Essays on Local Impact of International Trade

by

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For my parents Deniz and Levent

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

In my dissertation I study how changes in international trade policies affect economic or institutional outcomes. I focus on local geographical regions as the unit of analysis, and analyze the variation of economic and other characteristics of sub-regions within a country to explain the potential effect of economic shocks.

Chapter 1 analyzes the distributional welfare effects of trade policies by focusing on the potential effects of Trans-Pacific Partnership tariff reductions on welfare of U.S. states. I compute the welfare predictions using a standard international trade model that includes data on a sample of countries and U.S. states. I drop the assumption of full labor mobility across the United States by introducing heterogeneous tastes for locations in order to generate real income differentials across locations. My quantitative results show that while TPP leads to a very small increase in U.S. real wages, the variation across states are considerably high due to different specialization of states in their production and trade partners. I explain the channels that lead to this variation through the lens of the model and break down the effects of real wages to sectoral and trade partner related decompositions. Subsequently, I show that relying on trade exposure measures that are based on sectoral composition of local geographies cannot substitute for regional trade flow data. I compare two trade exposure specifications: with real trade data, and with a sectoral production based trade exposure. I find that when real trade data are omitted, the high export and import volumes of particular regions with partners of trade agreements will not be accounted for. Therefore, their exposure due to a trade liberalization will be greatly understated whereas some other regions' gains would be overstated. Finally I implement robustness checks on various measures of migration and trade elasticity and present how relevant they are for an analysis for local geographies.

Chapter 2 examines the effect of international trade on skill premium using an international trade model suitable for local geographies, local level data and multiple skills or tasks in the production process as factors. I split the labor force into three

groups with low-skilled, medium-skilled, and high-skilled workers using data on earnings and employment by occupation, industry and geography. I calibrate the model using data on production, trade, input-output linkages and skill/occupation measures to predict the implications of two specific trade policies: Trans-Pacific Partnership tariff reductions, and unilateral elimination of U.S. tariffs on Chinese goods. I find the effects of these policies on real wages of three skill groups in each U.S. states, and show the changes in skill premium, defined as the income difference between high-skilled and low-skilled workers.

Chapter 3 studies how exposure to international trade affects political opinions for secessionism. I focus on the Catalan independence movement and test whether sub-regions of Catalonia that specialize in sectors that are more open to international trade with low trade volumes with the rest of Spain are more likely to exhibit higher stances for secession from Spain. I use an international trade model and treat secession of Catalonia from Spain as if it is a negative trade policy shock that increases trade costs between Catalonia and Spain. I find potential costs of secession to each sector through the model and generate a variation in terms of exposure from Catalan independence for each Catalan municipality according to their sectoral specialization. Then, I statistically test whether the variation in exposure to independence can explain political opinions for independence in Catalan municipalities by using vote shares of political parties that have a pro-independence position as a proxy for opinions for secession in each municipality. I control for other possible determinants and endogeneity. I find that moving from a municipality that is at the 25th percentile of negative exposure value to a municipality around the 75th percentile exposure increases independence opinions for secession by 9.2 percentage points in terms of vote share.

CHAPTER 1

LOCAL WELFARE IMPACT OF TRADE POLICY: TRANS-PACIFIC PARTNERSHIP AND U.S. STATES

1.1 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 sub-grouping 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 for 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, by assuming that changes in consumer prices would be identical across regions, previous studies have not analyzed changes in real-incomes or welfare of local labor markets. Different

[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.

markets might demonstrate variation through various channels in their exposure to a trade agreement; their gains (or losses) might result from production and sales, or from 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 will 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, but that 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 of 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

[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.

[4]In general trade models predict low welfare effects and 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. These models use changes in tariff rates as trade policy instrument, and these changes are often small, which generate relatively small effects in terms of welfare. Yet, the long-term effects of international trade on nominal earnings and employment are

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 of 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 for 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 from the price effects due to cheaper imports. Agricultural and food producing states such as Iowa, Kansas, and 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 import prices, and some of 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 their neighboring regions.

This paper is related to a growing body of literature on distributional effects of

well-documented in the economics literature.

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 subcomponents 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 of the labor market adjustment of the U.S. states due to a global productivity shock. They incorporate a dynamic labor market adjustment framework into 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 transmits 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 on 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

[5] Another strand of the literature studies the effects of global shocks on different skill groups. I focus on the occupational implications of trade policies in chapter 2. See also 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 find consequences of international trade for different skill groups.

for ex-post welfare evaluation after observing the data on domestic trade shares, but does not explain the factors that lead to differences in gains from trade across regions.

The results of this paper have several implications for trade policy. First, the 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; this 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 provides 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.

1.2 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.

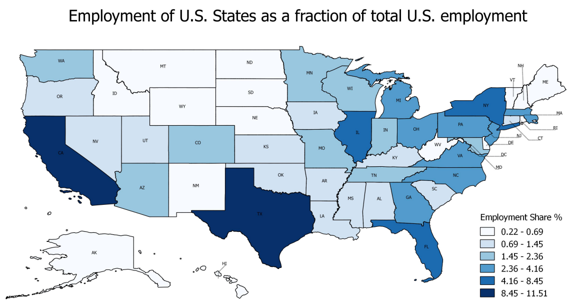
[6] See Glaeser and Gottlieb (2008) for a survey on place-based government welfare programs. Other programs on an individual or industrial basis are also implemented due to trade policies.

1.2.1 U.S. States versus Countries

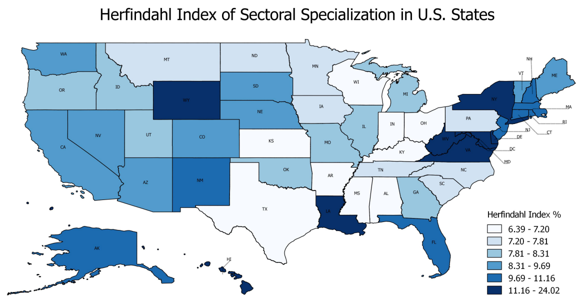
The U.S. economy is distinctive in its structure of being formed by many large states, each of which could be classified as relatively large countries on their own. The largest U.S. state in terms of its economic size, California, could be the 6th or 7th largest economy in the world on its own, which 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 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 1.1: Employment, GDP per capita, sectoral specialization and traded good production of U.S. States in 2012

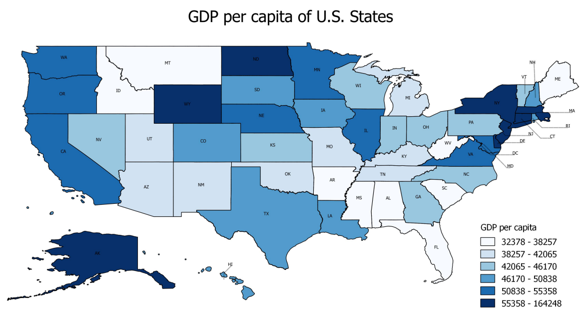
(a) Employment



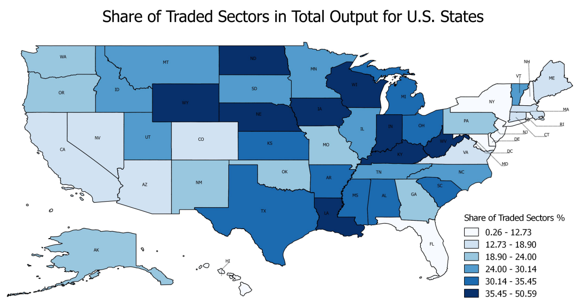
(b) Specialization



(c) Gross Domestic Product



(d) Traded Good Production



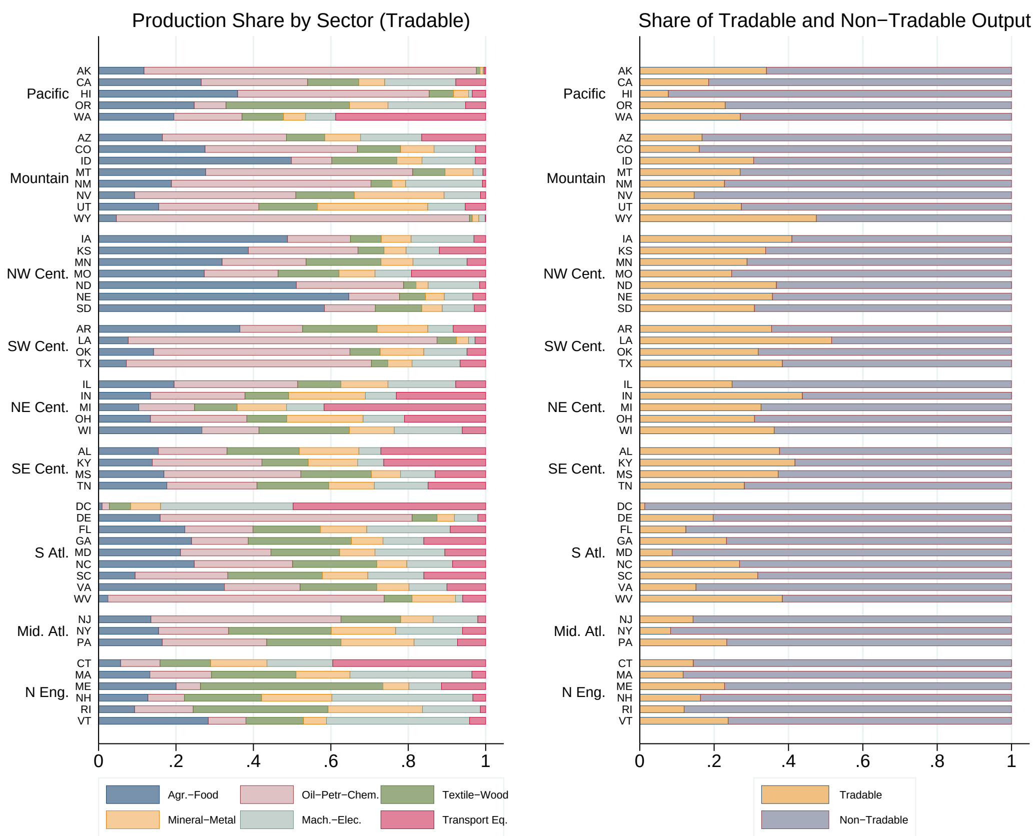
Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

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 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 1.2: U.S. State Sectoral Production in 2012

(a) Tradable Production

(b) Tradable and Non-Tradable Production



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

[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.

1.2.2 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]

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.

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.

[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.

Figure 1.3: U.S. State Sales by Destination in 2012

(a) Exports (b) Total Sales

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

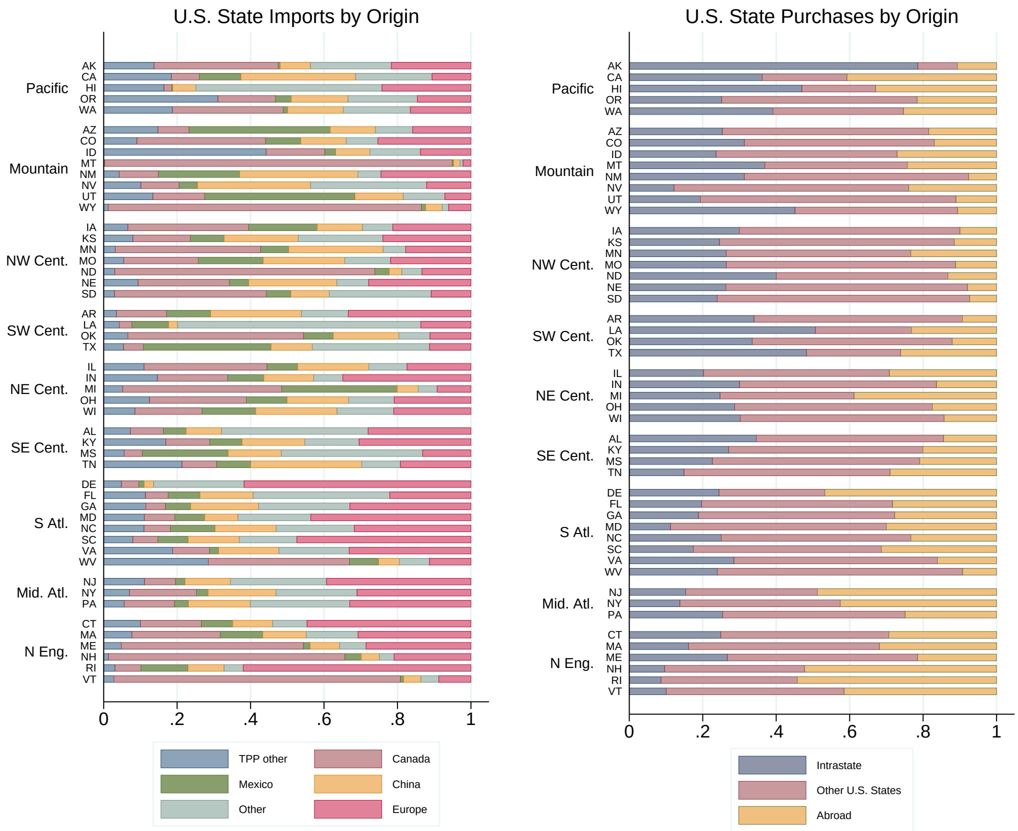
1.2.3 Trade Exposure Measures

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 1.4: U.S. State Purchases by Origin in 2012

(a) Imports (b) Total Purchases



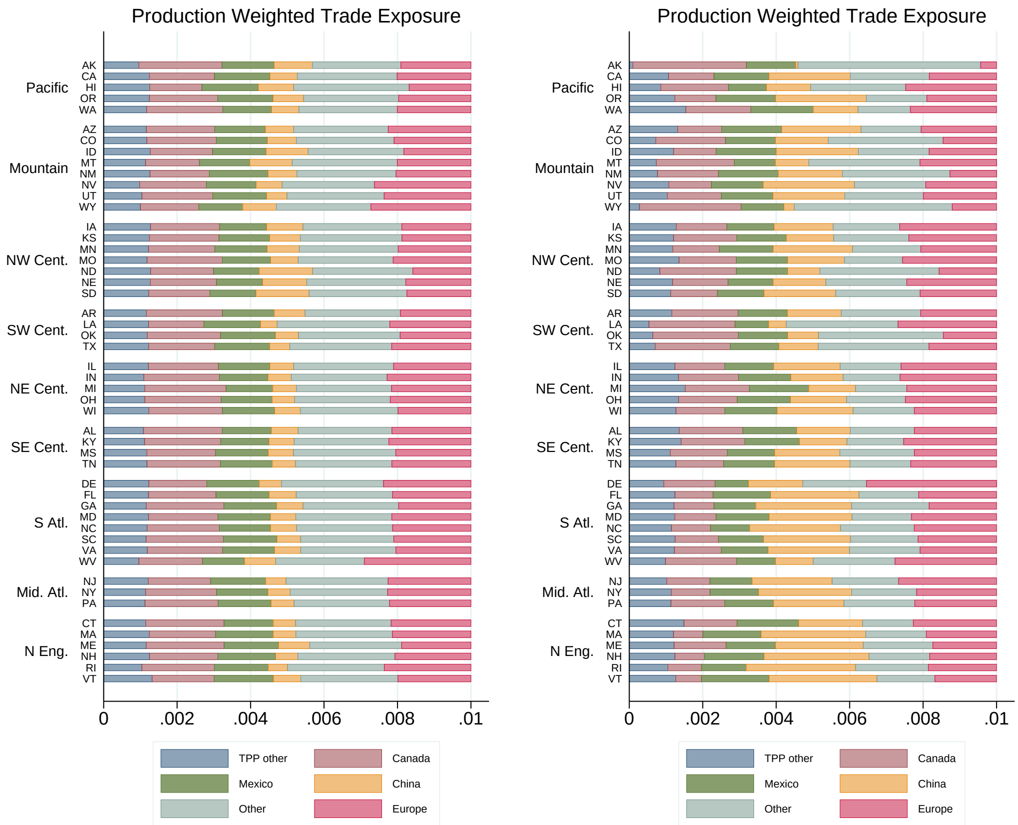
Source: BEA Regional Economic Accounts, Commodity Flow Survey, U.S. Census Merchandise Trade Statistics and own calculations.

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, although 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.

Figure 1.5: U.S. State Exports and Imports with Sectoral Production-weighted Trade Exposure

(a) Exports by Destination (b) Imports by Origin



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

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.

1.3 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.

1.3.1 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 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.

[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.

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

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

$$C_i = \prod_{j=1}^{J} \left(C_i^j\right)^{\beta_i^j} \tag{1.1}$$

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

$$U_s(\nu) = b_i(\nu) C_i \tag{1.2}$$

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

$$\frac{L_s}{L_{US}} = \frac{B_s\left(w_s/P_s\right)^{\varepsilon}}{\sum\limits_{s'\in S} B_{s'}\left(v_{s'}/P_{s'}\right)^{\varepsilon}} \tag{1.3}$$

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.

[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.

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

$$c_i^j = \xi_i^j (w_i)^{\gamma_i^{0j}} \prod_{k=1}^{J} \left(P_i^k\right)^{\gamma_i^{kj}} \tag{1.4}$$

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

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

[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.

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

$$P_i^j = \left[\int_0^1 p_i^j \left(\omega^j\right)^{1-\sigma^j} d\omega^j \right]^{1/(1-\sigma^j)} \tag{1.5}$$

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 $X_i^j = P_i^j M_i^j + P_i^j C_i^j$.

1.3.2 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

$$\pi_{ni}^j = \frac{X_{ni}^j}{\sum_{m=1}^N X_{mi}^j} = \frac{\left(\Phi_{ni}^j\right)^{-\theta^j}}{\sum_{m=1}^N \left(\Phi_{mi}^j\right)^{-\theta^j}} \tag{1.6}$$

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

$$\Phi_{ni}^j = \frac{c_n^j d_{ni}^j \left(1 + \tau_{ni}^j\right)}{\left(T_n^j\right)^{\gamma_n^{0,j}}} \tag{1.7}$$

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

$$P_i^j = \Gamma^j \left[\sum_{n=1}^{N} \left(\Phi_{ni}^j \right)^{-\theta^j} \right]^{-\frac{1}{\theta^j}} \tag{1.8}$$

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.

$$X_i^j = \sum_{k=1}^{J} \gamma_i^{j,k} Y_i^k + \beta_i^j I_i \tag{1.9}$$

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

$$Y_i^j = \sum_{n=1}^{N} \frac{X_{in}^j}{1 + \tau_{in}^j} = \sum_{n=1}^{N} \frac{\pi_{in}^j X_n^j}{1 + \tau_{in}^j} \tag{1.10}$$

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

$$I_i = w_i L_i + R_i + D_i \tag{1.11}$$

Total trade imbalances are the sum of sectoral deficits given by

$$D_i = \sum_{j=1}^{J} D_i^j = \sum_{j=1}^{J} \left(X_i^j - Y_i^j - R_i^j \right) \tag{1.12}$$

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

$$R_i = \sum_{j=1}^{J} R_i^j = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\tau_{ni}^j}{1 + \tau_{ni}^j} \pi_{ni}^j X_i^j \tag{1.13}$$

It is implied from these equations that labor market clearing condition will determine

[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.

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 $j = 1,...,J$

$$w_i L_i = \sum_{j=1}^{J} \gamma_i^{0,j} Y_i^j = \sum_{j=1}^{J} \gamma_i^{0,j} \sum_{n=1}^{N} \frac{\pi_{in}^j X_n^j}{1+\tau_{in}^j} \tag{1.14}$$

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 (2.3), unit cost function (2.5), trade share (2.7), price index (2.9), total expenditure equation (2.10), trade balance (2.13) and labor market clearing equation (2.15).*

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 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.

