require the following two criteria. First, the firm names have to match between the two datasets up to spelling variation. Second, either the address or the phone number has to match. If there are multiple successful matches, we pick the one with the highest match score. Then we compare the matching results across years and use the results with the highest score. This procedure results in the match rate of 93.0% from all firm IDs in BSOBA to firm IDs in TSR.

We match BSJBSA and TSR data by the similar method except that we have BSJBSA data from the year of 1995. The resulting match rate for all firm IDs in BSJBSA in year 2007-2016 is 88.9%. Figure B.6 summarizes the data-linking strategy set out above by the schematic diagram.

⁴²<http://newspat.csis.u-tokyo.ac.jp/geocode/> (in Japanese, accessed on July 27, 2018)

⁴³We do not assign any points for the match at the level of todofuken because it is too coarse.

Figure B.6: Schematic Data-linking Strategy

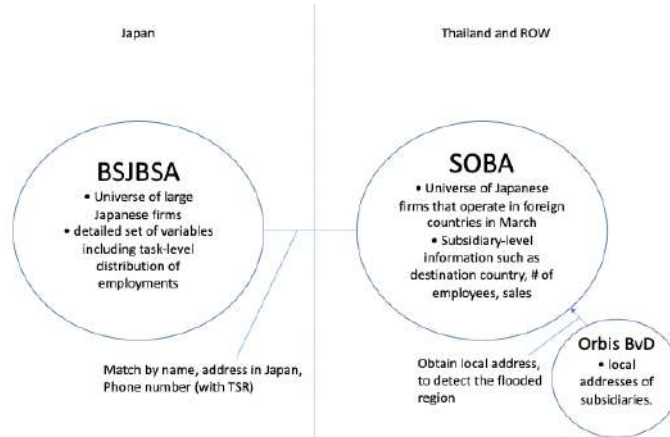
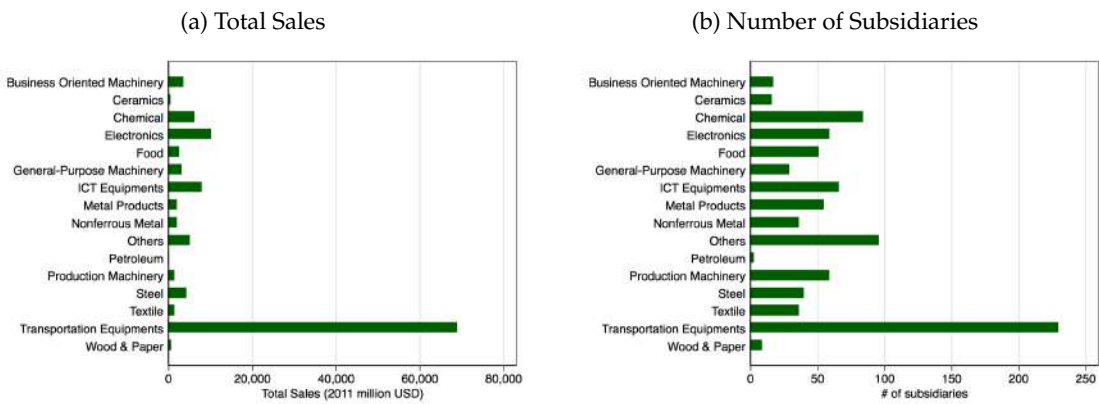


Figure B.7: Industry Distribution of the Treated Subsidiaries of Japanese firms, 2011



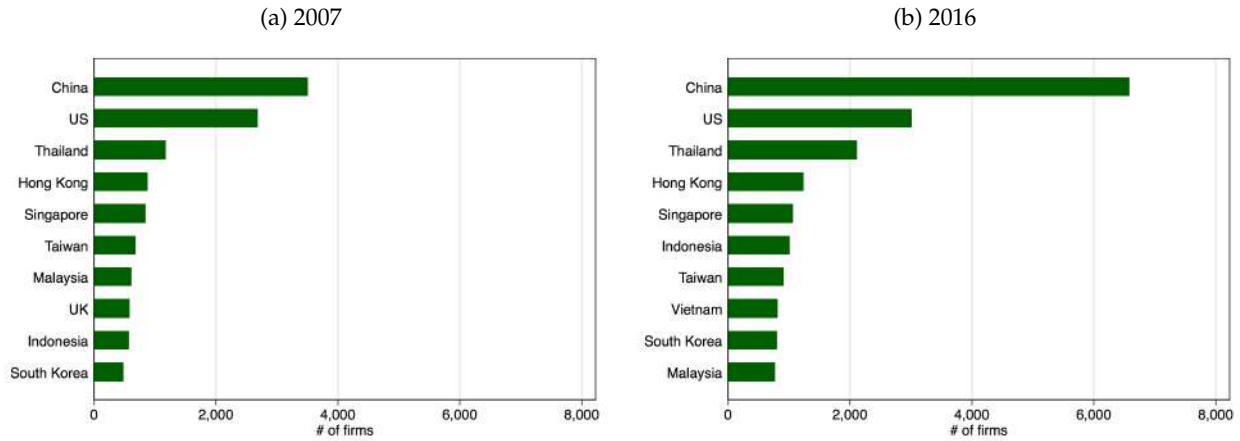
B3.3. Overview of Japanese Subsidiaries in Thailand

Using the datasets described above, we show some statistics about the production in the flooded region. First, to understand the industry clustering patterns in detail, Figure B.7 shows the distribution of industry of the Japanese subsidiaries in the flooded region in Thailand in sales in 2011. As we mentioned, most of the subsidiaries in the flooded region engage in the production of Transportation Equipment, including automobiles, both in total sales and the number of local subsidiaries. In total sales, the second largest sector is Electronics, whereas it is Others and Chemicals. The difference between Transportation Equipment and other industries is less dramatic when we see by the number of subsidiaries than the one by total sales. Part of the reasons is that the unit value of Transportation Equipments is high.

B3.4. Destination Countries of Japanese MNEs

To support our empirical analyses, we mention the strong relationship with respect to FDI from Japan to Thailand. From the perspective of Thailand, Japan is the largest country that invests in Thailand in 2011. On the other hand, from the perspective of Japan, Thailand is the third largest destination country of investment in 2011. Therefore, the flooding shock in Thailand is not only the

Figure B.8: Top 10 Regions in which Japanese Firms Have Subsidiaries



local shock but non-negligible to the Japanese economy and employment.

To confirm this pattern, Figure B.8 shows the top 10 regions in which Japanese firms have subsidiaries, in 2007 and 2016. During these 10 years, the ranking of top five regions has not changed (China, U.S., Thailand, Hong Kong, and Singapore), which indicates the stable economic relationship between these countries and Japanese firms.

B3.5. Balancing Analysis

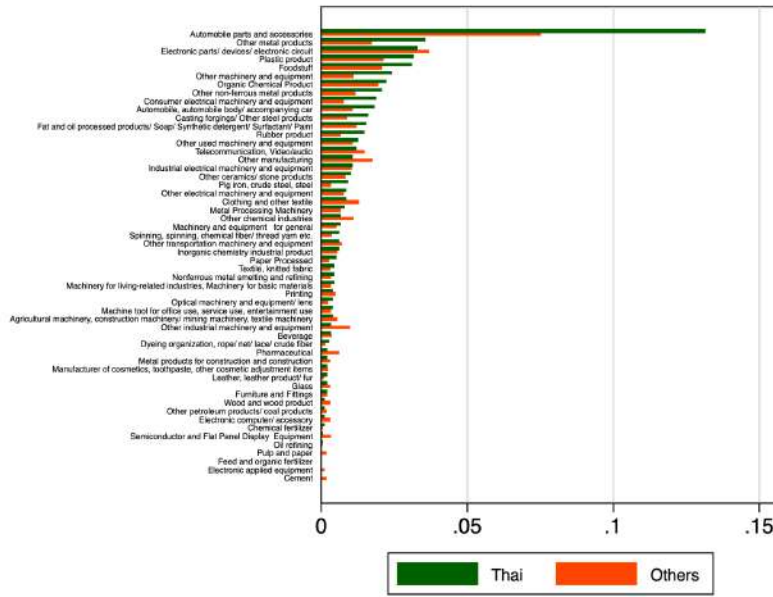
To check how similar the flooded firms and non-flooded firms, we conduct several balancing tests. Figure B.9 shows the industry distribution of subsidiary manufacturing firms for the group of parent firms that invest in the flooded region in Thailand (labeled Thai) and others (labeled Others) in 2011. Qualitatively, the industries that have many firms in in the flooded region of Thailand are likely to have higher number of firms in other countries. The flooded region has relatively more of the industry “Automobile parts and accessories” relative to other countries.

