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**A U.S. REGIONAL MODEL OF
IMPORT COMPETITION AND JOBS**

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ABSTRACT

We develop an industry-specific partial equilibrium model that quantifies the impact of trade policy on workers in the United States, while recognizing that transportation costs separate U.S. product markets and labor markets into sub-national regions. The model illustrates, in a simple way, how nationally uniform changes in trade policy or in other costs of importing can have significantly different effects on employment in different parts of the United States, depending on differences in import penetration into the regions. We use the model to simulate the impact of an illustrative ten percent reduction in the cost of importing household appliances from China on employment in the competing U.S. industry. If the U.S. product market is fully integrated nationwide, then the reduction in import charges is estimated to reduce industry employment in all regions of the country by 12.03 percent. If the product market is separated into regions and there are no inter-regional shipments, then the employment effects vary significantly across the regions, including an estimated 5.08 percent reduction in industry employment in the East and an estimated 27.68 percent reduction in the West. Finally, in a more realistic intermediate case with inter-regional shipments estimated with an industry-specific gravity model, the employment effects are an estimated 6.28 percent reduction in industry employment in the East and an estimated 24.46 percent reduction in the West. The model also estimates changes in the prices faced by consumers in each region.

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1. Introduction

In this paper, we develop an industry-specific partial equilibrium model that quantifies the impact of changes in trade policy on workers in the United States, while recognizing that transportation costs separate U.S. product markets and labor markets into sub-national regions. The model illustrates how nationally uniform changes in trade policy or in other costs of importing can have significantly different effects on employment in different parts of the United States, depending on differences in import penetration into the regions.

The model is motivated by the large and expanding literature on the economic impact of international trade on local labor markets within the United States. This literature includes recent studies by Autor, Dorn, and Hanson (2013a, 2013b, 2016), Acemoglu, Autor, Dorn, Hanson, and Price (2016), Hakobyan and McLaren (2016), and Monte (2016). These studies recognize that labor markets in the United States are geographically segmented, and that differences in the industry shares of employment in different parts of the country result in differences in workers' exposure to international trade and, ultimately, in regional differences in the effects of trade on employment and wages.

While this literature focuses on the fact that labor markets are geographically segmented within the United States, the studies implicitly assume that there are no costs of shipping goods within the United States or, equivalently, that the United States comprises a single, perfectly integrated product market. Autor, Dorn, and Hanson (2013a, 2013, 2016), Acemoglu, Autor, Dorn, Hanson, and Price (2016), and Monte (2016) calculate the exposure of local labor markets to imports from China based on industry shares of local employment and total U.S. imports in each industry, regardless of where the imports enter the United States. Following this approach, if local labor markets in California and Massachusetts had the same industry composition of local employment, then they would be considered equally exposed to imports from China, though most imports from China arrive on the West Coast and are costly to ship to the East Coast. Similarly, the measure of the exposure of local labor markets to NAFTA tariff reductions in Hakobyan and McLaren (2016) combines industry-level measures of trade exposure with data on the industry composition of local employment to measure trade exposure: the authors assign imports to local labor markets based on the location's share of national employment in the industry regardless of where the imports enter

the United States.¹ However, if the country is not a single, perfectly integrated product market, then analysis of the effects of trade on local labor markets should take into account where the imports enter the country. The simplifying assumption of a nationally integrated product market is no doubt adopted in this literature because there is only very limited information on shipments of products between different parts of the country, but it is not a realistic assumption. Shipping goods within the country is clearly not costless.²

This paper is an attempt to relax this assumption and estimate how product market segmentation within the United States affects the geographic distribution of the labor market effects of changes in U.S. trade policy and other import costs. There are many possible approaches to modeling the geographic segmentation of U.S. product markets. This paper starts with two extreme scenarios, one in which the 48 contiguous states are fully integrated in a single national product market (but labor markets are segmented into sub-national regions, as in the local labor markets literature cited above) and another in which the product markets in the United States are segmented into sub-national regional markets (and labor markets are again segmented into sub-national regions).³ If the product markets are regionally segmented, then there are differences in employment effects across the regions that reflect asymmetries in import penetration ratios and export shares. Our simple model is a “test kitchen” for evaluating which of the data inputs and modeling assumptions have the largest effects on estimated changes in industry employment.

We use the model to simulate the impact of an illustrative ten percent reduction in the cost of importing household appliances from China on employment in the competing U.S. industry. If the U.S. product market is fully integrated nationwide, then the reduction in import charges is estimated to reduce U.S. industry employment in all regions of the country by 12.03 percent. If the product market is separated into regions and there are no inter-regional shipments, then the employment effects vary significantly across the regions, including an estimated 5.08 percent reduction in industry employment in the East and an estimated 27.68 percent reduction in industry

¹ The econometric models of wages in Hakobyan and McLaren (2016) include a dummy variable for locations close to the U.S.-Mexican border as an explanatory variable, but distance to the border is not part of the authors’ measure of the location’s exposure to the NAFTA tariff reductions.