1.3.3 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 employment 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

$$\widehat{L}_s = \frac{\left(\widehat{w}_s/\widehat{P}_s\right)^{\varepsilon}}{\sum\limits_{s' \in S} \frac{L_{s'}}{L_{US}} \left(\widehat{w}_{s'}/\widehat{P}_{s'}\right)^{\varepsilon}} \tag{1.15}$$

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

$$\widehat{P}_s = \prod_{j=1}^{J} \left(\widehat{P}_s^j\right)^{\beta_s^j} \tag{1.16}$$

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 $j = 1, ..., J$

$$\widehat{c}_i^j = \widehat{w}_i^{\gamma_i^{0,j}} \prod_{k=1}^{J} \left(\widehat{P}_i^j\right)^{\gamma_i^{k,j}} \tag{1.17}$$

$$\widehat{P}_i^j = \left[\sum_{n=1}^{N} \pi_{ni}^j \left(\widehat{c}_n^j \widehat{(1 + \tau_{ni}^j)}\right)^{-\theta^j}\right]^{-1/\theta^j} \tag{1.18}$$

$$\widehat{\pi}_{in}^j = \left[\frac{\widehat{c}_i^j \left(\widehat{1 + \tau_{in}^j}\right)}{\widehat{P}_n^j}\right]^{-\theta^j} \tag{1.19}$$

Total Expenditures. The new expenditure level, $(X_i^j)'$ is the analog of equation (2.10) with using the new levels of variables for $i = 1, ..., N$ and $j = 1, ..., J$

$$\left(X_i^j\right)' = \sum_{k=1}^{J} \gamma_i^{j,k} \sum_{n=1}^{N} \frac{\widehat{\pi}_{in}^j \pi_{in}^j \left(X_n^j\right)'}{\left(1 + \tau_{in}^j\right)'} + \beta_i^j \left(\widehat{w}_i w_i L_i' + R_i' + D_i\right) \tag{1.20}$$

where the new tariff revenue level is given by

$$R_i' = \sum_{j=1}^{J}\sum_{n=1}^{N} \frac{\left(\tau_{ni}^{j}\right)'}{\left(1+\tau_{ni}^{j}\right)'} \left(X_{ni}^{j}\right)' \tag{1.21}$$

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 $i = 1, ..., N$

$$\sum_{j=1}^{J}\sum_{n=1}^{N} \frac{\left(X_{ni}^{j}\right)'}{\left(1+\tau_{ni}^{j}\right)'} - D_i = \sum_{j=1}^{J}\sum_{n=1}^{N} \frac{\left(X_{in}^{j}\right)'}{\left(1+\tau_{in}^{j}\right)'} \tag{1.22}$$

$$w_i' L_i' = \sum_{j=1}^{J} \gamma_i^{0,j} \left(Y_i^{j}\right)' = \sum_{j=1}^{J}\sum_{n=1}^{N} \frac{\widehat{\pi}_{in}^{j} \pi_{in} \left(X_n^{j}\right)'}{\left(1+\tau_{in}^{j}\right)'} \tag{1.23}$$

1.3.4 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 (2.16) and (2.17).
3. Find $\widehat{\pi}$ using equation (2.18).

Table 1.1: 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^{0j}_i	VA share in production	IO Tables
γ^{kj}_i	Int. good share	IO Tables
β^j_i	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. Using $\widehat{\mathbf{w}}$ and $\widehat{\mathbf{P}}$, find $\widehat{L_s}$ for each $s \in S$ from equation (2.19). For new tariff revenue, use $(R_i)'$ from existing X^j_n, and new tariff $\left(1+\tau^j_{in}\right)'$ and new trade share $\left(\pi^j_{ni}\right)'$.
5. Using L'_s solve for $(X^j_i)'$ from equation (2.20).
6. Check if new deficit vector implied by $(X^j_n)'$, 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.

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 (1.1). See the data appendix section for a more detailed explanation.

1.4.1 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 (1.2). 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 (1.3). Sectors 1-15 are tradable, and sectors 16-27 are non-tradable.

1.4.2 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.

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

[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, 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".

Table 1.2: Country Sample and Descriptive Statistics

Country	*GDP %*	*Exp. %*	*Imp. %*	*Country*	*GDP %*	*Exp. %*	*Imp. %*
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 Rep.	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 States	1.27	0.66	1.03	UK	3.24	2.78	3.78
Hungary	0.18	0.61	0.51	ROW	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 1.3: 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	Accommodation 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.

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.

1.4.3 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.

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

[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.

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 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

[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 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.

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.

1.4.4 Other Parameters

Sectoral consumption share: I find the shares of each sector in final household consumption, β_i^j are from equation (2.10). 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

$$X_s^j = \sum_{k=1}^{J} \gamma_s^{jk} Y_s^k + \beta_{US}^j (w_s L_s + R_s + D_s) + E_s^j \tag{1.24}$$

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.

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

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 $j = 1, ..., 15$. 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.

1.4.5 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 $j = 1, ..., 15$.[23] I denote tariff rates from country i to j in sector j as τ^j_{in}. I use the "effectively applied rates" 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 1.4). 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 (1.5) and (1.6) the sectoral breakdown of U.S. tariffs on its imports and the tariffs that its trade partners impose on U.S. exports.

1.5 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

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

Table 1.4: 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 1.5: 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 1.6: 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

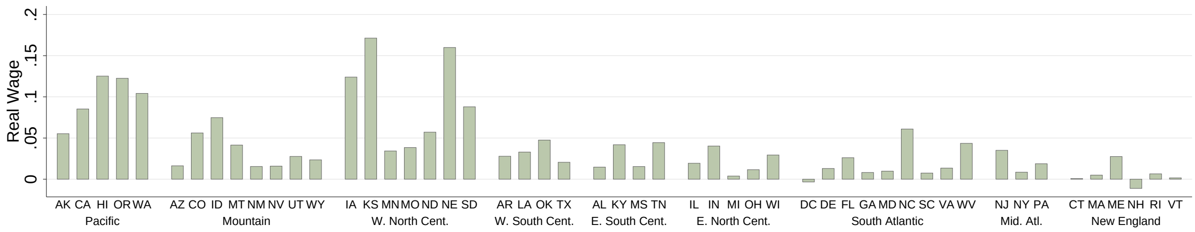
Source : TRAINS bilateral tariffs database obtained from WITS (http://wits.worldbank.org). The tariffs are the ad valorem equivalent of "effectively applied rates" for 2-digit ISIC Rev. 3 sectors. Effectively applied rates represents the effective rate at which tariffs are applied, and lie between the 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.

China to the agreement (and removing tariffs in all sectors to zero).

1.5.1 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 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 1.6: Percent changes in Real Wages of U.S. States due to TPP: Benchmark Scenario

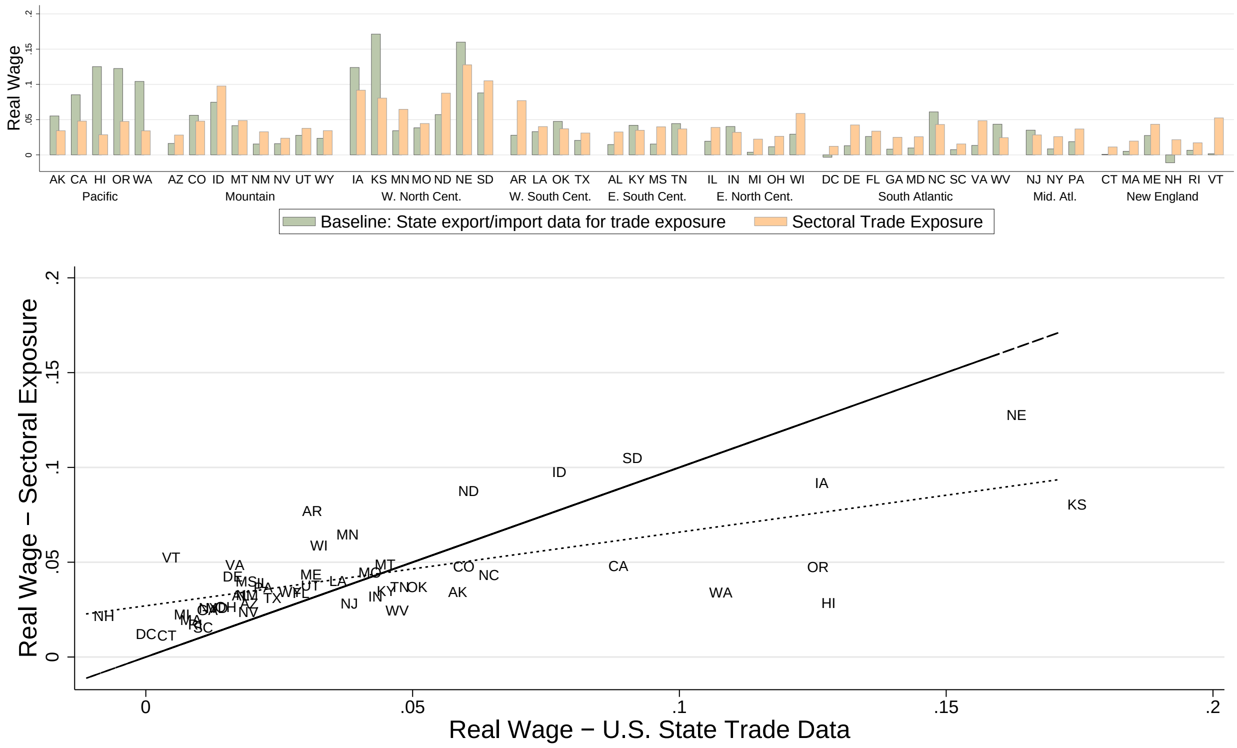


Note: Trade elasticity $\theta^j = 4.14$ for all sectors, labor mobility parameter $\varepsilon = 1.34$.

Figure (1.6) 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 (1.7) 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 (1.7) the difference between using the benchmark data (Data1) and the sectoral trade exposure data (Data2).

Figure 1.7: Data Specification: Trade Exposure

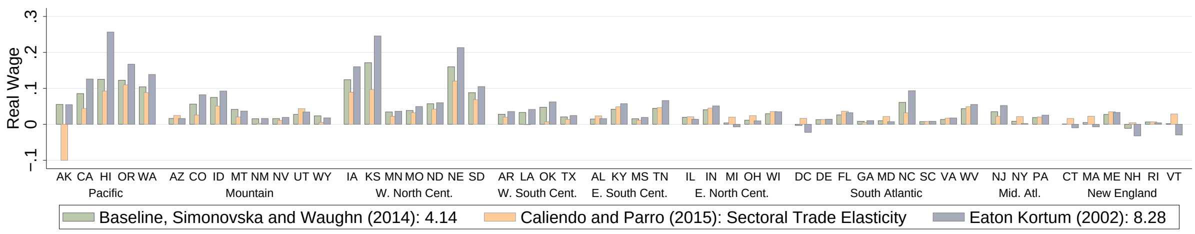


It turns out that the real wages of the Pacific states and agriculture-food producing states would be greatly understated and the real wage changes of states on the East would be overstated if we were to use a trade exposure based on sectoral production. The sectoral based measure can still explain to 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 (1.7) 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 (1.8). First I report the real wage changes

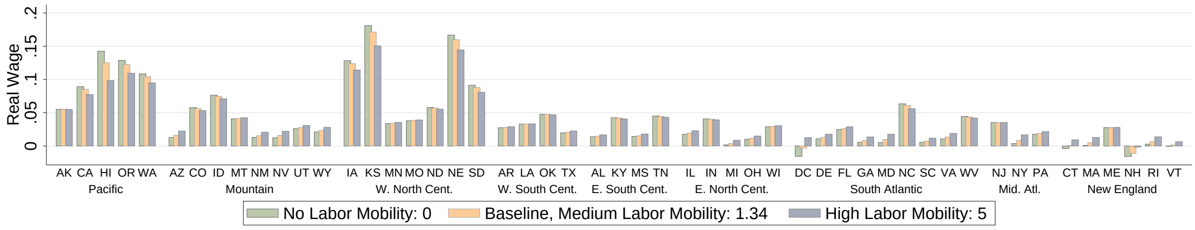
Figure 1.8: Simulation Results: Sensitivity to Trade Elasticity



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 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.

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

Figure 1.9: Simulation Results: Sensitivity to Migration Elasticity



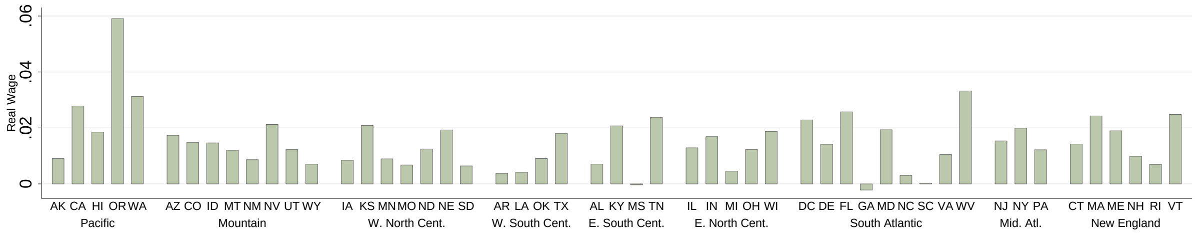
do not observe a one to one relationship between real wages and labor mobility. We would need a much higher labor mobility elasticity (around 50 or more) to eliminate real wage differentials. A higher number of this sort is unreasonable to be supported with data in the short and medium run.

1.5.2 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.

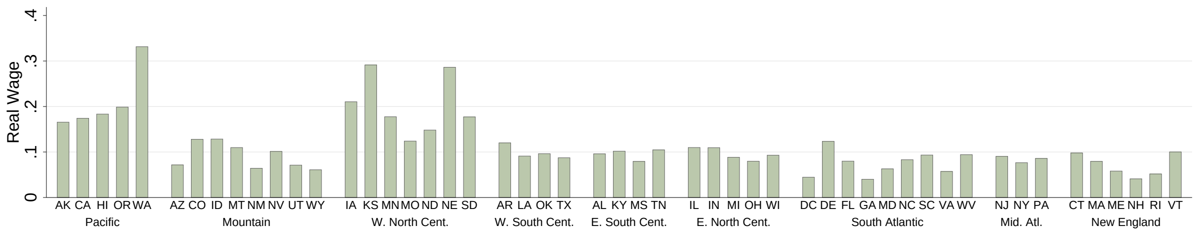
The most striking fact is the U.S. trade deficit with China whereas U.S. enjoys a surplus with the TPP members. Hence, any trade agreement that lowers tariffs between the U.S. and China will be reflected on mainly consumption (imports), and not production (exports) for the U.S. states, and it is likely 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 agriculture and food sectors from the TPP agreement, are shown on figure (1.10). 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

Figure 1.10: Simulation Results: No Reductions in Agriculture-Food sectors



gains when agriculture and food sectors are not included in this agreement.

Figure 1.11: Simulation Results: Adding China to TPP



I plot on figure (1.11) 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 (1.7). For most TPP countries including agriculture and food sector tariffs improve welfare whereas incorporating China to the agreement can triple these gains.

1.6 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

Table 1.7: 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.

decomposition where I take into account all specifications of the model with multiple sectors, input-output linkages and trade imbalances.

1.6.1 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}

$$X_{in}t_{in} = \frac{\left(\frac{w_i \delta_{in} t_{in}}{T_i}\right)^{-\theta}}{\Phi_n} X_n \tag{1.25}$$

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.

$$\Phi_n = \sum_{h=1}^{N} \left(\frac{w_h \delta_{hn} t_{hn}}{T_h}\right)^{-\theta} \tag{1.26}$$

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

$$w_i L_i = \sum_{n=1}^{N} X_{in} \tag{1.27}$$

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

$$\widetilde{X}_{in} + \widetilde{t}_{in} = \widetilde{X}_n - \theta\left(\widetilde{w}_i + \widetilde{t}_{in}\right) - \widetilde{\Phi}_n \tag{1.28}$$

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

$$\widetilde{w}_i = \sum_{n=1}^{N} \eta_{in} \widetilde{X}_{in} \qquad \text{Labor market clearing condition} \tag{1.29}$$

$$\widetilde{X}_{in} = \widetilde{X}_n - \theta \widetilde{w}_i - (1+\theta)\widetilde{t}_{in} - \widetilde{\Phi}_n \qquad \text{Gravity equation} \tag{1.30}$$

$$\widetilde{X}_n = \widetilde{w}_n \qquad \text{Trade Balance: Expenditure = Income} \tag{1.31}$$

$$\widetilde{\Phi}_n = \sum_{h=1}^{N} \pi_{hn}(-\theta)\left(\widetilde{w}_h + \widetilde{t}_{hn}\right) \qquad \text{Competitiveness} \tag{1.32}$$

This system reduces to a single equation

$$\widetilde{w}_i = \sum_{n=1}^{N} \eta_{in} \left[\widetilde{w}_n - \theta \widetilde{w}_i - (1+\theta)\widetilde{t}_{in} - \sum_{h=1}^{N} \pi_{hn}(-\theta)\left(\widetilde{w}_h + \widetilde{t}_{hn}\right) \right] \tag{1.33}$$

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.

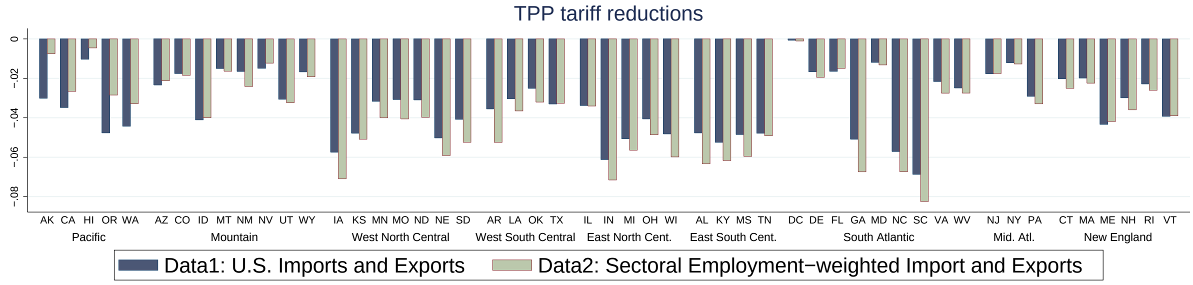
1.6.2 Partial Direct Effects

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

$$IC_i^{PE} = \theta \sum_{n=1}^{N} \sum_{h \neq i}^{N} \eta_{in} \pi_{hn} \widetilde{t}_{hn} \tag{1.34}$$

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 (1.12) 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 1.12: Direct Import Competition (PE) Effects - U.S. States

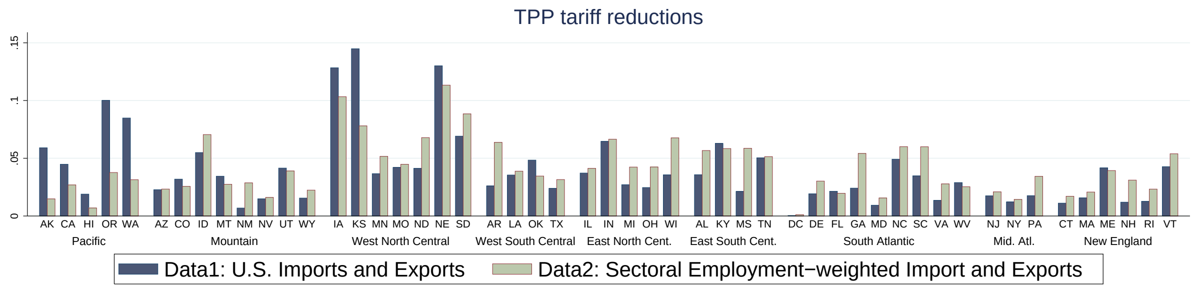


On the other hand, there is a direct positive effect on region i if tariffs imposed on region i by other markets decrease, i.e. $\widetilde{t_{in}} < 0$. I define this positive direct effect by market access

$$MA_i^{PE} = \sum_{n=1}^{N} \eta_{in} \left[-(1 + \theta - \theta \pi_{in}) \widetilde{t_{in}} \right] \tag{1.35}$$

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 (1.13). 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).