Figure B.10 shows the distribution estimate of the size of subsidiary firms of the parent firms that invest in the flooded region of Thailand and others. We measure the size by log sales in 2011. The estimation is performed by Kernel density estimation with Epanechnikov kernel. At the top of the distribution, the flooded group (labeled Thai) and the other group (labeled Others) have similar densities, while in the bottom of the distribution the Thailand group dominates the Others group. The Kolmogorov-Smirnov test rejects the same distribution between the two groups.

B3.6. Other Trends

Complementing the relative aggregate trend analysis in Section 4.1.1., we show the trend of investment and sales in Figure B.11. The left panel shows the trend of investment and the right the sales. The red vertical line indicates the year of the flood, 2011. Interestingly, the investment trend in the flooded region and the rest of the world follows the parallel path before the flood, while the trend breaks sharply after the flood. This is intuitive because for the purpose of reconstruction after the

Figure B.9: Industry Distributions, Flooded Region of Thailand vs Others



flood damage the plants in the damaged area differentially increase the investment. On the other hand, the sales trend on the right hand side does not show the parallel pattern before the flood.

B3.7. Choice of Treatment Groups

As we overview in Section 4.1.1., the flood severely affected *Ayutthaya* Province and *Pathum Thani* Province. It is important to acknowledge these particular provinces, because overall Thailand did not relatively decrease the employment or counts of subsidiaries from Japanese MNEs after the flood. This point is clarified in Figure B.12, which shows the differential trend of the employment and the count of subsidiaries in and out of Thailand, rather than the flooded provinces. As one can see, the impact on the total employment and count of subsidiaries is not stark as it is when we compare the flooded provinces versus the rest of the world in Figure 8. Therefore, in our main analysis, we take the particularly flooded provinces as the shocked regions and construct the IV based on the idea. Note again that, for this purpose, it is critical to link our BSOBA data, which only contains the country information of each plant of Japanese MNEs, to Orbis BvD that contains the specific address of the plant.

B4. Details of Calibration

B4.1. Detail in σ estimation

Following the recent development in estimating the capital-labor elasticities (Oberfield and Raval, 2014; Raval, 2019), we estimate our σ . We estimate the regression equation (20). Our coefficient of interest is b_1 since we interpret $\sigma = b_1 + 1$.

To obtain the factor payment ratio $(rk/wl)_i$, we use the *Census of Manufacture* (CoM). Recall that

Figure B.10: Sales Distributions, Flooded Region of Thailand vs Others

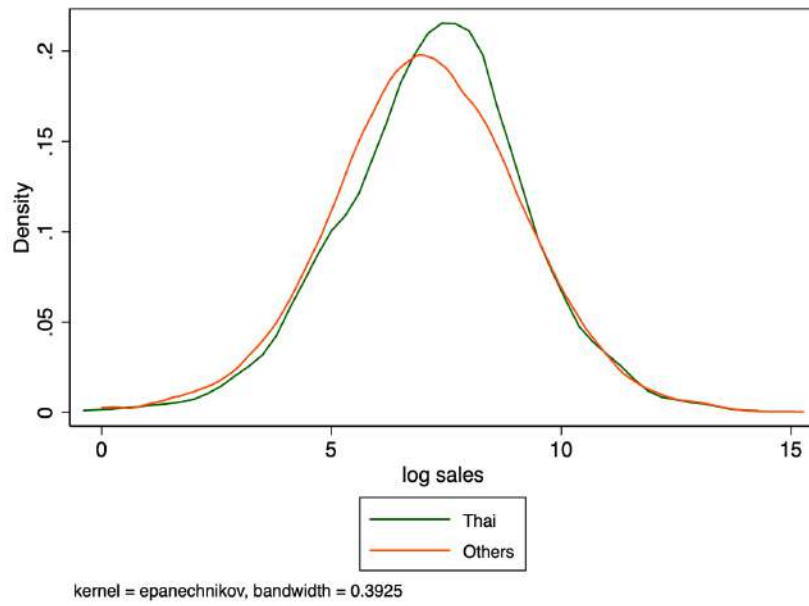
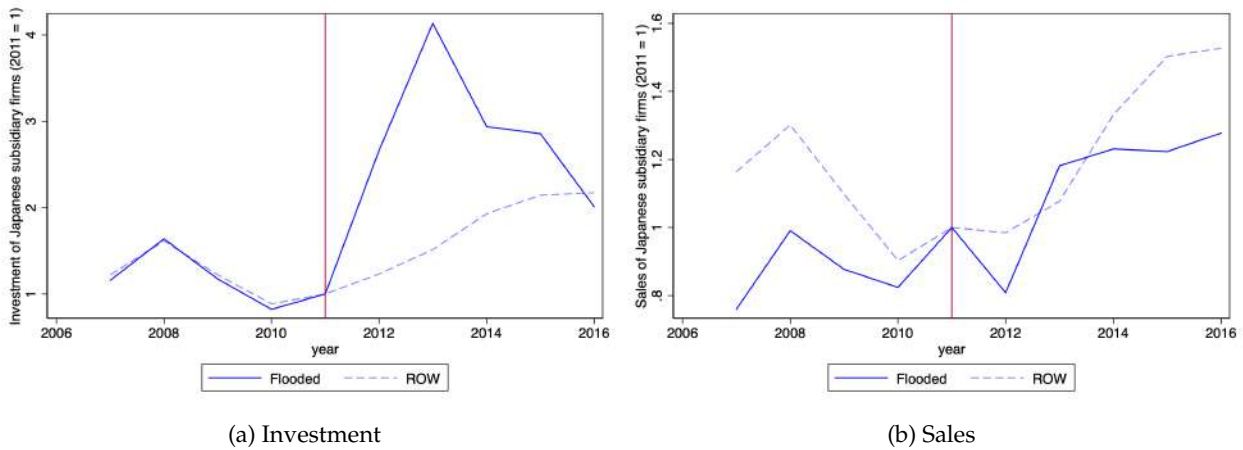


Figure B.11: Relative Trend of Japanese MNEs, Detailed

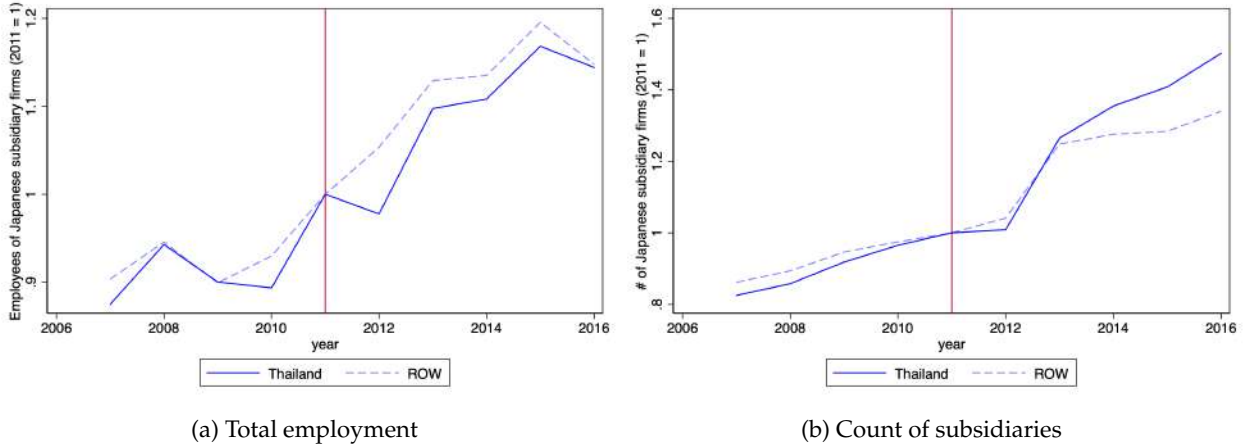


the CoM is an annual survey. We use the initial stock of tangible asset in the next year survey. To obtain the total payment to workers, we use the variable total payroll for all workers. All workers include both full-time and part-time workers. Since we can obtain the rental rate of capital at industry level, it drops with the industry-fixed effect in specification (20). Finally, CoM also offers the variables on the municipality, 4-digit industry, and multiplant status. The multiplant status includes three values: no other plants or headquarter office; no other plant but with headquarter office; have other offices. We include the fixed effect for all of these values in specification (20).

For the local wage, we use the municipality-level wage taken from the long-run economic database of the Japan's Cabinet Office. The long-run trend data offers the taxpayer-per-capita taxable income from 1975 to 2013.⁴⁴ The municipality unit is as of the last day of April 2014. We convert the munic-

⁴⁴The primary data source of this dataset is the *Survey of Municipality Taxation*, administered by Ministry of Internal

Figure B.12: Relative Trend of Japanese MNEs, Thailand versus ROW



pality code in each analysis year to the one as of April 2014 using *Municipality Map Maker* (Kirimura et al., 2011).

