Local Welfare Impact of Trade Liberalization
Trans-Pacific Partnership and U.S. States

Ibrahim Gunay *

University of Michigan

November 15, 2015

JOB MARKET PAPER

Abstract

This paper studies the local welfare impact of trade liberalization by analyzing the potential effects of the Trans-Pacific Partnership agreement on U.S. states. I use a multi-region and multi-country trade model with input-output linkages, interregional/international trade, data and production statistics. The predictions of the model show that removing tariffs among TPP partner countries increases aggregate U.S. real wages by 0.03 percent while the variation in real wage changes across the states is from -0.01 percent to 0.18 percent. I use sectoral import and export data for the U.S. states instead of imputing them according the sectoral characteristics of labor markets as has been done in the previous literature. I show that using sectoral based trade data leads to large biases in welfare predictions. This is the case because trade data measures that only rely on sectoral factors fail to account for the heterogeneity in trade openness and trade partners of local labor markets. By decomposing the changes in real wages into separate channels, I show the role of geographical and sectoral linkages, and demonstrate whether welfare gains of U.S. states are attributable to production or consumption.

JEL classification: F10, F11, F13, F16, F17.
Keywords: Trade policy, local labor markets, welfare evaluation, geographical and sectoral linkages.

*PhD Candidate, Department of Economics, University of Michigan, igunay@umich.edu. I thank my advisor Alan Deardorff for his support and guidance. I would like to thank Javier Cravino, Ugo Troiano, Sebastian Sotelo, Iain Osgood, Andrei Levchenko, Dominick Barthelme, Kyle Handley and Linda Tesar for their useful comments and feedback. All errors are my own.

1 Introduction

International trade literature has long analyzed one important issue: the impact of trade liberalization on welfare.[1] Most of the studies, using quantitative trade models, have focused on the national level of geographical aggregation. However, any regional subgrouping can be a trade model's unit of analysis. Most countries have significant regional differences in sectoral production and trade relationships, therefore economic shocks can cause geographically disproportionate effects. Conducting an analysis at the local geographical level will allow us to identify the winners and losers arising from an economic shock. The results of such a study will influence the policies of local politicians in regards to trade agreements and place-based welfare programs to compensate trade related losses.

The literature studying local labor market effects of international trade has shown the significant ramifications of trade on local employment and earnings.[2] Most of this research has focused on the direct impact of a trade shock without taking into account spillovers between regions and general equilibrium interactions. In addition, previous studies have not analyzed changes in real-incomes or welfare of local labor markets by assuming that changes in consumer prices would be identical across regions. Different markets might demonstrate a variation through various channels in their exposure to a trade agreement; their gains (or losses) might result from production and sales, or consumption and prices. The gains and losses from trade due to production or consumption channels are usually reflected on different groups of individuals within a region, and thus, determining the contribution of these channels sheds a light on policy decisions regarding trade policies.

The collection of trade data at local geographical levels would allow us to study the local welfare impact of trade policies using trade models that can take into account intertwined interactions between many sectors and regions. Due to the unavailability of such data, previous studies such as Autor, Dorn and Hanson (2013) and Caliendo, Dvorkin and Parro (2015) have instead imputed foreign trade data of local labor markets with measures based on the sectoral characteristics of these locations. I argue that these alternative imputations for trade data fail to take into account the geographical aspect of trade relationships because they only rely on sectoral variations. In order to fully consider the intersection of geographical and sectoral heterogeneity of trade across U.S. states, I use multiple sources to construct a dataset that includes sectoral bilateral trade flows between U.S. states and partner countries. I apply this dataset to a quantitative trade model to study the potential effects of the Trans-Pacific Partnership agreement on real wages of U.S. states.[3]

In particular, I use a multi-region and multi-sector Eaton and Kortum (2002) model with input-output linkages. I allow for countries to have sub-regions, which act as the geographical units of the model. I assume that labor is immobile across country boundaries,

[1] See Deardorff and Stern 1990, Baldwin and Venables 1995 and Bhagwati and Krishna 1999.

[2] Autor, Dorn and Hanson (2013) discuss the impact of Chinese import competition on employment and incomes of U.S. commuting zones, and Kovak (2013) studies the effects of a trade liberalization in Brazil on its local labor markets.

[3] TPP is a multi-dimensional trade agreement that aims to foster economic opportunities between Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, Vietnam and the United States. The partner countries have reached an agreement on October 5, 2015.

but it is partially mobile across regions of the same country. In the utility function, I introduce local amenities for which workers have heterogeneous tastes in order to create frictions to labor mobility within a country. In my sample, the United States economy is comprised by its states while the other countries are considered as single sub-regions. After quantifying the model with the data, I implement a counterfactual policy exercise in which the tariff schedule among TPP partner countries changes. Subsequently, I look at how this policy affects real wages of U.S. states.

The results of this policy exercise show that aggregate U.S. real wages increase by 0.033 percent whereas the variation of real wages across the states is from -0.01 percent (New Hampshire) to 0.18 percent (Kansas).[4] The agricultural and food producing states as well as states on the Pacific coast gain more while states on the East coast experience very small changes due to this tariff reduction policy.

I have compared my welfare predictions using the U.S. state import and export data with alternative simulations I have computed using the imputed trade data based on sectoral variation of states. I find that using the sectoral based trade data leads to large biases as it decreases the heterogeneity across U.S. states in terms of their trade partners, and hence it miscalculates the impact of TPP on U.S. state real wages. For instance, Oregon reports high gains with my data and very low gains with the sectoral based trade data. Similarly, Vermont does not have real wage changes with my data whereas it enjoys a high real wage increase with the sectoral based trade data. The trade model that I use considers the heterogeneity in production by sector, trade flows by partner, and the changes in tariff rates for country-sector pairs for computing predictions on real wages. Therefore, the results of this policy exercise are very sensitive to the choice of foreign trade data specifications.

In order to explain why these states are affected differently, I decompose the real wage effects into separate economic channels. After finding the direct exposure of regions to changes in in the tariff schedule, I solve the system using a first-order approach and account for the general equilibrium interactions. First, I calculate the competition effects on the states. For instance, I compute how much market access Oregon gains in Malaysia, or how much loss Georgia faces against the Vietnamese textile sector in the U.S. market. In addition, I calculate the geographical spillover effects due to regions having supply and demand relationships with each other. Finally, I find the price effects on each region, which are mainly attributable to changes in import prices. By aggregating the impact on these channels emanating from various sectors and regions, I show the aggregate breakdown of the welfare effects on each U.S. state according to these channels.

The summary of this breakdown is as follows. Pacific coast states gain both due to the expansion of their competitiveness in Japan and other Asian markets, and the price effects due to cheaper imports. Agricultural and food producing states such as Iowa, Kansas Nebraska benefit mainly from the competition effects, but not as much from price effects. However, states on the East coast mainly benefit from reductions in imports, and some of

[4]In general trade models predict low welfare effects and greatly underestimate the impact of trade liberalizations. For comparison, Caliendo and Parro (2015) predicted the welfare gains of United States from NAFTA using a similar model as 0.1 percent.

them such as Georgia and North Carolina lose their competitiveness and face losses due to the tariff reductions. Some states such as Wyoming gain mainly due to geographical spillovers thanks to the improvements in its neighboring regions.

This paper is related to a growing body of literature on distributional effects of international trade.[5] My research complements the existing literature that studies the consequences of trade on local labor markets by applying a quantitative trade model that has interregional trade and foreign trade by sector and input-output linkages. I show disproportionate effects of trade liberalization on regional welfare, and its sub-components in terms of production and consumption. The earlier studies only display cross-sectional differences across local labor markets in terms of nominal wages and do not evaluate welfare outcomes (Topalova 2007, Autor, Dorn and Hanson 2013, Kovak 2013, Dix-Carneiro and Kovak 2014). They assume that consumer price effects, would be common to everyone in the economy, and hence can be omitted from the analysis. Since my dataset has sectoral import data of U.S. states by country of origin, I can find how much prices change due to a trade shock, and therefore I can show welfare effects. My paper is related to the literature that studies the international geography of an economy using trade models (Allen and Arkolakis 2014, Caliendo et al. 2014, Caliendo, Dvorkin and Parro 2015, Bartelme 2015, and Redding 2014). The closest study in this line of research to my paper is Caliendo, Dvorkin and Parro's (2015) analysis on the labor market adjustment of the U.S. states due to a global productivity shock. They incorporate a dynamic labor market adjustment framework to an international trade model that includes internal geography. However, they do not use export and import data of the U.S. states, and hence cannot identify exposure to trade shocks. With a novel interregional dataset that covers all sectors of the U.S. economy, I provide the first quantitative analysis on local welfare effects of trade liberalization using a standard trade model.

My paper also analyzes the network effects in an economy that arise from geographical and sectoral linkages. Acemoglu et al. (2012), and Acemoglu, Akcigit and Kerr (2014) study the network structure of the macroeconomy that has input-output linkages across its sectors and show that networks can propagate and enhance the impact of economic shocks. The trade model I work with is a special case of their network framework since it has an input-output structure and geographical linkages through trade. I identify the sources of economic channels that create separate effects on regions, and provide a breakdown of these channels given a trade policy shock. My first-order solution of the model demonstrates how any type of productivity or trade policy shock transmit through network linkages. By breaking the model to different parts, and laying out the sources of heterogeneity across regions due to a trade policy shock, I improve Arkolakis, Costinot and Rodríguez-Clare (2012)'s sufficient statistics approach based on changes in domestic trade share and trade elasticity. Their method can only be applied for ex-post welfare evaluation after observing the data on domestic trade share, but does not explain the factors that lead to differences in gains from trade across regions.

[5]Another strand of the literature studies the effects of global shocks on different skill groups. See Goldberg and Pavcnik (2007) for a literature review. Recent studies such as Galle, Rodriguez-Clare and Yi (2015), and Cravino and Sotelo (2015) use quantitative general equilibrium models to consequences of international trade on different skill groups.

The results of this paper have various implications for trade policy. First, geographical distribution of exposure to trade policies can interest policy makers and local politicians for the welfare of their constituents. Especially in countries that have a decentralized political system with local governments, such as the United States, potential welfare exposure of regions to trade can influence policy decisions. Second, identifying how trade policies will impact specific regions is crucial for shaping place-based government welfare programs.[6] Third, the real wage decomposition mechanism that I construct can be used to analyze in detail the impact of any multidimensional economic shock, which is a practical policy tool to evaluate benefits and losses of trade liberalizations. With this decomposition, we can also determine whether the gains or losses are reflected on producers or consumers. Finally, this model provide potential welfare outcomes under various trade policy scenarios of the TPP agreement. Previously, Petri and Plummer (2012) and Deardorff (2013) analyzed the implications of Trans-Pacific Partnership on partner countries.

The paper is organized as follows. Section 2 provides a background on economic characteristics of U.S. states and discusses the role of local trade data. Section 3 lays out the theoretical model to study local welfare effects of trade policy changes. Section 4 describes the data sources and calibration mechanism of model parameters. Section 5 exhibits the welfare predictions of the TPP agreement on the U.S. states. Section 6 provides a real wage decomposition tool to separate effects of trade policy changes into multiple channels to identify sources of variation from a trade policy. Section 7 concludes.

2 Production and Trade Patterns of U.S. States

In this section, I provide the background information for the economic differences across U.S. states in terms their of production and trade partners, which will be the sources of variation in their exposure to the Trans-Pacific Partnership agreement. I rely on a dataset I have constructed, which has data on production and trade data by sector for each U.S. State. Subsequently, I compare my trade data to an alternative trade measure based on sectoral characteristics of states similar to what Autor, Dorn and Hanson (2013) and others have implemented previously. I describe my dataset in detail in section 4 and the data appendix.

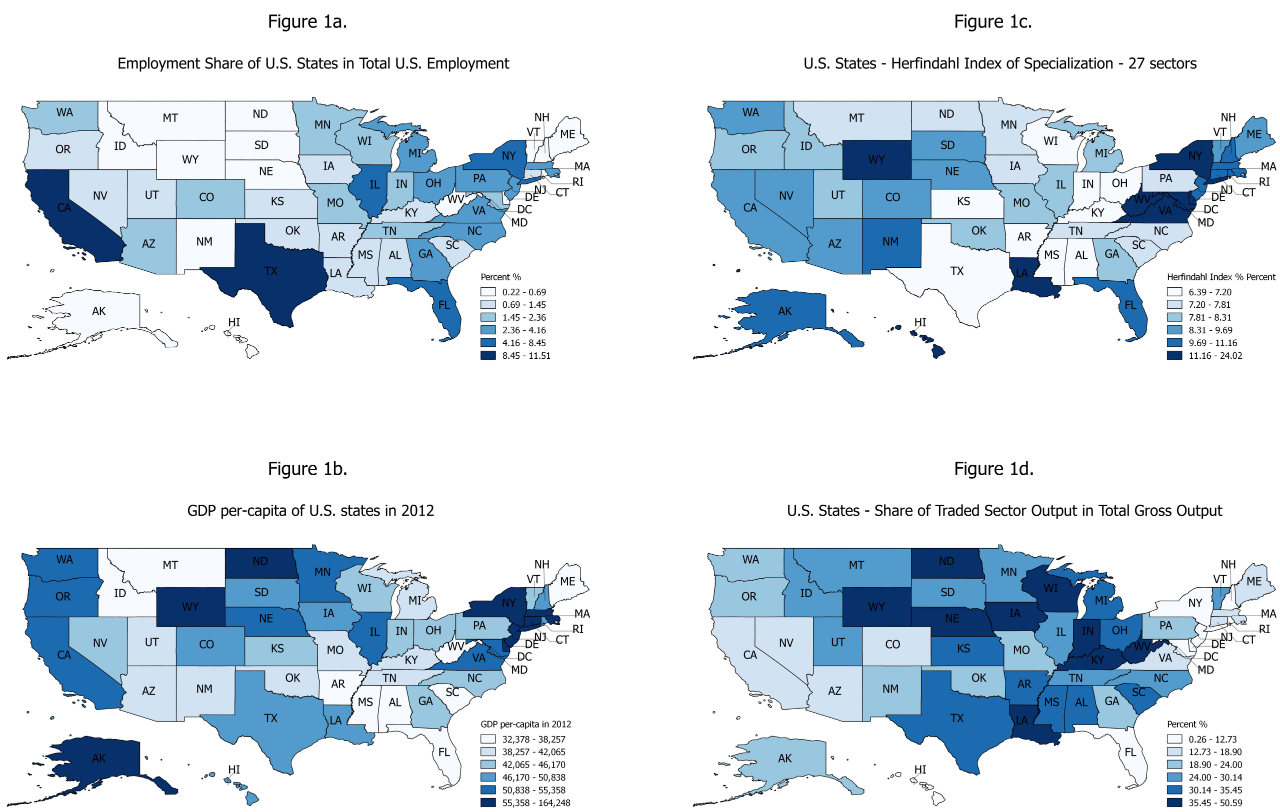
2.1 U.S. States versus Countries

The U.S. economy is distinctive in its structure of being formed by many large states, each of which could be classified as relatively large countries on their own. The largest U.S. state in terms of its economic size, California, could be the 6th or 7th largest economy in the world on its own, which has a gross domestic product comparable to Brazil and Italy. In addition, the average U.S. state population is about 6.25 million, which is higher than

[6] See Glaeser and Gottlieb (2008) for a survey on place-based government welfare programs. Other programs on an individual or industrial basis are also implemented due to trade policies.

the population of several developed economies such as Finland and Norway, but lower than the average country population of 18.7 million in the European Union and average country population of 37.3 million in the world.

Figure 1: Employment, GDP per capita, sectoral specialization and traded good production of U.S. States in 2012



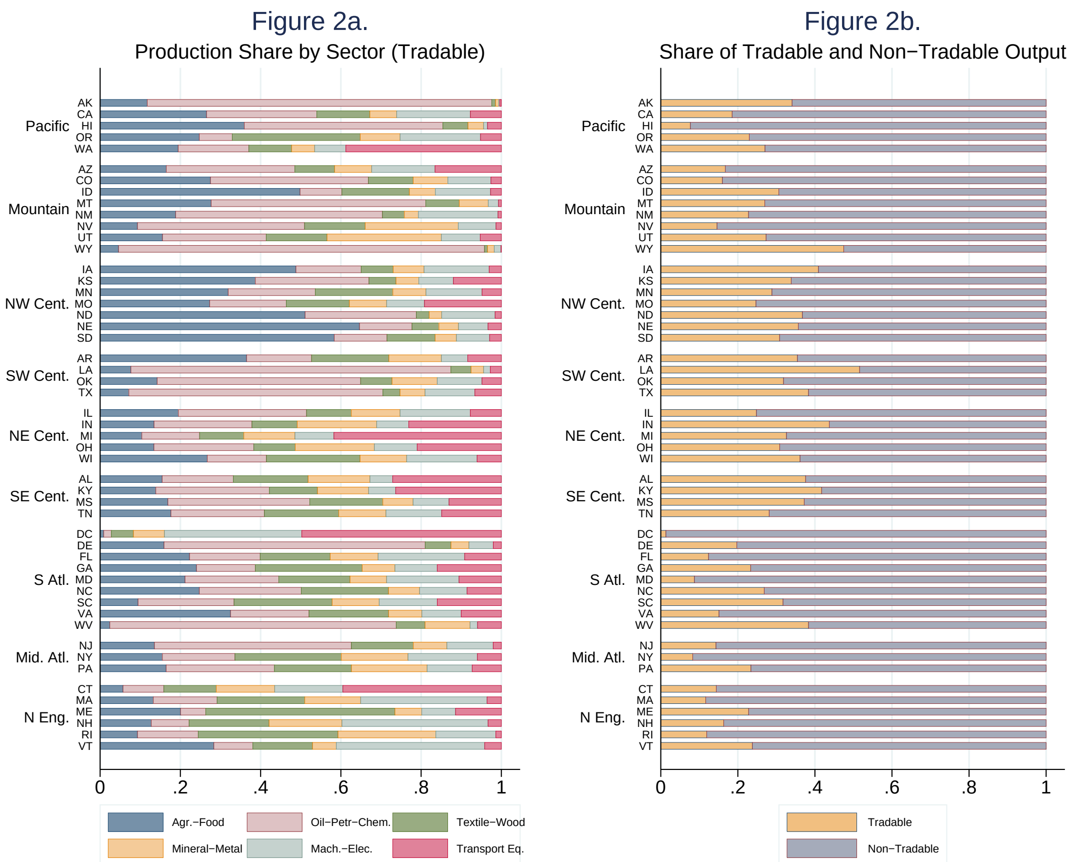
Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

However, U.S. states are slightly more specialized in their sectoral production structure than many countries and display a much faster labor adjustment process than countries. The lifetime of an economic shock is 5 to 7 years across the U.S. states, and the long-term adjustment is twice as higher in the EU, but this difference has been decreasing in the last two decades (Blanchard and Katz 1992, Decressin and Fatás 1995, Beyer and Smets 2015). The average Herfindahl index of production across U.S. states is 9.38 percent, whereas it is 7.38 percent for EU countries.[7] In addition, while U.S. states are more dependent on

[7] The Herfindahl index of production is based on a sample of 27 sectors that I use in this paper, which is described in detail in the data section. Herfindahl index is found by the squared sum of production shares of each sector. Specifically it is given by, $HI_i = \sum_{j=1}^{27} \left(y_i^j\right)^2$ where y_i^j is the share of sector j in region i's total gross output.

each other in terms of trade in goods, they do not display a much difference than the EU economy in this regard. Both U.S. states and EU countries trade about 79 percent of their traded good output with U.S. states and other EU countries respectively.