Figure 1.13: Direct Market Access (PE) Effects - U.S. States



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 deviation analogue are given by

$$P_i = \Phi^{-1/\theta} \tag{1.36}$$

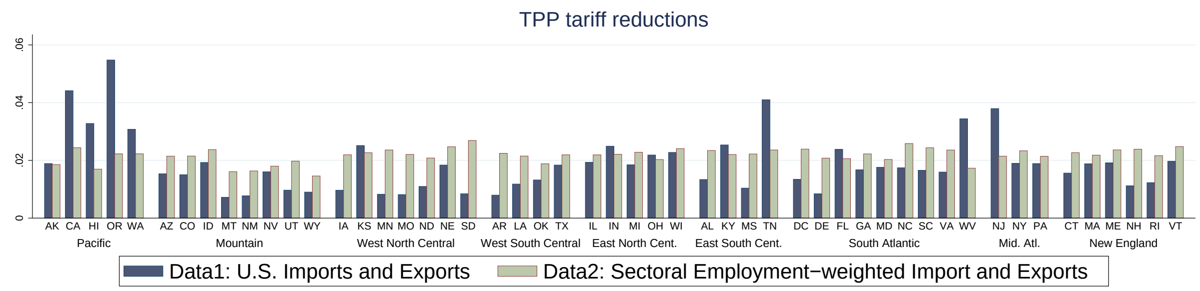
$$\widetilde{P_i} = \sum_{n=1}^{N} \pi_{ni} \left(\widetilde{w}_n + \widetilde{t}_{ni} \right) \tag{1.37}$$

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

$$CPI^{PE} = -\sum_{n=1}^{N} \pi_{ni} \widetilde{t}_{ni} \tag{1.38}$$

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 (1.14 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 1.14: Direct Price Index (PE) Effects - U.S. States



1.6.3 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 (1.33). First, grouping the endogenous wage terms and the exogenous terms together we can express this equation as

$$\widetilde{w}_n = \sum_{h=1}^{N-1} \alpha_{ih}\widetilde{w_h} + MA_i^{PE} + IC_i^{PE} \tag{1.39}$$

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

$$\widetilde{w}_i = \sum_{h=1}^{N-1} \left(\alpha_{ih} - \alpha_{iN}\frac{L_h}{L_W}\right)\widetilde{w}_h + MA_i^{PE} + IC_i^{PE} \tag{1.40}$$

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

$$(\mathbf{I} - \mathbf{A})\mathbf{w} = \mathbf{B} \tag{1.41}$$

which solves for wages

$$\mathbf{w} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{B} \tag{1.42}$$

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]

$$\widetilde{w}_i = \sum_{h=1}^{N-1} \mu_{hi}(MA_h^{PE} + IC_h^{PE}) \tag{1.43}$$

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

$$GEO_i = \sum_{h=\neq i}^{N-1} \mu_{hi}(MA_h^{PE} + IC_h^{PE}) \tag{1.44}$$

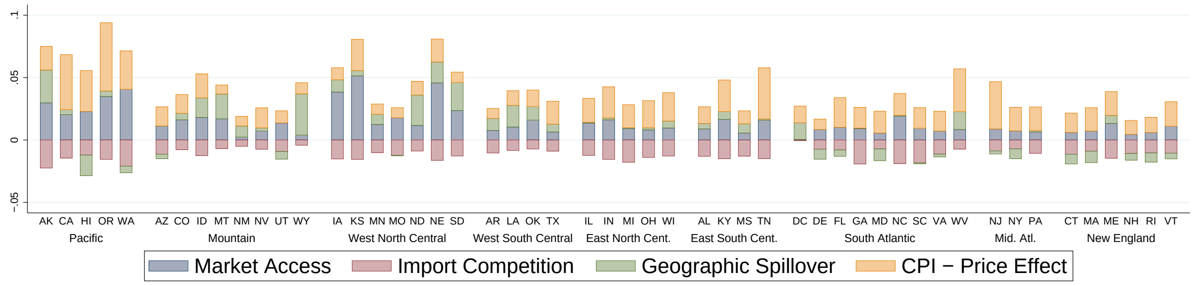
Then, I also plug in the wage term in the price equation and write real wages as

$$\begin{aligned} \widetilde{w}_i - \widetilde{P}_i &= \mu_{ii}MA_i^{PE} + \mu_{ii}IC_i^{PE} + GEO_i + CPI_i^{PE} && (1.45) \\ &= MA_i + IC_i + GEO_i + CPI_i && (1.46) \end{aligned}$$

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

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

Figure 1.15: Real Wage Decomposition



(1.15).[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 regions benefit from a trade agreement, but if the

[25]Note that the scale on figure (1.15) is different than the results I have presented in section 5 on graph (1.6) since the decomposition method here uses first-order approximations and report smaller changes compared to exact values.

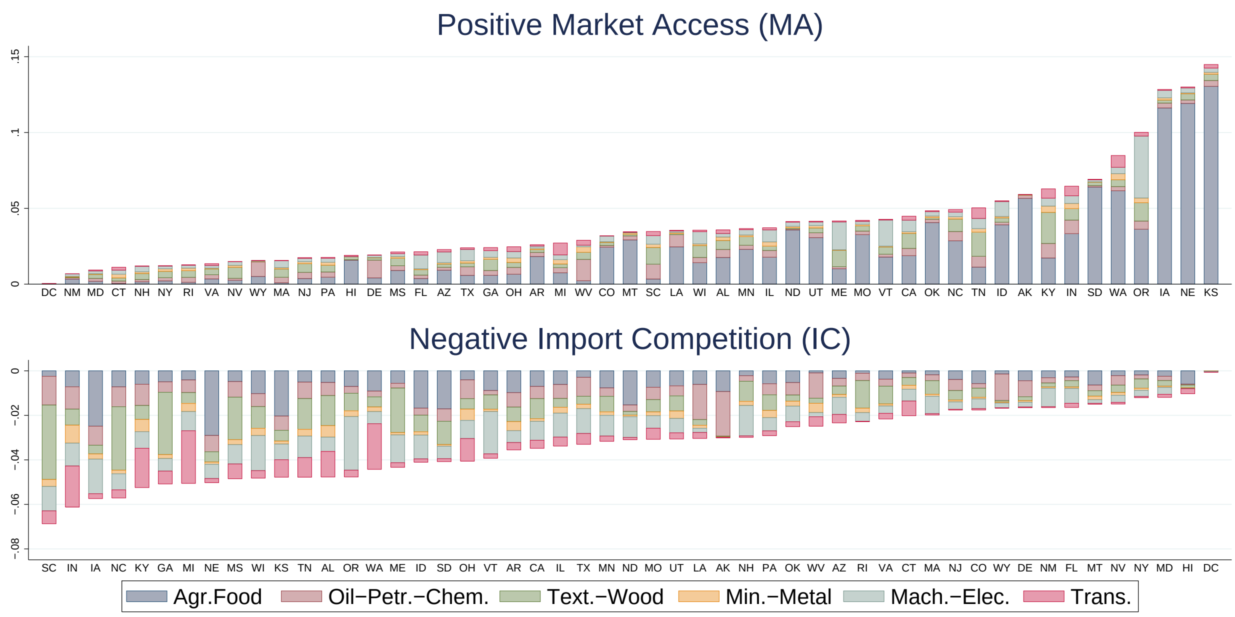
gains are not reflected on production, focusing on the overall gain might give misleading predictions for sentiments on trade policy. In particular, the import competition effect, which denotes the losses in wages due to reductions in market access and sales, has been the main focus of the research on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

1.6.4 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).

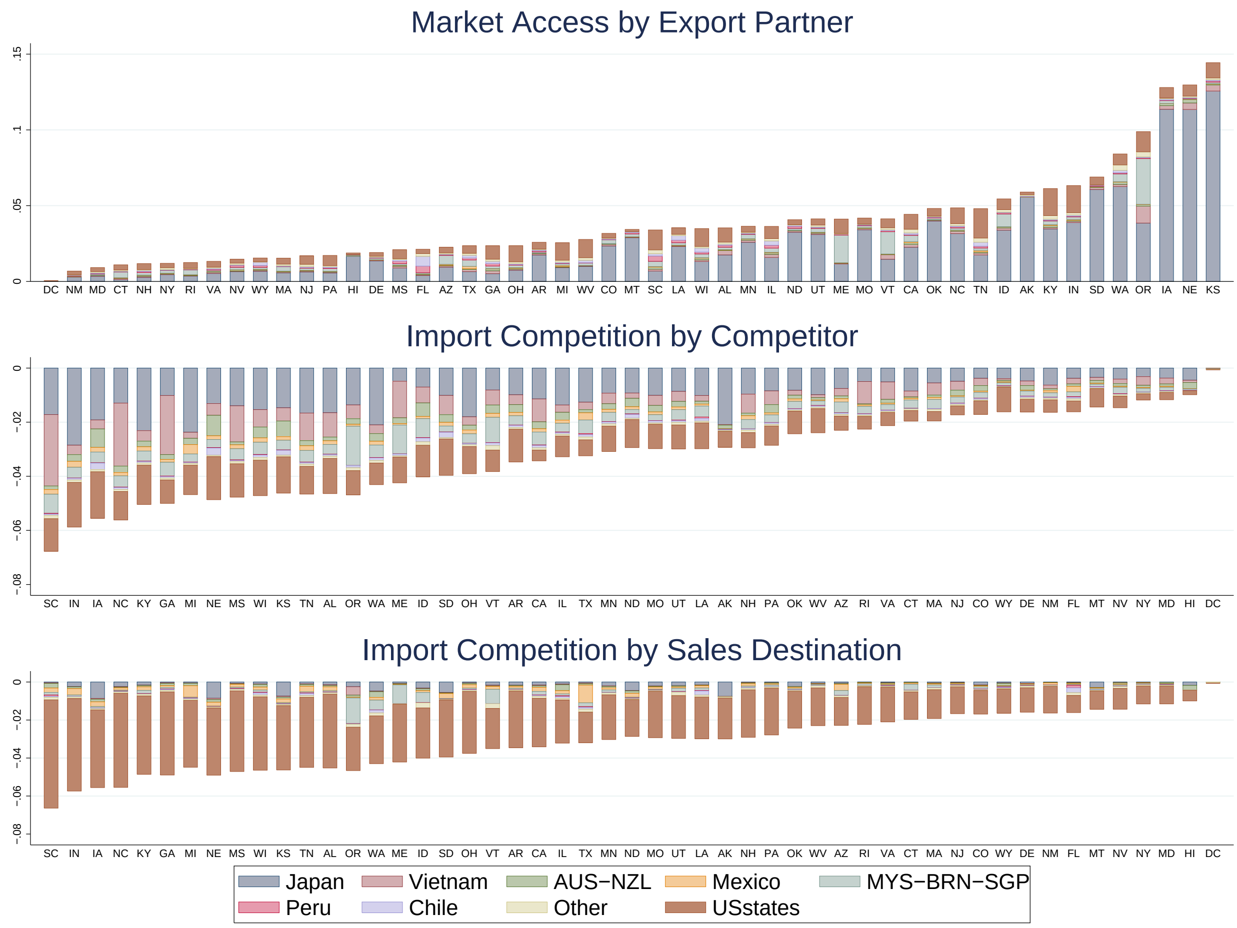
Figure (1.16) shows the sectoral decomposition of market access and import competition effects before the real adjustment with the price index. Agriculture and food sectors dominate over the market access effect while machinery and textile sectors also play a role for some states. As for the import competition 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 1.16: Sectoral Decomposition of Market Access and Import Competition



Similarly, I show on figure (1.17) 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 $\vec{c}_i^j$. Tariff reductions with TPP countries result in cheaper intermediate goods originating there, which increase their competitiveness of U.S. states almost everywhere.

Figure 1.17: 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 (1.17) 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.

1.7 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.

CHAPTER 2

OCCUPATIONAL IMPLICATIONS OF INTERNATIONAL TRADE

2.1 Introduction

The distributional impact of international trade is a popular and controversial topic of interest. Most trade economists agree that removing trade barriers generates aggregate welfare gains. However, most researchers also note that international trade and globalization create winners and losers as the gains from trade may not be shared evenly across different types of individuals. One issue that stimulates interest for researchers and policy makers is the effect of trade policies on low-skilled workers, and the widening of the skill premium, that is, the income gap between high-skilled (or educated) and low-skilled workers.

Theoretically, the factor price equalization theorem suggests that when two countries open up to trade, and if there are two types of labor, say high-skilled, and low-skilled, then the earnings of low-skilled workers in more developed countries would fall. However, most trade policies involve a complex set of sectors and countries, which do not guarantee that winners and losers will always be a certain group. Can we always say that the low-skilled or low-income workers in a developed country, such as the United States, would be worse off from globalization? How can we measure the gains of different types of workers due to trade policies? These are the questions I answer in this chapter.

I work with a multi-sector and multi-region international model based on an Eaton and Kortum (2002) framework where I work with sub-regions of countries as the unit of analysis. Low-skilled, medium-skilled, and high-skilled workers, and intermediate goods are used in the production process as inputs. I calibrate the share of each skill group in each industry and region using income data of different skill groups. I allow for labor mobility across sub-regions of a country, and each skill group can have different migration elasticities, which are calibrated according to the migration data. I use the trade flows and production data of U.S. states, and a set of countries that represent the entire world economy.

I apply the model to the data to find the implications of two specific trade policies. First, I find the effect of the Trans-Pacific Partnership (TPP) tariff reductions on real wages of low, medium, and high-skilled groups in each U.S. state. I find that the TPP agreement would benefit low-skilled workers greatly in states where there are positive welfare gains due to their proximity to the Pacific region, such as Hawaii, Oregon, and Washington, and in agricultural and food producing states such as Kansas and Nebraska. The real wages of medium-skilled workers decline as production becomes costlier overall, due to increases in nominal wages of low-skilled workers.

Second, I show the implications of removing U.S. tariffs on Chinese goods in all sectors. I find that both nominal and real wages of low-skilled workers decline, and real wages of medium-skilled and high-skilled workers increase. The skill premium increases and this leads to an increase in inequality across skill groups. The highest losses in real wages occur in textile producing states such as Georgia, North Carolina, and South Carolina since textiles is one of the sectors with the highest protection against Chinese products.

This chapter is related to the previous literature on multiple dimensions. It is an extension of the Eaton and Kortum (2002) model where I implement quantitative exercises to compute the exposure of regions to trade policies as in Levchenko and Zhang (2012), and Caliendo and Parro (2015). It is also an extension to my first chapter, which is related to the strand of the literature that analyzes the local exposure to trade policies, as in Autor, Dorn, and Hanson (2013), Redding (2014), and Caliendo et al. (2014). However most importantly, this chapter is related to the literature that studies the uneven distributional gains from trade such as Galle, Rodríguez-Clare, and Yi (2015), Artuç et al. (2010), Burstein and Vogel (2012), Cravino and Sotelo (2015), and Burstein, Morales, and Vogel (2015).

The findings of this chapter provide useful political and economic implications. We can use local level data on production, trade, and employment in order to find the exposure of different segments of the workforce in local labor markets to international trade shocks. Policy makers often face tradeoffs due to having winners and losers from economic policies, and especially the potential losses of the most vulnerable workers who work in precarious jobs with limited labor mobility become a political and economic concern during the negotiation phases of trade policies. As long as we have detailed data at the local level, state-of-the-art international trade models can help determine the distributional effects of many economic policies.

The rest of the chapter follows the following order. In section 2, I describe the occupational employment across the United States in different industries and U.S. states, and discuss the heterogeneity in labor mobility across different skill groups. In section 3, I lay out the theoretical model and solution procedure to implement quantitative exercises. In section 4, I describe the construction of variables and data that I have used for the model. In section 5, I present the results of the quantitative exercises. Section 6 concludes.

2.2 Employment By Occupation in the United States

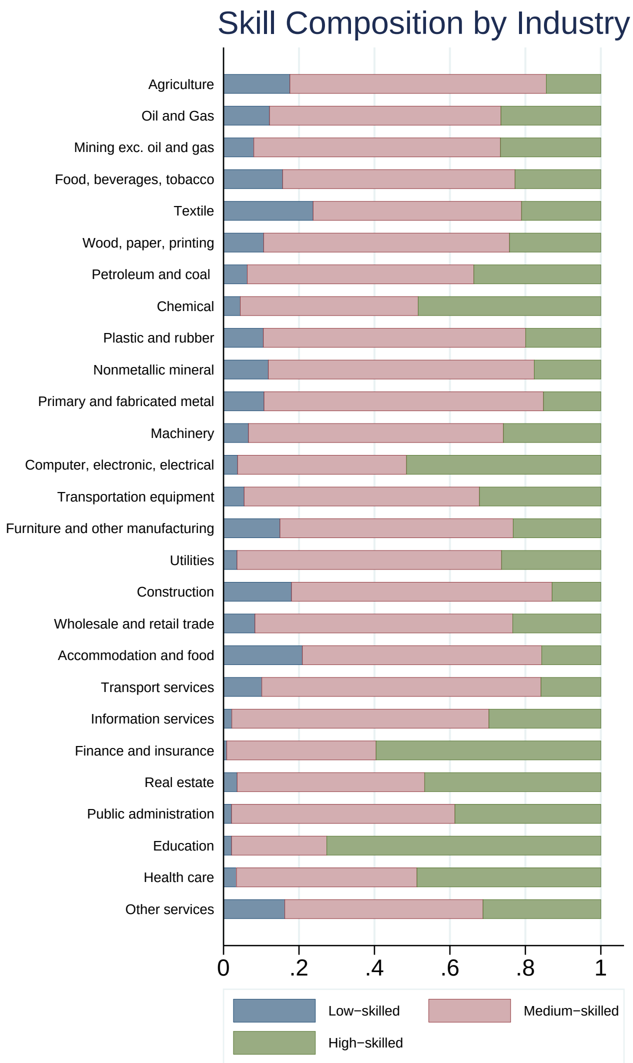
In this section, I briefly discuss the skill composition of the U.S. economy and its states. In addition, I go over several statistics on geographical labor mobility across the United States.

There might be multiple definitions for "occupation" or "skill" groups. The most direct definition of occupation is given by classifications such as the Standard Occupational Classification (SOC) system of the Bureau of Labor Statistics. According the this classification, every occupation group is defined according to the title and the type of the work involved such as being a manager, teacher, or a driver. Several studies such as Goldberg and Pavcnik (2007) break down the labor force in terms of the educational attainment of its workers. According to this definition, we can determine that a worker is low-skilled, or high-skilled according to a threshold rule in years of education. Another way to define occupations, and ranks between them is by looking at the average wage of occupation groups, and then break the labor force into more broad categories such as low-skilled and high skilled workers (See Autor and Dorn). In this study, I rely on census data due to data limitations on type of workers and occupations, and define low-skilled, medium-skilled, and high-skilled workers according to educational attainment.[1]

Figure (2.1) reports the breakdown of the labor force in various industries in the United States in 2014. There is a great heterogeneity in terms of what type of labor each industry uses. Agriculture, textile, construction, and accomodation and food services sectors are those that have a higher share of low-skilled labor force whereas chemical manufacturing, computer and electronic manufacturing, finance, and education sectors are those that employ a highly educated workforce.

[1] See the data section for a detailed description.

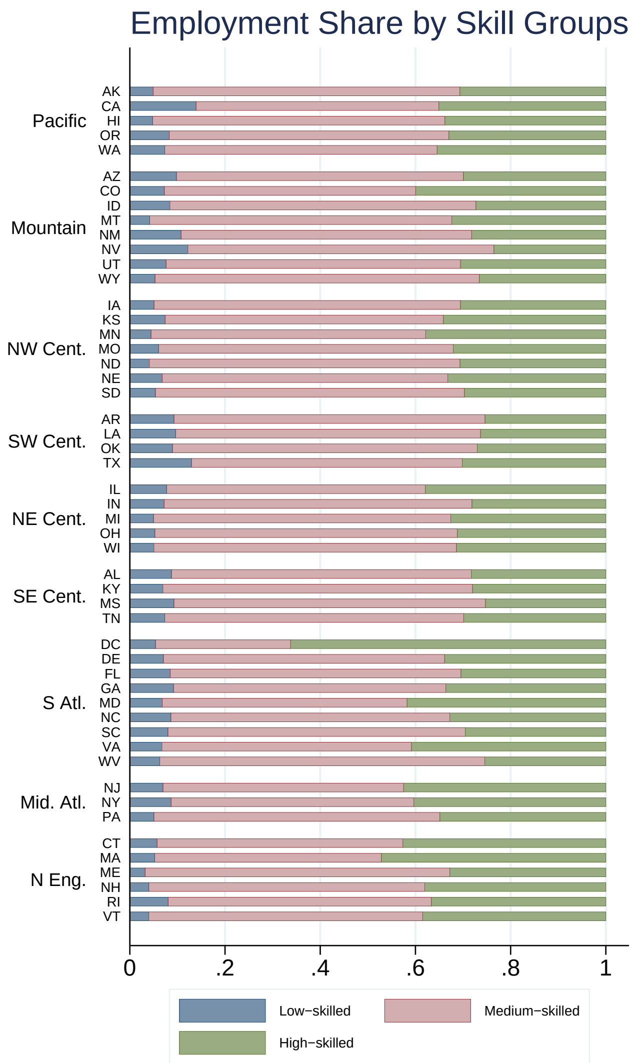
Figure 2.1: U.S. Industry Employment by Occupation Groups in 2014



Source: American Community Survey, 5 year 5% sample in 2014

We can also see the variation of the labor force in terms of its skill composition across the U.S. states in figure (2.2). Southern and larger states tend to have a higher share of their workforce in low-skilled occupations whereas northeastern states have a relatively higher share in the high-skilled worker group. Economic shocks create an exposure of the labor force depending on the initial composition of labor force within a region, and in addition, also depending on the composition of the labor force within an industry in that region. How much a sector uses of an occupation group is directly related to how workers with different skills will be exposed to economic shocks. Skill premium - that is the difference between the earnings of high and low-skilled workers - will be affected by how a certain trade policy is formulated in terms of its coverage of partner countries and sectors.

Figure 2.2: U.S. State Employment by Occupation Groups in 2014



Source: American Community Survey, 5 year 5% sample in 2014

In addition to the sectoral, geographical, and occupation exposure to trade policies, one important determinant is geographical labor mobility. If workers are not able to move across locations, negative and positive effects will linger, and the adjustment process after an economic shock will be slower. I document the differences in labor mobility across different education groups in the United States in table (2.1). This table shows the fraction of the work force with different educational levels who stayed in their location, who moved to a different economic region within the state they resided in, and who moved to another state. We can see that more educated workers are more mobile in terms of interstate moves, and this pattern is also consistent with within state moves except for those with postgraduate degrees, who prefer interstate moves.