We need to control the endogeneity in equation (20). For this purpose, we use the shift-share instruments (Bartik, 1991; Goldsmith-Pinkham et al., 2018). Specifically, estimation equation (20) may be biased with the existence of labor-augmenting productivity shocks to a locality $m(i)$. If $m(i)$ receives the positive shock, then $w_{m(i)}$ increases whereas $(rK/wL)_i$ decreases. Therefore, β would be negatively biased. To obtain the exogenous shifter that changes $w_{m(i)}$ but not $(rK/wL)_i$ without the influence through $w_{m(i)}$, we take the average of national growth in employment weighted by the base-year employment share of non-manufacturing industries. In particular, from the Employment Status Survey (ESS), we take the ten years growth of employment at industry n as $g_{n,t} = \ln(L_{n,t}/L_{n,t-10})/10$. We then take the base-year industry- n share of employment $\omega_{m,n,t-10}$ in municipality m . Then we calculate our shift-share instrument by

$$z_{j,t} = \sum_n \omega_{m,n,t-10} g_{n,t}.$$

Table B.2 shows the result of regression (20). In the table, we show the result in 1997 since it is the nearest year to the ESS survey years.

B4.2. Detailed Results regarding ε and CS^M

Figure B.13 shows the distribution of measured markups. The distribution has a spike at the value slightly larger than one, and longer tail on the right than left. Our estimate $\varepsilon = 4$ is based on the peak value of measured markup $m = 4/3$ and standard in the literature (Oberfield and Raval, 2014).

To calculate CS^M at firm level, the global total cost is calculated by the sum of domestic cost and multinational cost. The domestic cost is the sum of the following items: advertising expense, information processing communication cost, mobile real estate rent, packing and transportation costs, total payroll, depreciation expense, welfare expense, taxes, interest expense, and lease payments.

Affairs and Communications, Japan.

Table B.2: Estimates of $\sigma - 1$

	OLS, CO	OLS, BSWs, all	OLS, BSWs, manuf.	IV, CO	IV, BSWs, all	IV, BSWs, manuf.
$\log(w_{m(i)})$	-0.60*** (0.05)	-0.20*** (0.04)	-0.13*** (0.03)	-1.15*** (0.18)	-1.24*** (0.18)	-0.88*** (0.13)
Num. obs.	51477	51477	51477	51477	51477	51477

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

CO indicates that the wage data is from the Cabinet Office. BSWs indicates that the wage data is from the Basic Survey of Wage Structures. "BSWs, all" indicates that the wage variable is taken from all industries, while "BSWs, manuf." indicates that the wage variable is taken from manufacturing industries. See the text for detail.

All regressions include industry FE and multiunit status indicator.

Standard errors are clustered at municipality level.

The international cost is the sum of each subsidiaries total costs. Each subsidiary's total cost is total sales minus total purchase of intermediate goods.

B5. Delta Method for $se(\hat{\lambda})$

This section is devoted to derive the standard error estimate of our estimator of λ obtained by

$$\begin{aligned}\widehat{b}_{IV} &= \frac{(\sigma - \hat{\lambda}) WS^F + (\varepsilon - \sigma) CS^F}{\hat{\lambda} - 1 + (\sigma - \hat{\lambda}) WS^F + (\varepsilon - \sigma) CS^F} \\ \Leftrightarrow \hat{\lambda} &= \frac{\widehat{b}_{IV} (1 - \sigma WS^F + (\sigma - \varepsilon) CS^F) + \sigma WS^F - (\sigma - \varepsilon) CS^F}{\widehat{b}_{IV} (1 - WS^F) + WS^F}.\end{aligned}$$

Recall that a standard argument holds for our standard two-stage least square estimate \hat{b} . Hence it satisfies $\sqrt{n}(\hat{b} - b_0) \rightarrow_d N(0, \Sigma)$. Thus, by the delta method we have

$$\sqrt{n}(\hat{\lambda} - \lambda_0) \rightarrow_d N\left(0, \left(\frac{\varepsilon s_0^F}{b_0^2}\right)^2 \Sigma\right).$$

Thus, in our case $se(\hat{\lambda}) = (\varepsilon s_0^F / \widehat{b}^2) \sqrt{\widehat{\Sigma}} = (4 \times 0.024 / (0.19)^2) \times 0.05 \approx 0.13$. Given our point estimate $\hat{\lambda} = 1.4$, we can test if $H_0 : \lambda \leq 1$, namely, the home labor and foreign labor are gross complements. The standard t -value is $t = 0.40 / 0.13 \approx 3.08$. Hence, we reject H_0 with the significance level 0.1 percent.

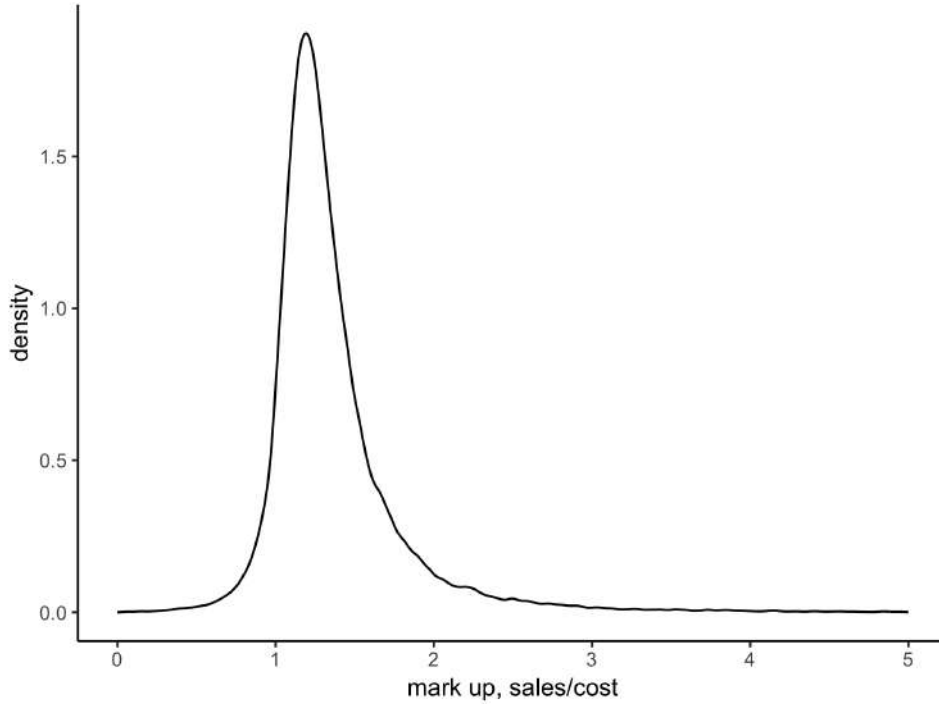
B6. Robustness Checks

B6.1. Alternative extensive-margin instrument

We consider the following instrumental variable

$$Z_{it}^{EXT} = \mathbf{1} \left\{ L_{i,2011}^{treated} > 0 \cap t \geq 2012 \right\}. \quad (\text{B.1})$$

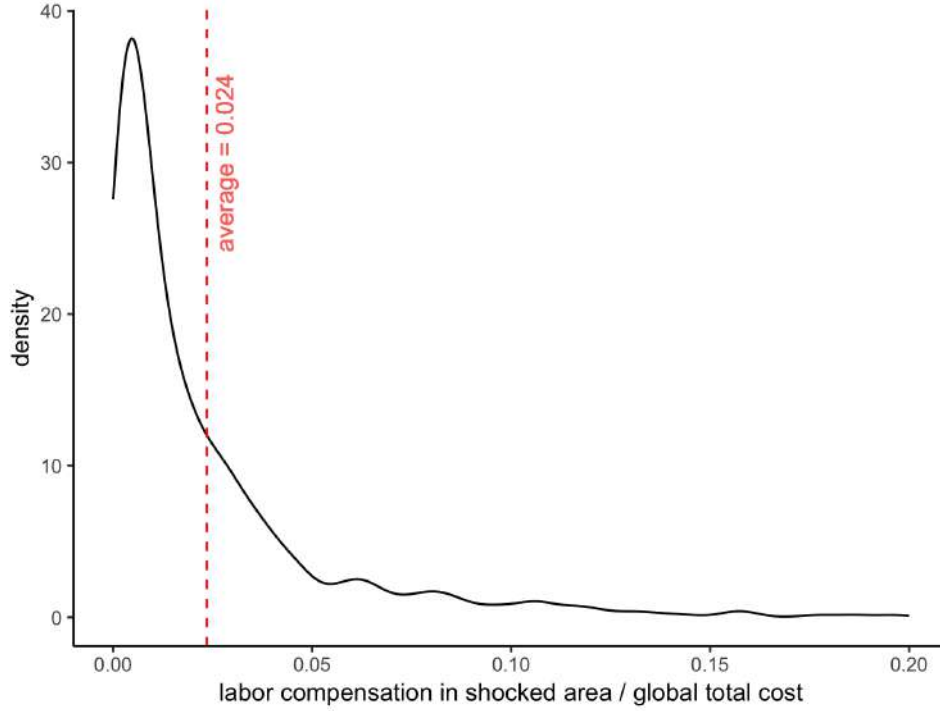
Figure B.13: Distribution of measured markup m



Source: Census of Manufacture, 2011. Estimates are obtained from inverting the markup, following Oberfield and Raval (2014). The markup is defined as sales divided by the sum of costs from capital, labor, and materials.