Figure 2: U.S. State Sectoral Production in 2012



Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

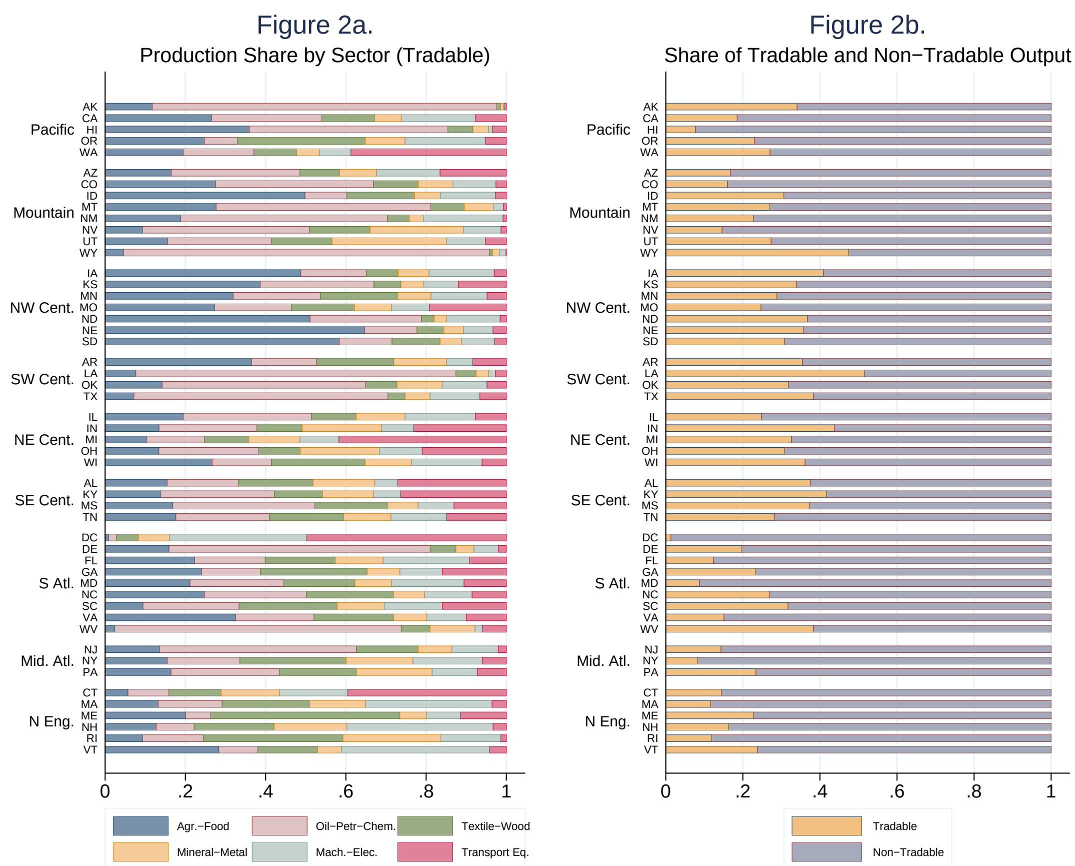
2.2 Variation in Economic Activity within the United States

The U.S. states have significant differences from each other in terms of size, income, production and trade partners, illustrated in figures (1)-(4). Figure (1) displays the distribution across states in employment, GDP per-capita, Herfindahl index of specialization and share of production in the tradable sectors.[8]

[8] For sectoral production and interstate trade flows, I mainly rely on Commodity Flow Survey and BEA sectoral GDP statistics. For sectoral imports and exports of U.S. states with foreign partners, I use U.S. Census Merchandise Trade Statistics (Origin of Movement and State of Destination Series) as well as other sources.

Throughout the paper, I focus mainly on the tradable sectors (goods, merchandise or commodities), which comprise agriculture, mining and manufacturing industries. Tradable goods are more relevant for my analysis since changes in tariffs have a direct impact on these industries, and tradable goods accounted for 70 percent of U.S. exports and 83 percent of U.S. imports in 2013 according to the U.S. Department of Commerce estimates. I show on figures (1d) and (2b) the distribution of production between tradable and non-tradable sectors across the United States. Non-tradable sectors include services sectors such as construction, finance and education. Although the overall U.S. economy produces only 23.3 percent of its output in the tradable sectors, some states such as Indiana, Louisiana and Wyoming produce more than 40 percent of their output in the tradable sectors, whereas Maryland and New York have less than 10 percent of their production in traded sectors.

Figure 3: U.S. State Sectoral Production in 2012



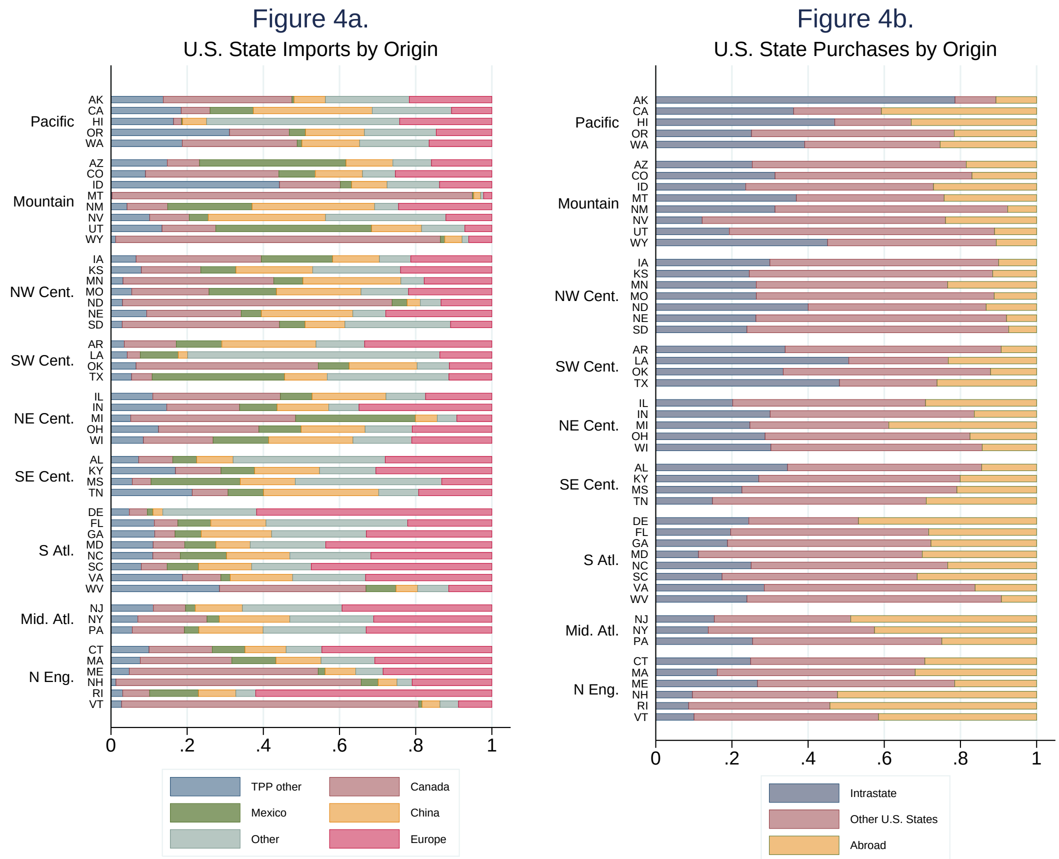
Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

I plot on figure (2a) the distribution of economic activity across main groupings within the tradable sectors. Two characteristics are worth observing. First, industrial production in some sectors such as agriculture-food manufacturing, textile and transportation equipment is clustered around geographical regions. Second, some states such as Wyoming, Alaska and Nebraska display very high degrees of specialization in a few sectors. Furthermore, U.S. states differ considerably from each other in terms of their domestic and foreign trade partners, both in terms of exports and imports (See figures 3 and 4). Geographical distance is one of the most important factor determining trade patterns, but it is not the sole one. Size and sectoral specialization of partners also have an effect on trade relationships. In general, western states have higher trade volumes with countries in the Pacific, and eastern states trade more with Europe. Yet, even though Oregon, Washington and California import a lot from Japan, so do more distant Midwestern states such as Michigan, Indiana and Ohio. The intra-industry trade and trade in intermediate goods between these locations create a trade relationship despite being further away from each other.

Figure 4: U.S. State Sales by Destination in 2012

Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

Figure 5: U.S. State Purchases by Origin in 2012



Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

2.3 Trade Exposure Measures

Researchers are constrained with data limitations when they analyze local labor markets. Interregional trade and production data are not readily available for most countries. Even in cases when the data exist, they may not cover all sectors, and the data are prone to measurement and reporting errors. I use interregional trade flows from two sources, Commodity Flow Surveys for interstate trade flows, and U.S. Import and Export Merchandise trade statistics for the sectoral trade flows between U.S. states and countries. For sectors that do not have reliable export data in these datasets such as agriculture and mining, I use production and trade data of detailed commodities to impute trade flows. I explain the description of these data sets and my method of constructing unavailable data in the data section.

Previous studies such as Autor, Dorn and Hanson (2012), Kovak (2013) and Caliendo, Dvorking and Parro (2015), have relied on imputed trade exposure measures based on

Figure 6: U.S. State Exports and Imports with Sectoral Production-weighted Trade Exposure

Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

sectoral characteristics due to unavailability of trade data at local levels. First, they find the employment share of a local labor market within a sector in the United States. Then, they distribute total U.S. exports of this sector to each destination country using the employment share of labor market. There are two problems with this approach. First, the heterogeneity due to having different trade partners cannot be explained only by the sectoral variation since geography also plays a huge role determining trade relationships due to distance and transportation costs. For instance, Washington is more likely to trade with Japan compared to a state on the East coast even if they produce similar products.

In addition, a sectoral based trade measure may fail to explain the overall trade openness of local labor markets, as it assumes identical trade openness for all sectors throughout the country. For instance, altough Wyoming and West Virginia produce similar amounts of coal in terms of total value, Wyoming exports only 1 percent of its coal abroad while West Virginia exports about 23 percent of its coal production. This could be attributable to geographical factors and transportation costs. Wyoming produces a low-quality and heavy-weight coal, which is more costly to be transported overseas, whereas West Virginia produces high-quality and lighter-weight coal. If we were to impute coal exports of these two states according to how much they produce, these two states would receive an identical treatment. Hence, not only would we incorrectly determine their export destinations, but also their overall exports and trade openness.

I display the total exports and imports of U.S. states by destination by constructing a trade exposure statistic similar to the aforementioned studies on figure (5). It turns out that this trade exposure, which is solely based on the sectoral production composition of a locality, can explain only a very small amount of the heterogeneity in trade partners. Using a trade dataset can lead to misleading predictions for the effects of a trade policy shock, e.g. effects of Trans-Pacific Partnership.

3 Model

In this section, I lay out the theoretical framework to analyze the implications of the Trans-Pacific Partnership on U.S. state real wages. First, I provide an overview of the model, then present formally the equations, and finally define its equilibrium and the solution method. I will apply a change in the tariff schedule to compute the changes in real wages of U.S. states in section 5.

3.1 Overview

I work with a multi-sector and multi-region Ricardian international trade model based on the Eaton and Kortum (2002) framework, enriched by Caliendo and Parro (2015) to include trade policy and input-output linkages. The model has sub-regions of countries as the unit of analysis. In practice, every country except for the U.S. consists of a single region, and the United States consists of 51 sub-regions: its states and District of Columbia. Sectors include both tradable and non-tradable industries. Labor, which is the only factor in production, is immobile across regions of different countries, but it is partially mobile across regions of the same country. While workers do not face any relocation costs, I assume that each region has local amenities for which workers have heterogeneous tastes. This setup, incorporated by Redding (2014) in a trade model, creates frictions for labor mobility and prevents real incomes to equalize across locations. In addition, labor is assumed to be perfectly mobile across sectors within a region.[9]

There are two types of goods, varieties and composite final goods. Varieties are produced by competitive firms in each location using labor and intermediate goods as inputs. Firms located in separate regions are different from each other in terms of production

[9] See Moretti (2011) for a spatial local labor market model with a partial labor mobility across locations. More recently, Caliendo, Dvorkin and Parro (2015) introduced a dynamic labor choice adjustment problem into the Eaton and Kortum (2002) model by including both local amenities and relocation costs of migration.

technologies and geography. Each region is endowed with a specific fundamental sectoral productivity, common to all of its firms, that determines the comparative advantage of a region. Variety producers can trade their output, but they are subject to iceberg trade costs while shipping their products across destinations.[10] Varieties are aggregated by a transformation function to form a composite final good, which can be either used as household consumption, or intermediate goods by variety producers.

Here is the notation used for the sectors and regions in the model. There are N regions (including all U.S. states and countries) indexed by i and n, and J sectors indexed by j. Bilateral variables, such as trade flows from region i to region n in sector j are represented by X_{in}^{j}. For a variable related to only one region, for instance gross output Y_i^j, the index i and j represent the region and sector respectively. There are C countries excluding the United States. When countries and states are represented separately, index $c \in C$ denote countries and $s \in S$ denote U.S. states. When referring to the U.S. economy in general, the index US is used.

Household Utility and Labor Mobility. There are L_i households in each region i. Employment of countries L_c is fixed for all $c \in C$ and $c = US$. Households work and provide labor for firms, and each of them receive labor income w_i, and tariff revenue R_i/L_i. Households can purchase final goods from all sectors for consumption purposes. I denote the sectoral consumption by C_i^j. I assume that consumption is proportional to the total income in that region, given by β_i^j, and will be held constant. Using these shares, consumers aggregate their consumption using a Cobb-Douglas function

$$C_i = \prod_{j=1}^{J} \left(C_i^j\right)^{\beta_i^j} \tag{1}$$

Households cannot move across country boundaries, but they can move to any other region within the same country without incurring any cost. In my model this special case only occurs for the United States since all other countries are formed by a single sub-region. Households receive positive utility from local amenities in each location. The amenity that household ν in region i is represented by $b_i(\nu)$. The utility of the household residing in region i is given by the combination of the local amenity and final good consumption

$$U_s(\nu) = b_i(\nu) C_i \tag{2}$$

While labor is perfectly mobile and there are no costs to migration, I incorporate frictions to labor mobility by assuming that households have heterogeneous tastes for local amenities. In particular, each household ν draws local amenity $b_i(\nu)$ from a Fréchet distribution that has location parameter of B_i for region i and shape parameter $\varepsilon > 1$. The cumulative distribution function with these parameters is given by $G_s(x) = e^{-B_i x^{-\varepsilon}}$.

Every worker decides to move to the state that gives her the highest net utility $b_s(\nu)C_s$. Using the properties of the Fréchet distribution, we can show that, in equilibrium, the

[10]Trade costs include both physical terms such as distance modeled in the form of iceberg trade costs, and policy terms such as tariffs.

share of employment in state s in total U.S. employment, L_s/L_{US}, is given by

$$\frac{L_s}{L_{US}} = \frac{B_s\left(w_s/P_s\right)^{\varepsilon}}{\sum_{s'\in S} B_{s'}\left(v_{s'}/P_{s'}\right)^{\varepsilon}} \tag{3}$$

where w_s is the nominal wage of state s and P_s is the overall price index of consumption goods given by $P_s = \prod_{j=1}^{J}\left(P_s^j\right)^{\beta_s^j}$, and w_s/P_s are real wage of state s. The variable ε determines the degree of labor mobility, and I will denote this variable as the migration elasticity with respect to real wages. If $\varepsilon \to \infty$, there will be no frictions in labor mobility, and hence real incomes will equalize[11].

Variety Producers. The production and trade side of the model borrows tools from the Eaton and Kortum (2002) model of international trade that focuses on the concept of comparative advantage.[12] There is a continuum of variety producers ω^j in each industry over the interval $[0,1]$. Each variety producer uses labor and intermediate goods to produce a variety, where the production function of the variety producer ω^j in region i and sector j is given by

$$y_i^j(\omega^j) = z_i^j(\omega^j)\left[T_i^j l_i^j(\omega^j)\right]^{\gamma_i^{0,j}} \prod_{k=1}^{J}\left[m_i^{k,j}(\omega^j)\right]^{\gamma_i^{k,j}}$$

Labor used in the production is denoted by $l_i^j(\omega^j)$. The intermediate goods used by sector j from sector k are represented by $m_i^{kj}(\omega^j)$. The term z_i^j is the idiosyncratic productivity of the firm, which is distributed with a Fréchet distribution with location parameter of 1 and shape parameter of θ^j whose distribution function given by $F^j(x) = e^{-x^{-\theta^j}}$. Larger values of the shape parameter of the distribution, θ^j, result in lower variance in firm productivity, and hence higher substitutability of goods across firms. Hence, θ^j is also interpreted as the trade elasticity of sector j in this model. In addition, each firm has a region-sector specific fundamental labor productivity denoted by T_i^j. The parameters γ_i^{0j} and γ_i^{kj} determine the weight of labor and intermediate goods in the production function.

Unit costs of firms in region i and sector j are given by

$$c_i^j = \xi_i^j\left(w_i\right)^{\gamma_i^{0j}} \prod_{k=1}^{J}\left(P_i^k\right)^{\gamma_i^{kj}} \tag{4}$$

[11]Even though real wages differ across locations due to idiosyncratic tastes in the case of $\varepsilon < \infty$, the expected utility in any state $s \in S$ will be identical and will be equal to

$$\bar{U}_{US} = \delta\left[\sum_{s=1}^{N} B_s\left(w_s/P_s\right)^{\varepsilon}\right]^{1/\varepsilon}$$

where δ is a constant that is equal to $\Gamma\left(\frac{\varepsilon-1}{\varepsilon}\right)$ and $\Gamma(\cdot)$ is the Gamma function.

[12]See Dekle et al. (2008), Levchenko and Zhang (2012) and Caliendo and Parro (2015) for a multi-sector version of the Eaton and Kortum (2002) model for trade policy analysis.

where w_i is the wage in region i and P_i^k is the price index of sector k products in region i.[13] This setup assumes that labor is perfectly mobile across sectors of a particular region since there is only one regional wage, which applies to all sectors. In addition, I assume that intermediate goods and final goods are perfectly substitutable for simplicity, and hence the price index for both type of goods originating from the same region and sector are identical.

Variety producers from region i and sector j incur iceberg trade costs δ_{in}^j to ship their goods to region n. Iceberg trade costs include physical terms such as distance, language barriers, historical and specific relationship between locations and industries. The iceberg trade costs represent the fraction of shipment lost during the journey. In addition, the variety producer might be subjected to pay an ad-valorem tariff τ_{in}^j to the destination region n.[14]

I assume that the lowest-cost supplier beats the market and can deliver its goods. Therefore, the price of variety ω^j in region i will be given by

$$p_i^j\left(\omega^j\right) = \min_n \left\{ \frac{c_n^j \delta_{ni}^j \left(1 + \tau_{ni}^j\right)}{z_n^j\left(\omega^j\right)\left(T_n^j\right)^{\gamma_n^{0j}}} \right\}$$

Composite Final Good Aggregator. A final good aggregator in sector j of region i transforms the varieties $\omega^j \in [0,1]$ into an aggregate sectoral final good Q_i^j without a profit seeking behavior. The production function of the final good aggregator is CES (Constant Elasticity of Substitution) with sectoral elasticity σ^j. Total output of final goods in region i and sector j is given by

$$Q_i^j = \left(\int_{\omega \in \Omega^j} q_i^j(\omega^j)^{\frac{\sigma^j - 1}{\sigma^j}} dH(\omega) \right)^{\frac{\sigma^j}{\sigma^j - 1}}$$

where $q_i^j(\omega^j)$ is the demand for variety ω^j of sector j in region i given by

$$q_i^j(\omega^j) = \frac{p_i^j(\omega^j)^{-\sigma^j}}{\left(P_i^j\right)^{1-\sigma^j}} X_i^j$$

Price index of sector j good in region i is expressed as

$$P_i^j = \left[\int_0^1 p_i^j\left(\omega^j\right)^{1-\sigma^j} d\omega^j \right]^{1/(1-\sigma^j)} \tag{5}$$

[13] ξ_i^j is given by $(\gamma_i^{0j})^{\gamma_i^{0j}} \prod_{k=1}^J (\gamma_i^{kj})^{\gamma_i^{kj}}$

[14] When region n receives sector j good X_{in}^j from i, it collects $[\tau_{in}^j/(1+\tau_{in}^j)]X_{in}^j$ as tariff revenue, and region i receives $[1/(1+\tau_{in}^j)]X_{in}^j$ as payment.

The composite final good can be used either by households as a consumption good C_i^j, or by variety producers as intermediate goods $M_i^j = \int_{\omega^k} m_i^{jk}(\omega^k) d(\omega^k)$. The composite final good is perfectly substitutable across these two product categories. Total quantity consumed of the composite final good is represented by $Q_i^j = M_i^j + C_i^j$ and the total output in value (expenditures) are represented by $X_i^j = P_i^j M_i^j + P_i^j C_i^j$.

3.2 Equilibrium

In this section I describe the equilibrium expressions for trade flows, price index, total expenditures, trade balance and labor supply.