In addition, we can look at the mobility patterns of workers according to their

Table 2.1: Labor Mobility by Education in the United States

	Stay		Move within state		Interstate move	
Education	*Population*	*Share*	*Population*	*Share*	*Population*	*Share*
Less than High School	8,688,633	96.52%	191,568	2.13%	121,940	1.35%
High School	25,852,932	96.13%	622,267	2.31%	417,518	1.55%
Some College	32,389,120	95.16%	993,126	2.92%	653,137	1.92%
College Graduate	21,714,776	93.78%	755,239	3.26%	684,758	2.96%
Postgraduate	12,184,450	94.19%	332,784	2.57%	418,280	3.23%

Source: American Community Survey, 5 year 5% sample in 2014. The sample is reduced to wage earners in the 18-64 age group who have had a full-time job in 2014.

occupation classification (SOC) in table (2.2). We see from this table that most of the occupations that have higher mean wages have a more mobile labor force. For instance, 4.15 percent of the workers in the life, physical, and social science group moved to another state in 2014 whereas 1.41 percent of workers in the production group made interstate moves. Among the lower-income occupations, the food preparation and serving related group made relatively higher interstate moves, which demonstrates how mobile that occupation is across the U.S., whereas the highest wage group, management, made relatively lower interstate and within state moves.

2.3 Model

In this section, I present the economic model in order to compute the occupational and regional outcomes due to trade policies. Initially, I demonstrate a brief summary of the economic model, and then provide the equations formally. Secondly, I show how to solve for deviations around an initial steady-state equilibrium that are the results of a trade policy change.

2.3.1 Overview

I work with an extended version of the Eaton and Kortum (2002) model that I have used in my first chapter. The model also comprises a multi-sector and multi-region heterogeneity. In addition, I break down the labor force into low-skilled, medium, and high-skilled occupations, and I allow for different locations to have heterogeneity in their use of different occupational types in each sector. Each country will be composed of sub-regions, where the workers in each occupational group will be able to work

Table 2.2: Labor Mobility by Occupation in the United States

		Stay		Move within state		Interstate move		
Soc Code	*Occupation Name*	*Population*	*Share*	*Population*	*Share*	*Population*	*Share*	*Mean Wage*
11	Management	10,805,309	95.22%	275,092	2.42%	267,727	2.36%	110,550
13	Business and Financial Operations	5,227,440	94.56%	159,277	2.88%	141,651	2.56%	71,020
15	Computer and Mathematical	3,066,658	93.53%	104,423	3.18%	107,602	3.28%	82,010
17	Architecture and Engineering	2,138,245	93.96%	64,100	2.82%	73,359	3.22%	80,100
19	Life, Physical, and Social Science	878,459	92.15%	35,263	3.70%	39,571	4.15%	69,400
21	Community and Social Service	1,750,366	94.50%	58,135	3.14%	43,771	2.36%	44,710
23	Legal	1,158,152	95.07%	32,123	2.64%	27,929	2.29%	99,620
25	Education, Training, and Library	6,079,613	95.30%	163,179	2.56%	136,477	2.14%	51,500
27	Arts, Design, Entertainment, Sports, and Media	1,386,162	92.89%	51,458	3.45%	54,721	3.67%	55,580
29	Healthcare Practitioners and Technical	6,003,355	94.67%	177,532	2.80%	160,268	2.53%	74,740
31	Healthcare Support	2,521,787	95.45%	74,758	2.83%	45,403	1.72%	28,300
33	Protective Service	2,500,444	95.24%	75,420	2.87%	49,414	1.88%	43,510
35	Food Preparation and Serving Related	4,590,100	93.37%	181,633	3.69%	144,301	2.94%	21,580
37	Building and Grounds Cleaning and Maintenance	3,415,575	96.52%	73,142	2.07%	50,030	1.41%	26,010
39	Personal Care and Service	2,325,256	94.59%	78,266	3.18%	54,784	2.23%	24,710
41	Sales and Related	9,748,426	94.66%	312,192	3.03%	237,385	2.31%	38,200
43	Office and Administrative Support	14,122,479	95.71%	381,431	2.58%	252,128	1.71%	34,900
45	Farming, Fishing, and Forestry	747,560	95.70%	19,400	2.48%	14,217	1.82%	24,330
47	Construction and Extraction	5,174,711	95.59%	139,371	2.57%	99,259	1.83%	45,630
49	Installation, Maintenance, and Repair	3,739,184	95.53%	100,755	2.57%	74,050	1.89%	44,420
51	Production	7,072,044	96.34%	165,273	2.25%	103,415	1.41%	34,930
53	Transportation and Material Moving	6,316,289	95.69%	169,834	2.57%	114,413	1.73%	33,860

Source: American Community Survey, 5 year 5% sample in 2014. The sample is reduced to wage earners in the 18-64 age group who have had a full-time job in 2014.

in the same occupation group elsewhere within the country. Labor is fully mobile across sectors within a location, but I assume that workers are not able to work in a separate occupation group, or another country. The model includes a set of tradable and non-tradable sectors, where trade is subject to distance and policy-related trade costs. The environment is static, and labor mobility for each occupation group will be modeled by assuming that workers have heterogeneous tastes for local amenities across locations within a country. Workers from different occupation groups can have different intensities of labor mobility. In the model, workers in different occupations can have a different shape parameter, which governs the variation of heterogeneous tastes for local amenities. In this setting, each occupation group will have a unique real wage within a sub-region of a country, and the occupational real wage will not equalize across locations within a country.

Similar to chapter 1, the production process is represented by two types of producers. Variety producers use labor from three occupations, and intermediate goods. Their output is traded in tradable sectors subject to trade costs, and varieties are converted into a composite final good by a final good aggregator. The share of labor from low-skilled, medium, and high-skilled occupations can vary by sector and industry, and this way separate regions have innate differences in terms of their productive potential.

The summary of the notation I have used in the theoretical model is as follows. All regions in the model are represented by $i, n = 1, ..., N$, and each of these regions can be a sub-region of a country. In practice, countries except for the United States are composed of a single sub-region, and I do not provide any additional notation to identify sub-regions. However, the U.S. is composed of 51 sub-regions (states and D.C.), and they are also represented by the same subscript i or n. In order to represent the entire U.S. economy, I use subscript $i = US$. The only difference between a U.S. state and another country is that labor will not be able to move into or ot of any other country. Sectors are represented by $j = 1, ..., J$, and occupations are represented by $o = 1, ..., O$.[2]

Utility and Mobility. Each country i has a fixed supply of labor L_i^o in each occupation $o = 1, ..., O$. Workers that have a specific occupation can move across sub-regions of a country. Therefore in application, L_i^o for all countries i other than U.S., and L_{US}^o will be fixed. Household ν in occupation o in sub-region i works and supplies one unit of labor. In return, she earns labor income w_i^o, and spends her income on a basket of consumption goods $C_i(\nu)$. The basket of consumption goods is given by a Cobb-Douglas aggregate of consumption goods across J sectors, each of whose share is given by β_i^j,

[2]In the application I have three occupation groups $o = 1$ low-skilled, $o = 2$ medium-skilled, and $o = 3$ high-skilled respectively.

where j denotes the sector.[3]

$$C_i(\nu) = \prod_{j=1}^{J} \left(C_i^j(\nu)\right)^{\beta_i^j} \tag{2.1}$$

Each worker is free to move to any other sub-region within the country without any relocation cost. Workers receive utility from local amenities given by $b_i^o(\nu)$ and the consumption bundle $C_i(\nu)$. Local amenities represent all aspects that generate additional benefits to worker due to being located in a particular sub-region such as weather, public goods, family relationships. The utility of the household ν that has occupation o is given by

$$U_s^o(\nu) = b_i^o(\nu)C_i(\nu) \tag{2.2}$$

I assume that workers have heterogeneous tastes for the local amenity. The amenities follow a Fréchet distribution function $G_s^o(x) = e^{-B_i^o x^{-\varepsilon^o}}$ that has a mean parameter of B_i^o, and a shape parameter ε^o for each occupation o and sub-region i. Worker ν with occupation o draws an amenity from this distribution function, and then according to the real wages $\left\{w_i^o(\nu)/P_i\right\}_i$ across all sub-regions within a country, the worker can move to the sub-region that maximizes his utility. The Fréchet distribution properties lead to a spatial labor market equilibrium that expresses the occupational labor share of each sub-region s (or state) in the U.S. according to a relative index of average amenity and occupational real wage

$$\frac{L_s^o}{L_{US}^o} = \frac{B_s^o \left(w_s^o/P_s\right)^{\varepsilon^o}}{\sum_{s' \in S} B_{s'}^o \left(w_{s'}^o/P_{s'}\right)^{\varepsilon^o}} \tag{2.3}$$

where w_s^o denotes the nominal wage of occupational group o in state s, P_s is the price index in state s, which is a Cobb-Douglas aggregate of sectoral price indices.[4]. The parameter ε^o governs the strength of geographical labor mobility. As shown in equation (2.3), when ε^o is high, the labor market outcomes become more sensitive to changes in real wages. This shape parameter might have different values for each occupation group. This variable can be thought as a labor migration elasticity with respect to changes in real wages. Having different shape parameters for the distribution for local amenities means that different groups of people might have separate labor migration elasticities.[5]

Production. There are two types goods that are produced in this economy. The first set

[3] I assume that workers in each occupation group are identical in terms of their consumption shares across different sectors within a country.

[4] The price index is given by $P_s = \prod_{j=1}^{J} \left(P_s^j\right)^{\beta_s^j}$.

[5] As I have documented in the previous section, different occupational groups can have different migration intensities depending on the geographical mobility of the labor market for different occupation groups.

of goods are called varieties, which are produced by variety producing firms. These firms use different types of labor plus intermediate goods and sell their output in the world markets by being subject to iceberg trade costs and tariffs. The markets are perfectly competitive and the lowest-cost supplier is able to ship their goods to a particular destination. A firm ω^j in region i and sector j is endowed with a region-sector specific labor productivity T_i^j, and an idiosyncratic firm-specific labor productivity $z_i^j(\omega^j)$. The region-sector specific labor productivity is common to all firms that produce in a certain location. The mass of firms in each location is constant and assumed to be on a interval $\omega^j \in [0,1]$. The idiosyncratic labor productivity $z_i^j(\omega^j)$ is drawn from a Fréchet distribution $F^j(x) = e^{-x^{-\theta^j}}$. The term θ^j represents the dispersion of the productivity distribution, and can be interpreted as the trade elasticity. The production function of a firm ω^j in region i and sector j is given by

$$y_i^j(\omega^j) = z_i^j(\omega^j)\left[T_i^j \prod_{o=1}^{O}\left(l_i^{o,j}(\omega^j)\right)^{\alpha_i^{o,j}}\right]^{\gamma_i^j} \prod_{k=1}^{J}\left[m_i^{k,j}(\omega^j)\right]^{\gamma_i^{k,j}} \tag{2.4}$$

where $l_i^{o,j}(\omega^j)$ is the labor used by the firm in occupation group o, and $m_i^{k,j}$ is the amount of intermediate goods used from sector k. The share γ_i^j represents the share of value added in production, and $\gamma^{k,j}$ is the share of usage of intermediate good in terms of value from sector k in value of total output. Their sum adds up to 1, e.g. $\gamma_i^j = 1 - \sum_{k=1}^{J} \gamma_i^{k,j}$. In addition, the parameter $\alpha_i^{0,j}$ denotes the share of occupation group o's contribution in the labor force. I also assume that $\sum_{o=1}^{O} \alpha_i^{o,j} = 1$.

Unit costs of firms in region i and sector j are provided by a Cobb-Douglas aggregate of occupational wages and intermediate good prices

$$c_i^j = \xi_i^j \left(\prod_{o=1}^{O}\left(w_i^o\right)^{\alpha_i^{o,j}}\right)^{\gamma_i^j} \prod_{k=1}^{J}\left(P_i^k\right)^{\gamma_i^{k,j}} \tag{2.5}$$

where w_i^o denotes the wage of the occupation o in region i, and P_i^k represents the price index of goods to be purchased in region i and sector k.[6]

When variety producers in region i and sector j ship their products to region n, their output is decreased proportionally due to iceberg trade costs δ_{in}^j. If they would like to ship a good with value 1, they need to ship an amount that has value $\delta_{in}^j > 1$. They also pay ad valorem tariffs τ_{in}^j to region n. The price that prevails in market i for a variety

[6] ξ_i^j is a constant that is given by $\prod_{o=1}^{O}(\alpha_i^{o,j}\gamma_i^j)^{\alpha_i^{o,j}\gamma_i^j} \prod_{k=1}^{J}(\gamma_i^{k,j})^{\gamma_i^{k,j}}$

ω^j is the lowest cost for this variety amongst all producers

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

These varieties $\omega^j \in [0,1]$ are aggregated by a composite final good aggregator, and this final good can be used either for consumption or production. The final good Q_i^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 σ^j is the elasticity of substitution, and $q_i^j(\omega^j)$ is the demand for variety ω^j of sector j in region i.[7] The price index of sector j good in region i is expressed as

$$P_i^j = \left[\int_0^1 p_i^j\left(\omega^j\right)^{1-\sigma^j} d\omega^j \right]^{1/(1-\sigma^j)} \tag{2.6}$$

2.3.2 Equilibrium

In this section I will lay out the equilibrium expressions for trade flows, price index, total expenditures, trade balance and labor supply. These expressions will be similar to those I have presented in chapter 1, but will also include market clearing for different occupational labor groups.

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

$$\pi_{ni}^j = \frac{X_{ni}^j}{\sum_{m=1}^N X_{mi}^j} = \frac{\left(\Phi_{ni}^j\right)^{-\theta^j}}{\sum_{m=1}^N \left(\Phi_{mi}^j\right)^{-\theta^j}} \tag{2.7}$$

[7]The demand for variety ω^j in region i is given by $q_i^j(\omega^j) = \frac{p_i^j(\omega^j)^{-\sigma^j}}{\left(P_i^j\right)^{1-\sigma^j}} X_i^j$

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

$$\Phi_{ni}^{j} = \frac{c_n^j d_{ni}^j \left(1 + \tau_{ni}^j\right)}{\left(T_n^j\right)^{\gamma_n^{0,j}}} \tag{2.8}$$

The price index in region i and sector j in equilibrium is given by

$$P_i^j = \Gamma^j \left[\sum_{n=1}^{N} \left(\Phi_{ni}^j\right)^{-\theta^j}\right]^{-\frac{1}{\theta^j}} \tag{2.9}$$

where Γ^j is a constant.[8]

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, and total sectoral output Y_i^k is the sum of all shipments net of tariffs payments

$$X_i^j = \sum_{k=1}^{J} \gamma_i^{j,k} Y_i^k + \beta_i^j I_i \tag{2.10}$$

$$Y_i^j = \sum_{n=1}^{N} \frac{X_{in}^j}{1 + \tau_{in}^j} = \sum_{n=1}^{N} \frac{\pi_{in}^j X_n^j}{1 + \tau_{in}^j} \tag{2.11}$$

Disposable income is given by the sum of labor earnings of all occupational groups, tariff revenue, and trade imbalances

$$I_i = \sum_{o=1}^{O} w_i^o L_i^o + R_i + D_i \tag{2.12}$$

Total trade imbalances are the sum of sectoral imbalances, and tariff revenue is the sum of ad valorem tariff times imports

$$D_i = \sum_{j=1}^{J} D_i^j = \sum_{j=1}^{J} \left(X_i^j - Y_i^j - R_i^j\right) \tag{2.13}$$

$$R_i = \sum_{j=1}^{J} R_i^j = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\tau_{ni}^j}{1 + \tau_{ni}^j} \pi_{ni}^j X_i^j \tag{2.14}$$

Labor market clears for each occupation group o in each region i, and the total earnings

[8] $\Gamma^j = \Gamma\left(1 + \frac{1-\sigma^j}{\theta^j}\right)^{1/(1-\sigma^j)}$, and $\Gamma(\cdot)$ is the Gamma function $\Gamma(t) = \int_0^\infty x^{t-1} e^{-x} dx$.

for occupation group o in region i is given by

$$w_i^o L_i^o = \sum_{j=1}^{J} \alpha_i^{0,j} \gamma_i^j Y_i^j \tag{2.15}$$

Definition 2. *Given parameters $\gamma_i^j, \gamma_i^{k,j}$, $\alpha_i^{o,j}$, β_i^j, θ^j, σ^j, ε^o, iceberg trade costs δ_{in}^j, region-sector specific productivity T_i^j, average amenities B_i^o, ad valorem tariffs τ_{in}^j, and country employment L_c^o and L_{US}^o for $i,n = 1,...,N$, $c \in C$, $j = 1,...,J$, $j = 1,...,J$, and $o = 1,...,O$; an equilibrium is an occupational wage vector $\{w_i^o\}_{i=1,o=1}^{N,\,O}$, sectoral prices $\{P_i^j\}_{i=1,j=1}^{N,J}$ and U.S. state employment vector $\{L_s^o\}_{s,o}$ that solves spatial labor market equilibrium (2.3), unit cost function (2.5), trade share (2.7), price index (2.9), total expenditure equation (2.10), trade balance (2.13) and labor market clearing equation (2.15).*

2.3.3 Counterfactual Equilibrium

Holding all the other parameters constant, every tariff schedule τ results in a new equilibrium $\mathbf{w}$ and $\mathbf{P}$. When we start at an initial steady state equilibrium that is provided from actual data on model variables and tariff schedule, and initial parameters, we can compute a new counterfactual equilibrium using a new tariff schedule τ' holding all the other parameters constant. However, finding the actual values of parameters such as region and sector-specific productivity T_i^j, and distance terms δ_{in}^j is a difficult process. Instead of solving for these parameters, I follow Jones' (1965), and then Dekle, Eaton, and Kortum (2008)'s "hat algebra" method of expressing the model parameters in deviations around the initial steady state. Most fundamental parameters drop thanks to this method, and we can compute wages in the new counterfactual equilibrium using hat algebra analogs of the equations of the model. [9]

I denote the change by $\widehat{x} = x'/x$, where x' denotes the value of variable x in the counterfactual equilibrium, and x denotes its initial value. I will solve for the equilibrium by the following procedure.

1. Initially, start with a guess for the change in occupational wage $\widehat{w_i^o}$ for each $i = 1,...,N$ and $o = 1,...,O$.

[9]Jones (1965) rewrote a general equilibrium model in percent deviations around the steady state where his method is a first-order Taylor approximation, which will not lead to exact results especially when changes in the policy variable (e.g. tariff rates) are not small. Yet, Dekle, Eaton, and Kortum (2008) express the deviations around the steady state in gross relative shares, an thereby resulting in an exact solution.

2. Find changes in unit costs and price index.

$$\widehat{c}_i^j = \prod_{o=1}^{O} \left(\widehat{w}_i^o\right)^{\alpha_i^o \gamma_i^j} \prod_{k=1}^{J} \left(\widehat{P}_i^j\right)^{\gamma_i^{k,j}} \tag{2.16}$$

$$\widehat{P}_i^j = \left[\sum_{n=1}^{N} \pi_{ni}^j \left(\widehat{c}_n^j \widehat{(1+\tau_{ni}^j)} \right)^{-\theta^j} \right]^{-1/\theta^j} \tag{2.17}$$

3. Plug these into the trade share equation and find the change in trade share.

$$\widehat{\pi}_{in}^j = \left[\frac{\widehat{c}_i^j \left(\widehat{1+\tau_{in}^j} \right)}{\widehat{P}_n^j} \right]^{-\theta^j} \tag{2.18}$$

4. Using the changes in occupational wages and price index,[10] find $\widehat{L}_s^o$.

$$\widehat{L}_s^o = \frac{\left(\widehat{w}_s^o / \widehat{P}_s\right)^{\varepsilon^o}}{\sum_{s' \in S} \frac{L_{s'}^o}{L_{US}^o} \left(\widehat{w}_{s'}^o / \widehat{P}_{s'}\right)^{\varepsilon^o}} \tag{2.19}$$

5. Solve for the new level of total expenditures $(X_i^j)'$

$$\left(X_i^j\right)' = \sum_{k=1}^{J} \gamma_i^{j,k} \sum_{n=1}^{N} \frac{\widehat{\pi}_{in}^j \pi_{in}^j \left(X_n^j\right)'}{\left(1+\tau_{in}^j\right)'} + \beta_i^j \left(\sum_{o=1}^{O} \widehat{w}_i^o w_i^o (L_i^o)' + R_i' + D_i \right) \tag{2.20}$$

where the new tariff revenue is given by

$$R_i' = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\left(\tau_{ni}^j\right)'}{\left(1+\tau_{ni}^j\right)'} \left(X_{ni}^j\right)' \tag{2.21}$$

6. Check if the new total expenditures solve the following trade balance equation

$$\sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\left(X_{ni}^j\right)'}{\left(1+\tau_{ni}^j\right)'} - D_i = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\left(X_{in}^j\right)'}{\left(1+\tau_{in}^j\right)'} \tag{2.22}$$

[10] The change in real wage of state s. The change in the overall consumption price index is given by

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

7. If they satisfy this equality, new occupational wages are given by $(w_i^o)' = \widehat{w}_i^o w_i^o$, and we have a solution.
8. If they are not equal, update the guess of $\widehat{w}_i^o$ locally and go to step 1.