The idea is to take the extensive margin of the shock—If a firm is located in the flooded region, and if such a firm change the employment relative to those in other regions. Table B.3 shows the result. Nobably, we found a remarkably similar estimate 0.212 for our \hat{b}_{IV} in column 3 to the one found in Table 2 column 3, 0.192. There is no statistical differences between these two estimates. Hence our finding is robust to the choice of IVs. Indeed, it is worthwhile to emphasize the differences in the reasons causing the same estimates. In Table B.3, column 4 and 5, we found significantly smaller first stage and reduced-form estimates than the corresponding values in Table 2. This is because we define the shock Z_{it}^{EXT} at extensive margin taking the binary value of zero or one, which has larger variance than $Z_{it} \in [0, 1]$ in equation (22). The larger variance in the regressor results in smaller estimates in columns 4 and 5. This signifies our choice of target reduced-form parameter (18)—Since we do not know the exact size of the flood shock, we do not have a precise measure for such a size. Therefore, arbitrary definitions of the shocks such as (22) or (B.1) would result in quantitatively different estimates of equations (15) and (16), recalling that they are *proportionally* corresponding to columns 4 and 5 up to the choice of the shock measure or IV. Our choice of the target parameter (18) does not depend on such choice. Specifically, as can be seen in the formula of 2SLS, the variance of the instrument does not affect the estimator, but the *relative* covariance with the regressand and regressor does. Therefore, our 2SLS produces stable and robust estimates.

Figure B.14: Share of Foreign Labor Cost in Total Cost CS^M



Note: Global total cost is calculated by the sum of domestic cost and multinational cost. The domestic cost is the sum of the following items: advertising expense, information processing communication cost, mobile real estate rent, packing and transportation costs, total payroll, depreciation expense, welfare expense, taxes, interest expense, and lease payments. The international cost is the sum of each subsidiaries total costs. Each subsidiary's total cost is total sales minus total purchase of intermediate goods.

B6.2. Different Control Groups

In our main specification, we consider the sample firms as MNEs. The choice is justified because firms differ significantly between MNEs and non-MNEs, and because the inclusion of fixed effect in our regression (23) and (24) makes irrelevant the variation of the IV of firms that are never MNEs, since then $Z_{it} = 0$ for any t by definition (22), which is absorbed by the fixed effect. Having said that, to convince readers that the home employment trend did not differ significantly between MNEs and non-MNEs, we show the reduced form of 2SLS (23) and (24) with different control groups in Table B.4. Formally, the specification is

$$\ln(l_{it}^{IPN}) = a_i^{robustness} + a_t^{robustness} + b^{robustness} Z_{it} + e_{it}^{robustness},$$

with different samples and different definitions of IVs.

Columns 1-4 show the results with all firms in Japan. Since our data is unbalanced panel, we select firms that are observed throughout the period 2007-2016 and construct a balanced panel. Columns 5-8 show the results based on such a balanced panel. In columns 1 and 2, the results based on the IV Z_{it}^{EXT} defined in equation (B.1) (labeled “extensive”), whereas columns 3 and 4 Z_{it} in equation (22) (labeled “intensive”). Note that both of these IVs leverage the shock induced by the 2011 Thailand Flood, while the precise definition differs. Column 1 uses the definition of the flooded re-

Table B.3: Extensive Margin Estimates

VARIABLES	(1) $\ln l_{it}^{JPN}$	(2) $\ln l_{it}^{JPN}$	(3) $\ln l_{it}^{JPN}$	(4) $\ln l_{it}^{ROW}$	(5) $\ln l_{it}^{JPN}$
$\ln l_{ft}^{ROW}$	0.284*** (0.00394)	0.0271*** (0.00435)	0.212** (0.0921)		
Z_{ft}				-0.321*** (0.0854)	-0.0681** (0.0291)
Observations	22,795	22,795	22,795	22,795	22,795
Model	OLS	FE	2SLS	2SLS-1st	2SLS-reduced
Firm FE	-	YES	YES	YES	YES
Year FE	-	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.4: Different Reduced Form Specifications

VARIABLES	(1) extensive Flooded	(2) extensive Thailand	(3) intensive Flooded	(4) intensive Thailand	(5) extensive Flooded	(6) extensive Thailand	(7) intensive Flooded	(8) intensive Thailand
shock	-0.0497*** (0.0126)	-0.0159*** (0.00585)	-0.172*** (0.0667)	-0.127*** (0.0242)	-0.0490*** (0.0139)	-0.00747 (0.00612)	-0.249*** (0.0774)	-0.101*** (0.0248)
Observations	185,703	185,703	185,703	185,703	91,690	91,690	91,690	91,690
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Balanced panel?					YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

gion as Ayutthaya and Pathum Thani provinces, our preferred definition (labeled “Flooded”), while column 2 defines whole Thailand as the flooded area (labeled “Thailand”). The other columns shows the result based on the specifications following these basic structure. As readers notice, irrespective of the choice of sample and definition of the IV, we have robust result that the flood-affected firms *reduced* the employment in the home country, Japan.

Indeed, it is crucial to have the IV defined according to the flood-induced variation, no matter what the minor differences in definitions are between equation (22) and (B.1). In Section B7.1., we see that other widely-used definition of IV, Bartik instrument, does not work in our context, which highlights our choice based on the natural experiment and the power of identification.

B6.3. The 2011 Tohoku Earthquake

Furthermore, we consider a robustness of our results regarding the 2011 Tohoku Earthquake. Carvalho et al. (2016) give a concise description as follows: “On March 11, 2011, a magnitude 9.0 earth-

quake occurred off the northeast coast of Japan. This was the largest earthquake in the history of Japan and the fifth largest in the world since 1900. The earthquake brought a three-fold impact on the residents of northeast Japan: (i) the main earthquake and its aftershocks, directly responsible for much of the material damage that ensued; (ii) the resulting tsunami, which flooded 561 square kilometers of the northeast coastline; and (iii) the failure of the Fukushima Dai-ichi Nuclear Power Plant that led to the evacuation of 99,000 residents of the Fukushima prefecture.” (Carvalho et al., 2016)

Since our data is annual and the Thailand flood began to happen four months after the earthquake, one might be concerned that our results are qualitatively affected by the cooccurrence of the earthquake. There are two ways to address this concern. First, our specifications (23) and (24) include the fixed effects of firms. Therefore, we leverage the variation within the firm across years, but not the differences between firms that may or may not experience the earthquake. Second, in order to further mitigate the concern that the existence of the flooded firms in the main sample still biases the fixed effect estimator, we conduct the following robustness check exercise. We drop firms located in four severely hit prefectures in Japan—Aomori, Iwate, Miyagi, and Fukushima (called “damaged prefectures” below). These damaged prefectures include 36 municipalities that were designated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan after the earthquake. The definition is also employed by Carvalho et al. (2016), which an interested reader may refer to for the details of the reasons for the choice.⁴⁵

Table B.5 shows the result of the 2SLS regression based on equations (23) and (24) for the sample without firms in the damaged prefectures. We do not find statistically significant differences of the estimates between the two samples. The finding is expected given the similar samples considered. Because the 2011 Tohoku Earthquake hit severely the northeast regions in Japan, while the firms that intensively engages in FDI and multinational activities are skewed to large cities facing such as Tokyo and Osaka metropolitan areas. Given this fact, since our original estimation sample was the multinational firms, dropping the firms that suffered from the earthquake did not alter the sample largely. Therefore, we find the similar estimates in Tables 2 and B.5, which indicates the effect of the 2011 Tohoku Earthquake on our estimate is limited at most.

B6.4. Other Measures of Foreign Factors

In our main empirical specification, we use the foreign labor employment as the measure for the foreign factor. The choice is based on our data limitation that other factor employment quantities are hard to measure. On the other hand, our model shows the result that the foreign factor is more general than just labor employment. For example, the foreign factor may contain foreign capital and land that produce additional value added to the output of MNE from country H . To capture

⁴⁵ Although the propagation of the shock due to the input-output linkages makes it not trivial to measure the exact incident of the earthquake on each firm, we view our choice as a conservative test for the existence of the earthquake effect on our estimator. Namely, since the firms located in the defined four prefectures suffered the earthquake most, if there is any confounding effects of the earthquake on our estimator, dropping such firms should alter the estimate quantitatively. Thus, null differences between our full sample and sample without four prefectures are suggestive of the fact that the earthquake effects are not quantitatively significant.