Trade Flows and Price Index. The share of trade flows from n to i in sector j in total purchases of region i in sector j is given for the traded sectors by

$$\pi_{ni}^j = \frac{X_{ni}^j}{\sum_{m=1}^{N} X_{mi}^j} = \frac{\left(\Phi_{ni}^j\right)^{-\theta^j}}{\sum_{m=1}^{N} \left(\Phi_{mi}^j\right)^{-\theta^j}} \tag{6}$$

where Φ_{ni}^j is the effective competitiveness of region n in sector j with respect to region i

$$\Phi_{ni}^j = \frac{c_n^j d_{ni}^j \left(1 + \tau_{ni}^j\right)}{\left(T_n^j\right)^{\gamma_n^{0,j}}} \tag{7}$$

As for the non-tradable sectors, the trade shares are given by $\pi_{ii}^j = 1$ and $\pi_{ni}^j = 0$ for all $n \neq i$. I do not model them differently and assume that there are infinite iceberg trade costs between different regions in this sector, $\delta_{ii}^j = 1$ and $\delta_{ni}^j = \infty$ for $n \neq i$.

The price index in region i and sector j in equilibrium reduces to

$$P_i^j = \Gamma^j \left[\sum_{n=1}^{N} \left(\Phi_{ni}^j\right)^{-\theta^j} \right]^{-\frac{1}{\theta^j}} \tag{8}$$

where Γ^j is a constant parameter that is given by a gamma function $\Gamma^j = \Gamma\left(1 + \frac{1-\sigma^j}{\theta^j}\right)^{1/(1-\sigma^j)}$. In order for the price index to be finite, the parameters need to satisfy $\theta^j > \sigma^j - 1$.

Total Expenditures and Trade Balance. Total expenditures, X_i^j is the total value spent on intermediate goods used by variety producers and consumption goods by households.

$$X_i^j = \sum_{k=1}^{J} \gamma_i^{j,k} Y_i^k + \beta_i^j I_i \tag{9}$$

where Y_i^j is the gross output of sector j in region i and given by the sum of total sales to all destinations net of tariff payment

$$Y_i^j = \sum_{n=1}^{N} \frac{X_{in}^j}{1+\tau_{in}^j} = \sum_{n=1}^{N} \frac{\pi_{in}^j X_n^j}{1+\tau_{in}^j} \tag{10}$$

Note that $\pi_{in}^j X_n^j = X_{in}^j$ is another way to denote sales from i to n and will be a very useful identity for solving the equilibrium. Disposable income, I_i is the sum of total value added $w_i L_i$, tariff revenue R_i and total trade imbalance D_i in region i

$$I_i = w_i L_i + R_i + D_i \tag{11}$$

Total trade imbalances are the sum of sectoral deficits given by

$$D_i = \sum_{j=1}^{J} D_i^j = \sum_{j=1}^{J} \left(X_i^j - Y_i^j - R_i^j \right) \tag{12}$$

Total tariff revenue is the sum of tariff revenues of region i from its imports[15].

$$R_i = \sum_{j=1}^{J} R_i^j = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\tau_{ni}^j}{1+\tau_{ni}^j} \pi_{ni}^j X_i^j \tag{13}$$

It is implied from these equations that labor market clearing condition will determine total GDP, $w_i L_i$ in each region, which is the sum of sectoral value added ($\gamma_i^{0j} Y_i^j$) across all sectors $j = 1, ..., J$

$$w_i L_i = \sum_{j=1}^{J} \gamma_i^{0,j} Y_i^j = \sum_{j=1}^{J} \gamma_i^{0,j} \sum_{n=1}^{N} \frac{\pi_{in}^j X_n^j}{1+\tau_{in}^j} \tag{14}$$

Definition 1. *Given parameters $\gamma_i^{0j}, \gamma_i^{kj}$, β_i^j, θ^j, σ^j, ε, iceberg trade costs δ_{in}^j, region-sector specific productivity T_i^j, average amenities B_i, ad-valorem tariffs τ_{in}^j, and country employment L_c and L_{US} for $i, n = 1, ..., N$, $c \in C$, $j = 1, ..., J$ an equilibrium is a wage vector $\{w_i\}_{i=1}^N$, sectoral prices $\{P_i^j\}_{i=1,j=1}^{N,J}$ and U.S. state employment vector $\{L_s\}_{s \in S}$ that solves spatial labor market equilibrium (3), unit cost function (4), trade share (6), price index (8), total expenditure equation (9), trade balance (12) and labor market clearing equation (14).*

Under certain conditions this version of the Eaton and Kortum (2002) model with multiple regions and sectors, input-output linkages, and tariffs has a unique equilibrium, provided by Allen, Arkolakis and Li (2015). However, the conditions under which a

[15] I assume that the tariff revenue of the U.S. states is determined individually by their own imports, and I do not allow the states to share their tariff revenue in a redistributive manner, e.g. evenly. Since tariff revenue is only a very small part of total income for the United States economy, this method of calculating the tariff revenue does not create a significant difference than evenly sharing the total U.S. tariff revenue.

unique equilibrium exists are greatly restrictive (such as symmetric tariffs) and do not apply to the specifications of my model. Nevertheless, the possibility of multiple equilibria does not pose an issue for this analysis. I will start at an initial steady state equilibrium where wages and trade shares are computed using data on trade flows and other model parameters. Then, following a change in tariff rates, I will find the percent deviations of the model variables from their initial steady state values. This will be a new equilibrium under the new tariff structure without changing any other fundamental parameter of the model. Even if multiple equilibria exist, the new equilibrium under the new tariff structure will be a local deviation around the initial steady state, and will not belong to a different set of equilibria.

3.3 Counterfactual Equilibrium

The main goal of the model is to find the effects of changes in tariffs from τ to τ' on wages w_i and prices P_i. Instead of solving the model in levels and estimating the fundamental values such as as distances δ and productivity terms T, which are hard to come by, I follow the procedure implemented by Dekle, Eaton and Kortum (2008). They reformulate the model and express the variables in changes, and compute counterfactual equilibrium values for the changes in these variables. Hence, the initial value of most parameters such as distances and fundamental productivity parameters would drop from the analysis.

I denote the initial value of a variable at the steady state as x, and its final value as x'. Then, I work with the counterfactual equilibrium analogue of the model equations in terms of changes for the model variables, denoted by $\widehat{x} = x'/x$. The main policy change is moving to new set of tariffs τ' from initial tariffs τ. Following this change, I compute changes in wages, $\widehat{w}_i$ and prices $\widehat{P}_i$.

Spatial Equilibrium. The total labor supply of countries are constant, i.e. $\widehat{L}_c = 1$ for all $c \in C$, including the aggregate employment in the United States, $\widehat{L}_{US} = 1$. However, the emplyoment levels of U.S. states can change in a new equilibrium. The change in the labor supply of each state $s \in S$ is given by

$$\widehat{L}_s = \frac{\left(\widehat{w}_s/\widehat{P}_s\right)^{\varepsilon}}{\sum\limits_{s' \in S} \frac{L_{s'}}{L_{US}} \left(\widehat{w}_{s'}/\widehat{P}_{s'}\right)^{\varepsilon}} \tag{15}$$

where $\widehat{w}_s/\widehat{P}_s$ is the change in real wage of state s. The change in the overall consumption price index is given by

$$\widehat{P}_s = \prod_{j=1}^{J} \left(\widehat{P}_s^j\right)^{\beta_s^j} \tag{16}$$

Unit cost, Price Index and Trade Share. In any equilibrium, changes in sectoral unit cost $\widehat{c}_i^j$, sectoral price indices $\widehat{P}_i^j$ and trade shares $\widehat{\pi}_{in}^j$ must satisfy the following equations in terms of changes for $i,n=1,...,N$ and $j=1,...,J$

$$\widehat{c}_i^j = \widehat{w}_i^{\gamma_i^{0,j}} \prod_{k=1}^{J} \left(\widehat{P}_i^j\right)^{\gamma_i^{k,j}} \tag{17}$$

$$\widehat{P}_i^j = \left[\sum_{n=1}^{N} \pi_{ni}^j \left(\widehat{c}_n^j \widehat{(1+\tau_{ni}^j)}\right)^{-\theta^j}\right]^{-1/\theta^j} \tag{18}$$

$$\widehat{\pi}_{in}^j = \left[\frac{\widehat{c}_i^j \widehat{\left(1+\tau_{in}^j\right)}}{\widehat{P}_n^j}\right]^{-\theta^j} \tag{19}$$

Total Expenditures. The new expenditure level, $(X_i^j)'$ is the analog of equation (9) with using the new levels of variables for $i=1,...,N$ and $j=1,...,J$

$$\left(X_i^j\right)' = \sum_{k=1}^{J} \gamma_i^{j,k} \sum_{n=1}^{N} \frac{\widehat{\pi}_{in}^j \pi_{in}^j \left(X_n^j\right)'}{\left(1+\tau_{in}^j\right)'} + \beta_i^j \left(\widehat{w}_i w_i L_i' + R_i' + D_i\right) \tag{20}$$

where the new tariff revenue level is given by

$$R_i' = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\left(\tau_{ni}^j\right)'}{\left(1+\tau_{ni}^j\right)'} \left(X_{ni}^j\right)' \tag{21}$$

Trade Imbalances and Labor Market Equilibrium. In any equilibrium, the final trade imbalance equation must hold and wages must be given by the labor market clearing condition, for all $i=1,...,N$

$$\sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\left(X_{ni}^j\right)'}{\left(1+\tau_{ni}^j\right)'} - D_i = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\left(X_{in}^j\right)'}{\left(1+\tau_{in}^j\right)'} \tag{22}$$

$$w_i' L_i' = \sum_{j=1}^{J} \gamma_i^{0,j} \left(Y_i^j\right)' = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\widehat{\pi}_{in}^j \pi_{in} \left(X_n^j\right)'}{\left(1+\tau_{in}^j\right)'} \tag{23}$$

3.4 Solution

The solution of system will be found through a simple reiterative process. Most of the equations are linear, and the only endogenous variable that solves the system is the changes in wage vector $\{\widehat{w}\}_{i=1}^{N}$ under a new tariff schedule τ'. I choose the total world GDP as the numeraire in this model and do not change the value of total world GDP. In other words, I start with a given value for world GDP, $w_W L_W$, which must be equal to $w'_W LW$ under the new equilibrium. Equivalently, $\widehat{w}_W = 1$ and $\sum_{i=1}^{N} \frac{L_i}{L_W} \widehat{w}_i = 1$.

I assume that trade imbalances of each region will not be changed in the new equilibrium, $D'_i = D_i$ for all regions i. However, the amount of trade imbalance of a region can greatly disturb the real income in the case of huge surpluses or huge deficits. Hence, if we were to compare welfare predictions using real-incomes, we would observe a considerable heterogeneity due to just having a variation in trade imbalances. In order to circumvent this problem, I focus on the changes on real wages rather than real incomes, and do not pay attention to the role of trade imbalances. Here is the summary of the solution method. Refer to the appendix for a more detailed description.

1. Guess wage vector $\widehat{\mathbf{w}}$ with the restriction $\sum_{i=1}^{N} \frac{L_i}{L_W} \widehat{w}_i = 1$.
2. Find the change in unit costs $\widehat{\mathbf{c}}$ and prices $\widehat{\mathbf{P}}$ using equations (17) and (18).
3. Find $\widehat{\pi}$ using equation (19).
4. Using $\widehat{\mathbf{w}}$ and $\widehat{\mathbf{P}}$, find $\widehat{L_s}$ for each $s \in S$ from equation (15). For new tariff revenue, use $(R_i)'$ from existing X_n^j, and new tariff $\left(1 + \tau_{in}^j\right)'$ and new trade share $\left(\pi_{ni}^j\right)'$.
5. Using L'_s solve for $(X_i^j)'$ from equation (20).
6. Check if new deficit vector implied by $(X_n^j)'$, which is denoted by $\mathbf{D}'$ is equal to original deficit vector $\mathbf{D}$. If they are equal, the new $w'_i = \widehat{w}_i w_i$ for all $i = 1, ..., N$.
7. If the deficit vector does not converge, update the guess of $\widehat{\mathbf{w}}$ locally and go to step 1.

4 Data Description and Calibration

In this section I describe briefly the region and sector samples, and the datasets I have used to quantify the parameters and variables of the model. I work with multiple of datasets: production, input-output, trade, tariff and employment data. These datasets are based on various sources and sectoral classifications, a set of countries, and U.S. states. Parameters of the model are calibrated using data and secondary sources. The variables and parameters relevant to the paper are summarized on table (1). See the data appendix section for a more detailed explanation.

Table 1: List of Variables and Parameters

Symbol	*Description*	*Source*
$X^j_{cc'}$	Country-Country trade	OECD-Bilateral Trade - ISIC Rev.3
X^j_{cc}	Domestic sales	IO Tables and Gross-Output Statistics
$X^j_{ss'}$	Interstate trade	Commodity Flow Survey
X^j_{ss}	Domestic sales of states	CFS, BEA Reg. Accounts, USDA, EIA
X^j_{sc}-X^j_{cs}	State-Country trade	USA Trade, USDA Cash Receipts, EIA
$\tau^j_{cc'}$	Ad-valorem tariff	UNCTAD-TRAINS
γ_i^{0j}	VA share in production	IO Tables
γ_i^{kj}	Int. good share	IO Tables
β_i^j	Sectoral consumption share	Derived using model parameters, data
$\theta^j = 4.14$	Trade elasticity	Simonovska and Waugh (2014) and others
$\varepsilon = 1.3$	Income elasticity of migration	Serrato and Zidar (2014)
L_i	Employment by region	World Bank and BEA Reg. Accounts

4.1 Region and Sector Sample

There are 106 regions in the sample. First 55 regions are countries besides the United States. These countries are represented with a single region, and I do not break them down to smaller sub-national units. The remaining 51 regions are all U.S. states and District of Columbia. The list of countries in the sample with certain summary statistics is provided on table (2). Kuwait and Saudi Arabia are grouped together to form “Gulf Countries” as one region in the sample. The region “Rest of the World”, encompasses all other countries, which do not have consistent production or trade data available for my analysis. “Rest of the World” region represents 8.85 percent of world GDP. Country and U.S. state data are based on different sectoral classifications. The country-level data sets utilize the 2-digit ISIC Rev. 3 classification, and the U.S. state data are based on the 3-digit NAICS-2012 sectoral classification. I concord these two sectoral classifications onto a sample with 27 sectors displayed in table (3). Sectors 1-15 are tradable, and sectors 16-27 are non-tradable.

4.2 Country Data

I use input-output tables, national accounts, bilateral trade and tariff data for countries. I use the national input-output tables to obtain information on the share of value added and intermediate good usage in total production, which are denoted by γ_i^{0j} and γ_i^{kj} respectively.[16] I use total employment data from national accounts of these countries.

[16]National input-output tables for 40 countries are provided by WIOD Input Output Tables in 2011 (Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Czech Republic, Denmark, Estonia,

Table 2: Country Sample and Descriptive Statistics

Country	*GDP %*	*Exports %*	*Imports %*	*Country*	*GDP %*	*Exports %*	*Imports %*
United States	21.90	9.11	12.47	India	2.64	1.78	2.46
Australia	2.03	1.36	1.36	Indonesia	1.25	1.18	1.18
Brunei	0.03	0.08	0.03	Ireland	0.30	0.70	0.38
Canada	2.42	2.61	2.61	Israel	0.38	0.36	0.37
Chile	0.38	0.47	0.44	Italy	2.93	3.01	2.70
Japan	8.66	4.73	4.31	Korea	1.50	3.42	2.85
Malaysia	0.42	1.38	1.31	Latvia	0.04	0.07	0.14
Mexico	1.69	2.18	2.06	Lithuania	0.06	0.17	0.15
New Zealand	0.24	0.23	0.19	Luxembourg	0.07	0.07	0.15
Peru	0.26	0.27	0.24	Malta	0.01	0.03	0.10
Singapore	0.42	2.26	1.87	Netherlands	1.14	3.00	3.64
Vietnam	0.21	0.71	0.74	Norway	0.75	0.93	0.50
Argentina	0.84	0.49	0.39	Philippines	0.32	0.31	0.56
Austria	0.56	0.91	0.92	Poland	0.67	1.07	1.19
Belgium	0.74	2.62	2.19	Portugal	0.30	0.34	0.41
Brazil	3.03	1.48	1.45	Romania	0.26	0.34	0.39
Bulgaria	0.06	0.15	0.18	Russia	2.38	2.77	2.00
China	10.81	12.67	7.74	Slovakia	0.13	0.48	0.41
Cyprus	0.03	0.01	0.08	Slovenia	0.07	0.15	0.17
Czech Republic	0.28	0.92	0.76	South Africa	0.63	0.46	0.60
Denmark	0.42	0.57	0.53	Spain	2.02	1.62	1.85
Estonia	0.03	0.09	0.13	Sweden	0.71	0.97	0.86
Finland	0.33	0.41	0.45	Switzerland	1.01	1.31	1.41
France	3.71	3.30	3.86	Taiwan	0.64	1.81	1.76
Germany	4.90	8.13	6.27	Thailand	0.53	1.42	1.34
Greece	0.40	0.19	0.33	Turkey	1.01	0.93	1.10
Gulf Countries	1.27	0.66	1.03	United Kingdom	3.24	2.78	3.78
Hungary	0.18	0.61	0.51	Rest of the World	8.75	9.90	13.08

The GDP, export and import % report shares of statistics of countries in total world levels.
Source: OECD Bilateral Trade Database for Exports and Imports, various national input-output tables for export shares, value added shares and production data. The data is from year 2012.

Table 3: Sector Code Concordance

Sector Code	*Sector Name*	*ISIC3*	*NAICS*
1	Agriculture, fishing and forestry	1, 2, 5	11*
2	Oil and gas	11	211*
3	Mining exc. oil and gas	10, 12, 13, 14	212
4	Food, beverages, tobacco	15, 16	311, 312
5	Textile	17, 18, 19	313, 314, 315, 316
6	Wood, paper, printing	20, 21, 22	321, 322, 323, 511
7	Petroleum and coal industries	23	324
8	Chemical industries	24	325
9	Plastic and rubber	25	326
10	Nonmetallic mineral	26	327
11	Primary and fabricated metal	27, 28	331, 332
12	Machinery	29	333
13	Computer, electronic, electrical	30, 31, 32, 33	334, 335
14	Transportation equipment	34, 35	336
15	Furniture, other manufacturing	36, 37	337, 339
16	Utilities	40, 41	22
17	Construction	45	23
18	Wholesale and retail trade	50, 51, 52	42, 44, 45
19	Accomodation and food	55	72
20	Transport services	60, 61, 62, 63	48, 49
21	Information, telecommunications **	64	491, 492, 515, 517
22	Finance and insurance	65, 66, 67	52
23	Real estate	70	531
24	Public administration	75	92
25	Education	80	61
26	Health care	85	62
27	Other services	71, 72, 73, 74, 90, 91, 92, 93, 95, 99	512, 516, 518, 519, 532, 533, 54, 55, 56, 71, 81

Sectors 1-15 are tradable and 16-27 are non-tradable. ISIC Rev. 3 classification is used in national input-output tables, OECD Bilateral Trade database and TRAINS tariff data. NAICS classification is used in Commodity Flow Survey, U.S. State Export and Import Statistics, and BEA Regional Income Statistics.

* Not Available in the Commodity Flow Survey, and interstate trade flows are imputed using gross production data and interstate trade flow data from other sectors.

** Information services are not specified in ISIC3, but it is a mixture of ISIC3 22, 64 and 92. NAICS 492 corresponds to ISIC3 64, however 492 and 487-488 are integrated in the U.S. census and Commodity Flow Survey statistics. As a result, I placed all subgroups of NAICS 49 in the transportation sector.

I use export values for tradable ISIC rev. 3 sectors between countries in the sample including the United States in 2012 from the OECD Bilateral Trade Database.[17] Domestic sales in each sector, X_{ii}^{j} are not available in bilateral trade data sets. However, input-output tables and national account statistics provide information on gross-output by sector. After finding gross-output by sector, domestic sales X_{ii}^{j} is calculated by taking the difference between gross-output and total exports to all destinations.

I use UNCTAD-TRAINS database for ad-valorem tariffs of the tradable sectors, which are denoted as τ_{in}^{j}. This database reports these tariffs according to very detailed sectoral classifications. I use the weighted-average of tariff rates at the 2 digit ISIC3 classification. The reported tariffs are "effectively applied rates", which correspond to the tariff rates observed from tariff revenue and import volumes. One issue that arises in this approach is that some countries that have preferential trade agreements with each other might report tariff rates higher than the preferential rates, which are mostly 0 percent. The reason to this discrepancy is that some products do not qualify for preferential treatment and have to pay Most Favored Nation (MFN) tariff rates due to rules of origin regulations.