2.4 Data Description

In this section I explain the construction of the variables and parameters I have used in order to implement the quantitative exercises using the model. First, I go over the country and region sample, the industries, and occupation groups. Then, I provide the sources for the datasets I have used to find the necessary variables.

I work with 55 countries except for the United States. All of these countries are composed of a single sub-region. One of these countries is called “Rest of the World”, which groups all countries in the world for which there are not good quality data. In addition, I include the United States economy in the model by breaking it up into 51 sub-regions, which are 50 U.S. states and District of Columbia. Each of these countries and sub-regions (which I call as “regions”) can produce and trade in 15 traded sectors, which include agriculture, mining, and manufacturing. In addition, each region produces in 12 non-traded sectors.

For variables such as employment by region, trade flows between regions of the model, tariff rates, input-output table parameters, I rely on the datasets I have used in chapter 1, which are summarized in table (1.1).

2.4.1 Occupation Data

I break the labor force into three occupation, or skill groups in this study: low-skilled, medium-skilled, and high-skilled. The skill of a worker is defined as the level of her educational attainment. Low-skilled workers have an education level below high-school, medium skill workers are high school graduates and may have some college education, and high-skilled workers are those who hold a bachelor’s degree or more.

For countries other than the U.S., I use the WIOD Socio-Economic Accounts database for occupational income statistics. This dataset provides the share of earnings of workers in each industry with low-skilled, medium-skilled, and high skilled groups in total labor compensation of that industry. The data in this project are available for only 39 countries in my sample, and for the remaining 16 countries, I impute the missing information from the data of another country that is closest in terms of economic development or location.[11] $\alpha_i^{o,j}$ is the variable that denotes the share of earnings of

[11] I use the average of Indonesia and Taiwan’s statistics for Malaysia, Philippines, Singapore, Thailand,

country i workers from occupation group o in sector j, in the total value of labor compensation of sector j in the country. In addition, I find L_i^o using this dataset, which denotes the total labor force in occupation o in country i across all of its sectors. For countries that do not have data, I use the closest country's share of the labor force into low-skilled, medium-skilled, and high-skilled labor force, and I scale these shares with the total labor force of the country, which I have found from World Bank Development Indicators.

As for U.S. States, I rely on the public use micro data files of the American Community Survey 5 year samples (Ruggles, Genadek, Goeken, Grover, and Soebek 2015) in order to find the share of each skill group according to occupation in an industry in the total earnings of that industry. I limit the sample to the working age group 18-64 that have only labor income, who have worked more than 35 weeks, and have a full-time job. This provides me with $\alpha_s^{o,j}$ for each skill group o, in each sector j and each U.S. state s. In addition, I find the share of each skill group in the total labor force of the U.S. economy, and its states, and I scale them with the total labor force to find L_{US}^o and L_s^o.

2.4.2 Other Parameters

Consumption price index shares: I construct the share of consumption of each good in total household consumption β_i^j using the data available for intermediate good consumption and total income from equation (2.10). I have data on total expenditures X_i^j, intermediate good usage shares $\gamma_i^{k,j}$, output Y_i^j, occupational earnings $w_i^o L_i^o$ for each occupation group $o = 1,...,O$, tariff revenue R_s, and trade imbalances D_i. I solve for β_i^j for each $i = 1,...,N$ and $j = 1,...,J$. I use the same consumption shares for each U.S. state, which I calculate from total U.S. consumption. Similar to chapter 1, since I do not have data on services trade within the U.S., and the consumption shares will not solve equation (2.10), I include an additional deficit term E_s^j for each state s, which will be held constant in all exercises.

Trade elasticity (θ^j): The term θ^j represents the trade elasticity of in this model, since it captures the percent change in trade flows with respect to percent changes in trade costs, productivity, or wages. I use Simonovska and Waugh's (2014) estimate of 4.14, which will be identical across all sectors.

Migration elasticity (ε^o): The term ε^o represents the migration elasticity with respect to changes in real income. This term might be different for different occupation groups, and needs to be estimated. I do not have values for this variable, but given the fact

and Brunei. I use Brazil for Argentina, Chile, Peru, and the Rest of the World. I use Greece for Israel. I use Australia for New Zealand. I use Sweden for Norway. I use Turkey for South Africa and Persian Gulf States. I use Austria for Switzerland. I use Indonesia for Vietnam.

that low-skilled workers move over state boundaries much less than medium-skilled workers, and medium-skilled workers move over state boundaries less than high-skilled workers, I will have three parameters to make sure $\varepsilon^L < \varepsilon^M < \varepsilon^H$. Suárez-Serrato and Zidar (2014) have estimated this parameter for all occupation groups as 1.34. According to this average estimate I will use $\varepsilon^L = 1$ for low skilled, $\varepsilon^L = 1.34$ for medium-skilled, and $\varepsilon^L = 1.68$ for high-skilled workers.

2.5 Quantitative Exercises: Trade Policy and Skill Premium

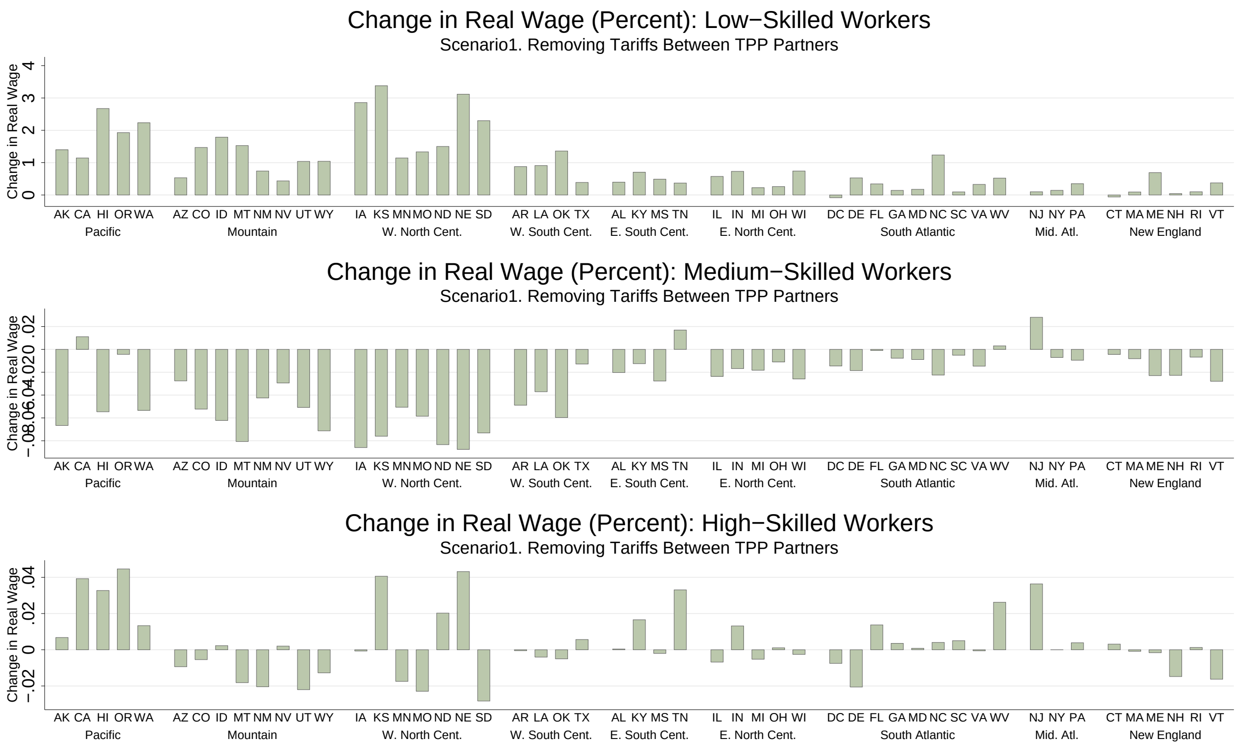
In this section, I demonstrate the results of the quantitative exercises that I will apply to the model in order to see the effects of certain trade policies on different skill groups across the United States. I can specifically show the effect of tariff changes for nominal and real wages of low, medium, and high-skilled workers. First, I show how much the tariff reductions due to the Trans-Pacific Partnership agreement will affect the earnings and welfare of workers with different skills in each U.S. state. In the second exercise, I demonstrate the implications of lowering of Chinese import tariffs with respect to the United States in all traded sectors. The definition of welfare is real wages of different skill groups in each region of the model, e.g. country or U.S. states.

2.5.1 Trans-Pacific Partnership

The first trade policy that I consider is the effects of the tariff reductions due to the Trans-Pacific Partnership agreement as I have implemented in chapter 1. I assume that the Trans-Pacific partnership will result on lowering tariffs in all traded sectors between the partners of this agreement. As we have seen in chapter 1, the U.S. states that produce agriculture and food manufacturing, and also those who trade more with the TPP partner nations, will benefit more from this agreement. Therefore, we will expect that the TPP will cause a larger effect on those states across different occupations. The focus of the exercise in this chapter is whether the TPP agreement will cause disproportionate gains or losses across separate occupational groups.

The implications of TPP for real wages of low, medium, and high-skilled workers are reported in figure (2.3). We observe that low-skilled workers in the states that benefit more from the TPP agreement such as Kanss, Nebraska, Hawaii, and Oregon face positive welfare gains. While average real wage gains for all occupation groups were about 0.1-0.2 percent, low-skilled workers realize about 2-3 percent welfare gains. As for medium-skilled workers, we observe negative, albeit small welfare losses in those states of around 0.06 percent. High-skilled workers are subject to small gains in the states where there are overall positive gains, but some of the agricultural and west coast states also face welfare losses in high-skilled occupations.

Figure 2.3: Change in Real Wages of Occupational Groups: Trans-Pacific Partnership



It should be noted that in the U.S. economy, low-skilled workers compose only 8.5 percent of the work force, medium-skilled workers form 57.4 percent of the labor force, and the share of high-skilled workers is 34.1 percent. Therefore, the disproportionately high gains of low-skilled workers in states such as Kansas do not represent into a large welfare gain for the overall labor force. The reason why low-skilled workers gain much more is because their gain in nominal wages is much higher than the increase in the overall price index in their state. The nominal wages of low-skilled workers increase because the sectors where low-skilled workers are disproportionately present such as agriculture and food manufacturing benefit more relative to other sectors. When nominal wages of low-skilled workers increase, this increases the price index in this state. However, if medium-skilled workers do not face nominal wage gains, the price index does not increase considerably given the small size of the low-skilled labor force. Hence, while nominal wages for low-skilled workers go up, their real wage goes along with it.

The results of this exercise point out that if the United States is able to convince other nations such as Japan to lower their tariffs on sectors where the low-skilled labor force is larger in the United States such as agriculture, low-skilled workers will be able to face very significant welfare gains. While there is hesitation in the public for signing trade agreements due to their potential negative impact on low-skilled workers, a policy might in fact be beneficial for low-skilled workers depending on which sectors and countries are covered as the part of the agreement.

2.5.2 Chinese Tariffs

I evaluate the impact of lowering U.S. tariffs on Chinese exports in my second exercise. The potential effects of import competition due to China's accession to international markets have been discussed greatly and documented in studies such as Autor, Dorn, and Hanson (2013). Here I consider the case where all U.S. tariffs against Chinese exports are removed unilaterally, and I show their disproportionate welfare impact on different occupation groups.

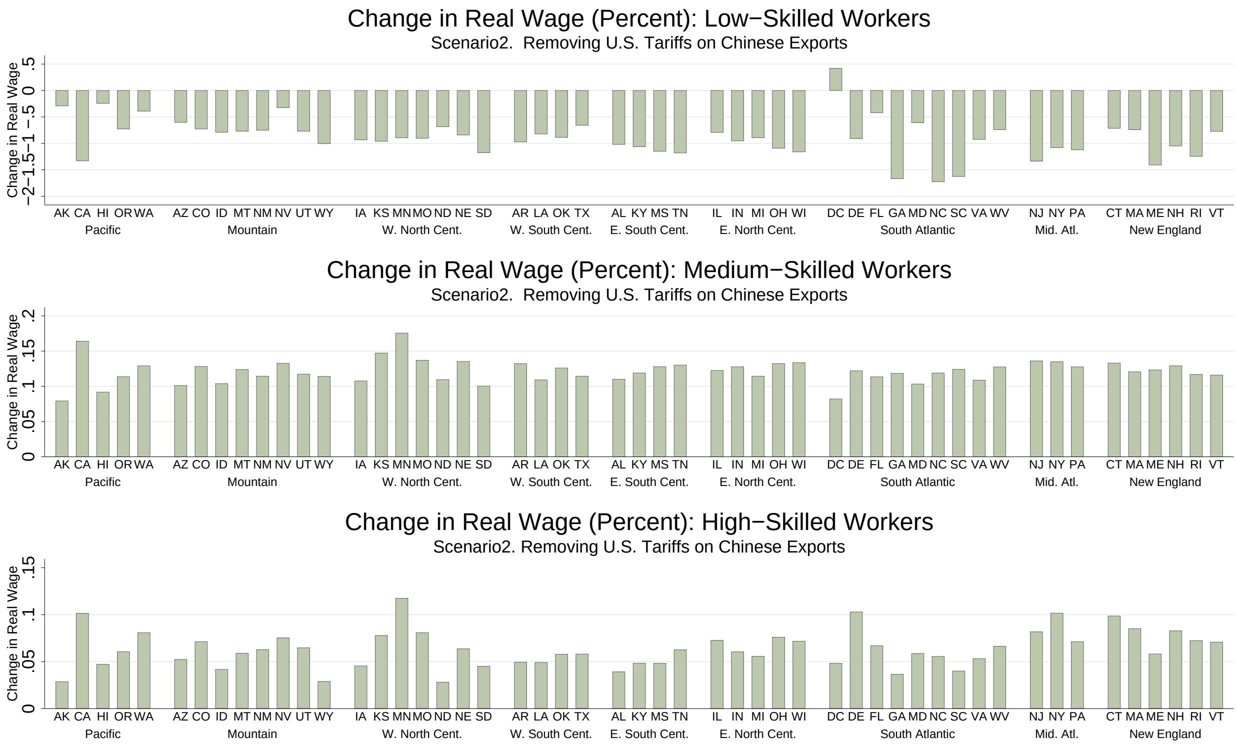
The results of removing tariffs on Chinese exports to the U.S. are reported on figure (2.4). It turns out that such a policy will disproportionately hurt low-skilled workers, as nominal wages decrease in sectors in which China has a comparative advantage against U.S. producers such as the textile industry. Georgia, North Carolina, and South Carolina are three states that face the highest losses for the low-skilled occupation group mostly due to their specialization in the textile sector. We do not observe a geographical pattern when tariffs on Chinese goods are removed, and industry specialization determines the magnitude of welfare gains and losses.

2.5.3 Changes in Skill Premium

Based on the results I have shown in figures (2.3) and (2.4), we can find the change in the skill-premium, that is the difference in earnings between high-skilled and low-skilled workers. I use per-capita nominal wages as the definition of earnings, and do not consider real wages since the change in price indices for low-skilled and high-skilled labor force is assumed to be identical since I do not have data on the price index for different types of workers. Figure (2.5) reports the change in the skill premium for the two tariff policy scenarios.

The TPP agreement reduces the skill premium between high-skilled and low-skilled workers about 1-3 percent in the western and agricultural states, where the impact is very low on east-coast and midwestern states. While nominal wages increase for high-skilled workers in states such as Kansas or Oregon, the gains of low-skilled workers are so high that the skill premium narrows down. As for the lowering of tariffs on Chinese goods, we observe that skill premium goes up about 1 percent in most states. The states that face the highest skill premium gains are Georgia, North Carolina, and

Figure 2.4: Change in Real Wages of Occupational Groups: Removing Tariffs on China



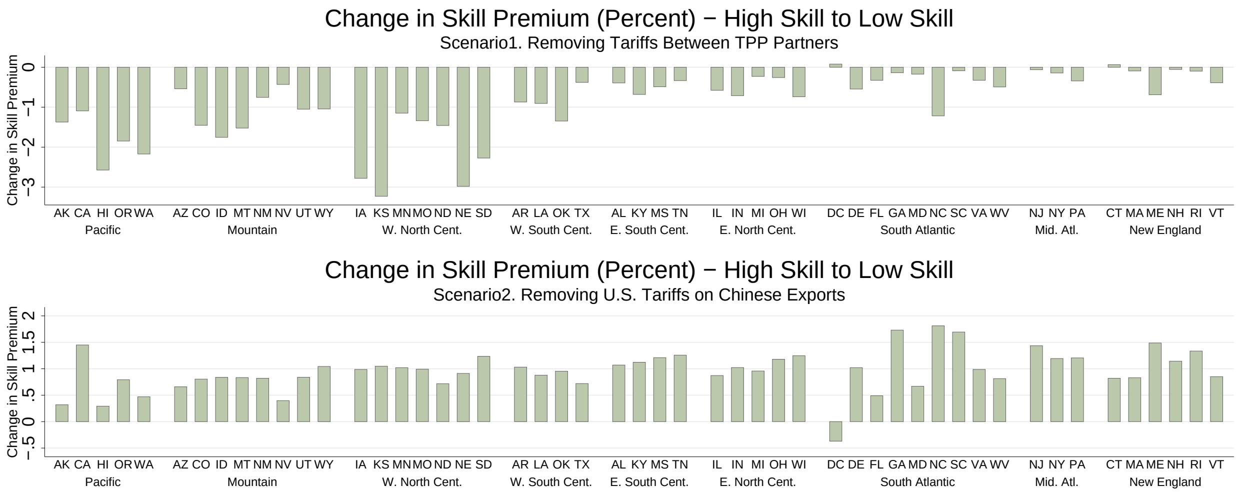
South Carolina.

2.6 Conclusion

In this chapter I investigated the potential effects of two trade policies, (i) signing the Trans-Pacific Partnership agreement, and (ii) removing U.S. tariffs on Chinese goods, on different skill groups within the U.S. Using a standard international trade model that has regional data on trade flows and employment by occupation, I showed how much the real wages of low-skilled, medium-skilled, and high-skilled workers are affected, and how much skill premium between high and low-skilled workers would change after these trade policies. While the Trans-Pacific Partnership tariff reductions reduce skill-premium, and increase real-wages of low-skilled workers, removing tariffs on Chinese goods generates the opposite effect, and leads to an increase in skill-premium.

The findings of this chapter shed a light on the distributional impacts of trade policies to determine the winners and losers from trade. Looking at both geographical and occupational dimensions of the distributional implications of economic shocks, we can provide an analysis that can influence the decision making process regarding trade policies. Labor mobility is one important factor which will also determine how long these effects will stay across different skill groups. The fact that low-skilled workers are

Figure 2.5: Change in Skill Premium due to Trade Policy Shocks



less able to move, either due to the type of job they have, or due to financial constraints, will leave more persistent shocks in labor markets that have higher fractions of these workers in their labor force.

CHAPTER 3

INTERNATIONAL TRADE AND POLITICAL INDEPENDENCE: EVIDENCE FROM CATALONIA

3.1 Introduction

Over the recent decades, the world has gone through a massive transformation of higher globalization and international trade. Not only have countries signed trade agreements, and lowered quotas and tariffs with each other that led to higher exchange of goods and factors, but they have also formed political and economic entities such as the European Union. Similar political and economic unions with similar ambitions have been on the agenda for some other regions. Yet, several authors such as Alesina, Spolaore and Wacziarg (2000) have suggested that globalization and economic integration decreases economic incentives for staying in a larger jurisdiction, i.e. a national state, and thus, deeper economic integration could lead to higher demands for political separatism and secession.

Indeed, separatist movements have gained momentum in various regions such as Catalonia, Quebec, Scotland and Belgium with the aim of establishing new national states. In addition, several political movements that are critical of the European Union, usually referred to as Eurosceptics, have been urging their governments to exit the EU. They argue that the gains from global free trade dominate gains from regional free trade agreements, i.e. the EU, and instead of remaining in a political union with others, they can instead control their domestic economic or social policies autonomously. Therefore, while political unions such as the EU, or trade agreements such as the WTO have been formed in order to reduce the effect of borders and economic barriers between nations, these very institutions ironically can lead to the formation of new sets of borders, and further impediments to free-trade and economic exchange.