² For example, Hillberry and Hummels (2008) estimate that manufacturers’ shipments within the United States are extremely localized: shipments within zip codes are three times larger than shipments outside of the zip code. Hummels and Schaur (2012) estimate that one day in transit is equivalent to a 0.6 and 2.1% ad valorem trade cost. Ramondo, Rodríguez-Clare, and Saborío-Rodríguez (2016) find that acknowledging domestic trade costs is important to reconciling theories of international trade with scale economies to available data.

³ We also consider intermediate scenarios with some inter-regional product shipments in Section 6, but we focus first on these two extreme market integration scenarios to establish a range of employment effects.

employment in the West.⁴ Finally, in a more realistic intermediate case with inter-regional shipments estimated with an industry-specific gravity model, the employment effects are an estimated 6.28 percent reduction in industry employment in the East and an estimated 24.46 percent reduction in the West.

We also use the model to estimate the changes in the prices faced by consumers in each region. The estimated reduction in consumer prices is 3.36 percent if the product market is national, and the regional price effects range from a 1.44 percent reduction to a 7.61 percent reduction if the product markets are segmented into regions.

The rest of the paper is organized into six sections. The next section presents the modeling framework. Section 3 discusses the data requirements of the model, and Section 4 discusses econometric estimates of the key elasticity parameter. Section 5 reports simulations of the employment effects of reducing the cost of importing household appliances from China. Section 6 extends the model to include inter-regional shipments of U.S. production. Section 7 offers concluding remarks.

2. Modeling Framework

The model demonstrates how geographic product market segmentation affects the link between trade policy and labor market outcomes. In this section, we consider two extreme scenarios. In the first scenario, the country is divided into regions and that there are *prohibitively high costs* of shipping the products between the regions, though there is still international trade. In the second scenario, there are *not any costs* of inter-regional shipping. For example, if there were two regions in the country, then the first scenario has a separate product market for each region, and the second scenario has a single national product market.

In the industry-specific model, there are CES demands for varieties of the product. Each firm, domestic and foreign, produces a unique variety, so the products of the industry are differentiated by firm, and because different firms are located in different regions and countries, the products are differentiated by country of origin and by sub-national region within the United States. In the equations below, we use the variable k to index different markets, which are in some cases sub-

⁴ The estimated reductions in industry employment could lead to wage losses if workers are compensated according to their firm-specific or industry-specific productivity and experienced workers are significantly more productive than new hires. In this case, the reductions in industry employment translate into income losses for the displaced workers.

national regions within the United States and in other cases foreign countries. We assume that consumer preferences are identical across the sub-national regions.⁵

Equation (1) represents the percent change in expenditure in U.S. region r on the products of domestic producers in industry j in U.S. region r' .

$$\hat{E}_{jr'r} = \hat{E}_r + (\sigma_j - 1) \sum_k s_{jkr} (\hat{p}_{jk} + \hat{\tau}_{jkr}) - (\sigma_j - 1) (\hat{p}_{jr'} + \hat{\tau}_{jr'r}) \quad (1)$$

The variable $E_{jr'r}$ is expenditure in region r on the products in industry j in region r' , and

$\hat{E}_{jr'r} \equiv dE_{jr'r} / E_{jr'r}$. The variable E_r is total expenditure in region r , p_{jk} is the producer price of the products of U.S. region or foreign country k , and τ_{jkr} is gross import charges included in the delivered prices of these products in region r . Gross import charges, often called the *power* of the trade costs, are equal to one plus the ad valorem rate of trade costs. For international shipments, these trade costs include tariffs and other trade barriers as well as international shipping costs. For inter-regional shipments within the country, they only include shipping costs. The parameter σ_j is the constant elasticity of substitution among varieties in industry j , and s_{jkr} represents the share of expenditures in region r on the industry j products from U.S. region or foreign country k .

Likewise, equation (2) is the percent change in expenditure in U.S. region r on industry j imports from country f .

$$\hat{E}_{jfr} = \hat{E}_r + (\sigma_j - 1) \sum_k s_{jkr} (\hat{p}_{jk} + \hat{\tau}_{jkr}) + (1 - \sigma_j) (\hat{p}_{jf} + \hat{\tau}_{jfr}) \quad (2)$$

We assume that there is monopolistic competition as well as CES demands, following Krugman (1980), Melitz (2003) and the extensive literature on trade with imperfect competition. Delivered prices in region r are a constant markup over the marginal cost of production, represented by the wage of the workers in U.S. region or foreign country k (w_k), multiplied by the unit labor requirement (a_{jk}) and the trade cost factor (τ_{jkr}).