4.3 State Data

Acquiring production and trade data for U.S. states is more complicated than for countries, since trade data are usually collected at the ports, and production data and input-output tables at the regional levels do not exist at all for some sectors. Since U.S. state do not have input-output tables, I use the national U.S. input output tables to find the values for share of value added γ_i^{0j} and intermediate good usage γ_i^{kj} in total output.

I obtain foreign export and import flows of states from the U.S. Import and Export Merchandise Trade Statistics in 2012.[18] For interstate trade flows by sector, I use the U.S. Commodity Flow Survey in 2012. In addition, I use BEA Regional Economic Accounts for state employment, sectoral GDP, and production and trade statistics from other sources for certain sectors that do not have reliable data from these sources.

Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Taiwan, Turkey, United Kingdom, United States and Rest of the World, see Timmer et al. 2015). I use the Asian Input Output Tables in 2005 (AIOT) for Malaysia, Philippines, Singapore and Thailand. I use OECD-Input Output Database for Argentina (1997), Chile (2003), Israel (2004), New Zealand (2002/3), Norway (2005), South Africa (2005), Switzerland (2001) and Vietnam (2000). I use national input-output tables for Kuwait in 2010 for Kuwait and Saudi Arabia, in addition to their national income accounts. I use Peruvian (2007) and Brunei (2005) input output tables and national account statistics.

[17] The OECD Bilateral Trade Database does not report exports of some of the countries which are grouped in the "Rest of the World" region. However, imports of countries in the sample from of all other countries in the world are reported. For the "Rest of the world" region, I used imports of each country in the OECD database from the "Rest of the world" countries and denoted the sum of imports from them as exports of "Rest of the world".

[18] The U.S. Import and Export Merchandise Trade Statistics are prepared by the Economic Indicators Division of U.S. Census Bureau. The data set can be downloaded on USA Trade Online website: http://usatradeonline.census.gov.

State Exports and Imports: The U.S. Import and Export Merchandise Trade Statistics report export and import flows of U.S. states to all countries in the world according to NAICS 3-digit and 4-digit sectoral classification. The import data are referred to as State of Destination series, which specifies the ultimate destination of an import shipment, but not the port of acceptance.

The export data, also referred to as Origin of Movement (OM) series, specifies the state where a shipment has begun its journey. For shipments that are consolidated at warehouses this dataset may not represent the true origin of production for some sectors and states. However, as Cassey (2009) points out, the OM series provides a reasonable substitute for the origin of production for manufacturing sectors. In addition, the export values for the mining sector (coal, metal ore and other minerals) is mostly consistent with production except for some cases.

However, agricultural exports, which are usually shipped through intermediaries and consolidated at warehouses report much higher export values for port states and low values for inward states. For instance, Louisiana exports more than four times of what it produces in the agricultural sector according to this data set.[19] Hence, the OM series cannot be used as a reliable substitute for agricultural exports of U.S. states.

Instead of using the Origin of Movement series for the agricultural sector, I construct a new series of agricultural exports by matching detailed commodity based production data in each state with U.S. exports of agricultural commodities by destination. I retrieve production in each state by agricultural commodities from the U.S. Department of Agriculture "State-Level Farm Income and Wealth Statistics: Annual Cash Receipts by Commodity, U.S. and States" database for the year 2012. This database reports farm cash-receipts for many agricultural commodities, which I use to calculate production shares of each commodity within the U.S. Then I convert these commodities to Harmonized System (HS) classifications of exports and distribute the U.S. exports of each commodity by destination to the states depending on their share of each commodity's production. Finally, I concord the HS classification to NAICS 4-digit codes and aggregate trade flow values over these sectors. Cash receipts of states on fishing and forestry sub-sectors are not provided by USDA. For these sub-sectors, I use the Origin of Export series since their export values are not large and do not bias the general results. Once I have exports of each state by destination and NAICS 4-digit sectors within the agricultural sectors, I aggregate them to NAICS 11 heading, which groups all agriculture, farming, forestry and fishing sectors together.

Interstate Trade Flows: The Commodity Flow Survey (CFS) reports shipments between U.S. states by establishments in NAICS sectors except for agriculture (NAICS 11) and oil-gas (NAICS 211) sectors. Only the shipments that have a domestic purpose are counted and shipments designated for foreign deliveries are not classified in the trade flows.[20] I

[19] USDA Farm Income and Wealth statistics indicate that Louisiana's gross output in the agricultural sector was \$4.32 billion in 2012 whereas it exported \$19.58 billion worth of agricultural goods in 2012 according to the Origin of Movement export series.

[20] The CFS has a question indicating whether a shipment is destined for exports to Canada, Mexico and other countries and the value of exports amounts to 7.9% of the value of all shipments. I dropped these

scaled the total domestic flows in each sector to match the total U.S. domestic shipments.[21]

For agriculture and oil-gas sectors, first I find the gross-output in each state using data from USDA and Economic Census[22]. Subsequently, I subtract exports from gross-output of each state and redistribute the remainder domestic sales as trade flows to each other state using the shipments of agricultural commodities, according to the Standard Classification of Transported Commodities (SCTG) from the Commodity Flow Survey in 2012. SCTG refers to the type of commodity transported during the shipment, but not the shipping establishment. Even though this does not perfectly identify the agriculture since the shipping establishment might be in another sector, I use the commodities transported as a proxy for possible trade relationship between states in the agricultural sector.

For crude oil and natural gas gross-output, I find the gross-output of this sector in each state and distribute the trade flows using an imputation method. For the oil sector, I use crude-oil shipments between 6 PADD regions, and when I cannot disaggregate the trade flows between states, I use trade flows from other sectors to distribute trade flows among states that are in the same PADD region. For natural gas shipments, I use state-to-state pipeline capacity values to impute trade flows.

4.4 Other Parameters

Sectoral consumption share: I find the shares of each sector in final household consumption, β_i^j are from equation (9). I know the value of each variable in this equation using trade data and production function parameters, and solve for β_i^j. For U.S. states, I solve for the total expenditure equation for the U.S. economy, and find a unique β_{US}^j for each sector j and use this share for all states in order to have consistent comparisons in terms of welfare. However this formulation leads to one complication. Since I do not explain the possible trade in services due to data limitations, the states that produce too much services would not consume their entire output and there will be a gap between sales Y_i^j and expenditures X_i^j. Similarly, for states that do not produce enough services but consume identical to that of the aggregate U.S. economy, they will have more purchases than consumption.

To deal with this problem, I reformulate the total expenditures equation by adding an excess deficit term E_s^j for each state $s \in S$ and sector $j = 1, ..., J$ to satisfy the equality

$$X_s^j = \sum_{k=1}^{J} \gamma_s^{jk} Y_s^k + \beta_{US}^j (w_s L_s + R_s + D_s) + E_s^j \tag{24}$$

export related shipments from the sample.

[21]See Helliwell (1997, 1998), Wei (1996), and Anderson and van Wincoop (2003) for discussions of handling inconsistencies of Commodity Flow Survey with total domestic U.S. shipments. A detailed explanation on forming the consistency across different data sets is explained in the data appendix.

[22]USDA Farm Income and Wealth statistics reports gross-output of agriculture in each state in 2012.

This excess deficit term E_s^j will reflect the possible trade in services from other states, and I will hold this term E_s^j unchanged during the counterfactual exercises. Alternatively, I can

Trade elasticity (θ^j): The shape parameter of the Fréchet distribution for idiosyncratic firm productivity, θ^j, is equivalent to the trade elasticity in this model. The estimation of trade elasticity has received a great attention in the trade literature, however there are still disagreements on the correct values of trade elasticity. Since the choice of trade elasticity can alter the results, I will consider various choices of estimates from the literature for the Eaton and Kortum (2002) model. For the baseline case I use Simonovska and Waugh's (2014) estimate of $\theta^j = 4.14$ for all tradable sectors $j = 1, \ldots, 15$. However in alternative specifications I will use Eaton and Kortum (2002)'s estimate of $\theta^j = 8.28$ and Caliendo and Parro's (2015) sectoral estimates ranging from [1.15-64.85], which have an aggregate value of 4.45.

Migration elasticity (ε): The shape parameter of the Fréchet distribution can be interpreted as the migration elasticity with respect to real income. Suárez-Serrato and Zidar (2014) estimated this number as 1.34 using a structural model by regressing changes in state employment on changes in real wages, and using local tax policy changes as an instrument. They have used data at decadal frequencies and their estimate could be interpreted as a short-medium run elasticity parameter. In alternative specifications, I will present the sensitivity of the results to higher values of ε, and hence higher degree of labor mobility.

While presenting the simulation results, I will show the sensitivity of the welfare differentials to the choice of the migration elasticity. It turns out that we will need huge migration elasticities to completely get rid of welfare differentials and reasonable degrees of labor mobility will always lead to substantial welfare differentials, because a decrease the negative effect of inward migration on nominal wages is mostly offset by a lower price index due to having lower nominal wages. For a more detailed discussion, see section 5.

4.5 Tariff Data and TPP

Trans-Pacific Partnership is a trade agreement that will regulate trade between Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, United States and Vietnam. The partner countries of TPP have agreed on this treaty on October 5, 2015, and their parliaments need to ratify the agreement. The draft of the agreement has been recently published on November 5, 2015, and covers trade in goods and services, intellectual property, state-investor relationships, and environmental and labor laws. In this paper, I focus only the tariff reduction aspect of this agreement.

To obtain initial tariff rates between all countries in my sample, I use the UNCTAD-TRAINS database to obtain ad-valorem tariff rates in the tradable sectors $j = 1, \ldots, 15$.[23] I denote tariff rates from country i to j in sector j as τ_{in}^j. I use the "effectively applied rates"

[23] See http://wits.worldbank.org for the TRAINS tariff database.

according to the 2 digit ISIC3 classification. For sectors that are combination of multiple ISIC3 2-digit sectors, I take a trade weighted average of tariff rates. I found the ad-valorem tariff for the "Rest of the World" region by taking a trade weighted average of ad-valorem tariff rates of all countries designated in this region. If a tariff data of a sector between two countries are missing, I used the MFN tariff rate for this country. U.S. states use a common U.S. rate with all other countries.

Initial tariff rates between TPP partners vary considerably (See table 4). Some of these countries are already engaged in free-trade agreements with each other, and the tariffs for most products are already at zero percent levels. However, the agriculture-food and textile-apparel sectors are the most protected, since most free-trade agreements do not cover these industries. Although the United States have low import tariffs for most goods, it still preserves relatively high tariff rates for agriculture, food and textile sectors. The variation in terms of sectoral production and trade partners across U.S. states will play a role while determining the exposures of its states to tariffs changes with particular sectors and countries. I provide on tables (5) and (6) the sectoral breakdown of U.S. tariffs on its imports and the tariffs that its trade partners impose on U.S. exports.

5 Welfare Effects of TPP

In this section, I show the effects of tariff reductions due to the TPP agreement on real wages of U.S. states. I do not consider non-tariff aspects of this agreement such as regulations on non-tariff barriers, intellectual property or environmental law. The benchmark case that I consider is removing tariffs between TPP partners to zero percent in all sectors. The variable of interest is real wages of U.S. states. First, I show the effects of TPP under the baseline scenario on U.S. real wages. Then, I compare the results that I obtain under two data specifications: Data1 (using U.S. state exports and imports by sector), which is the baseline specification, and Data2 (sectoral employment based trade exposure). Subsequently, I show the sensitivity of the results to different trade elasticity (θ^j) and migration elasticity (ε) estimates.

In the second part of this section, I show how U.S. real wages would change under two alternative tariff reduction scenarios. The first scenario that I consider is keeping the TPP sector tariffs in agricultural and food sectors at their initial levels, and removing only tariffs in other sectors to zero percent. The second alternative scenario is adding China to the agreement (and removing tariffs in all sectors to zero).

5.1 Baseline TPP: Removing tariffs between TPP members to zero in all sectors

The tariff schedule of the TPP agreement is published on November 5, 2015. The tariff schedule is extensively long, and includes a gradual phased-in progression for some products. Although almost all sectors are included in this agreement, some sectors such

Table 4: Export and Import Tariffs of Selected Countries

	Importers						
Exporter	*TPP*	*TPP-Agr.*	*TPP-Tex.*	*U.S.*	*Japan.*	*China*	*EU*
United States	2.26	36.93	3.09	0.00	0.92	8.74	1.83
Japan	4.07	6.89	9.96	1.24	0.00	10.09	3.41
Mexico	2.72	19.45	4.54	0.00	12.79	6.25	0.22
Canada	7.77	18.92	8.01	0.03	11.69	3.42	1.11
Australia	2.51	12.73	5.57	0.07	3.18	3.15	2.33
New Zealand	3.37	7.00	0.75	2.62	10.51	3.63	25.48
Malaysia	0.35	1.24	3.56	1.68	0.31	2.22	0.62
Vietnam	3.51	8.80	7.94	7.01	1.90	8.87	3.20
China	3.74	9.55	10.33	2.66	3.93	0.00	2.12
Germany	2.64	10.02	10.89	1.17	0.77	10.60	0.00
Indonesia	1.29	1.88	5.14	3.97	0.44	2.01	2.47
Korea	2.62	14.98	9.60	1.08	2.24	8.03	1.11

	Exporters						
Importer	*TPP*	*TPP-Agr.*	*TPP-Tex.*	*U.S.*	*Japan.*	*China*	*EU*
United States	0.58	1.32	4.93	0.00	1.24	2.66	1.12
Japan	3.48	21.27	5.15	0.92	0.00	3.93	4.90
Mexico	7.22	24.08	20.70	7.44	4.49	4.43	5.14
Canada	1.67	6.20	10.70	0.20	3.07	3.88	2.86
Australia	1.28	0.13	0.79	0.04	3.80	3.64	3.06
New Zealand	2.30	2.72	6.66	1.91	4.43	3.78	2.79
Malaysia	3.93	7.47	4.72	1.82	8.90	5.49	4.35
Vietnam	3.36	4.51	9.87	4.16	5.39	5.64	6.46
China	5.68	11.99	7.00	8.74	10.09	0.00	9.46
Germany	2.36	7.61	7.30	2.19	3.13	2.21	0.00
Indonesia	2.50	3.80	1.18	3.94	7.92	1.32	5.58
Korea	6.06	42.27	10.91	9.05	4.88	6.14	12.91

The entry in each cell represents the ad-valorem tariff rate (in percentage) that an importer charges from the exporter country. If importer and exporters are a combination of countries, their trade-weighted average tariff rate is reported.

Source: Tariff data is from UNCTAD-TRAINS dataset. OECD-Bilateral Trade data is used to take a weighted average of multiple countries. TPP-Agr. represents tariffs for agriculture and food-beverage sectors. TPP-Tex. represents the tariffs for textile-apparel sectors.

Table 5: Tariffs on U.S. Imports by Sector

Country	*Agr.-Food*	*Oil-Petr.-Chem.*	*Text.-Wood*	*Mineral-Metal*	*Mach.-Elec.*	*Trans. Eq.*
Australia	3.65	0.00	0.36	0.00	0.00	0.00
Brazil	4.61	0.31	1.71	0.22	0.11	0.01
Brunei	0.00	0.95	13.47	2.18	0.53	0.02
Canada	1.26	0.00	0.00	0.00	0.00	0.00
Chile	1.73	0.00	0.00	0.00	0.00	0.00
China	4.54	2.90	8.95	2.64	0.64	1.57
EU	4.32	1.48	2.24	1.63	0.92	1.06
India	5.63	2.25	6.64	1.59	1.17	0.80
Japan	4.65	2.64	2.08	1.66	0.87	1.11
Malaysia	0.75	4.06	6.82	1.36	0.22	1.01
Mexico	0.29	0.00	0.00	0.00	0.00	0.00
New Zealand	7.16	2.13	1.75	0.83	0.38	1.16
Peru	0.25	0.00	0.00	0.00	0.00	0.00
ROW	1.67	0.71	5.91	0.51	0.18	0.19
Singapore	1.64	0.00	0.01	0.00	0.00	0.00
Vietnam	3.64	2.48	12.00	1.07	0.71	0.79

Source : TRAINS bilateral tariffs database obtained from WITS (http://wits.worldbank.org). The tariffs are the ad-valorem equivalent of "effectively applied rates" for 2-digit ISIC Rev. 3 sectors. Effectively applied rates represents the effective rate at which tariffs are applied, and lie between the preferential rate (if there is one) and most favoured nation rate between two countries. Tariffs for the 6 sectoral groups are found by taking the trade-weighted average of the 2-digit ISIC Rev. 3 tariff rates.

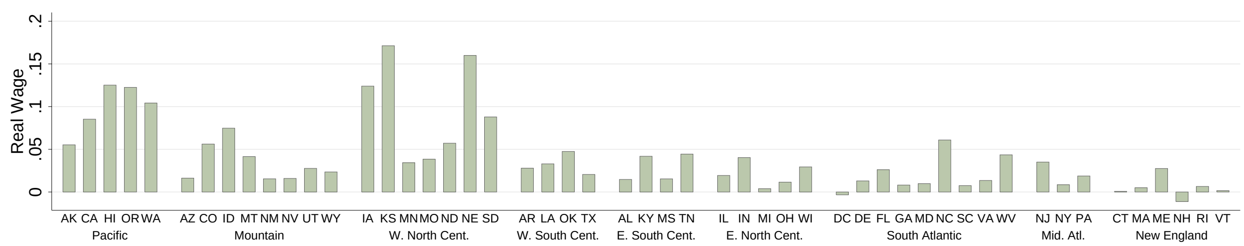
Table 6: Tariffs on U.S. Exports by Sector

Country	*Agr.-Food*	*Oil-Petr.-Chem.*	*Text.-Wood*	*Mineral-Metal*	*Mach.-Elec.*	*Trans. Eq.*
Australia	0.00	0.01	0.91	0.00	0.00	0.00
Brunei	0.02	0.54	2.27	0.05	8.82	0.90
Canada	9.93	0.00	0.00	0.00	0.00	0.00
Chile	0.87	0.69	1.50	0.66	0.86	0.56
China	6.65	4.42	4.27	6.92	4.02	11.81
EU	8.69	2.08	2.55	1.80	1.16	2.54
India	27.70	6.09	9.60	9.44	6.12	6.95
Japan	21.32	0.84	5.65	1.26	0.06	0.00
Malaysia	2.23	4.85	5.67	11.21	1.17	0.57
Mexico	42.39	2.34	6.87	2.08	2.55	6.14
New Zealand	2.46	1.80	3.28	3.33	1.98	1.78
Peru	3.47	0.57	5.11	0.85	0.59	1.10
ROW	9.18	3.39	5.27	4.38	3.52	6.67
Singapore	0.00	0.00	0.00	0.00	0.00	0.00
Vietnam	4.95	3.14	4.82	9.25	1.18	8.97

Source : TRAINS bilateral tariffs database obtained from WITS (http://wits.worldbank.org). The tariffs are the ad-valorem equivalent of "effectively applied rates" for 2-digit ISIC Rev. 3 sectors. Effectively applied rates represents the effective rate at which tariffs are applied, and lie between the preferential rate (if there is one) and most favoured nation rate between two countries. Tariffs for the 6 sectoral groups are found by taking the trade-weighted average of the 2-digit ISIC Rev. 3 tariff rates.

as dairy have seen only small reductions in the tariff rates. In this paper, I consider as if all sector tariffs are removed to zero percent in the benchmark scenario. I keep the trade elasticity as 4.14 for all sectors and the migration elasticity as 1.34 for the baseline case, but I will report simulation results under alternative estimates for these parameters.