In this paper, I analyze whether there is a relationship between economic integration and separatism by focusing on how potential economic costs and benefits due to secession affect opinions on political independence. In particular, I use a standard international trade model with a municipal level dataset that has production, trade and political independence opinion data from Catalonia in Spain, and test if the sectoral variation in exposure to independence in Catalonia is causally linked to pro-independence opinions in Catalonia. I find under alternative specifications that moving from the 25th percentile to the 75th percentile in terms of potential gains from independence increases pro-independence opinions by 9.2 percentage points.

I use a standard international trade model with trade and production data from Catalonia and rest of Spain to find the potential exposure of each Catalan sector to independence of Catalonia from Spain. I assume that the sole effect of Catalan independence is represented by increases in trade costs between Catalonia and the rest of Spain. Subsequently, I find the average exposure of each Catalan municipality to independence of Catalonia depending on the size of each sector's employment in that municipality. Finally, I empirically test the effect of exposure of municipalities to Catalan independence on the political opinions of their residents for independence, which I compute by using vote shares of pro-independence parties in the general and local elections in a municipality.

The main contribution of this paper is that it links potential effects due to a change in trade policy to the political opinions about that policy at the municipality level. Standard trade policy exercises test predictions of trade models for how an agent would shape her opinions about a trade policy depending on her skills, income level or sectoral specialization. However, it is not straightforward to map economic characteristics of a region to opinions on trade policy outcomes since electoral outcomes for trade policies almost do not exist, as trade policies are not voted through a referendum, or do not stand as the main factor of political debates in elections. As a result, these studies mostly rely on opinion surveys in which respondents are asked about their economic, demographic and political opinions. The main drawback with opinion surveys besides the cost and sample size is that most of them do not contain information on all of the economic, demographic and political variables simultaneously unless the opinion survey itself is specifically designed by an agency to address the research question. In this study I utilize an alternative method to conduct a trade policy exercise based on characteristics of local geographies without relying on opinion surveys. I work with the same geographical boundaries as economic census and political districts, and hence have a one-to-one connection. Furthermore, the policy in question, Catalan independence, is an issue that dominates other policies in elections in Catalonia. Hence, every election does contain significant information about opinions on Catalan independence. The advantage of following this approach is that it allows us to map economic and political variables within a local geography that has data on sectoral employment and political outcomes. The main disadvantages are, first that the economic and voting outcomes are averaged and hence we do not know which resident is voting for which outcome, and second is that people change their residences over time.

The local labor market effects of international trade shocks have become a point of interest in the trade literature, where Autor, Dorn and Hanson (2013) show the effect of China's increased competitiveness on the labor outcomes of commuting zones in the United States. Kovak (2013) shows the effect of trade liberalization by Brazil on its local labor markets. I follow a similar method and use independence of Catalonia as the main policy change by assuming that secession of Catalonia from Spain would impose additional trade barriers, thus a deliberalization, between rest of Spain and Catalonia.

In addition, this paper contributes to the political economy of country formation and nationalism and globalization literature that explore the question whether there is a relationship between international trade and political opinions on separatism. While multiple explanations are provided for this relationship in theoretical papers, only a few empirical tests have been implemented. Cross-country tests have been conducted by Brancati (2014), Sorens (2004), and Zinn (2006), where the authors of these studies ask whether there is a causal relationship between trade openness and separatist movements. This relationship is not always supported by data and also depends on other country and region-specific factors. In this study I improve this analysis using a cross-sectional dataset from a single region. By exploiting the variation within Catalonia, I forge a causal link between the variables of interest. While I focus on evidence from a single region, I believe that this is a further step in analyzing the relationship between international trade and its effects on policy choices and opinions on political separatism.

Section 2 provides a brief review of the international trade literature on trade costs and border effects, and the political economy literature on country formation and decentralization. Section 3 presents a standard Armington international trade model that allows me to compute potential exposure of sectors to Catalan independence, and relate it to the political decision making problem of an agent. Section 4 provides information on the empirical strategy and data. Section 5 presents empirical results, and section 6 concludes.

3.2 Independence and Trade Costs

Several authors have argued about the benefits of centralization, decentralization and full independence of countries, and how globalization has been affecting economic and political institutions of countries. Alesina et. al. (2000) stated that economic integration leads to political disintegration since benefits of belonging to a larger market through a unitary state diminishes with higher international trade integration that creates more economic opportunities with the rest of the world. They assume that every agent has a desired preference point based on ideology, ethnicity, or another characteristic, and therefore that agents will be closer to their ideal policy preferences in a smaller jurisdiction. Bolton and Roland (1997) provide an example on heterogeneous preferences on tax policy, and how differences in the ideal tax policy and redistribution choices could lead to higher demands for independence while taking into account the potential losses from separation. They describe the sources of the efficiency losses due to a breakup as lower economic activity resulting from having a separate currency, lower trade volume with the rest of the former union, and higher costs of public good provision. Meadwell and Martin (1996) stated that higher international trade with the rest of the world for a region lowers the barriers to exit and the short-term transition cost of independence, and enhances the long-term viability of a region upon independence. Shulman (2000) pointed out that nationalist political movements might be pro-trade because foreign ties of a minority region within a national state increases diversification and reduces the dependency of the minority region on the national state. For instance international regulations such as the EU treaties limit the power of a centralized state on its regions and minorities. Shulman (2000) additionally provides examples from Quebec, India and Ukraine on how nationalist parties react to globalization and international trade.

However some authors have also elaborated on the benefits of staying in larger jurisdictions and centralized states. Persson and Tabellini (1996) assert that larger fiscal units are more effective at risk sharing and pooling economic resources to provide insurance for regions that are adversely affected by unexpected economic shocks. Rodrik (1998), and Scheve and Slaughter (2004) argue that globalization increases volatility and aggregate economic risk.

Atkeson and Bayoumi (1993) state that integrated capital markets are likely to produce large flows of capital across regions or national boundaries, but they are unlikely to provide a substantial degree of insurance against regional economic fluctuations, except to the extent that capital income flows become more correlated across regions. Therefore, this task will continue to be primarily the business of the government. Krugman (1991) argues that as regions become more specialized, they become increasingly vulnerable to the global market shocks, and therefore will have fewer incentives to rely solely on themselves to provide insurance. Garrett and Rodden (2000) argue that the relationship between globalization and decentralization is ambiguous due to the fact that globalization and international trade increase risks, which might lead the voters to prefer higher centralization. It is pointed out in the empirical literature that globalization may not always cause separatism. Brancati (2014) asserts that since different regions do not benefit from economic integration equally, the demand for independence need not be increased in a region that is worse off. Zinn (2006) pointed that economic integration and separatism are statistically correlated, but there does not exist a causal relationship. Sambanis (2006) stated that the increased demand for independence might be offset by a federal or decentralist solution. For example, the British government offered Scotland higher autonomy and decentralization as an alternative to full independence prior to the independence referendum in September 2014.

Previous studies show how sensitive international trade is with respect to border effects and how country breakups might affect economic outcomes. Fidrmuc and Fidrmuc (2003) analyze the dissolution of Czechoslovakia and report that intra-Czechoslovakian trade was 43 times more than their trade with the rest of the world before the dissolution of Czechoslovakia, but decreased to 7 after the breakup. Djankov and Freund (2000) find that the trade between Russia and newly formed former Soviet republics have decreased significantly especially due to new trade barriers and border effects. In addition to these studies, we can also see the changes of country breakup on trade costs using data on domestic production and trade flows over time. I inferred trade costs between Czech Republic and Slovakia and their other trade partners after the formation of Czech Republic and Slovakia in January 1st, 1993. Figure (3.1) shows that the trade costs τ_{in}[1] between Czech Republic and Slovakia increased upon the dissolution of their union whereas trade costs between Czech Republic and its other main trade partners had been decrasing in this period[2]. On the effect of border effects

[1] I start with the demand equation from a standard Armington model, that is given by

$$x_{in} = \frac{(w_i t_{in})^{(1-\sigma)}}{P_n^{1-\sigma}} I_n$$

where x_{in} is the trade flows from i to n, w_i is the wage in country i, P_n is the price index of the composite good in country n and I_n is the aggregate income, or gross domestic product. The term t_{in} costs, referred as iceberg trade costs represent the frictions between countries that take into account tastes, geographic distance, economic and political policies such as tariffs or non tariff barriers and all other border effects.

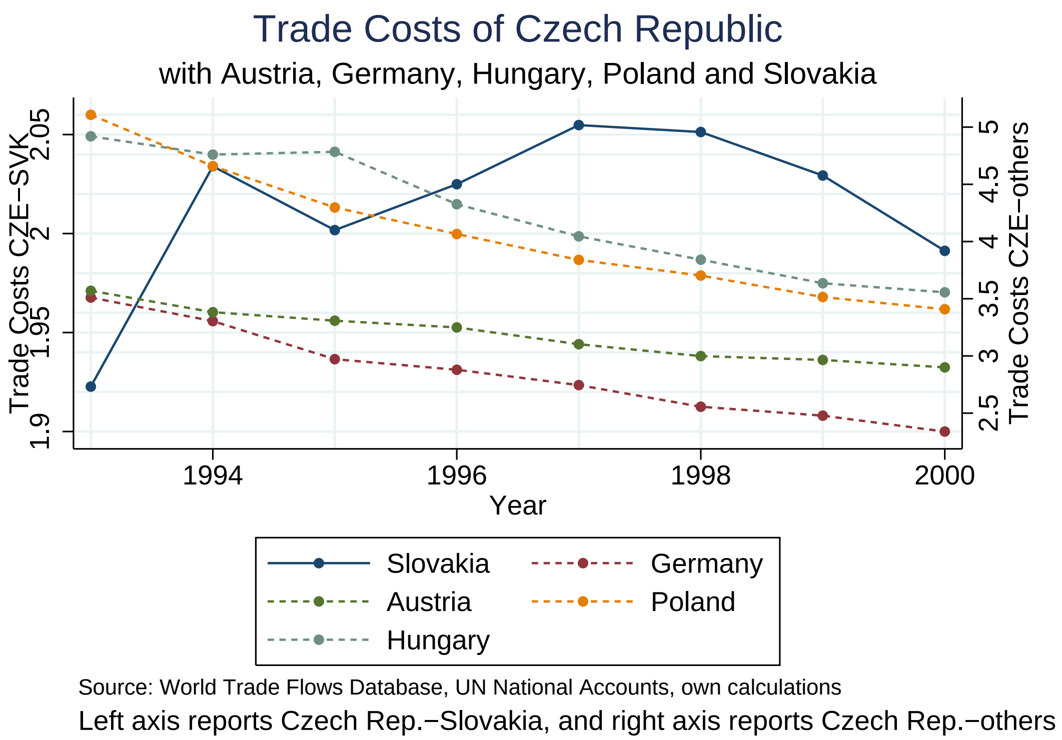
This setup leads the trade costs to be inferred from data such that

$$\tau_{in} = \frac{t_{in} t_{ni}}{t_{ii} t_{nn}} = \left(\frac{x_{ii} x_{nn}}{x_{in} x_{ni}}\right)^{2(1-\sigma)}$$

[2] I do not have interregional trade data between Czech Republic and Slovakia prior to the dissolution

of trade, McCallum (1995) reported that Canadian province traded twenty times more with each other than with US states comparable to the Canadian provinces in size and distance. Anderson and van Wincoop (2003) use a more robust specification and find that borders reduce trade flows between countries by twenty to fifty percent. Comerford and Rodriguez-Mora (2014) measured the hypothetical losses that Catalan and Scottish independence would bring on these regions and find that independence would reduce GNI in Catalonia by 10.4% and in Scotland by %5.5.

Figure 3.1: Trade Costs between Czech Republic and Slovakia upon independence



We do not know the exact effect of country breakups and independence on trade costs and trade flows. Border effects matter and inter-regional trade costs between regions are shown to have increased after dissolution of country unions in the past. Several explanations have been provided in the literature such as the effects of currency unions, distribution and transportation networks, ethnic networks and language, preferences, home market effects or boycotts (See Anderson and van Wincoop 2004 for a survey).

Finally, I do not focus on the other potential effects of secession such as changes in domestic production costs, government expenditure, risk-sharing, tax policy, redistribution or social or identity issues. I control for variable that would possibly affect the decisions of individuals such as ethnicity or income, however I do not explicitly model their effect and take these for given.

of Czechoslovakia, therefore it is not possible to observe changes in trade costs between 1992 and 1993.

3.3 Model

The economy is represented by a Armington model of international trade with multiple sectors and 3 regions. Each region $i = 1, 2, 3$ is endowed with a fixed amount of labor supply in each sector $j = 1, ..., J$, represented as L_i^j, which is immobile across regions and sectors. Region 1 and 2 are two regions within a country or union, and region 3 is rest of the world. For the empirical setup, the region of interest Catalonia will be region 1, and region 2 will be rest of Spain.

3.3.1 Demand

Agents in each region $n = 1, 2, 3$ consume varieties of goods produced by regions $i = 1, 2, 3$ from sectors $j = 1, 2, .., J$. The utility of each agent in region n is aggregated by a Cobb-Douglas utility function

$$U_n = \prod_{j=1}^{J} \left(C_n^j \right)^{\beta_j} \tag{3.1}$$

where C_n^j denotes the consumption of sector j good in region n, and β_j denotes the share of each sector in the utility function with $\sum\limits_{j=1}^{J} \beta_j = 1$.

Each sector's final good C_n^j is given by a CES aggregate of domestic and foreign varieties that are produced by and shipped from each region $i = 1, 2, 3$,

$$C_n^j = \left[\sum_{i=1}^{3} \left(Q_{in}^j \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{3.2}$$

where Q_{in}^j denotes the consumption of region n of good j produced in region i. The parameter $\sigma > 1$ is the elasticity of substitution across varieties originating from alternative destinations.

The Cobb-Douglas utility function implies that the demand for each variety is given by $P_n^j C_n^j = \beta_j I_n$, in other words expenditure final goods for each sector good j is a constant fraction of the total income I_n. The CES structure states that each variety Q_{in}^j of sector j good produced in i and sold in n that has a price p_{in}^j will have the following demand equation

$$X_{in}^j = p_{in}^j Q_{in}^j = \frac{(p_{in}^j)^{1-\sigma}}{(P_n^j)^{1-\sigma}} \beta_j I_n \tag{3.3}$$

where P_n^j is the price index of good j consumed in country n

$$P_n^j = \left[\sum_{k=1}^{J} (p_{kn}^j)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{3.4}$$

3.3.2 Production

Each good is produced using a linear and one to one production function $q_{in}^j = l_{in}^j$ that transforms each labor unit into one unit of output. Trade is subject to variable iceberg trade costs so that a shipment that arrives as Q_{in}^j from i to n requires $\tau_{in}^j Q_{in}^j$ units to be shipped, and the amount $(\tau_{in}^j - 1)Q_{in}^j$ is assumed to be lost during the journey, where $\tau_{in}^j \geq 1$. Since labor is immobile across sectors, each sector will have its own wage w_i^j, which will be a function of all of the model parameters and variables. The markets are assumed to be perfectly competitive and there are no costs of entry. As a result, profits will be zero and profit maximization leads to prices

$$p_{in}^j = w_i^j \tau_{in}^j \text{ for } j = 1, \ldots, J \tag{3.5}$$

The non-tradable sectors are not modeled as a separate sector in the model, however assuming that non-tradable sectors have infinite trade costs $\tau_{in}^j = \infty$ will result in zero trade flows for these sectors across regions.

I do not assume that labor productivity is equal to one. This does not pose a problem, since I am only interested in the percentage changes on wages in each sector after the policy shock (independence). Since labor productivity will not be differen in the new equilibrium, it is redundant to incorporate into the model.

3.3.3 Market Clearing

Since labor is the only factor, and is fixed across sectors and regions, labor market clearing within each sector leads the sectoral income to be equal to total production and sales. In other words the following equality must hold for each $i = 1, 2, 3$ and $j = 1, \ldots, J$

$$w_i^j L_i^j = \sum_{n=1}^{3} X_{in}^j \tag{3.6}$$

This equality also insures that trade is balanced across regions

$$\sum_{j=1}^{J}\sum_{n=1}^{3} X_{in}^{j} = \sum_{j=1}^{J}\sum_{n=1}^{3} X_{ni}^{j} \tag{3.7}$$

Combining equation (3.6) with the demand equation (B.1), profit maximization condition (B.2) and the price index (3.5) leads to

$$w_i^j L_i^j = \sum_{n=1}^{3} X_{in}^{j} = \sum_{n=1}^{3} \frac{(w_i^j \tau_{in}^j)^{1-\sigma}}{(P_n^j)^{1-\sigma}} \beta_j I_n \tag{3.8}$$

where aggregate income I_n, and price index P_n^j are given by

$$I_n = \sum_{j=1}^{J} w_n^j L_n^j \tag{3.9}$$

$$(P_n^j)^{1-\sigma} = \sum_{k=1}^{J} (w_k^j \tau_{kn}^j)^{1-\sigma} \tag{3.10}$$

Equation (3.8) is a non-linear system of $3J$ equations and $3J$ unknowns. Equilibrium wages can be solved using this equation, and the equilibrium can be defined accordingly.

Definition 3. *Given L_n^j and τ_{in}^j, an equilibrium is a wage vector $\mathbf{w} = \{w_i^j\}_{j=1,i=1}^{J,N}$ that satisfies equation (3.8) where income and prices are given by equations (3.9) and (3.10) for $j = 1, ..., J$ and $i, n = 1, 2, 3$.*

Instead of solving the model, and then computing the effect of policy changes on model outcomes, I find the counterfactual effects of policy changes by focusing on percentage deviations around the equilibrium. After writing the model in deviations, they compute the counterfactual effects of tariff or trade cost changes on using data on exports, imports and production[3] .I log-deviate each variable and work with percentage changes of sectoral wages for each sector in country 1 after region 1 becomes independent.

As explained before, the sole effect of a breakup between regions 1 and 2 is the imposition of higher trade barriers between regions 1 and 2. In other words, the trade costs τ_{12}^j and τ_{21}^j will increase in each sector. I will assume that independence of region 1 will not significantly affect their relationship with the rest of the world, hence the trade costs with respect to the rest of the world will not change. Similarly, the trade

[3]See similar approaches in Arkolakis et al. (2012), Costinot et al. (2010), Caliendo and Parro (2014), and Costinot and Rodriguez-Clare (2013).

costs of each region with respect to their domestic market, τ_{ii}^j will not change. For further simplicity, the trade cost changes in each sector between region 1 and 2 will be assumed to be identical. Each variable will be denoted by its log-deviation, or percentage change $\widehat{x} = \frac{\Delta X}{X} = d\log X$ around the initial value X prior to the change. The structure of the changes in trade costs $\widehat{\tau}_{in}^j$ is summarized as

Assumption 1. *Independence affects trade costs only between regions 1 and 2 :* $\widehat{\tau}_{i3} = \widehat{\tau}_{3i} = \widehat{\tau}_{ii} = 0$ *for all* $i = 1, 2, 3$.

Assumption 2. *Percentage changes in trade costs is identical across all sectors and regions 1 and 2 :* $\widehat{\tau}_{12}^j = \widehat{\tau}_{21}^j = \widehat{T}$ *for all* j*, for a scalar* $\widehat{T}$.

Log differentiating equation (3.8) around the initial equilibrium results in

$$\sigma \widehat{w}_i^j = \sum_{n=1}^{3} \theta_{in}^j \left[\widehat{I}_n - (\sigma - 1)\widehat{\tau}_{in}^j + (\sigma - 1)\widehat{P}_n^j \right] \tag{3.11}$$

with $\theta_{in}^j = \frac{X_{in}^j}{\sum_{n=1}^{3} X_{in}^j}$ is the share of region i's sales of good j to region n in its total sales of j. Note that since L_i^j is assumed to be fixed, its deviations will be zero, $\widehat{L}_i^j = 0$. The change of the price index, $\widehat{P}_n^j$, and aggregate income $\widehat{I}_n^j$ can be expressed in terms of the endogenous variables and other parameters

$$\widehat{P}_n^j = -\frac{1}{\sigma - 1} \sum_{k=1}^{3} \phi_{kn}^j \left[-(\sigma - 1)(\widehat{w}_k^j + \widehat{\tau}_{kn}^j) \right] \tag{3.12}$$

$$\widehat{I}_n^j = \sum_{j=1}^{J} \lambda_n^j \widehat{w}_n^j \tag{3.13}$$

where $\phi_{kn}^j = \frac{X_{kn}^j}{\sum_{l=1}^{3} X_{ln}^j}$ is the share of region k's sales to region n in sector j in the total expenditure of region n of good j. Since aggregate income is given by $I_n = \sum w_n^j L_n^j$, the constants $\lambda_n^j = \frac{w_n^j L_n^j}{\sum_{g=1}^{J} w_n^g L_n^g}$ denotes the share of total income of sector j in the aggregate income of country n. Plugging equations (12) and (13) into equation (3.11) results in the following expression

$$\sigma \widehat{w}_i^j = \sum_{n=1}^{3} \theta_{in}^j \left[\sum_{j=1}^{J} \lambda_n^j \widehat{w}_n^j - (\sigma - 1)\widehat{\tau}_{in}^j + (\sigma - 1) \sum_{k=1}^{3} \phi_{kn}^j (\widehat{w}_k^j + \widehat{\tau}_{kn}^j) \right] \tag{3.14}$$

This equation indicates that given certain changes on trade costs $\widehat{\tau}_{in}^j$, elasticity of substitution σ, and data $(\theta_{in}^j, \phi_{in}^j, \lambda_{in}^j)$ for each i, n, j, the changes in wages $\widehat{w}_n^j$ can be solved from a linear system of $3J$ equations and $3J$ unknowns. As a result, the only endogenous variables are the sectoral wage losses $\widehat{w}_i^j$ for $i = 1, 2, 3$.