Table B.5: Specification without Earthquake-hit Firms

VARIABLES	(1) $\ln l_{it}^{JPN}$	(2) $\ln l_{it}^{JPN}$	(3) $\ln l_{it}^{JPN}$	(4) $\ln l_{it}^{ROW}$	(5) $\ln l_{it}^{JPN}$
$\ln l_{it}^{ROW}$	0.448*** (0.00684)	0.0601*** (0.0107)	0.192*** (0.0502)		
Z_{it}				-0.730*** (0.108)	-0.140*** (0.0368)
Observations	5,551	5,551	5,551	5,551	5,551
Model	OLS	FE	2SLS	2SLS-1st	2SLS-reduced
Firm FE	-	YES	YES	YES	YES
Year FE	-	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

this feature of the model, we consider the value added measure by subtracting all intermediate good purchase values from total sales of each subsidiary. We then aggregate such subsidiary-level sales for each MNE to construct the MNE-level foreign value added measure VA_{it}^{ROW} . Then we may conduct the regression with specification

$$\ln(l_{it}^{JPN}) = a_i^{VA} + a_t^{VA} + b^{VA} \ln(VA_{it}^{ROW}) + e_{it}^{VA}. \quad (B.2)$$

In addition, we also check the use of raw sales measure rather than our constructed value added measure. We also construct the flood shock-based IV by the same idea as the main text, but with our value added measure:

$$Z_{it}^{VA} = \frac{VA_{i,2011}^{flooded}}{VA_{i,2011}^{JPN} + VA_{i,2011}^{ROW}} \times \mathbf{1}\{t \geq 2012\}. \quad (B.3)$$

Since both our IVs (22) and (B.3) satisfy the standard requirements for IVs under our maintained assumption that the flood was unexpected augmentation shock to the MNEs located in the damaged region, we conduct the robustness exercise based on both definitions.

In Table B.6, we report the result with our VA-based regressor specification (B.2) and preferred IV (22), while in Table B.7 we show the result with the same specification but with IV defined in equation (B.3). Both tables share the same structure—Columns 1-3 show the result with our VA_{it}^{ROW} as the regressor, while columns 4 and 5 with the crude sales measure. In column 1 and 4, we show the first stage to check the relevance of the IV. In column 2, we show the reduced form relating the IV with the outcome variable. Note that the reduced form is shared between the choice of the regressor, value added or crude sales. Finally, column 3 and 5 show the 2SLS results. Particularly worth mentioning is the qualitatively the same results of the 2SLS regressions, *no matter what regressors and IVs were used*. Therefore, we view our preferred result reported in Table 2 as robust to the choice of variables of foreign factor employment and IVs.

Table B.6: VA-based Regressor with IV (22)

VARIABLES	(1) $\ln VA_{it}^{ROW}$	(2) $\ln l_{it}^{JPN}$	(3) $\ln l_{it}^{JPN}$	(4) $\ln sales_{it}^{ROW}$	(5) $\ln l_{it}^{JPN}$
Z_{it}	-0.762*** (0.105)	-0.132*** (0.0374)		-0.549*** (0.0849)	
$\ln(VA_{it}^{ROW})$			0.173*** (0.0494)		
$\ln(sales_{it}^{ROW})$					0.240*** (0.0685)
Observations	5,460	5,460	5,460	5,460	5,460
Model	2SLS-1st	2SLS-reduced	2SLS	2SLS-1st	2SLS
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

B6.5. Long-difference Specification

Our main empirical specification (23) and (24) are meant to identify the long-run elasticity after the flood for five years. Another way to approach this is to conduct the long-difference specification by taking the difference between variables after the flood and before. Specifically,

$$\Delta \ln \left(l_i^{JPN} \right) = a^{LD} + b^{LD} \Delta \ln \left(l_i^{ROW} \right) + \Delta e_i^{LD},$$

where the time difference Δ takes the difference between after-the-flood average (2012-2016) and before-the-flood average (2007-2011). We instrument the regression with the long-difference IV

$$\Delta Z_i = \frac{l_{i,2011}^{flooded}}{l_{i,2011}^{JPN} + l_{i,2011}^{ROW}}.$$

Table B.8 shows the result. Column 1 shows the 2SLS first stage, column 2 the 2SLS reduced form, and column 3 the 2SLS result. Although the sample size reduced significantly due to time-averaging, the qualitative result of the regressions remain the same as Table 2—strong first-stage correlation (column 1), weaker but significant negative correlation in the reduced form (column 2), and the implication that the positively significant 2SLS estimate (column 3). The difference from the preferred 2SLS estimate (column 3 of Table 2) is statistically insignificant.

B7. Further Empirical Results

We conduct several extension exercises of linear regression results discussed in Section 4.2.2..

Table B.7: VA-based Regressor with IV (B.3)

VARIABLES	(1) $\ln VA_{it}^{ROW}$	(2) $\ln l_{it}^{JPN}$	(3) $\ln l_{it}^{JPN}$	(4) $\ln sales_{it}^{ROW}$	(5) $\ln l_{it}^{JPN}$
Z_{it}^{VA}	-0.957*** (0.210)	-0.144* (0.0749)		-0.791*** (0.173)	
$\ln(VA_{it}^{ROW})$			0.173*** (0.0494)		
$\ln(sales_{it}^{ROW})$					0.183** (0.0846)
Observations	5,460	5,460	5,460	5,460	5,460
Model	2SLS-1st	2SLS-reduced	2SLS	2SLS-1st	2SLS
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

B7.1. Shift-share-type Instrument and identifying the substitution elasticity

Hummels et al. (2014) considered a type of offshoring where output are offshored—A firm does not hire foreign factors directly, but imports the intermediate good instead of producing it in home country. We call their offshoring as *output offshoring* whereas our concern of multinational firms' foreign employment as *factor offshoring*. Hummels et al.'s firm-level specification is

$$\ln l_{it} = a_i^{HJMX} + a_t^{HJMX} + b^{HJMX} \ln m_{it} + e_{it}^{HJMX},$$

where l_{it} is firm f 's employment at year t and m_{it} is the value of offshoring, measured by the value of import.⁴⁶ They instrumented the endogenous offshoring value by the shift-share instrument at country and product level,

$$I_{it} = \sum_{c,k} s_{ick} I_{ckt},$$

where s_{ick} is the pre-sample year (1994) share of country c -product k pair in total material imports of firm f , and I_{ckt} is world export shifter, such as world export supply or transport costs of country c , product k , at year t .

Therefore, in our *factor offshoring* framework, the relevant regression is

$$\ln l_{it}^{JPN} = a_i^{FO} + a_t^{FO} + b^{FO} \ln l_{it}^{ROW} + e_{it}^{FO}, \quad (\text{B.4})$$

where l_{it}^{ROW} is employment of offshore workers and the instrument is

$$I_{it}^{ROW} = \sum_c s_{ic}^O L_{ct}^{ROW},$$

⁴⁶More specifically, this corresponds to Hummels et al. (2014), Table 3, Column 2, the row named "log employment," with the point coefficient of 0.044.

Table B.8: Long-difference Specification

VARIABLES	(1) $\ln VA_{it}^{ROW}$	(2) $\ln l_{it}^{JPN}$	(3) $\ln l_{it}^{JPN}$	(4) $\ln sales_{it}^{ROW}$	(5) $\ln l_{it}^{JPN}$
Z_{it}^{VA}	-0.957*** (0.210)	-0.144* (0.0749)		-0.791*** (0.173)	
$\ln(VA_{it}^{ROW})$			0.173*** (0.0494)		
$\ln(sales_{it}^{ROW})$					0.183** (0.0846)
Observations	5,460	5,460	5,460	5,460	5,460
Model	2SLS-1st	2SLS-reduced	2SLS	2SLS-1st	2SLS
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

where s_c^O is the pre-sample year (in our case, 2007) share of offshore employment in country c of firm i , and $emp_{ct}^{O,-JPN}$ is leave-Japan-out stock of workers working at subsidiaries of multinational firms. However, we do not find a relevant measure for L_{ct}^{ROW} . Therefore, we need a proxy for that.

Note that Desai et al. (2009) took the instrumental variable of GDP growth rate in each country, with the idea that “national economic growth is associated with productivity gains that correspond to declining real input costs.” (p. 186) Problems about this proxy one can imagine is that the GDP growth rate does not necessarily reflect the offshorability or availability of offshore factors in the destination country—for example, the GDP growth rate might not reflect the political instability (Pierce and Schott, 2016). If a country has high growth with high political instability that makes difficult the employment by multinational firms, then the GDP growth might overstate the actual offshorability in the country. Moreover, Desai et al. (2009)’s measure is GDP growth rate, rather than the level of GDP, where as Hummels et al. (2014) take world trade value levels to construct the instrumental variable. With these cautions in mind, we calculate the instrumental variable as follows

$$\tilde{l}_{it}^{ROW} = \sum_c s_{ic}^O g_{ct},$$

where g_{ct} is the GDP growth rate of country c from year $t - 1$ to year t .