Figure 7: Percent changes in Real Wages of U.S. States due to TPP: Benchmark Scenario



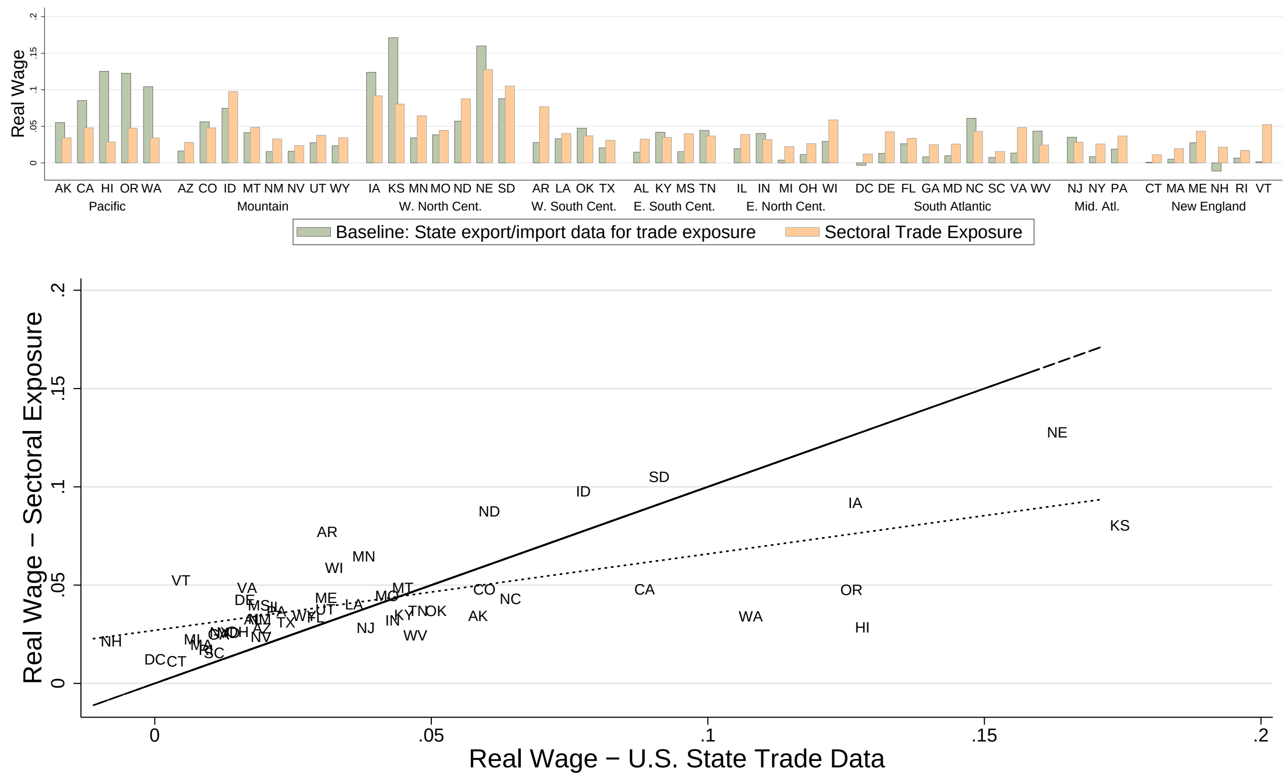
Note: Trade elasticity $\theta^j = 4.14$ for all sectors, labor mobility parameter $\varepsilon = 1.34$.

Figure (7) shows the effect of tariff reductions in all sectors among all partner countries to the TPP agreement on U.S. states. Overall effect on real wages are 0.033 percent for the U.S. economy. However, the variation in real wages vary from -0.01 in New Hampshire to 0.18 in Kansas. Pacific states such as Hawaii, Washington and Oregon gain more than 0.1 percent, while states on the Atlantic coast do not observe changes in their real wages. Agricultural and food manufacturing states (Kansas, Nebraska, Iowa) gain considerably due to the fact that initial tariffs especially between Japan and the United States is significantly high in these sectors. Pacific states gain more because they have high exports and imports with the TPP countries relative to other states. I provide a more detailed sectoral and trade partner related decomposition and the sources of this heterogeneity in section 6. Column (1) of table (7) displays the effect of TPP on real wages of other countries in the sample. Vietnam and Malaysia enjoys highest increases (1.53 percent and 0.82 percent respectively).

Trade Data Specification. In order to see how much alternative foreign data specifications can alter the results, I recompute the welfare computations by using a trade exposure measure based on sectoral characteristics of U.S. states instead of relying on their exports and imports data. I follow Autor, Dorn and Hanson (2013) and Caliendo, Dvorkin and Parro (2015), and substitute exports and imports by destination and origin in each sector by distribution sectoral aggregate U.S. exports and imports to each state depending on the shares of each state's production in total U.S. production in each sector as weights. In particular, I denote $y_s^j = Y_s^j / Y_{US}^j$ by the share of state s's gross output in sector j in total U.S. gross output in this sector. Suppose X_{USc}^j and X_{cUS}^j denote U.S. exports and imports to and from country c in sector j. The exports and imports of each state to and from a destination country c are given by $X_{sc}^j = y_s^j X_{USc}^j$ and $X_{cs}^j = y_s^j X_{cUS}^j$ respectively. I repeat the simulations and plot on figure (8) the difference between using the benchmark data (Data1) and the sectoral trade exposure data (Data2).

It turns out that the real wages of the Pacific states and agriculture-food producing states would be greatly understated and the real wage changes of states on the East would be

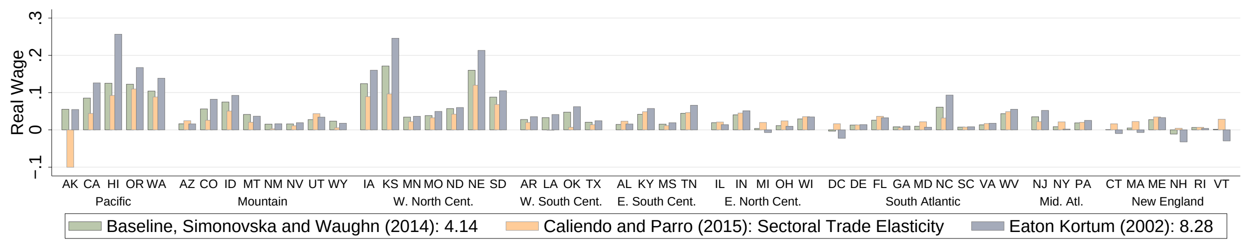
Figure 8: Data Specification: Trade Exposure



overstated if we were to use a trade exposure based on sectoral production. The sectoral based measure can still explain to a certain extent the variation across the exposure since it takes into account sectoral variation, and TPP related tariff reductions affect agriculture and food sectors more than others. I show on the lower-hand side of figure (8) a scatter plot between the two predictions, and the slope is given by 0.38. This alternative data specification distributes U.S. trade according to sectoral differences, and hence does not fully take into account geographical aspect of trade. Transportation costs and distance are important factors that lead some regions to have larger trade flows with regions that are close to them.

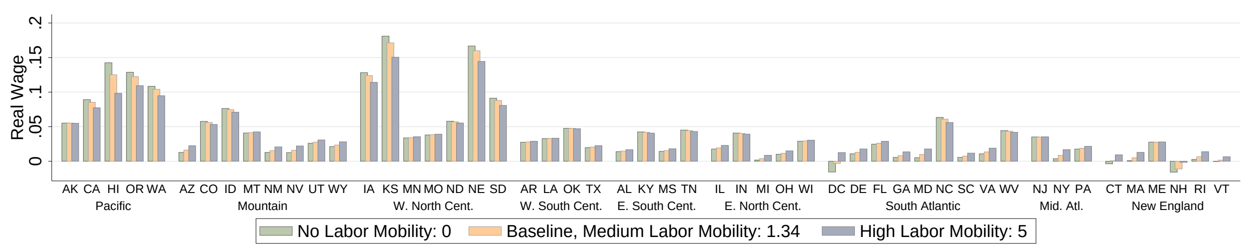
Sensitivity to Trade and Migration Elasticity. I replicate the benchmark scenario tariff changes with alternative measures for the trade elasticity (θ^j) and migration elasticity (ε) and report the results on figure (9). First I report the real wage changes with a trade elasticity measure of 4.14, taken from Simonovska and Waugh's (2014) estimates. The first alternative measure is Caliendo and Parro's (2015) sectoral trade elasticities that range from 1.1 to 64, but have an aggregate elasticity of 4.45, close to what Simonovska and Waugh (2014) have found. The results using this elasticity are mostly similar to the benchmark case except for few outliers. Alaska would lose about -0.12 percent of its real wages due to the TPP agreement under these elasticity estimates, while it had reported a considerable increase under the benchmark scenario. It turns out that Alaska would lose its petroleum market access (in its own economy) to Japan when Japanese tariffs in

Figure 9: Simulation Results: Sensitivity to Trade Elasticity



petroleum, which is originally 5 percent is reduced to 0 percent. With a very high elasticity (64), Japan would increase its market share from 6% in Alaska to 55 percent. However when this elasticity is low (4.14), Japan can only slightly increase its market share and Alaskan production is not affected. I also report Eaton and Kortum's (2002) aggregate estimates of 8.28. With a higher elasticity estimate, states such as Hawaii, Oregon, Kansas and Nebraska can increase their market shares furthermore in their export markets, and this increased production results in higher nominal wages, and hence higher real wages.

Figure 10: Simulation Results: Sensitivity to Migration Elasticity



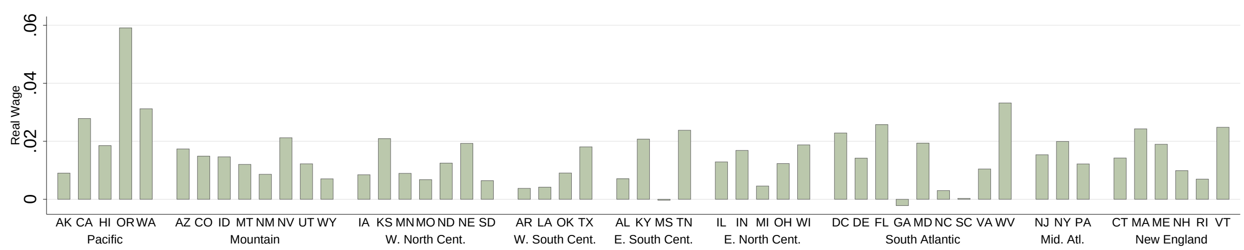
As for the migration elasticity, I consider three cases, no labor mobility ($\varepsilon = 0$), baseline medium labor mobility ($\varepsilon = 1.3$) and a higher labor mobility ($\varepsilon = 5$). The migration elasticity does not have a definite value in the literature. However, the results show that even under much higher measures of labor mobility, the differences in real wages still persist. The reason is because under higher values of migration elasticity, employment increases in places that have real wage gains, this decreases nominal wages, which decreases prices, and hence increases real wages slightly. Therefore, we do not observe a one to one relationship between real wages and labor mobility. We would need a much higher labor mobility elasticity (around 50 or more) to eliminate real wage differentials. A higher number of this sort is unreasonable to be supported with data in the short and medium run.

5.2 Alternative Tariff Scenarios

There are various tariff reduction scenarios to be considered for the TPP agreement. I provide here two alternative tariff reduction scenarios to analyze two important policy questions. In the first alternative scenario, which I denote as scenario (2), I show the impact of keeping agricultural and food tariffs at their initial levels, and only removing tariffs in other sectors. These two sectors are the most protected sectors for which there is a strong opposition from agriculture and food producers in many countries. In the second alternative scenario, which I denote by scenario (3), I consider the effect of including China to the TPP agreement. China is one of the primary destination for U.S. exports and origin for U.S. imports. Its economic size is comparable to the TPP countries as a whole, and it represents 17.4 percent of total U.S. imports and 7.1 percent of U.S. exports, whereas TPP countries besides Canada and Mexico account for 11 percent of U.S. imports and 11.7 percent of U.S. exports.

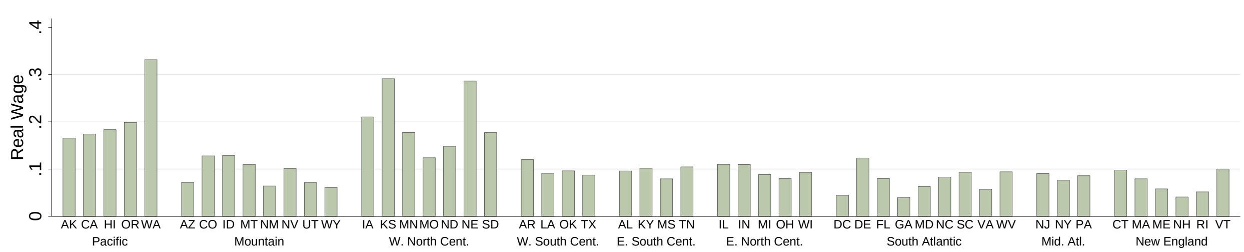
The most striking fact is the U.S. trade deficit with China whereas U.S. enjoys a surplus with the TPP members. Hence, any trade agreement that lowers tariffs between the U.S. and China will be reflected on mainly consumption (imports), and not production (exports) for the U.S. states, and it is likely that U.S. states will face reductions in output due to higher competitiveness of China in the U.S. market. If China also removes its tariffs with the other Pacific countries, U.S. exports will face another import competition in these countries from China. The welfare changes in U.S. states under scenario (2), excluding

Figure 11: Simulation Results: No Reductions in Agriculture-Food sectors



agriculture and food sectors from the TPP agreement, are shown on figure (11). Compared to scenario (1), real wage effects are lower in most states except for small increases (around 0.02 percent) in some states such as Vermont, New Hampshire and Massachusetts. Oregon is the only states that still preserves a relatively high real wage increase (0.06 percent). Iowa, Kansas and Nebraska do not report high welfare gains when agriculture and food sectors are not included in this agreement.

Figure 12: Simulation Results: Adding China to TPP



I plot on figure (12) the effect of adding China to the TPP agreement on U.S. state real wages. When China is included in the TPP agreement, aggregate U.S. real wages increase by 0.1 percent, which is about three times the effects under the full TPP specification that includes all sectors. While all states benefit in terms of real wage by adding China to the agreement, the Pacific and West North Central region still preserves higher welfare gains than others. Some states such as North Carolina and Georgia, which specialize in textile and apparel goods, face higher competition effects from China when tariffs on Chinese textile products are removed.

I display the the effect of these three scenarios on real wages of all countries in the sample on table (7). For most TPP countries including agriculture and food sector tariffs improve welfare whereas incorporating China to the agreement can triple these gains.

6 Decomposition of Real Wage

In this section I provide a framework to analyze the channels through which regions are exposed to a trade policy change. First, in order to have a simple illustration, I present a special case of the model by dropping sector superscripts j and excluding input-output linkages. In addition, I assume that trade is balanced and tariffs do not generate revenue. In the appendix section I provide a general version of this decomposition where I take into account all specifications of the model with multiple sectors, input-output linkages and trade imbalances.

6.1 First-order solution: One sector, no intermediate good case

I start with the gravity equation, which gives an expression for the sales of region i to region n, denoted b X_{in}

$$X_{in}t_{in} = \frac{\left(\frac{w_i \delta_{in} t_{in}}{T_i}\right)^{-\theta}}{\Phi_n} X_n \tag{25}$$

where X_n represents the total demand in region n. It is equal to $w_n L_n$ if trade is balanced and when labor is the only factor in production. w_i is wage of region i, δ_{in} is the iceberg trade cost between region i and n, $t_{in} = 1 + \tau_{in}$ where τ_{in} is the ad-valorem tariff region n on region i products. T_i is the labor productivity of region i. The denominator Φ_n includes wage, trade costs and productivity terms in all regions.

$$\Phi_n = \sum_{h=1}^{N} \left(\frac{w_h \delta_{hn} t_{hn}}{T_h}\right)^{-\theta} \tag{26}$$

Total income of region i is $w_i L_i$, equal to its total sales

$$w_i L_i = \sum_{n=1}^{N} X_{in} \tag{27}$$

Table 7: Real Wage Changes (%) due to TPP

Country Name	*(1)*	*(2)*	*(3)*	*Country Name*	*(1)*	*(2)*	*(3)*
United States	0.033	0.018	0.103	Greece	0.001	0.000	0.007
Australia	0.125	0.044	0.340	Hungary	-0.002	-0.003	-0.007
Brunei	0.149	0.139	0.331	Indonesia	-0.006	-0.011	-0.020
Canada	0.104	0.015	0.179	India	-0.003	-0.002	-0.014
Chile	0.480	0.090	0.560	Ireland	0.000	-0.001	-0.002
Japan	0.134	0.065	0.360	Israel	-0.002	-0.003	-0.007
Mexico	0.097	0.033	0.158	Italy	-0.003	-0.002	-0.011
Malaysia	0.819	0.715	1.339	Korea	-0.021	-0.007	-0.087
New Zealand	0.382	0.131	0.499	Lithuania	0.000	0.001	0.007
Peru	0.093	0.073	0.163	Luxembourg	-0.001	0.001	0.010
Singapore	0.386	0.220	0.379	Latvia	0.003	0.004	0.018
Vietnam	1.534	1.141	2.585	Malta	-0.014	-0.006	0.008
Argentina	0.003	-0.001	0.005	Netherlands	-0.003	-0.004	-0.001
Austria	-0.002	-0.001	-0.001	Norway	-0.001	-0.001	-0.002
Belgium	-0.008	-0.003	-0.012	Philippines	-0.011	-0.003	-0.028
Bulgaria	-0.004	0.001	-0.004	Poland	0.000	-0.001	0.003
Brazil	-0.002	-0.000	0.001	Portugal	-0.001	-0.001	-0.006
Switzerland	-0.004	0.002	-0.003	Romania	-0.001	0.000	-0.000
China	-0.009	-0.006	0.314	Russia	0.003	-0.002	0.006
Cyprus	0.012	0.004	0.047	Gulf Countries	0.001	-0.001	-0.003
Czech Republic	-0.002	-0.003	-0.004	Slovakia	-0.001	-0.004	-0.002
Germany	-0.003	-0.003	-0.007	Slovenia	0.001	-0.001	0.006
Denmark	-0.004	0.001	0.001	Sweden	-0.001	-0.001	0.001
Spain	-0.002	-0.001	-0.001	Thailand	-0.028	-0.039	-0.110
Estonia	0.017	-0.001	0.031	Turkey	-0.001	-0.001	-0.005
Finland	-0.001	-0.001	0.004	Taiwan	-0.003	-0.012	-0.124
France	-0.004	-0.002	-0.006	South Africa	0.003	-0.000	0.013
United Kingdom	-0.003	-0.002	-0.002	Rest of the World	0.004	-0.005	0.010

Each entry reports the percent change in real wages of each country.
(1) refers to the first scenario with full TPP specification. (2) refers to the second TPP scenario without agriculture and food sector tariff reductions. (3) refers to third scenario by adding China to the TPP agreement.

The only exogenous parameters in this formulation are tariff rates t, iceberg costs δ and productivity T. Suppose that iceberg trade costs and productivity terms are always constant. And also consider only changes in the tariff schedule τ_{in}, but not productivity. In order to work with simpler linear expressions to separate non-linear terms, I convert this system into its first-order deviation analogue by denoting $\widetilde{x} = d\log x$ as the log deviations from the initial steady state

$$\widetilde{X}_{in} + \widetilde{t}_{in} = \widetilde{X}_n - \theta\left(\widetilde{w}_i + \widetilde{t}_{in}\right) - \widetilde{\Phi}_n \tag{28}$$

I define $\pi_{in} = \frac{X_{in}t_{in}}{X_n}$ as the share of expenditures of region n on region i products, i.e. market share of region i in market n. I also define by $\eta_{in} = \frac{X_{in}}{\sum_{m=1}^{N} X_{im}}$ as the share of sales of region i to market n in its total sales. Combining these equations, and assuming that labor is fixed, i.e. $\widetilde{L_i} = 0$, will result in the following system of four equations

$$\widetilde{w}_i = \sum_{n=1}^{N} \eta_{in}\widetilde{X}_{in} \qquad \text{Labor market clearing condition} \tag{29}$$

$$\widetilde{X}_{in} = \widetilde{X}_n - \theta\widetilde{w}_i - (1+\theta)\widetilde{t}_{in} - \widetilde{\Phi}_n \qquad \text{Gravity equation} \tag{30}$$

$$\widetilde{X}_n = \widetilde{w}_n \qquad \text{Trade Balance: Expenditure = Income} \tag{31}$$

$$\widetilde{\Phi}_n = \sum_{h=1}^{N} \pi_{hn}(-\theta)\left(\widetilde{w}_h + \widetilde{t}_{hn}\right) \qquad \text{Competitiveness} \tag{32}$$

This system reduces to a single equation

$$\widetilde{w}_i = \sum_{n=1}^{N} \eta_{in}\left[\widetilde{w}_n - \theta\widetilde{w}_i - (1+\theta)\widetilde{t}_{in} - \sum_{h=1}^{N} \pi_{hn}(-\theta)\left(\widetilde{w}_h + \widetilde{t}_{hn}\right)\right] \tag{33}$$

In order to solve this system, I use the world GDP as numéraire, so there is no change in total world GDP $\sum_{i=1}^{N} L_i/L_W\tilde{w}_i = 0$, where L_W is total world employment.