In addition, since region 3 is very large compared to region 1 and 2, there are very small changes on w_3^j, therefore we can assume that $\widehat{w}_3^j = 0$ for all $j = 1, ..., J$ for simplicity. Since all region 3 wages are zero, any of w_3^j can be designated as the numeraire good.

After these assumptions, we will have two sets of endogenous variables $\widehat{w}_1^j$ and $\widehat{w}_2^j$ for $j = 1, ..., J$. The variable of interest of the model, the sectoral change in region 1, $\widehat{w}_1^j$ can be thus computed using data on θ_{in}^j, ϕ_{in}^j and λ_{in}^j. There will be $2J$ equations and $2J$ unknowns given by equation (3.14). Using the trade cost change structure, expressed in assumptions (1) and (2), the trade cost terms will be either zero or $\widehat{T}$. Therefore, given the elasticity of substitution σ, change in trade costs $\widehat{T}$, and parameters derived from data θ_{in}^j, ϕ_{in}^j and λ_i^j, the change in wages in region 1 and 2 can be expressed as

$$\widehat{w}_1^j = a_1^j \widehat{I}_1 + b_1^j \widehat{I}_2 + c_1^j \widehat{T} + d_1^j \widehat{w}_2^j \tag{3.15}$$

$$\widehat{w}_2^j = a_2^j \widehat{I}_1 + b_2^j \widehat{I}_2 + c_2^j \widehat{T} + d_2^j \widehat{w}_1^j \tag{3.16}$$

where the constants are given by[4]

$$a_1^j = \frac{\theta_{11}^j}{K_1^j}, \quad a_2^j = \frac{\theta_{21}^j}{K_2^j}, \quad b_1^j = \frac{\theta_{12}^j}{K_1^j}, \quad b_2^j = \frac{\theta_{22}^j}{K_2^j}$$

$$c_1^j = \frac{(\sigma-1)(\theta_{12}^j(\phi_{12}^j - 1) + \theta_{11}^j \phi_{21}^j)}{K_1^j}, \quad c_2^j = \frac{(\sigma-1)(\theta_{21}^j(\phi_{21}^j - 1) + \theta_{22}^j \phi_{12}^j)}{K_2^j}$$

$$d_1^j = \frac{(\sigma-1)(\theta_{11}^j \phi_{21}^j + \theta_{12}^j \phi_{22}^j + \theta_{13}^j \phi_{23}^j)}{K_1^j}, \quad d_2^j = \frac{(\sigma-1)(\theta_{21}^j \phi_{11}^j + \theta_{22}^j \phi_{12}^j + \theta_{23}^j \phi_{13}^j)}{K_2^j}$$

[4] $K_1^j = \sigma - (\sigma-1)(\theta_{11}^j \phi_{11}^j + \theta_{12}^j \phi_{12}^j + \theta_{13}^j \phi_{13}^j)$ and $K_2^j = \sigma - (\sigma-1)(\theta_{21}^j \phi_{21}^j + \theta_{22}^j \phi_{22}^j + \theta_{23}^j \phi_{23}^j)$.

Solutions of system (15) and (16) give the following equality for wages in region 1.[5]

$$\widehat{w}_1^j = \left(A^j E_1 + B^j E_2 + C^j\right)\widehat{T} \tag{3.17}$$

The constants A^j and B^j indicate how much each sector is affected through changes in the reductions in the aggregate income of regions 1 and 2. When aggregate income falls in regions 1 and 2, their demands for all products decline, and if a sector j trades significantly with regions 1 and 2, the magnitudes of A^j and B^j will be higher accordingly, and sector j will face higher losses. On the other hand, the term C^j denotes the direct effect of trade cost increases on sectoral wage j, that is independent of the

[5]Upper case constants A_1^j, A_2^j, B_1^j, B_2^j, C_1^j and C_2^j are given by

$$D^j = 1 - d_1^j d_2^j$$

$$A_1^j = \frac{a_1^j + d_1^j a_2^j}{D^j} \qquad A_2^j = \frac{a_2^j + d_2^j a_1^j}{D^j}$$

$$B_1^j = \frac{b_1^j + d_1^j b_2^j}{D^j} \qquad B_2^j = \frac{b_2^j + d_2^j b_1^j}{D^j}$$

$$C_1^j = \frac{c_1^j + d_1^j c_2^j}{D^j} \qquad C_2^j = \frac{c_2^j + d_2^j c_1^j}{D^j}$$

Greek letter constants: $\alpha_i, \beta_i, \gamma_i$: summed over all sectors $j = 1, ..., J$:

$$\alpha_1 = \sum_{j=1}^{J} \lambda_1^j A_1^j \qquad \alpha_2 = \sum_{j=1}^{J} \lambda_2^j A_2^j$$

$$\beta_1 = \sum_{j=1}^{J} \lambda_1^j B_1^j \qquad \beta_2 = \sum_{j=1}^{J} \lambda_2^j B_2^j$$

$$\gamma_1 = \sum_{j=1}^{J} \lambda_1^j C_1^j \qquad \gamma_2 = \sum_{j=1}^{J} \lambda_2^j C_2^j$$

Change in I_1 and I_2 (aggregate income) :

$$E_1 = \frac{\beta_1\gamma_2 - \beta_2\gamma_1 + \gamma_1}{1 - \alpha_1 - \beta_2 + \alpha_1\beta_2 - \alpha_2\beta_1}$$

$$E_2 = \frac{\beta_2\gamma_1 - \beta_1\gamma_2 + \gamma_2}{1 - \alpha_2 - \beta_1 + \alpha_2\beta_1 - \alpha_1\beta_2}$$

$$\widehat{I_1} = E_1\widehat{T}$$

$$\widehat{I_2} = E_2\widehat{T}$$

Sectoral output loss:

$$\widehat{w}_1^j = \left(A_1^j E_1 + B_1^j E_2 + C_1^j\right)\widehat{T}$$

$$\widehat{w}_2^j = \left(A_2^j E_1 + B_2^j E_2 + C_2^j\right)\widehat{T}$$

general equilibrium effects through the change in aggregate income of regions 1 and 2.

Overall, equation (3.17) expresses the change in sectoral wages in region 1, $\widehat{w}_1^j$, after region 1 becomes independent, or in other words when trade costs of each sector between regions 1 and 2 increase by the same percentage. The disproportionate effects of trade cost changes on each sector are generated due to differences in sectoral characteristics, that are simply variations in θ_{in}^j, ϕ_{in}^j and λ_i^j. Therefore, the model and the data will result in variations in each sector will be proportional to the increases in trade costs $\widehat{T}$, which I call as the counterfactual border effect between regions 1 and 2. We do not know the magnitude of $\widehat{T}$ after the secession of region 1. Since I do not have potential estimates on $\widehat{T}$ at this point, I will refer to the magnitudes of sectoral wage changes in terms of $\widehat{T}$ from equation (3.17). Note that the border effect $\widehat{T}$ might also be changing over time, and therefore different counterfactual trade cost changes will lead to different scaling effects on $\widehat{w}_1^j$.

For now, I will assume that the border effects are and unknown number $\widehat{T}$ and time invarying. The following proposition summarizes the effect of independence on sectoral wages in region 1.

Proposition 1. *Given assumptions (1) and (2), if trade costs increase by $\widehat{T}$ percent in each sector due to breakup of region 1 from region 2, percentage changes wages in each sector j in region 1 $\widehat{w}_1$ percent are given by*

$$\widehat{w}_1^j = \left(A^j E_1 + B^j E_2 + C^j\right)\widehat{T}$$

where the constants A^j, B^j, C^j, E_1 and E_2 are constants with model parameters.

3.3.4 Political Decision Problem

The region of interest is region 1 in this paper. As a result, I will remove the country subscripts as the remaining analysis will be only focusing on developments in region 1; $\widehat{w}_1^j$, which will be denoted as $\widehat{w}^j$. Region 1 is composed of M municipalities indexed by $m = 1, ..., M$. Each municipality m is populated with L_m workers, and L_m^j of those work in sector j. An agent i who lives in m has a type $\mu^i = (\mu_0^i, \mu_1^i)$, which represents her preferences for union μ^i and independence μ_1^i. Agent i receives utility from wages of the sector in which she is working, and from her preference for independence and union in each state. Specifically, the utilities under independence and union will be given by

$$W_i^j(1) = w_1^j \mu_1^i \tag{3.18}$$

$$W_i^j(0) = w_0^j \mu_0^i \tag{3.19}$$

where $W_i^j(s)$ denotes the welfare under state $s = 0$ (union) and $s = 1$ (independence).

Agent i who works in sector j will be inclined towards independence if $W_i^j(1) > W_i^j(0)$. The preference term μ^i results from various factors that affect an agent's opinions on independence. Such factors are ethnicity, political ideology, income level of the individual other than the average sector level wage, education, age and various other variables.

Given this configuration, the probability that an agent who works in sector j will support independence will be given by

$$\begin{aligned} p^j =& prob\Big(W_i^j(1) > W_i^j(0)\Big) \\ =& prob\Big(\log W_i^j(1) - \log W_i^j(0) > 0\Big) \\ =& prob(\widehat{w}^j > -\widehat{\mu}^i) \end{aligned}$$

where $\widehat{w}^j$ denotes the percentage change in the sectoral wage of sector j, that is computed with the economic model, and given by Proposition (1). This number $\widehat{w}^j$ will have a negative value if the effect of independence on wages is negative, i.e. $\widehat{w}^j < 0$. Therefore, she will have a higher probability of voting for independence, holding other variables constant, if wage losses are small, or wage change is positive, i.e. $\frac{\partial p^j}{\partial \widehat{w}^j} > 0$. I assume that the change in preference parameter $\widehat{\mu}^i$ follows a probability distribution $F(\cdot)$ where each agent is independently and identically distributed.

The decision rule can be expressed with the observable characteristics of the agent with the equation

$$p_i = \alpha + \beta\widehat{w}^{j(i)} + \gamma\mathbf{x}_i + \nu_i \tag{3.20}$$

where p_i denotes the probability that an agent will be inclined towards independence, $\mathbf{x}_i$ is the observable characteristics, and ν_i is an error term that represents the variation for agent i given the sectoral wage loss from independence and observable characteristics.

Unfortunately a dataset that provides statistics on political opinions and economic characteristics such as wages or industry of employment at the individual level are not available at the same time. As a result, I cannot implement an empirical test for equation (3.20). Nevertheless, election results and employment distribution statistics are available at local geographic levels in many countries. In my empirical tests, I use data from Catalan municipalities.

Hence, I can use an aggregated version of equation (3.20) by using political, economic and demographic statistics of municipalities. I work with average and aggregate statistics for independence opinions, economic outcomes, namely $\widehat{w}_i$, and other economic and demographic characteristics. The main empirical equation will transform into

$$Indep_{mt} = \alpha_t + \beta exposure_{mt} + \gamma \mathbf{X}_{mt} + \mu_m + \varepsilon_{mt} \tag{3.21}$$

where dependent variable is the independence proxy $Indep_{mt}$, which is the average pro-independence opinions in municipality m at date t. The main explanatory variable is $exposure_{mt}$, which is the average change in wages in municipality m at time t that is constructed as a weighted sum using the labor distribution of municipality m at time t and potential losses of sectors from independence, $\widehat{w}^j$.

$$exposure_{mt} = \sum_{j=1}^{J} \left(\frac{L_{mt}^j}{L_{mt}} \right) \widehat{w}_t^j \tag{3.22}$$

L_{mt}^j is the employment of municipality of m at time t in sector j, and L_{mt} is the total labor force of municipality m at date t. $\mathbf{X}_{mt}$ is the vector of other explanatory variables such as average wage of municipality, percentage born outside of Catalonia, percentage of residents of m who speak Catalan, average education level and average age. The fixed effects that affect independence opinions in a municipality is given by μ_m, and ε_{mt} is the residual term.

3.4 Data Description and Econometric Specification

3.4.1 Data Description

In order to perform the empirical tests, I collected data from various sources. I used input-output tables from Catalonia and Spain to compute the sectoral wage losses $\widehat{w}^j$ due to independence. Employment and demographic data at the municipal level is available from population surveys. The independence opinions at the municipal level are constructed using election results and political opinion surveys. International trade flow data, and sectoral production data is used for exogenous sectoral changes and developments in other countries. Here is the detailed description for each of these sources and how they are used to construct the variables.

Input-Output Tables: I used regional Catalan input-output tables, and Spanish national input-output tables, which provide information for retrieving all the parameters ($\theta_{in}^j, \phi_{in}^j, \lambda_i^j$) of the model. The National Institute of Statistics of Spain (INE) has constructed input-output tables for Spain for years 1985-2011, however the Catalan Statistical institute (IDESCAT) prepared the Catalan input-output tables only for years 1987, 2001, 2005 and 2011. Therefore I was able to construct the sectoral loss $\widehat{w}_t^j$ only for years the Catalan input-output tables are available. Since these tables are constructed by different sources and at different years, various industry classifications for each of the tables have been used. For each of the years I use the necessary concordance tables and work with the same industry classifications.

Once both Catalan and Spanish input-output tables report the statistics for the same industry classifications, information on trade flows between regions 1,2 and 3, and total production are necessary to compute the model parameters. The regional trade flows between two Catalonia (region 1) and rest of Spain (region 2), X_{12}^j and X_{21}^j for each $j = 1,...,J$ are derived from Catalan input output tables as they report imports from rest of Spain and exports to rest of Spain for each sector. The Catalan exports to the rest of the world, and imports of Catalonia from the rest of the world are also reported, and hence I derive X_{13}^j and X_{31}^j for each sector. In addition, total production values in each sector are available, which will be denoted as $Y_1^j = w_1^j L_1^j$, and the domestic trade flows from Catalonia to Catalonia will be production net of total exports, $X_{11}^j = Y_1^j - X_{12}^j - X_{13}^j$. I derive the exports and imports of the rest of Spain with respect to the rest of the world by substracting Catalan exports and imports from total Spanish imports and exports, and hence find X_{23}^j and X_{32}^j. Accordingly, production of each sector for the rest of Spain will be total Spanish production net of total Catalan production within a sector, which is given by $w_2^j L_2^j$. Accordingly, the domestic tradeflows from rest of Spain to itself will be production net of total exports to Catalonia and the rest of the world, $X_{22}^j = Y_2^j - X_{21}^j - X_{23}^j$. With this information, I compute the export shares θ_{in}^j for $in \in \{11,12,13,21,22,23\}$, ϕ_{in}^j for $in \in \{11,21,31,21,22,23\}$, shares of each sector in production λ_i^j for $i = 1,2$ for each sector $j = 1,...,J$. The remaining variables for the rest of the world such as total production in each sector, $Y_3^j = w_3^j L_3^j$ or the total trade flows from the rest of the world to itself will not be used, since the changes to the rest of the world are assumed to be negligible, and hence $\widehat{w}_3^j = 0$, and the import share of the rest of the world from Catalonia and Spain will also very small and will be assumed as zero, i.e. $\phi_{13}^j = \phi_{23}^j = 0$ for all $j = 1,...,J$. λ_1^j and λ_2^j are calculated using $Y_!^j$ and Y_2^j according to the definition in the previous section.

Population Census: I used the population census of Catalan municipalities for the necessary employment, occupation and demographic variables. The National Statistical Institute of Spain (INE) has conducted population censuses in 1991, 2001 and 2011, and the Catalan Statistical Institute (IDESCAT) has conducted its own population censuses in 1986, 1991 and 1996. These censuses contain information on employment by sector, employment by occupation, age distribution, education levels by categories, knowledge of Catalan, region of birth, and other characteristics.

The employment statistics in each census years are prepared with different classifications. 1991 Census has its own 26 sector classification that is an aggregated version of

CNAE-74 classification. The 2001 census provides employment in industries at the 3 digit NACE Rev. 1 level, and 2011 census provides employment in industries at the 3 digit NACE Rev. 2 level. The sectors are aggregated up to the sectoral classification used in the corresponding input-output tables. Occupation in each sector is provided using CNO-74 in 1991, CNO-94 in 2001 and CNO-2011 in 2011. Income level of municipalities are not avaiable, however we can construct and average wage variable using the occupation distribution in a municipality and the average earnings of each occupation in Spain for that year. Specifically, the $AverageWage_{mt}$ is given by

$$AverageWage_{mt} = \sum_{k=1} \frac{l_{mt}^k}{L_{mt}} e_t^k \tag{3.23}$$

where e_t^k denotes the mean earnings of occupation k in Spain at date t and l_{mt}^k represents the number of residents of m at date t who hold the occupation k. The average earnings in each year t is retrieved from INE's 4 yearly survey employment. The dates available are 1995, 2001 and 2012 and if the wage in the occupation for a year is not available, the year that is the closest to the statistic is used. The variables that control ethnicity are denoted as $BornOutside_{mt}$ and $SpeakCatalan_{mt}$, which are respectively the fraction of the residents of m at date t who are born outside of Catalonia, and the fraction who speak Catalan.

Political Data: In order to construct the proxy for independence, I work with Spanish general and Catalan regional election results for party strength in each municipality, and opinion surveys to find stances of each parties' supporters on independence of Catalonia[6].

There are many different political parties that participate in Catalan elections. These political parties occasionally form alliances, change names or join other parties. However the main parties that have had strong support from the public, and kept their core party structure are CiU (Convergence and Union), ERC (Rebuplican Left of Catalonia), ICV (Initiative for Catalonia Greens), PSC (Socialists' Party of Catalonia) and PP (Popular Party).

ERC has always supported full-independence whereas CiU, which is a right-center nationalist political party, and ICV-Greens had supported higher autonomy for Catalonia historically, however they shifted their stance towards full-independence gradually. PSC is the Catalan branch of PSOE (Spanish Socialist Workers' Party), which had a strong popularity in Catalonia as a major left-wing political party, adopted an anti-independence federalist position, and lost its popularity in the recent years. As for the

[6]The election data is retrieved from the Interior Ministry of Spain.
Informacion Electoral - Ministerio del Interior, http://www.interior.gob.es/web/interior/informacion-electoral

other parties, Popular Party of Catalonia, which is the Catalan branch of the Spanish-wide conservative Popular Party, and the newly formed C's (Party of the Citizenry) have a very clear anti-independence position. Finally, newly formed anti-establishment PODEMOS party in Spain supports self-determination of the Catalans, and want to hold a referendum for independence, but prefers to keep Spain united.

In order to gauge the stance of each political party for independence over time. I utilize opinion surveys by matching pro-independence opinions of voters of each party. ICPS (Institut de Ciencies Politiques y Social) in the Autonomous University of Barcelona has conducted a political opinion survey in 1991-2013 in Catalonia where respondents were asked about their characteristics and opinions on political outcomes, such as their demographic and economic characteristics, ideology, ethnicity and stances on certain issues. They were also asked for which party they have voted in the recent general and regional elections. I use the information on the parties for which the respondents have voted and their positions on independence to find an average score for each party's supporters' stance on independence.

In order to estimate the average pro-independence stance of voters of each party, I implemented a probit regression at each survey date t of independence opinion D_{it} on the party choice of the respondent, d_{ikt}. D_{it} is a dummy variable that takes the value 1 if the respondent has indicated that she supports independence and 0 otherwise. The variable d_{ikt} is also a dummy variable that takes the value 1 if respondent i voted for party k in the most recent elections prior to the time of the survey t. Since the survey data does not follow individuals over time, I estimated the coefficients at each date separately, and ran regressions for each of the years $t = 1991, ..., 2013$.

$$prob(D_{it} = 1) = \gamma_t + \sum_{k=1}^{K} \delta_{kt} d_{ikt} + \epsilon_{it} \tag{3.24}$$

The predicted $\widehat{\gamma_t}+\widehat{\delta_{kt}}$ will give the probability that a voter of party k has pro-independence position at date t. Using these predicted probabilities and vote shares of each party at date t, I predict the average pro-independence opinion in a municipality m

$$Indep_{mt} = \widehat{\gamma_t} + \sum_{k=1}^{K} \widehat{\delta_{kt}} v_{kmt} \tag{3.25}$$

where v_{kmt} is the vote share of party k in municipality m at date t. There are two types of elections, Catalan regional and Spanish general elections. I followed this strategy for both election types and found two independence proxies, one for Catalan regional elections and the other for Spanish general elections.