The results of Hummels et al. (2014) indicated statistically significant substitution of home labor with foreign imported intermediate input. In contrast, we find the results in Table B.9, which does not show the similar substitution result. This highlights the difficulty in using Bartik-type instrument to identify the effect of factor-usage offshorability on home employment, as we emphasized in the beginning of Section 4..

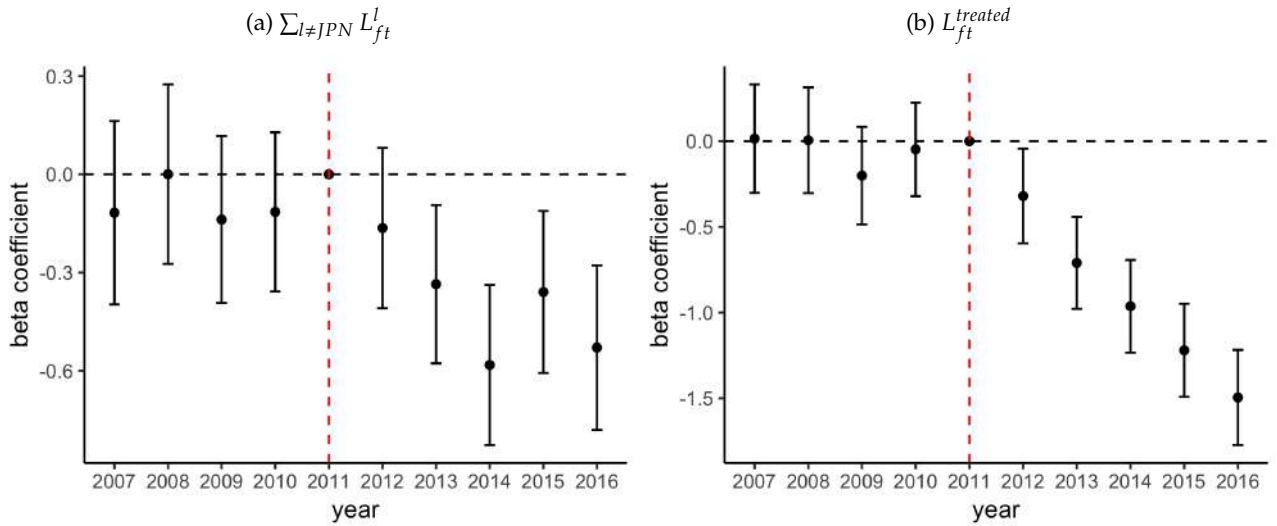
Table B.9: Results with GDP Growth-based Bartik Instruments

VARIABLES	(1) OLS	(2) FE	(3) 2SLS	(4) 2SLS first stage	(5) 2SLS reduced form
Log Subsidiary Employment	0.304*** (0.00364)	0.0314*** (0.00245)	0.0770 (0.0896)		
Shift-share Shock				0.435*** (0.123)	0.0335 (0.0388)
Observations	20,317	20,317	20,317	20,317	20,317
Firm FE		YES	YES	YES	YES
Year FE		YES	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure B.15: Results of Event Study Regression on Foreign Employment



B7.2. Long-run Impact on Foreign Employment

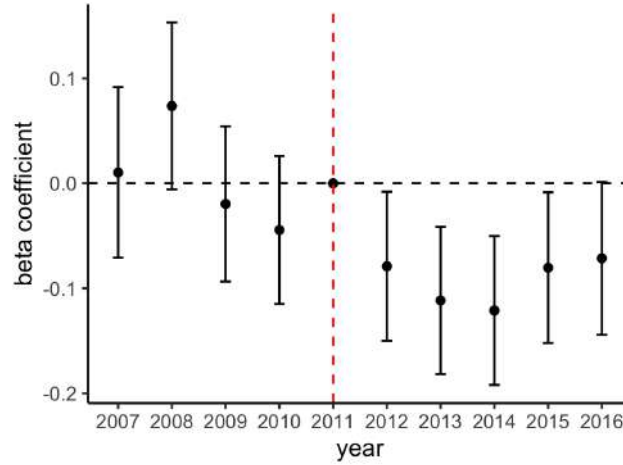
In our main specification (23) and (24), we consider the average long-run impacts, but not time-varying. As we saw in Figure 8, the flood had long-lasting effects on the employment in Thailand. To see if it is true at firm-level who was suffered by the flood, we consider the following event-study regression:

$$y_{it} = a_i^{ES} + a_t^{ES} + \sum_{\tau \neq 2011} b_{\tau}^{ES} \frac{l_{i,2011}^{flooded}}{l_{i,2011}^{JPN} + l_{i,2011}^{ROW}} \times \mathbf{1}\{t = \tau\} + e_{it}^{ES}. \quad (B.5)$$

We show an event-study plots of b_{τ}^{ES} 's in Figure B.15. These reveal that the flood had persistent effects on foreign employment. In this sense, we confirm that the effect of flood persisted for at least five years after the flood in terms of foreign employment.

We next turn to the long-run effect of Home employment. Namely, we take log employment in

Figure B.16: Results of Event Study Regression on Home Employment



Japan as y_{it} and run regression (B.5). Figure B.16 shows the result. Consistently with the reduced form results of our main specification in Table 2, we find negatively significant effects four years after the flood at 5 percent significance level. We can also confirm that the pre-trends are balanced since no coefficient before the year of the flood is statistically significantly different from zero. In 2016, the coefficient is negative but marginally insignificant from zero (still significant at 10 percent level). This revert to zero may imply recovery from the flood for the firms that were severely hit by it. However, even in Home country (Japan), the recovery in terms of employment took at least five years after the flood. In a nutshell, we interpret that the event-study analysis suggests the affirmative view on our interpretation of the shock—the medium-run impact on the worldwide factor employment of suffered firms.

B7.3. Third Country Substitution

Where do subsidiaries substitute the production after the flood? To check this in a brief manner, we can see the sales growth of subsidiaries in near countries (Indonesia, Laos, Malaysia, Phillippines, and Vietnam) between 2011 and 2012 for those firms hit by the flooding and those who are not hit. If the substitution of production happened in near countries, then those who are hit increases the sales in near countries relative to those who are not. In Figure B.17, we show the sales growth rates of foreign subsidiaries in each country near Thailand for those with subsidiaries in Thailand (labeled as “suffered”) and those without (labeled as “not suffered”). As one can see, for all countries except for Laos, we do not see the relative increase in sales for firms that are hit by the flooding. Therefore, on average, the production substitution to near countries did not happen very strongly, which adds validity of our main analysis of production substitution between Japan and Thailand.

To more formally and systematically study the substitution after the flood, we conduct the same regression specification as in the main text with modified coefficient notation of Third Country Substitution (TCS):

$$y_{it} = a_i^{TCS} + a_t^{TCS} + b^{TCS} Z_{it} + e_{it}^{TCS}, \quad (\text{B.6})$$

Figure B.17: Growth in Sales across firms located in Thailand in 2011 or not

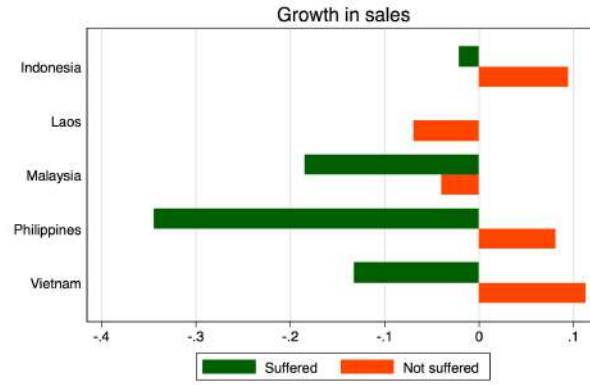


Table B.10: Third Country Substitution

VARIABLES	(1) $\ln emp_{it}^{SEA}$	(2) $\ln emp_{it}^{World}$	(3) $\ln sales_{it}^{SEA}$	(4) $\ln sales_{it}^{World}$
Z_{it}	0.443 (0.354)	-1.039*** (0.270)	-0.600** (0.253)	-0.951*** (0.184)
Observations	2,434	5,549	2,364	5,489
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