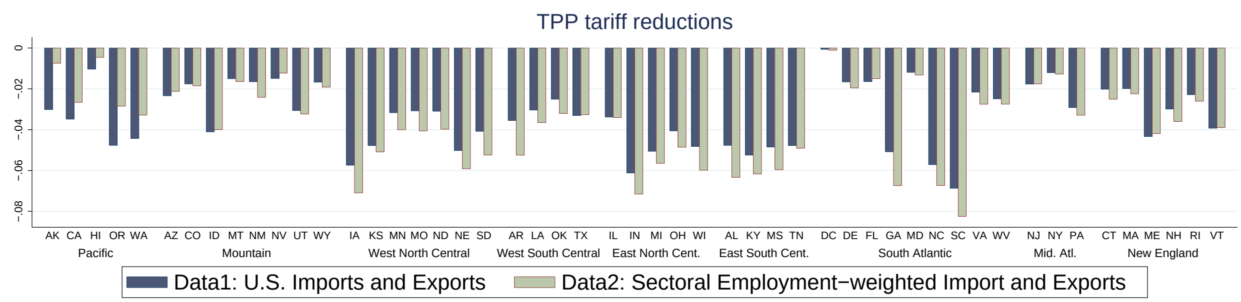
6.2 Partial Direct Effects

Before moving on to the solution, I analyze the direct effect of trade policy changes without taking into account the impact of these changes on wages in all other regions, and keeping them fixed. This approach is analogous to what Autor, Dorn and Hanson (2013) have implemented in their paper for a productivity change in China. I denote the partial equilibrium direct effects with a PE superscript. In particular, the import-competition index, which is the negative direct effects of trade policy can be given by

$$IC_i^{PE} = \theta\sum_{n=1}^{N}\sum_{h\neq i}^{N} \eta_{in}\pi_{hn}\widetilde{t}_{hn} \tag{34}$$

This equation shows how much region i's wages are affected when its competitors enjoy a tariff reduction, i.e. $\widetilde{t}_{hn} < 0$ for $h \neq i$. It is the interaction between how much region i sells to other market n, η_{in}, how much the market share of its competitors $h \neq i$ in these locations π_{hn}, and the percent change in tariffs of its competitors, $\widetilde{t}_{in}$. I plot the direct import competition index of U.S. states on figure (13) for two different sets of data specifications. The first specification (Data1) uses U.S. exports and imports, and the second specification (Data2) uses the sectoral employment weighted U.S. exports and imports. Data2 overstates the losses of most states while understating the potential losses of the states in the Pacific region. The reason is because Pacific countries that also benefit from this agreement export more to the states around the Pacific shore and this should create more negative effects for these states. On the other hand Data2 shows lower trade between Pacific countries and Pacific states as it tends to lower the variation in trade across U.S. states.

Figure 13: Direct Import Competition (PE) Effects - U.S. States



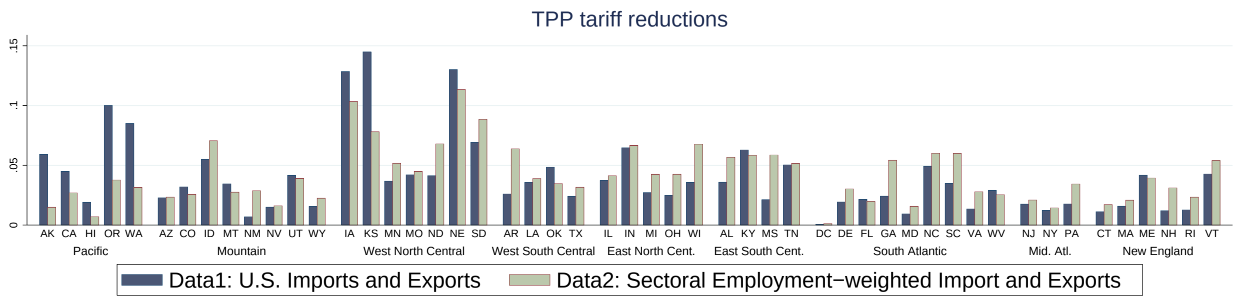
On the other hand, there is a direct positive effect on region i if tariffs imposed on region i by other markets decrease, i.e. $\widetilde{t}_{in} < 0$. I define this positive direct effect by market access

$$MA_i^{PE} = \sum_{n=1}^{N} \eta_{in} \left[-(1 + \theta - \theta \pi_{in}) \widetilde{t}_{in} \right] \tag{35}$$

This term briefly represents the interaction between how much region i sells to all destinations (η_{in}), and how much its tariff is reduced in these locations, $\widetilde{t}_{in} < 0$. I plot the market access effects under data specifications Data1 and Data2 on figure (14). First, the magnitude of positive market access effects are much higher than absolute value of import competition effects. This alone analyzes why there are positive wage effects on U.S. states due to the TPP agreement. Second, we can observe that the variation in market access effects between the two data specifications is much more apparent. The exports of states on the Pacific shore and in the West North Central region are greatly understated with Data2 specification, which results in huge differences in the market access terms. For instance, New Hampshire and Washington would get the same market access exposure according to Data2 (sectoral employment-weighted measure).

As for changes on consumer prices, we should take into account mainly the reductions in tariffs on region i's imports, i.e. $t_{ni} < 0$. Price index in levels and its first-order log

Figure 14: Direct Market Access (PE) Effects - U.S. States



deviation analogue are given by

$$P_i = \Phi^{-1/\theta} \tag{36}$$

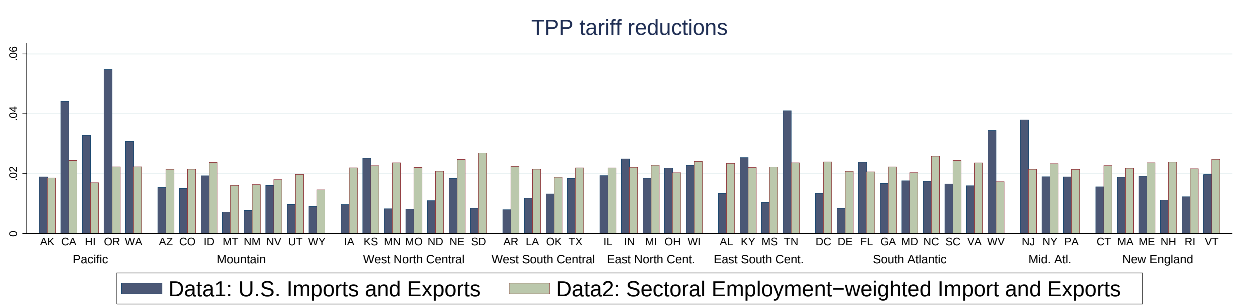
$$\widetilde{P_i} = \sum_{n=1}^{N} \pi_{ni} \left(\widetilde{w}_n + \widetilde{t}_{ni} \right) \tag{37}$$

Since reductions in prices increase consumer utility, I show the positive partial equilibrium direct price effects as

$$CPI^{PE} = -\sum_{n=1}^{N} \pi_{ni} \widetilde{t}_{ni} \tag{38}$$

The changes in the price index is just an interaction between how much region i purchases from other markets and its reduction in tariffs in these markets. I plot on figure (15 the positive price index effects and compare them between the two data specifications. The regions that trade considerably with TPP countries have lower effects in Data2 whereas inward states that do not have high trade volumes such as South Dakota have higher exposure.

Figure 15: Direct Price Index (PE) Effects - U.S. States



6.3 Solution of Wages and Indirect General Equilibrium Effects

In addition to these partial equilibrium direct effects, wages in every region would respond to these changes affect each region through three main channels. First, wages in each region have an influence on the competition term Φ_n. Second, changes in wage of a particular region affect its own competitiveness since even if it benefits from a positive exogenous shock, the increases in its wages will lower its competitiveness and offset some part of this benefit. Third, since regions sell to each other, any change in a regions wage, hence total demand, will directly affect others and create geographical spillovers.

In order to demonstrate the spillover effects, we need to solve the linear system (33). First, grouping the endogenous wage terms and the exogenous terms together we can express this equation as

$$\widetilde{w}_n = \sum_{h=1}^{N-1} \alpha_{ih}\widetilde{w_h} + MA_i^{PE} + IC_i^{PE} \tag{39}$$

Since the world GDP is numéraire, the wage in region N is given by $\widetilde{w}_N = -\sum_{n=1}^{N-1} \frac{L_n}{L_W}\widetilde{w}_n$, the log-linear wage of region $i = 1,...,N-1$ is given by the following equation

$$\widetilde{w}_i = \sum_{h=1}^{N-1} \left(\alpha_{ih} - \alpha_{iN}\frac{L_h}{L_W}\right)\widetilde{w}_h + MA_i^{PE} + IC_i^{PE} \tag{40}$$

In order to solve this linear system, I define a (N-1xN-1) matrix $\mathbf{A}$, where its row (i) and column (h) entry is given by $A(i,h) = \alpha_{ih} - \alpha_{iN}L_i/L_W$. I also define the following two wage and exogenous shock vectors $\mathbf{w} = \{w_i\}_{i=1}^{N-1}$, and $\mathbf{B} = \{MA_i^{PE} + IC_i^{PE}\}_{i=1}^{N-1}$. Taking the Leontief inverse of matrix $\mathbf{A}$, I express the system in the following form

$$(\mathbf{I} - \mathbf{A})\mathbf{w} = \mathbf{B} \tag{41}$$

which solves for wages

$$\mathbf{w} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{B} \tag{42}$$

This equation can be also represented in summation form by defining μ_{ih} as the row i and column h entry of matrix $(\mathbf{I} - \mathbf{A})^{-1}$. Wages in regions $i = 1,...,N-1$ are given by[24]

$$\widetilde{w}_i = \sum_{h=1}^{N-1} \mu_{hi}(MA_h^{PE} + IC_h^{PE}) \tag{43}$$

I define a geographical spillover term, which will be the effect of all other region's initial market access and import competition terms on region i

$$GEO_i = \sum_{h=\neq i}^{N-1} \mu_{hi}(MA_h^{PE} + IC_h^{PE}) \tag{44}$$

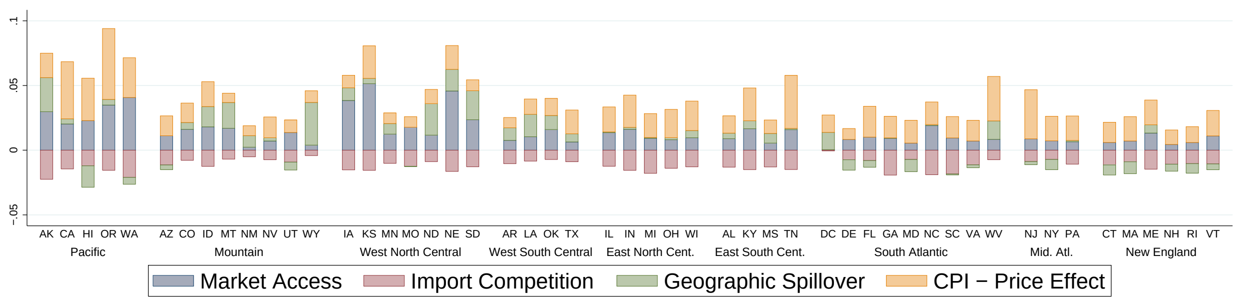
[24]The wage of region N is given by $\widetilde{w}_N = -\sum_{n=1}^{N-1} \frac{L_n}{L_W}\widetilde{w}_n$.

Then, I also plug in the wage term in the price equation and write real wages as

$$\widetilde{w}_i - \widetilde{P}_i = \mu_{ii} MA_i^{PE} + \mu_{ii} IC_i^{PE} + GEO_i + CPI_i^{PE} \tag{45}$$
$$= MA_i + IC_i + GEO_i + CPI_i \tag{46}$$

The overall break-down of the TPP agreement in real-wages are is provided on figure

Figure 16: Real Wage Decomposition



(16).[25] We can see from the real wage decomposition that Pacific states gain both from the market access effect and price effect whereas agricultural states (Iowa, Kansas, Nebraska) mainly gain due to increased market access, i.e. increased sales. For most of the other states except for the Mountain region there are positive and significant price effects, which can mainly explain the real wage effects, but are mostly offset by the negative import competition effect. The geographical spillovers differ across regions. They are negative in most of the Atlantic states since most of these states face nominal income losses given the fact that import competition effects are larger than market access effects. On the contrary, the geographical spillovers are positive for the states in the Mountain and West North Central regions since many states have positive market access effects, which lead to nominal wage increases, then they create spillovers across each other. Wyoming's real income gains are resulting entirely from the geographical spillover channel.

The sum of market access, import competition and geographical spillover effects denotes the share of welfare gains attributable to changes in nominal wages, and hence production. This can be interpreted as the change in the producer surplus, as wages are the only source for remuneration of income in this model. On the other hand, the consumer price index effect is the share of welfare gains attributable to changes in prices, and hence consumer surplus. The distinction between the production and consumption channels has important distributional implications. Within every region there is a heterogeneity across the residents in terms of how much they are exposed to consumption or production effects. This can determine their support or opposition for a trade agreement. In addition, it is often the case that producers can coordinate and lobby more easily as opposed to individual consumers since producers have more resources. As a result, even if some

[25]Note that the scale on figure (16) is different than the results I have presented in section 5 on graph (7) since the decomposition method here uses first-order approximations and report smaller changes compared to exact values.

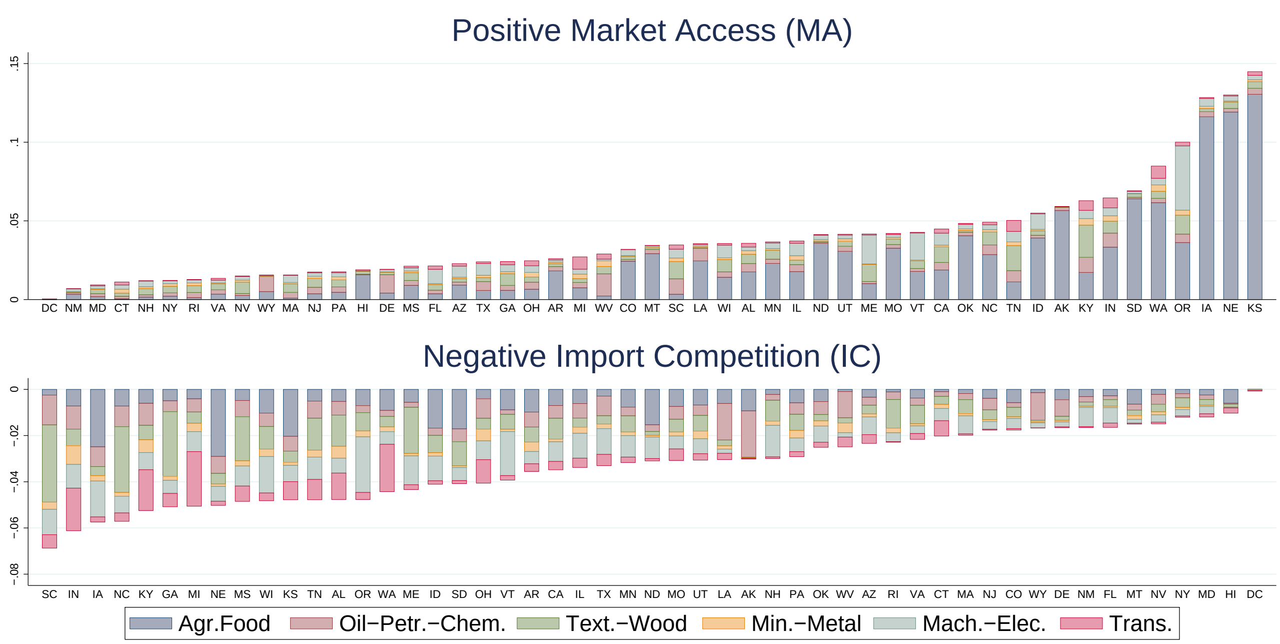
regions benefit from a trade agreement, but if the gains are not reflected on production, focusing on the overall gain might give misleading predictions for sentiments on trade policy. In particular, the import competition effect, which denotes the losses in wages due to reductions in market access and sales, has been the main focus of the research on labor market effects of trade liberalization.

6.4 Sectoral and Geographical Decomposition of Nominal Wage: General Case

In this subsection I show the detailed breakdown of the sectoral and geographical breakdown of the main two channels, market access MA_i, and import competition IC_i. I generalize the method I have presented in section 6.3 for the case with multiple sectors, input-output linkages and trade imbalances to include sectoral breakdown of these channels. The derivations for the solution are provided in appendix (A.1).

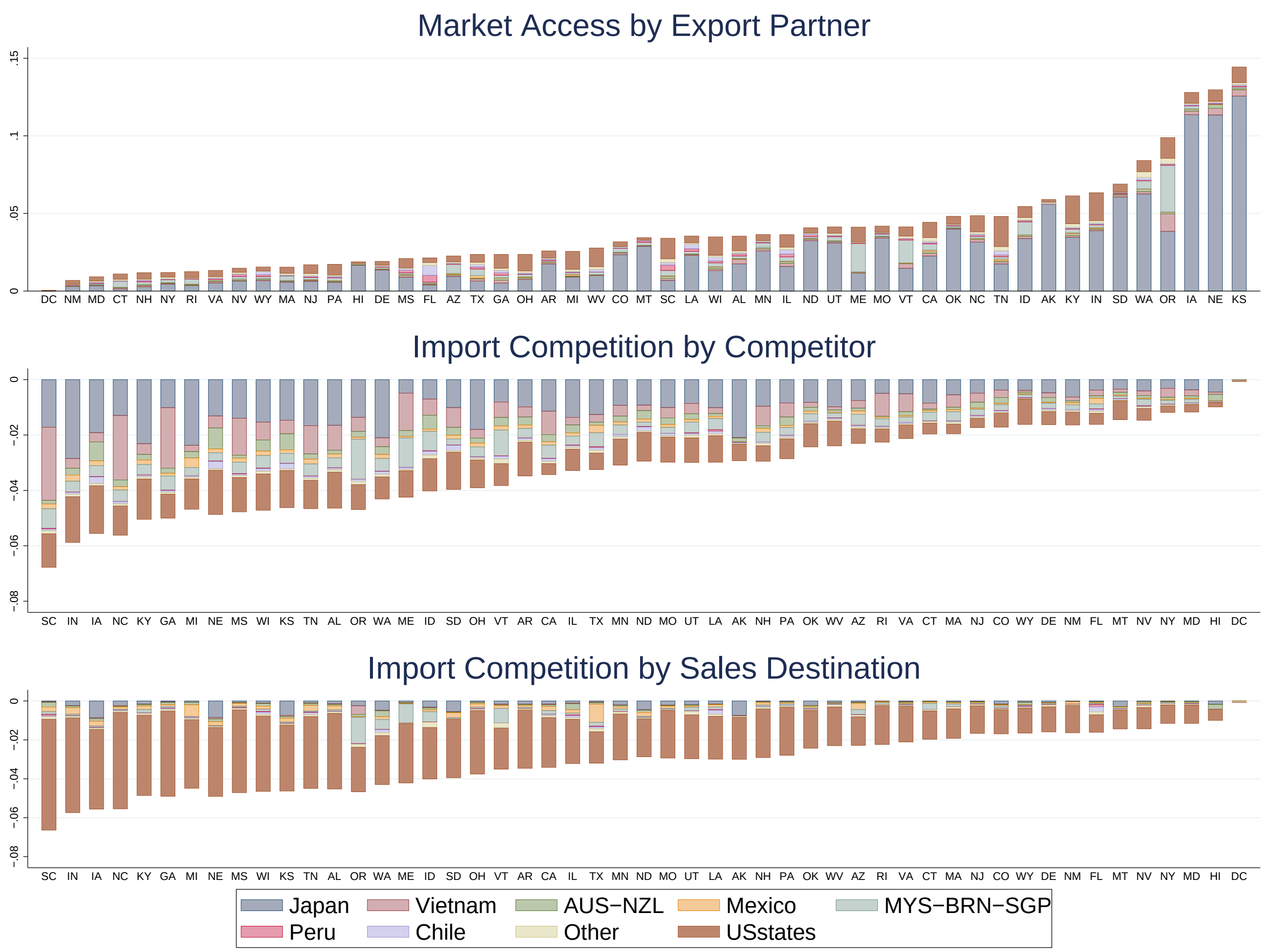
Figure (17) shows the sectoral decomposition of market access and import competition effects before the real adjustment with the price index. Agriculture and food sectors dominate over the market access effect while machinery and textile sectors also play a role for some states. As for the import competition effects, states such as South Carolina, North Carolina and Georgia lose in textile sectors where as Indiana, Kentucky and Michigan lose in the transportation sector.