I did not simply add the vote shares of pro-independence and nationalist parties due to three reasons. First, average pro-independence position of voters of each party are different even if both parties clearly express pro-independence or anti-independence opinions. Second, some parties such as PSC may not have a very clear position consistently on autonomy and independence of Catalonia, and my method can quantify their middle position. Third, the party stances and positions, or voters' perception of parties' positions might change over time.

3.4.2 Empirical strategy

After constructing the necessary variables, I move on to the estimation of equation (B.3). The estimation of equation (B.3) faces two serious problems, the fixed effects within a municipality, and endogeneity or measurement errors in the main regressor $exposure_{mt}$. In order to control for the fixed effects, I use a first-differencing approach by using the changes of each variable over time and rewrite the regression equation as

$$\Delta Indep_m = \Delta\alpha + \beta\Delta exposure_m + \Delta\gamma\mathbf{X}_m + \Delta\varepsilon_m \tag{3.26}$$

where Δx_m denotes the changes in x from initial period to the second period. I use census dates 1991 and 2011 for time $t = 1$ and $t = 2$ where the right-hand side variables $exposure_{mt}$ and $\mathbf{X}_{mt}$ will have their municipality values from the Spanish Census of 1991 and 2011. The industry statistics that I will use for these dates will be the IO tables for 1987 for date $t = 1$ and IO Tables in 2011 for date $t = 2$. I do not use the census year 2001 and the input-output tables in 2001 because there are small changes in terms of the right-hand side variable $exposure_{mt}$ between years 1991 and 2001. As a result, the first differencing method does not provide meaningful estimates. In addition, since there are also small changes in trade flows, the instrument that I have provided does not acccount for small changes in $exposure_{mt}$.

In order to form a causal relationship between $exposure_{mt}$ and $Indep_{mt}$, we need to be sure that the estimation will not be biased due to endogeneity of the regressors or measurement errors. First, there might be unobservable omitted variables that affect the independent and dependent variables jointly, which could lead to biased estimates. One source of a possible omitted variable is the omission of factors that affect the initial distribution of employment and sectors across Catalonia. I do not have an explanation on the distribution of employment for each sectors across municipalities. For instance if ethnically Spanish population for any reason work more in sectors that trade more with Spain, there will be a positive correlation between a negative and large $exposure_{mt}$ and low independence opinions $Indep_{mt}$.

In addition, if workers from the rest of Spain move to a municipality because it is close to a Spanish-owned factory that trades more with Spain, we will also see a positive correlation between independence opinions and exposure to independence, since workers from rest of the Spain will be very much against independence of Catalonia.

Another source of endogeneity might arise if the Catalan regional government has a role in shaping industry and trade reorientation towards more economic exchange with the rest of the world as a party of their political agenda. Meadwell and Martin (1996) argue that international trade increases economic viability of a region, which increases supports for independence. If this is the case, the municipalities in which there is more Catalan government influence or support would be more likely to increase their trade with the rest of the world, and also have higher support for independence.

Finally, the estimation procedure could face problems from measurement errors in the independent variable. Since I work with use municipal level data and the variable $exposure_{mt}$ is an average score that does not take into account the variation within a municipality, there is a serious concern about measurement errors for average exposure, and the variation of exposure within a municipality. The estimation does not take into account how conflicting interests that come from sectoral distribution within a municipality will result on the independence opinions.

In order to control for these problems, I provide an instrument Z_m, which is the exposure of each municipality to trade cost changes of sectors in various Western European countries excluding Spain[7]. In order to construct this instrument, I first use the inferred bilateral trade costs between each country in the sample.

$$\tau^j_{int} = \left(\frac{x^j_{iit} x^j_{nnt}}{x^j_{int} x^j_{nit}} \right)^{\frac{1}{2(\sigma-1)}} \tag{3.27}$$

where x^j_{int} and τ^j_{int} are respectively trade flows and trade costs from i to n in sector j at date t[8]. The trade flow data x^j_{int} is taken from United Nations Commodity Trade Database, and the sectoral production data in each country x^j_{iit} is retrieved from the OECD-STAN Database for Structural Analysis. I used to 2 digit ISIC Rev.3 aggregation, and computed the trade costs for only traded commodities. After inferring the trade costs from data, I averaged trade costs of each sector j at each t across country pairs, and find T^j_t, that is the average trade costs of sector j good at date t. Since I am interested in the change of these trade costs over time, I grouped dates 1992, 1993 and 1994 for the early period, and 2005, 2006 and 2007 for the later period. Then, I find the the percentage change of trade costs in each sector between these dates, which I denote by

[7] Austria, Germany, Denmark, Finland, Italy, Netherlands, Sweden, United Kingdom

[8] We need to assume that the bilateral trade costs are symmetric betweeen two destinations

g_τ^j

$$g_\tau^j = \frac{\tau^j_{laterperiod} - \tau^j_{earlyperiod}}{\tau^j_{earlyperiod}} \tag{3.28}$$

For relating this variable to the employment variation in each municipality, I use the earliest employment distribution as possible, which is provided in 1986 population census by IDESCAT. Then, I calculate an aggregate sum for the average exposure to the change in trade costs in each sector, that is given by

$$Z_m = \sum_{j=1}^{J} \frac{L^j_{m1986}}{L_{m1986}} g_\tau^j \tag{3.29}$$

Note that, non-tradable sectors will receive a value of 0 for g_τ^j. Positive and high values of Z_m indicate that trade costs have increased on average for the sectors that are more pervasive in m. The theoretical model states that these sectors should have traded less with these European countries, and should have lower and possibly negative values $\Delta exposure_{mt}$. Equivalently, a negative and large value of Z_m predict that the sectors within m should have reorientated their sales towards Europe due to European economic integration and lower trade costs. As a result, a municipality with a negative and large value of Z_m should have faced increases in $exposure_{mt}$.

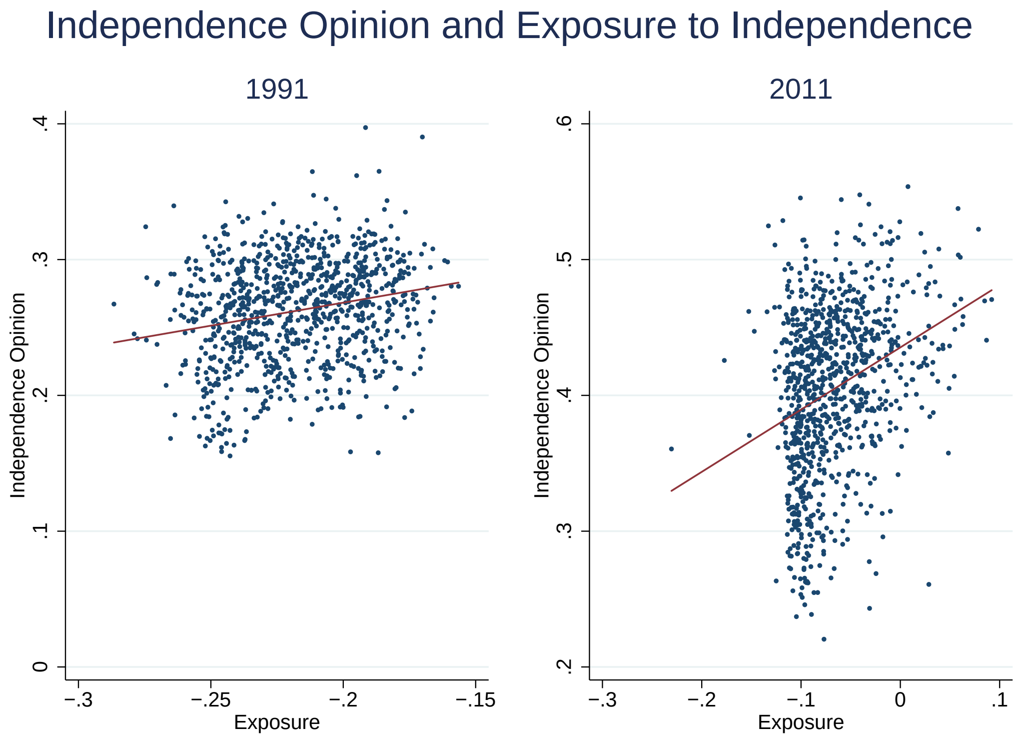
The first stage results show that this intuition is valid. As shown in table (1), there is a negative and significant relationship between Z_m and $\Delta exposure_{mt}$.

3.5 Empirical Results

Table (3.2) displays the results of equation (3.26). Columns (1) and (2) show the OLS results without using the instrument Z_m. All standard errors are clustered around local labor market areas (Els mercats de treball) in Catalonia that are prepared by the geographical planning directorate of the regional government of Catalonia according to the commuting data in 1991 (Generalitat de Catalunya, 1995).

The coefficient of interest, β is around 0.2 in both specifications, which indicate that moving from the 25th percentile to 75th percentile for the variable $exposure_{mt}$, increases pro-independence opinions by 1.2 percentage points. Columns (3)-(6) report the two stage least squares results when $\Delta exposure_{mt}$ is instrumented by Z_m. The results show that the coefficient β increases substantially to 1.67 in the full specification. In particular, moving from the 25th percentile to 75th percentile for $exposure_{mt}$ independence opinions increase by 9.2%.

Figure 3.2: Independence and Trade Costs



We also note that the effect of having a higher average income level results in increases in independence opinions, specifically, having 10,000 euros higher average income results in an increase of 7.56 percentage points for independence opinions. However, we see that neither the knowledge of Catalan language nor being from outside of Catalonia results in the desired direction, nor are significant. The first differencing method leads the fixed effects to be removed, which is highly indicative of the ethnic distribution within a municipality.

The huge difference in the coefficients of the main explanatory variable might be because the instrumental variable approach is correcting the measurement errors in the explanatory variable, which biases the coefficient towards zero in the OLS estimation. Another reason could be because historically there might be a correlation between locations and sectors that have higher independence opinions and lower exposure, and the change in exposure does not reflect much increases in independence opinions. However once we use the instrument Z_m, which shows the potential effects of the effect of European integration on sectors exogenously, we might be correcting for this bias. However, the substantial difference between the OLS and 2SLS results might be due to measurement errors in the instrument, or problems with the specification, for which additional robustness checks are needed with additional variables. So far the only control variable I have used are income and ethnicity since the fixed effects absorb for

Table 3.1: First Stage Results

	(1)	(2)	(3)	(4)
	$\Delta exposure$	$\Delta exposure$	$\Delta exposure$	$\Delta exposure$
Z	-0.0749***	-0.0727**	-0.0978***	-0.0978***
	(0.022)	(0.023)	(0.022)	(0.022)
$\Delta AverageWage$	-0.0295***	-0.0295***	-0.0438***	-0.0438***
	(0.004)	(0.004)	(0.004)	(0.004)
$\Delta BornAbroad$		0.00446	0.0127	0.0127
		(0.011)	(0.012)	(0.012)
$\Delta SpeakCatalan$			0.0283*	0.0283*
			(0.012)	(0.012)
Constant	0.160***	0.160***	0.166***	0.166***
	(0.003)	(0.003)	(0.003)	(0.003)
Observations	938	938	929	929
R^2	0.068	0.068	0.109	0.109

Robust standard errors in parentheses

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

all variable that do not change over time within a municipality.

Despite the potential errors in the specification, the results show that the variation in terms of potential losses that independence would incur on the municipalities in Catalonia are correlated with independence opinions in Catalonia in both OLS and 2SLS specifications. The 2SLS results indicate that there is a causal relationship of the exposure to potential losses of independence on independence opinions.

3.6 Conclusion

In this paper I test whether potential economic effects due to independence of a region from a country can affect political opinions on independence. Specifically, I find the effect on Catalan sectors due to increases in trade costs between Catalonia and Spain upon independence of Catalonia. Using employment data over the sectors in each Catalan municipality, I find the average exposure of each municipality and test the relationship between this potential exposure to independence and pro-independence opinions in municipalities.

The results show that controlling for fixed effects and endogeneity by using a first-difference and instrumental variable approach, independence opinions differ increase about 9.2% when moving from a more exposed municipality (25th percentile) to a less

Table 3.2: Estimation Results

	(1) OLS	(2) OLS	(3) 2SLS	(4) 2SLS	(5) 2SLS	(6) 2SLS
$\Delta exposure$	0.212***	0.232***	2.791*	2.146*	2.605	1.670**
	(0.053)	(0.055)	(1.126)	(0.939)	(1.455)	(0.569)
$\Delta AverageWage$		0.0170**	0.0841**	0.0651**		0.0756**
		(0.006)	(0.029)	(0.023)		(0.024)
$\Delta BornAbroad$		0.136***		0.0960***	0.101*	0.0986***
		(0.019)		(0.025)	(0.041)	(0.025)
$\Delta SpeakCatalan$		0.0261			0.0113	-0.0157
		(0.017)			(0.052)	(0.033)
Constant	0.111***	0.104***	-0.322	-0.211	-0.247	-0.145
	(0.010)	(0.010)	(0.181)	(0.151)	(0.221)	(0.099)
Observations	941	932	938	938	929	929

Robust standard errors clustered at the local labor market level in parentheses

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

exposed municipality (75th percentile). The results might be subject to measurement or aggregation errors due to the fact that the data is only available at the municipal and sectoral level, and the variation within municipalities or sectors are not taken into consideration.

However, by using economic and political data at the local geographic levels, I improve the earlier literature that solely focused on cross-country studies that has failed to even account for regional differences in terms of economic and political characteristics. In addition, I have contributed to the literature that studies local effects of international trade by providing how a potential "de-liberalization" can affect sub-regions differently, and how different exposures to trade can influence political opinions.

APPENDIX A

TECHNICAL APPENDIX FOR CHAPTER 1

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[1]. I start with the model equations below where $t_{in}^j = 1 + \tau_{in}^j$, and ξ_i^j and Γ^j are constants.

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

[1]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.

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

$$
\begin{aligned}
\widetilde{w_i} &= \sum_{j=1}^{J} \lambda_i^j \widetilde{Y_i^j} \\
\widetilde{Y_i^j} &= \sum_{n=1}^{N} \eta_{in}^j \left(\widetilde{\pi_{in}^j} + \widetilde{X_n^j} - \widetilde{t_{in}^j} \right) \\
\widetilde{X_n^j} &= \sum_{k=1}^{J} \kappa_n^{jk} \widetilde{Y_n^k} + \kappa_n^{j0} \widetilde{w_n} \\
\widetilde{\pi_{in}^j} &= -\theta^j \left(\widetilde{c_i^j} + \widetilde{t_{in}^j} \right) + \theta^j \sum_{h=1}^{N} \pi_{hn}^j \left(\widetilde{c_h^j} + \widetilde{t_{hn}^j} \right) \\
\widetilde{c_i^j} &= \gamma_i^{0j} \widetilde{w_i} + \sum_{k=1}^{J} \sum_{h=1}^{N} \gamma_i^{kj} \pi_{hi}^k \left(\widetilde{c_h^k} + \widetilde{t_{hi}^k} \right)
\end{aligned}
\tag{A.2}
$$

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[2].

Nominal Wage. The cost equation is solved in terms of wages and tariff terms and can be regrouped as follows[3]

$$
\widetilde{c_i^j} = \sum_{h=1}^{N} a_{hi}^j \widetilde{w_h} + TA_i^j \tag{A.3}
$$

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

[3] Moving the term that contains c_h^j to the left-hand side and taking its Leontief inverse, we can solve for costs in terms of wages and tariff terms

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

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

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[4]. 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 and obtain[5]

$$\widetilde{Y_i^j} = \sum_{h=1}^{N} f_{hi}^{j}\widetilde{w_h} + \sum_{h=1}^{N}\sum_{k=1}^{J}\sum_{n=1}^{N}\left(g_{hin}^{jk}MA_{hn}^{k} + s_{hin}^{jk}IC_{hn}^{k}\right) \tag{A.4}$$

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

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

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

$$\begin{aligned} a_{hin}^{j} &= -\theta^{j}\left(1-\pi_{ii}^{j}\right)a_{hi}^{j} + \theta^{j}\sum_{m\neq i}\pi_{mn}^{j}a_{hm}^{j} \\ MA_{in}^{j} &= -\widetilde{t_{in}^{j}} - \theta^{j}\left(1-\pi_{ii}^{j}\right)\left(TA_i^j + \widetilde{t_{in}^{j}}\right) \\ IC_{in}^{j} &= \theta^{j}\sum_{m\neq i}\pi_{mn}^{j}\left(TA_m^j + \widetilde{t_{mn}^{j}}\right) \end{aligned}$$

[5]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

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

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

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

$$\widetilde{w}_i = \sum_{j=1}^{J}\sum_{h=1}^{N-1}\sum_{k=1}^{J}\sum_{n=1}^{N}\left(G_{hin}^{jk} MA_{hn}^k + S_{hin}^{jk} IC_{hn}^k\right) \tag{A.5}$$

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 (A.5) 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

$$\widetilde{W_i} = \widetilde{w}_i - \widetilde{P_i}$$

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

$$\widetilde{W_i} = \sum_{h=1}^{N} \alpha_{hi} \widetilde{w_h} + CPI_i \tag{A.6}$$

where I substituted the cost function $\widetilde{c_n^j}$ into prices using equation (A.3)[6]. The term CPI_i, which represents the contribution of the changes in the consumer price index on

[6] $\widetilde{W_i} = \widetilde{w_i} - \sum_{j=1}^{J}\sum_{n=1}^{N} \beta_i^j \pi_{ni}^j \left[\sum_{h=1}^{N} a_{hn}^j \widetilde{w_h} + TA_n^j + \widetilde{t_{ni}^j}\right]$ 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 $h \neq i$.

real wages is given by

$$CPI_i = -\sum_{j=1}^{J}\sum_{n=1}^{N}\beta_i^j \pi_{ni}^j \left(TA_n^j + \widetilde{t_{ni}^j}\right) \tag{A.7}$$

Using equations (A.5), (A.6) and (A.7), 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

$$\widetilde{W_i} = MA_i + IC_i + GEO_i + CPI_i \tag{A.8}$$

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

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

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

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

APPENDIX B

DATA APPENDIX FOR CHAPTERS 1 AND 2

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 (1.3) 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[1]. 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[2].

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

[1] 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

[2] 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.

output of sector j in country c is denoted by Y_c^j.

$$\gamma_c^{0,j} = \frac{VA_c^j}{VA_c^j + INT_c^j} = \frac{VA_c^j}{Y_c^j} \tag{B.1}$$

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

$$\gamma_c^{k,j} = \frac{INT_c^{k,j}}{VA_c^j + INT_c^j} = \frac{INT_c^{k,j}}{Y_c^j} \tag{B.2}$$

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 $X_{cc'}^j$, 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_{cc}^j. For domestic sales, I first derive total gross output Y_c^j in each sector, then subtract total exports $\sum_{c' \neq c} X_{cc'}^j$ 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, $X_{cc}^j = X_c^j = Y_c^j$. 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

$$y_c^j = \frac{Y_c^j}{\sum_{k=1}^J Y_c^k} = \frac{Y_c^k(IO)}{\sum_{k=1}^J Y_c^k(IO)} = y_c^j(IO) \tag{B.3}$$

where the share on the right hand side can be computed for each sector from the IO tables, and using gross output Y_c^j for $j = 1,...,15$, the remaining Y_c^j $j = 1,...,27$ 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 $X^j_{USUS}(cfs) = X^j_{USUS}(oecd)$.

$$X^j_{ss'} = X^j_{ss'}(cfs)\left[\frac{X^j_{USUS}(oecd)}{X^j_{USUS}(cfs)}\right] \tag{B.4}$$

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

$$Y^j_s = \sum_{s'}^{S} X^j_{ss'} + \sum_{c=1}^{C} X^j_{sc} = \sum_{n=1}^{N} X^j_{sn} \tag{B.5}$$

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 $y^1_s = \frac{Y^1_s}{\sum_{s'=1}^{J} Y^1_{s'}}$, and find the gross output of each state s in sector 1 by

$$Y^1_s = y^1_s Y^1_{US}$$

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

I do not know the interstate trade $X^1_{ss'}$ (from state s to state s') in the agricultural sector. But I know $X^1_{sn}(usatrade)$ 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

$$X^1_{sUS} = Y^1_s - X^1_{sW}$$

. 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.[3] 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 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 $j = 16, ..., 27$ 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 $j = 1, ..., 15$.
2. Find U.S. value added $VA_{US}^j = \gamma_{US}^{0,j} Y_{US}^j$ for $j = 16, ..., 27$.
3. Find share of GDP (value added) of each state s and each sector $j = 16, ..., 27$ in

[3]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.

total U.S. GDP of that sector. Denote this share as v_s^j.

4. Find state value added in sector $j = 16,...,27$: $VA_s^j = v_s^j VA_{US}^j$.
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:

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

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