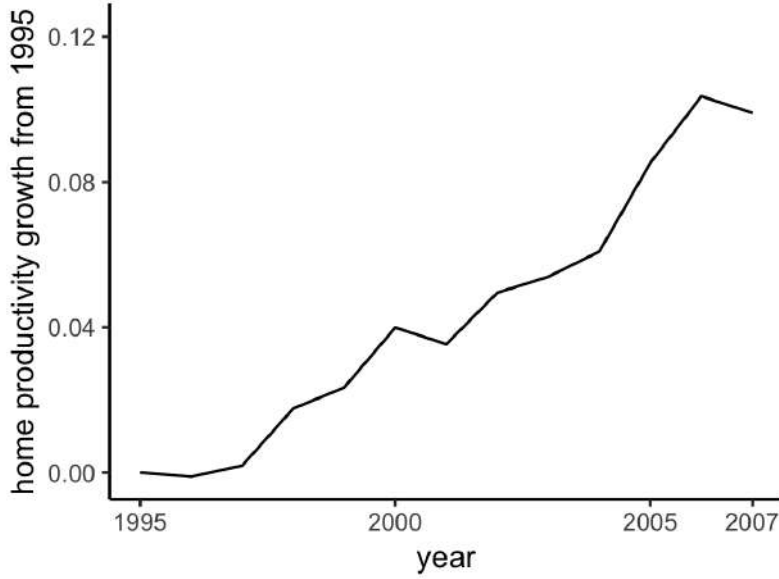
Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

but with the outcome variable about the operation in third countries. In particular, we take as an outcome variable log employment in Southeastern countries net of Thailand (Myanmar, Malaysia, Singapore, Indonesia, Philippines, Cambodia, Laos, with notation emp_{it}^{SEA}), log employment in the world net of Thailand and Japan (emp_{it}^{World}), log sales in Southeastern countries net of Thailand ($sales_{it}^{SEA}$), and log sales in the world net of Thailand and Japan ($sales_{it}^{World}$). To best control the unobserved subsidiary heterogeneity, we restrict the sample to subsidiaries located in Thailand, and compare the headquarters that have subsidiaries in the flooded regions versus not using our IV Z_{it} . Therefore, if the substitution to third country was significant, we would observe the positive coefficient $b^{TCS} > 0$.

Table B.10 shows the result of regression (B.6). Throughout columns 1-4, we do not find positive substitution from the flooded regions to non-flooded third countries. Perhaps surprisingly, we do find some strong *negative* effects on third country employment and sales. In fact, this is consistent with our interpretation that the flood decreased overall productivity of the suffered MNEs, so that they decrease the factor employment and sales *everywhere* in the world, including third countries and Japan. Recall that this productivity effect could be seen in our main regression result 2.

Figure C.1: Evolution of $d \ln a^L$



B7.4. Regression by Industries

We conduct the by headquarter industry-regression of specifications (22) and (B.1) in Table B.11. Panel B.11a shows the 2SLS results. B.12b and B.12c show the results of corresponding first stage and reduced-form regressions. In each panel, column 1 shows the results for aggregated manufacturing sector, whereas columns 2-6 show those for Chemical, Metal, General Machinery, Electronic Machinery, and Automobile industries, respectively, from the manufacturing sector.

C Quantification Appendix

C1. Details in Calibration

C1.1. Home Labor Productivity Growth since 1995

Figure C.1 shows the trend of the evolution of $d \ln a_t^L \approx \ln a_t^L - \ln a_{1995}^L$, with the base year 1995. Although there have been some increase in labor productivity growth in Japan since 1995, the significance is smaller than that of the foreign productivity growth shown in the left panel of Figure 9. In particular, from Figure 9, the foreign factor productivity grew from 1995 to 2007 by more than three log points, while Figure C.1 shows the increase of only 0.1 log point. This is consistent with our interpretation of foreign factor augmentation—over the period, the relative growth of countries out of Japan grew faster, which include the relative technological growths, and several liberalization events of international economy such as China's entry to WTO.

C1.2. Factor-biasedness and Implied Factor Augmentation

We argue another suggestive evidence that λ is likely to be greater than one, which indicates that foreign factor augmentation is foreign factor-biased technological change. Note that relative aggre-

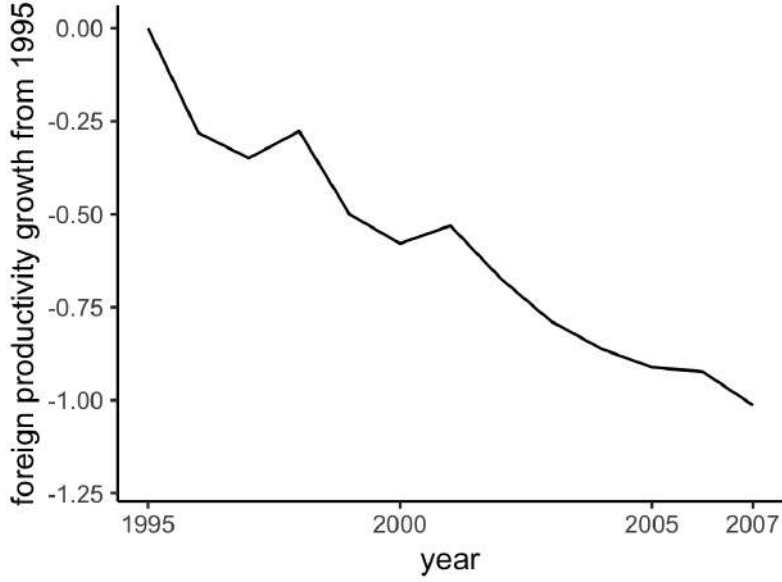


Figure C.2: Implied a^M trend when $\lambda = \sigma = 0.2$

gate relative employment L^F/L^H and wages w^F/w^H increased over the period of our interest. Then $\lambda < 1$ would imply that our model inversion

$$\frac{a_t^M}{a_t^L} = \left(\frac{M_t}{L_t} \right)^{\frac{1}{\lambda-1}} \left(\frac{p_t^M}{w_t} \right)^{\frac{\lambda}{\lambda-1}}$$

means *decreasing* relative foreign productivity. As a numerical example, Figure C.2 shows $d \ln (a_t^M/a_t^L) = d \ln a_t^M - d \ln a_t^L$ under the case of $\lambda = 0.2 (= \sigma)$. Therefore, $\lambda < 1$ would imply observed relative foreign factor *compression* over the period 1995-2007.

C1.3. Sensitivity to Parameters

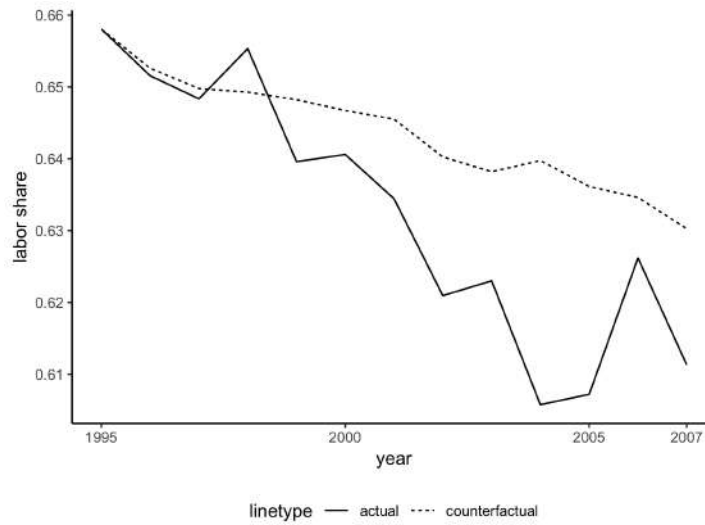
Our numerical results in Section 5.1. are sensitive to parameter values λ and σ , as we show some implied counterfactual results for different values in Figure C.3.

C2. Implications to a More Recent Trend, 1995-2015

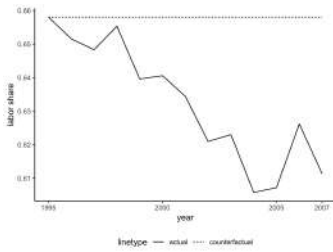
2008SNA offers the SNA data in 1994-2015. Many modifications are made relative to the previous SNAs. Among them is capitalization of Research and Development (R&D) expenditures. For our purpose, this modification bumps up the value added and drive down labor share.

Another qualification for the use of more recent trend is the Great Recession that began in 2008. In data, we see a halt in reduction in labor share in the mid 2000s. This is consistent with a widely found fact that labor share is countercyclical (Schneider, 2011). Since our focus is the structural change in foreign factor augmentation, we do not emphasize the period. Having said that, as detailed below, our mechanism of *relative* factor substitution of labor might help explain the countercyclicality.