Figure 17: Sectoral Decomposition of Market Access and Import Competition



Similarly, I show on figure (18) the decomposition of the nominal market access and import competition effects by trade partners. Japan dominates the market access effect, which points out that the reductions in agricultural and food sector tariffs are the main driver of how U.S. states can benefit from the TPP agreement. Some other sources such as Vietnam and Malaysia play a minor role for some other states. However, an interesting result is that market access of U.S. states in other U.S. states also increases, which is not a directly expected result since tariffs between them were already at zero percent and did not change under this trade policy exercise. What drives these positive market access effects between U.S. states is the reductions in unit costs $\tilde{c}_i^j$. Tariff reductions with TPP countries result in cheaper intermediate goods originating there, which increase their competitiveness of U.S. states almost everywhere.

Figure 18: Geographical Decomposition of Market Access and Import Competition



As for the import competition effects, we observe that Vietnam causes reductions in the nominal wages for South Carolina, North Carolina and Georgia whereas Japan causes reductions for the nominal wages of Indiana, Kentucky and Michigan. However, one other competitor of U.S. states is other U.S. states. Most states face declines in their nominal wages as a result of higher competition from other U.S. states since many of these states also gain competitiveness. On the third panel of figure (18) I show the markets where each U.S. state faced of negative competition effects. For almost all states, the domestic U.S. market is where they have lost competition more.

It is often difficult to determine the sources of exposure of regions to a multidimensional trade policy that includes many regions and sectors. This decomposition method of the real wage into the four economic channels I have described could be further broken down to sectoral and geographical sub-components channels to analyze trade policies. The market access term has three dimensions, (i) exporter region, (ii) export destination market, and (iii) sector that faces a shock. The import competition term on the other hand has four dimensions: (i) exporter region, (ii) export destination market, (iii) competitor and (iv) sector that faces a shock. Thus, any trade policy can be decomposed first into these sub-components market access and import competition, which determine the main variation on how different regions are exposed to a trade policy.

7 Conclusion

In this paper, I studied the effects of economic shocks on local geographies by applying a multi-sector international trade model to find how the Trans-Pacific Partnership agreement (TPP) would affect real wages of U.S. states. There is a considerable amount of variation across U.S. states in their exposure to this agreement due to their differences in production structure and trade partners. I quantified the model by constructing a dataset that has sectoral imports and exports of U.S. states using multiple data sources. Obtaining local level bilateral trade data is often challenging since trade statistics are collected at national ports. As a result, existing studies have imputed trade data with imperfect measures based on sectoral characteristics of labor markets. I compared my benchmark predictions of welfare due to TPP welfare reductions to predictions under alternative trade exposure measures that are based on the sectoral composition of local geographies. The results show that trade exposure data based on sectoral exposure can only partially explain the variation in the exposure to a trade shock, and cannot be a reliable proxy if one is interested in the geographical impact of trade policies.

In the last section of the paper, I broke down the changes in welfare into channels through which regions would be affected due to a trade policy shock. The decomposition method I have provided is a powerful method to analyze the effects of a multidimensional trade policy change that includes many sectors and regions. I discussed the direct and indirect effects of trade policy shocks, and showed how general equilibrium effects and geographical spillovers can amplify the impact of trade shocks. Finally, I discussed how much production and consumption contribute to welfare gains, and how the heterogeneity in terms of these channels within a region can lead to different trade policy implications.

Determining welfare effects of trade policies on local geographies is a step forward to understand the disproportionate effects due to trade liberalization. While regional disparities are likely to disappear in the long-run within a country due to factor mobility, the adjustment process may be slow due to labor market frictions. This model can be extended to incorporate different worker types in terms of skills and incomes, other labor market frictions that create unemployment, and other aspects of trade policy on investment regulations or non-tariff barriers. The implications of the might be an interest for policy makers regarding negotiations for trade agreements or designing welfare programs to compensate losers from trade.

References

[1] Acemoglu, Daron, Ufuk Akcigit, and William Kerr. 2015. "Network and the Macroeconomy: An Empirical Exploration." Forthcoming NBER Macroeconomics Annual.

[2] Acemoglu, Daron, Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi. 2012. "The Network Origins of Aggregate Fluctuations." *Econometrica*, 80(5): 1977-2016.

[3] Allen, Treb and Costas Arkolakis. 2014. "Trade and the Topography of the Spatial Economy," *Quarterly Journal of Economics*, 129(3): 1085-1140.

[4] Allen Treb, Costas Arkolakis and Xiangliang Li. 2015. "On the Existence and Uniqueness of Trade Equilibria". Working Paper.

[5] Anderson, James E., and Eric van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle ." *American Economic Review*, 93(1): 170-192.

[6] Arkolakis, Costas, Arnaud Costinot, and Andrés Rodríguez-Clare. 2012. "New Trade Models, Same Old Gains?" *American Economic Review*, 102(1): 94-130.

[7] Autor, David H., David Dorn, and Gordon H. Hanson. 2013. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States." *American Economic Review*, 103(6): 2121-68.

[8] Asian International Input-Output Project, IDE-JETRO. 2005. "Asian International Input-Output Table".

[9] Baldwin, Richard E. and Anthony J. Venables, "Regional Economic Integration." In *Handbook of International Economics, Vol. III*, edited by Gene Grossman and Kenneth Rogoff. 1597-1664. Amsterdam: Elsevier Science, 1995.

[10] Bartelme, Dominick. 2015. "Trade Costs and Economic Geograph: Evidence from the US," Working Paper.

[11] Beyer, Robert C. M. and Frank Smets. 2015. "Labour Market Adjustments in Europe and the U.S.: How different?", European Central Bank, Working Paper Series. No 1767.

[12] Bhagwati, Jagdish N., and Pravin Krishna. 1999. *Trading Blocs: Alternative Approaches to Analyzing Preferential Trade Agreements.* Cambridge : Mit Press.

[13] Blanchard, Olivier J. and Lawrence F. Katz. 1992 "Regional evolutions." *Brookings Papers on Economic Activity*, 1:1-75.

[14] Bureau of Economic Analysis. 2012. "Regional Economic Accounts". U.S Department of Commerce.

[15] Caliendo, Lorenzo, Maximiliano Dvorkin and Fernando Parro. 2015. "Trade and Labor Market Dynamics". Working Paper.

[16] Caliendo, Lorenzo, and Fernando Parro. 2015. "Estimates of the Trade and Welfare Effects of NAFTA." *The Review of Economic Studies* 82(1): 1-44.

[17] Caliendo, Lorenzo, Fernando Parro, Esteban Rossi-Hansberg, and Pierre-Daniel Sarte. 2014. "The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy", NBER Working Paper No. 20168.

[18] Cassey, Andrew J. 2009. "State Export Data: Origin of Movement vs. Origin of Production." *Journal of Economic and Social Measurement*, 34(4): 241-268.

[19] Costinot, Arnaud and Andrés Rodríguez-Clare. 2014. "Trade Theory with Numbers: Quantifying the Consequences of Globalization." *Handbook of International Economics* 4: 197-261.

[20] Cravino, Javier and Sebastian Sotelo. 2015. "Trade Induced Structural Change and the Skill Premium." Working Paper.

[21] Central Statistical Burau. 2011. "National Account Statistics 2011: A System of National Accounts 1993". State of Kuwait.

[22] Deardorff, Alan V. 2013. "Trade Implications of the Trans-Pacific Partnership for ASEAN and Other Asian Countries," Presented at the 2nd 2013 Asian Development Review Conference.

[23] Deardorff, Alan V., and Robert Mitchell Stern. 1990. *Computational Analysis of Global Trading Arrangements*. Ann Arbor : University of Michigan Press.

[24] Decressin, Jörg, and Antonio Fatas. 1995. "Regional labor market dynamics in Europe." *European Economic Review*, 39(9): 1627-1655.

[25] Dekle, Robert, Jonathan Eaton, and Samuel S. Kortum. 2008. "Global Rebalancing with Gravity: Measuring the Burden of Adjustment" *IMF Staff Papers*, 55(3): 511-540.

[26] Department of Economic Planning and, Development 2005. "Brunei Darussalam's Input-Output Tables 2005". Prime Minister's Office, Brunei Darussalam.

[27] Eaton, Jonathan, and Samuel Kortum. 2002. "Technology, geography, and trade." *Econometrica* 70(5): 1741-1779.

[28] Galle Simon, Andrés Rodríguez-Clare, and Moises Yi. 2015. "Slicing the Pie: Quantifying the Aggregate and Distributional Consequences of Trade." Working Paper.

[29] Glaeser, Edward and Joshua Gottlieb. 2008. "The economics of place making policies." *Brookings Papers on Economic Activity*.

[30] Goldberg, Pinelopi Koujianou, and Nina Pavcnik. 2007. "Distributional Effects of Globalization in Developing Countries." *Journal of Economic Literature*, 45(1): 39-82.

[31] Helliwell, John F. 1997. "National Borders, Trade and Migration." *Pacific Economic Review*, 2(3): 165-85.

[32] Helliwell, John. 1998. *How much do national borders matter?* Washington, DC: Brookings Institution Press.

[33] Instituto Nacional de Estadistica e Informatica, Peru, 2007. "Cuentas Nacionales".

[34] Levchenko, Andrei and Jing Zhang. 2012. "Comparative Advantage and the Welfare Impact of European Integration." *Economic Policy*, 27(72): 567-602.

[35] Moretti, Enrico. 2011. "Local Labor Markets". *Handbook of Labor Economics*, 4(B): 1237-1313.

[36] OECD. 2006. "OECD Input-Output Database edition 2006".

[37] OECD. 2012 "OECD STAN Bilateral Trade Database by Industry and End-Use (BTDIxE)".

[38] Ossa, Ralph. 2014. “Trade Wars and Trade Talks with Data.” *American Economic Review*, 104(12): 4104-46.

[39] Petri, Peter A. and Michael G. Plummer. 2012. “The Trans-Pacific Partnership and Asia-Pacific Integration: Policy Implications,” Policy Brief of the Peterson Institute for International Economics. Number PB12-16.

[40] Redding, Stephen J. 2014. “Goods Trade, Factor Mobility and Welfare” NBER Working Paper No. w18008.

[41] Suárez-Serrato, Juan Carlos, and Owen Zidar. 2014. “Who benefits from state corporate tax cuts? A local labor markets approach with heterogeneous firms”. National Bureau of Economic Research, Working Paper No. w20289.

[42] Simonovska, Ina, and Michael E. Waugh. (2014), “The elasticity of trade: Estimates and evidence.” *Journal of International Economics*, 92: 34-50.

[43] Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), “An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production” *Review of International Economics* 23: 575-605

[44] U.S. Census Bureau and Bureau of Transportation Statistics. 2012. “Commodity Flow Survey”.

[45] U.S. Census Bureau. 2012. “USA Trade Online State Export Data and State Import Data”.

[46] U.S. Department of Agriculture Economic Research System. 2011. “County Level Oil and Gas Production in the U.S.”

[47] U.S. Department of Agriculture Economic Research System. 2012 “U.S. and State Farm Income and Wealth Statistics”.

[48] U.S. Energy Information Administration. 2012. “Crude Oil and Natural Gas Statistics”.

[49] United Nations Conference on Trade and Development (UNCTAD). 2012 .“TRAINS (Trade Analysis and Information System)”. http://wits.worldbank.org.

[50] Wei, Shang-Jin. 1996. “Intra-National versus International Trade: How Stubborn are Nations in Global Integration?,” NBER Working Papers 5531, National Bureau of Economic Research, Inc.

A Appendix

A.1 Decomposition of Nominal Wage and Real Wage: General Case

In this subsection I generalize the decomposition of the changes in nominal wages and real wages that I have implemented in section 6 including multi-sectors, input-output linkages and trade imbalances. I ignore tariff revenue and labor mobility from the analysis for simplicity[26]. I start with the model equations below where $t^j_{in} = 1 + \tau^j_{in}$, and ξ^j_i and Γ^j

[26]Since tariffs and initial tariff revenue are low, the exclusion of tariff revenue does not change variation across regions in their exposure from the trade policy considerably. Removing tariff revenue simplifies the derivations below significantly.

are constants.

$$
\begin{aligned}
w_i L_i &= \sum_{j=1}^{J} \gamma_i^{0j} Y_i^j & Y_i^j &= \sum_{n=1}^{N} X_{in}^j / t_{in}^j \\
X_{in}^j &= \pi_{in}^j X_n^j & X_i^j &= \sum_{k=1}^{J} \gamma_i^{jk} Y_i^k + \beta_i^j (w_i L_i + D_i) \\
\pi_{in}^j &= \frac{\left[c_i^j \delta_{in}^j t_{in}^j (T_i^j)^{-\gamma_i^{0j}} \right]^{-\theta^j}}{\Phi_n^j} & \Phi_i^j &= \sum_{n=1}^{N} \left[c_n^j \delta_{ni}^j t_{ni}^j (T_n^j)^{-\gamma_n^{0j}} \right]^{-\theta^j} \\
c_i^j &= \xi_i^j w_i^{\gamma_i^{0j}} \prod_{j=1}^{J} (P_i^k)^{\gamma_i^{kj}} & P_i^j &= \Gamma^j (\Phi_i^j)^{-1/\theta^j}
\end{aligned}
\tag{47}
$$

Log-linearization of these equations around the steady state will lead to the following systems of equations

$$
\begin{aligned}
\widetilde{w_i} &= \sum_{j=1}^{J} \lambda_i^j \widetilde{Y_i^j} \\
\widetilde{Y_i^j} &= \sum_{n=1}^{N} \eta_{in}^j \left(\widetilde{\pi_{in}^j} + \widetilde{X_n^j} - \widetilde{t_{in}^j} \right) \\
\widetilde{X_n^j} &= \sum_{k=1}^{J} \kappa_n^{jk} \widetilde{Y_n^k} + \kappa_n^{j0} \widetilde{w_n} \\
\widetilde{\pi_{in}^j} &= -\theta^j \left(\widetilde{c_i^j} + \widetilde{t_{in}^j} \right) + \theta^j \sum_{h=1}^{N} \pi_{hn}^j \left(\widetilde{c_h^j} + \widetilde{t_{hn}^j} \right) \\
\widetilde{c_i^j} &= \gamma_i^{0j} \widetilde{w_i} + \sum_{k=1}^{J} \sum_{h=1}^{N} \gamma_i^{kj} \pi_{hi}^k \left(\widetilde{c_h^k} + \widetilde{t_{hi}^k} \right)
\end{aligned}
\tag{48}
$$

where λ_i^j is the share of sectoral value added of region i in its total value added (i.e. nominal GDP), η_{in}^j the share of sales of region i to destination n in sector j in its total sales to every destination (i.e. output) in this sector, κ_n^{jk} is the share of intermediate goods in total expenditures, and κ_n^{j0} is the share of household goods in total spending[27].

Nominal Wage. The cost equation is solved in terms of wages and tariff terms and can be regrouped as follows[28]

[27] $\lambda_i^j = \frac{\gamma_i^{0j} Y_i^j}{w_i L_i}$, $\eta_{in}^j = \frac{\pi_{in}^j X_n^j / (1+\tau_{in}^j)}{Y_i^j}$, $\kappa_n^{jk} = \frac{\gamma_n^{jk} Y_n^k}{X_n^j}$ and $\kappa_n^{j0} = \frac{\beta_n^j w_n L_n}{X_n^j}$.

[28] Moving the term that contains c_h^j to the left-hand side and taking its Leontief inverse, we can solve for

$$\widetilde{c_i^j} = \sum_{h=1}^{N} a_{hi}^j \widetilde{w_h} + TA_i^j \tag{49}$$

I plug the cost function into the trade share equation

$$\widetilde{\pi_{in}^j} - \widetilde{t_{in}^j} = \underbrace{-\widetilde{t_{in}^j} - \theta^j \left(1 - \pi_{ii}^j\right) \left[\sum_{h=1}^{N} a_{hi}^j \widetilde{w_h} + TA_i^j + \widetilde{t_{in}^j} \right]}_{\text{Market Access Effect}} + \underbrace{\theta^j \sum_{m \neq i} \pi_{mn}^j \left[\sum_{h=1}^{N} a_{hm}^j \widetilde{w_h} + TA_m^j + \widetilde{t_{mn}^j} \right]}_{\text{Import Competition Effect}}$$

$$= \sum_{h=1}^{N} a_{hin}^j \widetilde{w}_h + MA_{in}^j + IC_{in}^j$$

where a_{hin}^j is a constant, MA_{in}^j is direct market access effect of i with respect to region n, and IC_{in}^j is the direct import competition effect that is related to loss of i's market access in region n[29]. The gross-output equation is then given by

$$\widetilde{Y_i^j} = \sum_{n=1}^{N} \eta_{in}^j \left(\sum_{k=1}^{J} \kappa_n^{jk} \widetilde{Y_n^k} + \kappa_n^{j0} \widetilde{w_n} \right) + \sum_{n=1}^{N} \eta_{in}^j \left[\sum_{h=1}^{N} a_{hin}^j \widetilde{w}_h + MA_{in}^j + IC_{in}^j \right]$$

I solve this equation by taking the Leontief inverse of the right-hand side output variables

costs in terms of wages and tariff terms

$$\left[\widetilde{c_i^j} - \sum_{k=1}^{J} \sum_{h=1}^{N} \gamma_i^{kj} \pi_{hi}^k \widetilde{c_h^k} \right] = \gamma_i^{0j} \widetilde{w_i} + \sum_{k=1}^{J} \sum_{h=1}^{N} \gamma_i^{kj} \pi_{hi}^k \widetilde{t_{hi}^k}$$

$$(\mathbf{I} - \mathbf{C})\mathbf{c} = \mathbf{C_w}\mathbf{w} + \mathbf{C_t}\mathbf{t} \qquad \rightarrow \qquad \mathbf{c} = (\mathbf{I} - \mathbf{C})^{-1}\mathbf{C_w}\mathbf{w} + (\mathbf{I} - \mathbf{C})^{-1}\mathbf{C_t}\mathbf{t}$$

[29] The wage parameter, productivity and import competition terms are given by

$$a_{hin}^j = -\theta^j \left(1 - \pi_{ii}^j\right) a_{hi}^j + \theta^j \sum_{m \neq i} \pi_{mn}^j a_{hm}^j$$

$$MA_{in}^j = -\widetilde{t_{in}^j} - \theta^j \left(1 - \pi_{ii}^j\right) \left(TA_i^j + \widetilde{t_{in}^j}\right)$$

$$IC_{in}^j = \theta^j \sum_{m \neq i} \pi_{mn}^j \left(TA_m^j + \widetilde{t_{mn}^j}\right)$$

and obtain[30]

$$\widetilde{Y_i^j} = \sum_{h=1}^{N} f_{hi}^j \widetilde{w_h} + \sum_{h=1}^{N}\sum_{k=1}^{J}\sum_{n=1}^{N}\left(g_{hin}^{jk} MA_{hn}^k + s_{hin}^{jk} IC_{hn}^k\right) \tag{50}$$

where f_{hi}^j, g_{hin}^{jk} and s_{hin}^{jk} are constants that solve the output equation. Using $\widetilde{w_i} = \sum_{j=1}^{N} \lambda_i^j \widetilde{Y_i^j}$

$$\widetilde{w_i} = \sum_{j=1}^{N}\sum_{h=1}^{N} \lambda_h^j f_{hi}^j \widetilde{w_h} + \sum_{j=1}^{J}\sum_{h=1}^{N}\sum_{k=1}^{J}\sum_{n=1}^{N}\left(\lambda_h^j g_{hin}^{jk} MA_{hn}^k + \lambda_h^j s_{hin}^{jk} IC_{hn}^k\right)$$

Since world GDP is numéraire and held constant, the wage of region N is given by $\widetilde{w_N} = -\sum_{n=1}^{N-1} \frac{L_i}{L_W} \widetilde{w_i}$, and I convert the equation above and rearrange to obtain for each $i = 1, ..., N-1$

$$\left[\widetilde{w_i} - \sum_{j=1}^{N}\sum_{h=1}^{N-1}\left(\lambda_i^j f_{hi}^j - \frac{L_h}{L_W}\lambda_N^j f_{Nh}^j\right)\widetilde{w_h}\right] = \sum_{j=1}^{J}\sum_{h=1}^{N-1}\sum_{k=1}^{J}\sum_{n=1}^{N}\left(\lambda_h^j g_{hin}^{jk} MA_{hn}^k + \lambda_h^j s_{hin}^{jk} IC_{hn}^k\right)$$

Taking the Leontief inverse and rearranging the wage of region $i = 1, ..., N-1$ is determined by

$$\widetilde{w_i} = \sum_{j=1}^{J}\sum_{h=1}^{N-1}\sum_{k=1}^{J}\sum_{n=1}^{N}\left(G_{hin}^{jk} MA_{hn}^k + S_{hin}^{jk} IC_{hn}^k\right) \tag{51}$$

The wage of region N is given by $\widetilde{w_N} = -\sum_{n=1}^{N-1} \frac{L_i}{L_W} \widetilde{w_i}$. Equation (51) summarizes all geographical and sectoral linkages and how exogenous shocks tranmist through these linkages by breaking the exogenous shock to positive market access and negative import competition parts.