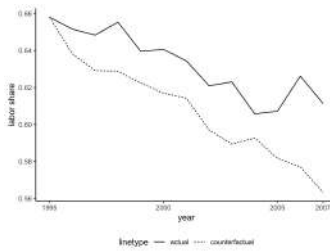
Figure C.3: Sensitivity Analysis to Parameter Values λ and σ



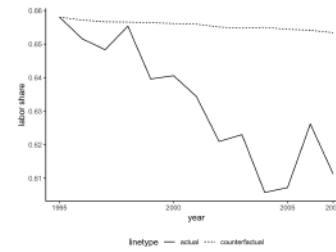
(a) (Preferred Calibration) $\lambda = 1.4, \sigma = 0.2$



(b) $\lambda = \sigma = 0.2$



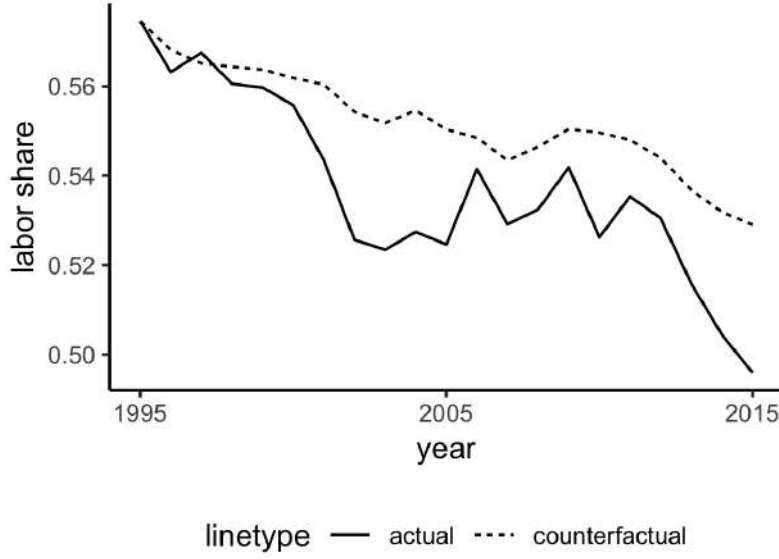
(c) $\lambda \rightarrow 1, \sigma = 0.2$



(d) $\lambda = 1.4, \sigma = 0.7$

In Figure C.4, we show the actual and counterfactual labor share trends derived by the same exercise as in Figure 10b. As we discussed, overall the labor share has been decreasing, while there is a halt in decline of labor share in the mid 2000s to early 2010s. Remarkably, the counterfactual trend shows a similar pattern—overall decline with the slow down during the period of Great Recession. To understand this, recall what drives the changes in the counterfactual trend. An important factor is the observed foreign factor augmentation (e.g., equation (25)), which is backed out by the relative foreign employment and wages. To the extent that during the Great Recession the globalization halted and MNEs' multinational activities stalled, the measured foreign factor augmentation process slowed down and even reversed. This implies the slow-down and increase of counterfactual labor share in Figure C.4. Although we do not centralize this hypothesis in the current paper, a more thorough examination of the validity of attributing the countercyclicality of labor shares to the countercyclicality of globalization would be a promising future research idea. Finally, out of the quantitative analysis, during period 1995-2015, 57.9 percent of the decrease in the labor share may be explained by the increased foreign factor productivities.

Figure C.4: Actual and Counterfactual Labor Shares, 1995-2015



C3. Standard Errors of the Method of Moments Estimator

To find the standard errors of the method of moments estimator given by (9), we refer to [Greene \(2003\)](#), Section 13.2.2, and conclude that

$$\sqrt{n}(\hat{\sigma} - \sigma_0) \rightarrow_d N\left(0, [\Gamma(\sigma_0)]^{-1} \Phi [\Gamma(\sigma_0)]^{-1}\right) \quad (\text{C.1})$$

under a set of regularity conditions, where n is the sample size, $\sigma \equiv (\sigma_{\tilde{k}p^M}, \sigma_{\tilde{l}p^M})'$ is the vector of target parameters, σ_0 is the true value and $\hat{\sigma}$ is the estimator implied by the sample analogue of equation (9). Furthermore, the 2×2 matrices $\Gamma(\sigma)$ and Φ 's are such that

$$\sqrt{n} \left(\frac{1}{n} \sum_i Z_i a_i(\sigma_0) \right) \rightarrow_d N(0, \Phi),$$

$$\frac{1}{n} \sum_i Z_i \nabla_{\sigma} a_i(\sigma) \rightarrow_p \Gamma(\sigma),$$

for any σ , where n is the effective sample size after removal of fixed effects, $a_i(\sigma) = (d \ln a_i^K(\sigma), d \ln a_i^L(\sigma))'$ and the dependence on σ is given by equations (10), (11), and Assumption 2. To learn more about $\nabla_{\sigma} a_i(\sigma)$, recall that the derivative of the inverse matrix is given by

$$\frac{\partial}{\partial \sigma_{\tilde{k}p^M}} (I + \Sigma_i(\sigma))^{-1} = - (I + \Sigma_i(\sigma))^{-1} \mathbf{0}_{(1,3)} (I + \Sigma_i(\sigma))^{-1}$$

where $\mathbf{0}_{(i,j)}$ is the 3×3 matrix filled with one in its (i,j) element and zeros elsewhere. because

$$\begin{aligned} 0 &= \frac{\partial}{\partial \sigma_{\widetilde{k p^M}}} I = \frac{\partial}{\partial \sigma_{\widetilde{k p^M}}} \left[(I + \Sigma_i(\sigma)) (I + \Sigma_i(\sigma))^{-1} \right] \\ &= \left[\frac{\partial}{\partial \sigma_{\widetilde{k p^M}}} (I + \Sigma_i(\sigma)) \right] (I + \Sigma_i(\sigma))^{-1} + (I + \Sigma_i(\sigma)) \left[\frac{\partial}{\partial \sigma_{\widetilde{k p^M}}} (I + \Sigma_i(\sigma))^{-1} \right] \end{aligned}$$

and rearranging it. Therefore, we may solve

$$\nabla_{\sigma} \mathbf{a}_i(\sigma) = \left(\frac{\partial}{\partial \sigma_{\widetilde{k p^M}}} \mathbf{a}_i(\sigma), \frac{\partial}{\partial \sigma_{\widetilde{l p^M}}} \mathbf{a}_i(\sigma) \right)$$

and

$$\begin{aligned} \frac{\partial}{\partial \sigma_{\widetilde{k p^M}}} \mathbf{a}_i(\sigma) &= I_{-(3,\cdot)} (I + \Sigma_i(\sigma))^{-1} \mathbf{0}_{(1,3)} (I + \Sigma_i(\sigma))^{-1} \mathbf{p}_i, \\ \frac{\partial}{\partial \sigma_{\widetilde{l p^M}}} \mathbf{a}_i(\sigma) &= I_{-(3,\cdot)} (I + \Sigma_i(\sigma))^{-1} \mathbf{0}_{(2,3)} (I + \Sigma_i(\sigma))^{-1} \mathbf{p}_i, \end{aligned}$$

where

$$I_{-(3,\cdot)} \equiv \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}, \quad \mathbf{p}_i = \begin{pmatrix} d \ln(rk_i) \\ d \ln(wl_i) \\ d \ln(p^M m_i) \end{pmatrix}.$$

To estimate Φ and $\Gamma(\sigma)$, we use the sample analogue of them $\widehat{\Phi}$ and $\widehat{\Gamma}(\sigma)$

$$\widehat{\Phi}_{j_1, j_2} = \frac{1}{n-1} \sum_i Z_i^2 d \ln a_i^{j_1}(\widehat{\sigma}) d \ln a_i^{j_2}(\widehat{\sigma}),$$

$$\widehat{\Gamma}(\sigma) = \frac{1}{n} \sum_i Z_i \nabla_{\sigma} \mathbf{a}_i(\sigma),$$

where $j_1, j_2 \in \{K, L\}$. We evaluate $\widehat{\Gamma}$ at the estimated parameter value $\sigma = \widehat{\sigma}$. We then estimate the finite approximation to the asymmetric distribution of the estimator (C.1) by

$$\frac{1}{n} \left[\widehat{\Gamma}(\widehat{\sigma}) \right]^{-1} \widehat{\Phi} \left[\widehat{\Gamma}(\widehat{\sigma}) \right]^{-1}.$$

Table B.11: Industry-level Regression

(a) 2SLS

VARIABLES	(1) 2SLS	(2) 2SLS	(3) 2SLS	(4) 2SLS	(5) 2SLS	(6) 2SLS
Log Subsidiary Employment	0.120** (0.0501)	-0.00447 (0.610)	0.168*** (0.0486)	0.0774 (0.0694)	-0.184 (0.162)	0.507* (0.292)
Observations	3,704	773	540	563	521	915
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry	manuf	chem	metal	machine	elec	auto

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) 1st	(2) 1st	(3) 1st	(4) 1st	(5) 1st	(6) 1st
Thai Flood Shock	-0.730*** (0.169)	-0.152 (0.173)	-1.655*** (0.358)	-2.223** (1.101)	-0.655*** (0.161)	-0.303** (0.132)
Observations	3,704	773	540	563	521	915
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry	manuf	chem	metal	machine	elec	auto

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(b) First Stage

VARIABLES	(1) reduced	(2) reduced	(3) reduced	(4) reduced	(5) reduced	(6) reduced
Thai Flood Shock	-0.0874** (0.0428)	0.000677 (0.0923)	-0.277*** (0.0594)	-0.172 (0.225)	0.120 (0.105)	-0.154** (0.0700)
Observations	3,704	773	540	563	521	915
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry	manuf	chem	metal	machine	elec	auto

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(c) Reduced Form