Price Index and Real Wage. The decomposition so far is related to the nominal wages, and we need to take into account how price index affects the real values of variables. Changes in real wage, denoted by $\widetilde{W_i}$, is the difference between changes in nominal wage and price index

$$\widetilde{W_i} = \widetilde{w_i} - \widetilde{P_i}$$

[30] I move the output terms to the left-hand side and solve $\widetilde{Y_i^j}$ in terms of $\widetilde{w_h}$ and exogenous tariff terms

$$\left[\widetilde{Y_i^j} - \sum_{n=1}^{N}\sum_{k=1}^{J}\eta_{in}^j \kappa_n^{jk} \widetilde{Y_n^k}\right] = \sum_{h=1}^{N} e_{hi}^j \widetilde{w}_h + \sum_{k=1}^{J}\eta_{in}^j MA_{in}^j + \sum_{k=1}^{J}\eta_{in}^j IC_{in}^j$$

$$(\mathbf{I}-\mathbf{Y})\mathbf{y} = \mathbf{Y_w w} + \mathbf{Y_{ma} MA} + \mathbf{Y_{ic} IC} \qquad \rightarrow \qquad \mathbf{y} = (\mathbf{I}-\mathbf{Y})^{-1}\mathbf{Y_w w} + (\mathbf{I}-\mathbf{Y})^{-1}\mathbf{Y_{ma} MA} + (\mathbf{I}-\mathbf{Y})^{-1}\mathbf{Y_{ic} IC}$$

where price index is given by

$$\widetilde{P_i} = \sum_{j}^{J} \beta_i^j \widetilde{P_i^j} = \sum_{j=1}^{J} \sum_{n=1}^{N} \beta_i^j \pi_{ni}^j \left[\widetilde{c_n^j} + \widetilde{t_{ni}^j} \right]$$

The change in real wage can be expressed as

$$\widetilde{W_i} = \sum_{h=1}^{N} \alpha_{hi} \widetilde{w_h} + CPI_i \tag{52}$$

where I substituted the cost function $\widetilde{c_n^j}$ into prices using equation (49)[31]. The term CPI_i, which represents the contribution of the changes in the consumer price index on real wages is given by

$$CPI_i = -\sum_{j=1}^{J} \sum_{n=1}^{N} \beta_i^j \pi_{ni}^j \left(TA_n^j + \widetilde{t_{ni}^j} \right) \tag{53}$$

Using equations (51), (52) and (53), converting nominal wage terms into real terms, and aggregating the exogenous terms over geography and sectors, we can express real wages in four channels: market access, import competition, geographical spillovers and price index effects

$$\widetilde{W_i} = MA_i + IC_i + GEO_i + CPI_i \tag{54}$$

I defined these terms by first rearranging the sums over indices h and m to convert

$$\sum_{h=1}^{N} \alpha_{hi} \widetilde{w_h} = \sum_{h=1}^{N} \alpha_{hi} \sum_{j=1}^{J} \sum_{m=1}^{N-1} \sum_{k=1}^{J} \sum_{n=1}^{N} \left(G_{min}^{jk} MA_{mn}^k + S_{min}^{jk} IC_{mn}^k \right)$$

into a simpler expression

$$\sum_{h=1}^{N} \alpha_{hi} \widetilde{w_h} = \sum_{h=1}^{N} \sum_{j=1}^{J} \sum_{k=1}^{J} \sum_{n=1}^{N} \left(\widetilde{G}_{hin}^{jk} MA_{hn}^k + \widetilde{S}_{hin}^{jk} IC_{hn}^k \right)$$

Then, I defined the MA_i, IC_i terms by only taking into account own region i feedbacks,

[31] $\widetilde{W_i} = \widetilde{w_i} - \sum_{j=1}^{J} \sum_{n=1}^{N} \beta_i^j \pi_{ni}^j \left[\sum_{h=1}^{N} a_{hn}^j \widetilde{w_h} + TA_n^j + \widetilde{t_{ni}^j} \right]$ and the constant α_{hi} is given by $\alpha_{ii} = 1 - \sum_{j=1}^{J} \sum_{n=1}^{N} \beta_i^j \pi_{ni}^j a_{in}^j$ and $\alpha_{hi} = -\sum_{j=1}^{J} \sum_{n=1}^{N} \beta_i^j \pi_{ni}^j a_{in}^j$ for $h \neq i$.

and I defined GEO_i by including feedbacks from all other regions as follows.

$$MA_i = \sum_{j=1}^{J}\sum_{k=1}^{J}\sum_{n=1}^{N} \widetilde{G}_{iin}^{jk} MA_{in}^{k}$$

$$IC_i = \sum_{j=1}^{J}\sum_{k=1}^{J}\sum_{n=1}^{N} \widetilde{S}_{iin}^{jk} IC_{in}^{k}$$

$$GEO_i = \sum_{h\neq i}\sum_{j=1}^{J}\sum_{k=1}^{J}\sum_{n=1}^{N} \left(\widetilde{G}_{hin}^{jk} MA_{hn}^{k} + \widetilde{S}_{hin}^{jk} IC_{hn}^{k} \right)$$

A.2 Data Appendix

In this data appendix I describe in detail the construction of the data set.

Country sample. There are $C = 55$ countries in the sample excluding the United States, and $S = 51$ U.S. regions, which are 50 U.S. states and District of Columbia. All regions (countries and states) will be indexed by $i, n = 1, ..., N$ in the final file where $N = 106$ is the total number of countries and states. The United States as a whole is indexed by the subscript US.

Industries. I work with 27 industries indexed by $j = 1, ..., J$ that correspond to a subset of ISIC Rev. 3, NAICS 2012 industry concordance, and national classifications of some countries in the sample. Most input-output data is based on ISIC Rev. 3. Commodity Flow Survey and USA Trade state imports and export databases use the NAICS 2012 industry classification. Table (3) reports the list of the sectors used in this study and correspondences between ISIC3 and NAICS. There are imperfect matches between the correspondence of NAICS2012 and ISIC3, however at the aggregation level that I use, the correspondence is fairly consistent. The inconsistencies that lead to an imbalance in production and trade across different types of trade data will be scaled down or up in order to make sure that total production of each region in each sector will be equal to total sales.

Notation. Variables in levels are denoted by capital letters such as Z_i^j for sector j and region i. $Z_i = \sum_{j=1}^{J} Z_i^j$ corresponds to its aggregate level summed over all sectors. X_{in}^j is trade flows from i to n in sector j. Sum of X_{in}^j over i is expenditures of n from all countries in sector j, that is given by X_i. Sum of X_{in} over n is sales of i to all countries or gross output, Y_i. Lower case letters are used to denote the prices of goods or factors, and Greek letters are used for parameters that denote shares of certain variables. All variables are summarized in table (1).

Bilateral Trade Flows, Gross Output, Expenditures. In this section I calculate gross output Y_i^j, total expenditure X_i^j and value added VA_i^j of each region (country or state) i in sector $j = 1, ..., J$. The main statistic I use is bilateral trade between countries and states with each other, X_{in}^j for the traded sectors, which will be adjusted to form consistency across all data sources. Gross output and value added of non-traded sectors will be found by using shares of non-traded sectors in total country gross output, which are provided in the input output tables or national income account statistics. In addition, I impute the missing trade data agriculture, oil and gas sectors for the U.S. states using information from other datasets that can I identify trade between U.S. states in these sectors. In cases when I cannnot fully account for the interstate trade, I use trade data from other sectors to distribute the trade flows across states. First, I start with all countries in the sample in addition to the entire U.S. economy, and in the second part I break U.S. data into the states.

Input-Output Tables and National Accounts. (Sectors $j = 1, ..., 27$) I use national input-output tables and income accounts of every country in the database. I use WIOD Input Output Tables in 2011 for 40 countries[32]. I use the Asian Input Output Tables in 2005 (AIOT) for Malaysia, Philippines, Singapore and Thailand. I use OECD-Input Output Database for Argentina (1997), Chile (2003), Israel (2004), New Zealand (2002/3), Norway (2005), South Africa (2005), Switzerland (2001) and Vietnam (2000). I use national input-output tables for Kuwait in 2010 for Kuwait and Saudi Arabia, in addition to their national income accounts. I use Peruvian (2007) and Brunei (2005) input output tables and national account statistics. In addition to these countries I construct a region that will represent the rest of the world. I use the input output tables for the rest of the world in the WIOD database for this region[33].

Here is the description of each parameter calculated from input-output tables and national account statistics.

1. $\gamma_c^{0,j}$: share of value added in total output of a sector j in country c. Value added is denoted by VA_{c^*} and total intermediate good usage is denoted by INT_c^j. Gross output of sector j in country c is denoted by Y_c^j.

$$\gamma_c^{0,j} = \frac{VA_c^j}{VA_c^j + INT_c^j} = \frac{VA_c^j}{Y_c^j} \tag{55}$$

2. $\gamma_c^{k,j}$: share of input usage of sector j from sector k in total gross output of sector j.

$$\gamma_c^{k,j} = \frac{INT_c^{k,j}}{VA_c^j + INT_c^j} = \frac{INT_c^{k,j}}{Y_c^j} \tag{56}$$

[32] Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Taiwan, Turkey, United Kingdom, United States

[33] Some non-WIOD countries whose input-output data is used to construct the rest of the world region in the WIOD database are separate regions in my sample. As a result, their data will be included in the rest of the world region. Since the input output tables from non-WIOD countries is not compatible across years, I do not make any changes for the rest of the world region for input-output statistics and mainly input-output usage share parameters. However, the bilateral trade flows in levels will be obtained from the OECD Bilateral trade database, and will be perfectly consistent for all countries across all sectors.

International Trade and Tradable Goods. (Sectors $j = 1, ..., 15$) OECD-STAN Bilateral Trade Database reports exports of all countries in the sample according to the ISIC Rev. 3 classification. I find trade flows $X^j_{cc'}$, from country c to c' in sector j using exports and imports. OECD database does not report exports of all countries in the world, however it reports imports of countries in the sample from every country in the world. I sum imports of countries in the sample from countries that are represented in rest of the world, and find trade flows from rest of the world to each country accordingly.

I use the trade flow data from the year 2012. There does not exist any consistent database for domestic sales, X^j_{cc}. For domestic sales, I first derive total gross output Y^j_c in each sector, then subtract total exports $\sum_{c' \neq c} X^j_{cc'}$ from gross-output. I use mainly input-output tables for gross-output statistics, however I convert 2011 values in the WIOD database to 2012 for consistency. For countries that have earlier values, I either use their national income statistics in 2012, or use GDP growth rates to scale their gross-output values from earlier years to impute for values in 2012.

Non-tradable sectors. ($j = 16, ..., 27$) For the non-tradable sectors $j = 15, ..., 27$, I assume that expenditures are equal to output, $X^j_{cc} = X^j_c = Y^j_c$. Even though some of these sectors can be traded, I do not have a good dataset on trade in services, and thus ignore the trade in services. In order to match the size of the output of these sectors with the other non-tradable sectors, I use the share of output of each sector from their IO folder so that we will have

$$y^j_c = \frac{Y^j_c}{\sum_{k=1}^J Y^k_c} = \frac{Y^k_c(IO)}{\sum_{k=1}^J Y^k_c(IO)} = y^j_c(IO) \tag{57}$$

where the share on the right hand side can be computed for each sector from the IO tables, and using gross output Y^j_c for $j = 1, ..., 15$, the remaining Y^j_c $j = 1, ..., 27$ are derived. By this method I can also deal with inconsistencies across different types of input output table statistics, years and currencies.

U.S States. U.S. States are indexed by s, and countries are indexed by c in this section. Index $c = US$ is used for U.S. totals over all states, and $c = W$ is used the represent all countries except for the United States. State trade flows with all other states and countries will be calculated in this section using the U.S. Census Merchandise Trade Statistics. For interstate trade flows I use Commodity Flow Survey. All data is from year 2012.

(i) U.S. State Exports and Imports: I use the U.S. Merchandise Trade Statistics (USATRADE Online) in 2012 for imports and exports of U.S. states with respect to all countries in the world. This database reports the trade values according to the 3 and 4 digit NAICS 2012 classification. After converting these tradable sectors to the sectoral classification that I use in my sample, I scale the trade flows in each tradable sector $j = 1, ..., 15$ to match the level of total U.S. imports and exports from OECD-Bilateral Trade Database. This scaling procedure provides consistency across different commodity classifications and any difference in the method of data collection between two different datasets.

1. I find the total exports and imports of the U.S. with respect to all countries using

OECD-Bilateral Trade and USA Trade by summing up all state imports and exports.

(a) Denote total U.S imports from these two datasets respectively as $X^j_{USW}(oecd)$ and $X^j_{USW}(usatrade)$.

(b) Denote $X^j_{WUS}(oecd)$ and $X^j_{WUS}(usatrade)$ for total U.S. imports.

2. I scale the USATRADE trade flows $X^j_{sc}(usatrade)$ and $X^j_{cs}(usatrade)$ between state s and country c to match total U.S. exports and imports with the rest of the world

$$X^j_{USW}(usatrade) = X^j_{USW}(oecd) \quad \Rightarrow \quad X^j_{sc} = X^j_{sc}(usatrade)\left[\frac{X^j_{USW}(oecd)}{X^j_{USW}(usatrade)}\right]$$

$$X^j_{WUS}(usatrade) = X^j_{WUS}(oecd) \quad \Rightarrow \quad X^j_{cs} = X^j_{cs}(usatrade)\left[\frac{X^j_{USW}(oecd)}{X^j_{USW}(usatrade)}\right]$$

Overall, export and import flows of each state s with respect to country n for tradable sectors $j = 1,...,15$ are given as X^j_{sc} and X^j_{cs} respectively.

(ii) Interstate Trade. $(j = 3,...,15)$ The Commodity Flow Survey (in 2012) reports the bilateral shipments of NAICS industries between U.S. states. It does not report agricultural (NAICS-11) or oil-gas (NAICS-211) sectors, and hence the data is available for only 13 sectors $(j = 3-15)$ according to my sector sample. I will discuss how to impute the trade flows for missing sectors $j = 1,2$ shortly.

1. Similar to what I have done above for USATRADE data, I will adjust the CFS shipments to match their totals with the global U.S. domestic sales. I sum shipments between all states s and s', $X^j_{ss'}(cfs)$ to find U.S. domestic sales $X^j_{USUS}(cfs)$, and scale each $X^j_{ss'}(cfs)$ to match $X^j_{USUS}(cfs) = X^j_{USUS}(oecd)$.

$$X^j_{ss'} = X^j_{ss'}(cfs)\left[\frac{X^j_{USUS}(oecd)}{X^j_{USUS}(cfs)}\right] \tag{58}$$

where $X^j_{USUS}(oecd)$ was the total sectoral domestic trade flows of the U.S. using input-output, gross-output data, and U.S. exports using the OECD Bilateral Trade Database. $X^j_{USUS}(cfs)$ is the total sectoral domestic shipments $X^j_{USUS}(cfs) = \sum_s \sum_{s'} X^j_{ss'}(cfs)$.

2. Gross output of each state in sector $j = 3,...,15$ is the sum of all shipments from state s to all other regions states s and countries c

$$Y^j_s = \sum_{s'}^{S} X^j_{ss'} + \sum_{c=1}^{C} X^j_{sc} = \sum_{n=1}^{N} X^j_{sn} \tag{59}$$

3. I use aggregate United States value added γ^j_{US} and intermediate good usage γ^{kj}_{US} shares for U.S. states in each sector.

(iii) Agriculture. (Sector $j = 1$) I use the total output and value added data from USDA/ERS U.S. and State Farm Income and Wealth Statistics that reports total agricultural production and gross value added in each state. The total production value may not be consistent with the other datasets. Therefore, I will use the shares of each state in total U.S. agricultural production $y_s^1 = \frac{Y_s^1}{\sum_{s'=1}^{J} Y_{s'}^1}$, and find the gross output of each state s in sector 1 by

$$Y_s^1 = y_s^1 Y_{US}^1$$

where Y_{US}^1 is the total U.S. agricultural output, that is found at an earlier step above.

I do not know the interstate trade $X_{ss'}^1$ (from state s to state s') in the agricultural sector. But I know $X_{sn}^1(usatrade)$ to other countries. I will adjust these shipments so that their U.S. total will be equal to total U.S. exports to the rest of the world (and repeat it for imports). As a result, for each state s, the total shipments of a state s to U.S. in sector $j = 1$ will be its output less its exports to the rest of the world

$$X_{sUS}^1 = Y_s^1 - X_{sW}^1$$

. The Commodity Flow Survey reports agricultural commodities according to its Standard Commodity Transported Goods (SCTG) classification. The commodity codes 01-09 represent agricultural commodities. While these goods are in fact shipped by establishments that are not registered in the agricultural sector (or farm sector), their trade of agricultural commodities provides a good proxy to impute the missing trade flows in the agricultural sector. The main sectoral classification NAICS represents the industry code of the establishment.

(iv) Oil and Gas: (Sector $j = 2$)For crude oil and natural gas gross-output, I use the total value of shipments and receipts for services of the NAICS-211 sector from "Mining: Geographic Area Series: Industry Statistics for the State or Offshore Area" series of the Economic Census of the United States in 2012. Trade flows for this sector does not exist in any source, however, I imputed trade flows for crude oil and natural gas using multiple sources. For oil shipments, I use the EIA domestic oil shipments data between the PADD districts.[34] There are only 6 PADD districts, and the shipments among them are not completely disaggregated at the state level. However, I disaggregated the PADD district trade flows using interstate trade data (CFS) for other sectors. Even though this does not perfectly match the data, interstate trade flows reflect the role of geography and can be an imperfect substitute to disaggregate these trade flows.

As for the natural gas shipments, I created trade flows using the EIA U.S. State-to-State natural gas pipeline capacity data. I found the share of outflow capacity of each state with respect to all other states and distributed their total value of natural gas to trade flows. I found the total value of oil and natural gas production of each state using EIA Crude Oil and Natural Gas Statistics and USDA-ERS Crude Oil and Natural Gas statistics. I converted the quantities of natural gas and crude oil to U.S. dollar values by using the

[34] Petroleum Administration and Defense Districts (PADD) are 6 regions (East Coast, Midwest, Gulf Coast, Rocky Mountain and West Coast) used for data collection purposes for crude oil.

average prices of \$94,88 per gallon of crude oil and \$3.95 per thousands of cubic feet of natural gas.

(v) Non-tradables. (Sectors $j = 16 - 27$) I assume that the trade flows between sectors (and the world) for these sectors are zero. Even though some of these services are traded (and in fact much more across U.S. states relative to international trade) there is no data available for the trade in services.

As a result, gross output will be equal to expenditures $X_s^j = Y_s^j$. Since I do not have trade flow data for these sectors, I will not be able to find gross output with the procedure above. I follow the following method to find output and value added for non-tradable sectors in each state.

1. Find total U.S. output Y_{US}^j for each $j = 16, \ldots, 27$ using their shares y_{US}^j from the input-output tables to the rest of the economy using total output Y_{US}^j of tradable sectors $j = 1, \ldots, 15$.
2. Find U.S. value added $VA_{US}^j = \gamma_{US}^{0,j} Y_{US}^j$ for $j = 16, \ldots, 27$.
3. Find share of GDP (value added) of each state s and each sector $j = 16, \ldots, 27$ in total U.S. GDP of that sector. Denote this share as v_s^j.
4. Find state value added in sector $j = 16, \ldots, 27$: $VA_s^j = v_s^j VA_{US}^j$.
5. Assume that the value added to output ratio for states, $\gamma_s^{0,j}$ are all equal to that of the U.S., $\gamma_{US}^{0,j}$ for the non-tradable sectors. Then find output of each state as:

$$Y_s^j = \frac{VA_s^j}{\gamma_{US}^{0,j}}$$