⁵ This means that two regions with the same prices will have the same expenditure shares of the products of each country and U.S. region.

$$P_{jkr} = \tau_{jkr} \left(\frac{\sigma_j}{\sigma_j - 1} \right) a_{jk} w_k \quad (3)$$

Equation (4) translates equation (3) into percent changes.

$$\hat{P}_{jkr} = \hat{\tau}_{jkr} + \hat{w}_k + \hat{a}_{jk} \quad (4)$$

In our partial equilibrium analysis, we assume that many of the economic variables remain fixed when there are small reductions in the cost of importing this specific product from a single country (China). The factors that remain fixed are total expenditures in the region ($\hat{E}_r = 0$), producer prices ($\hat{p}_{jk} = 0$), wages ($\hat{w}_k = 0$), unit labor requirements ($\hat{a}_{jk} = 0$), and trade costs on imports from all countries other than China ($\hat{\tau}_{jkr} = 0$). With these partial equilibrium simplifications, equations (1) and (2) reduce to equation (5) for all regions and countries other than China (indexed by k) and to equation (6) for China (indexed by c).

$$\hat{E}_{jkr} = (\sigma_j - 1) s_{jcr} \hat{\tau}_{jcr} \quad (5)$$

$$\hat{E}_{jcr} = (\sigma_j - 1) (1 - s_{jcr}) \hat{\tau}_{jcr} \quad (6)$$

Equations (5) and (6) quantify the impact of reductions in tariffs, but they can also quantify reductions in other types of import costs that do not vary by region, like exchange rate depreciations, or reductions in import costs that vary by region, like freight costs.

As long as the wages of the workers remain fixed, marginal costs are constant, and fixed costs of production are already sunk, total industry employment in the region would adjust in proportion to the changes in the revenue of the domestic producers in the region. Equation (7) is an accounting relationship between the percent change in industry employment and a share weighted average of the percent changes in revenues in all of the different markets indexed by k .

$$\hat{L}_{jr} = \sum_k \theta_{jrk} \hat{E}_{jrk} \quad (7)$$

The variable θ_{jrk} is the share of production in region r that is consumed in market k .

We also assume that the small reduction in the cost of importing the product into the United States will not have an effect on the exports of the U.S. producers, so $\hat{E}_{jrk} = 0$ if market k is a foreign country. With this simplification, and using equation (5), equation (7) reduced to equation (8).

$$\hat{L}_{jr} = \sum_{r'} \theta_{jrr'} (\sigma_j - 1) s_{jcr'} \hat{\tau}_{jcr'} \quad (8)$$

The variable r' indexes the sub-national regions in the United States.

In the extreme case where there are no inter-regional shipments, $\theta_{jrr} = 1 - \chi_{jr}$ and $\theta_{jrr'} = 0$ for all $r' \neq r$, where the variable χ_{jr} is the share of production in region r that is shipped from the United States to export markets. In this extreme case, equation (8) simplifies to equation (9).

$$\hat{L}_{jr} = (1 - \chi_{jr}) (\sigma_j - 1) s_{jcr} \hat{\tau}_{jcr} \quad (9)$$

In the other extreme case, where the product market is perfectly integrated across all of the sub-national regions, s_{jcr} is the same for all regions r since prices are perfectly arbitrated and preferences are identical across the regions. Assuming that $\hat{\tau}_{jcr}$ is the same for all regions (as is the case for a nationally uniform change in trade policy), equation (8) again simplifies to equation (9), with the national import penetration ratio prevailing in each of the sub-national regions.

According to equation (9), the employment effects depend on the magnitudes of the reductions in import costs, the region-specific penetration ratios for imports from China, the elasticity of substitution in the industry, and the export share of regional employment in the industry. If the product market is completely integrated across the country, then the employment effects depend on the national import penetration ratio and export share. If the product markets are regionally segmented, then the differences in employment effects across the regions reflect differences in regional import penetration ratios and export shares.

The employment effects in equation (9) could be quite large, for example, if there is a ten percent reduction in import charges, the export share is 20 percent, the elasticity of substitution is 5 and the expenditure share in the region on imports from China is 70 percent, then there is a 22.40 percent reduction in industry employment in the region in the partial equilibrium framework, according to equation (9). These relatively large employment effects reflect the large market share of imports from China in this industry, the elasticity of substitution, and the modeling assumption that labor

supply to the industry is perfectly elastic with respect to the small industry-specific change in import charges.⁶

On the other hand, if there were general equilibrium reductions in wages and the prices of domestic producers and general equilibrium increases in the prices of Chinese exporters, then these adjustments would lessen the reduction in industry employment. For example, if workers have only a limited ability to switch industries, then the simplifying assumption of perfectly elastic labor supply in our industry-specific model would be unrealistic.⁷

Equation (10) translates the percent change in industry employment in each region in equation (9) into a count of displaced workers.

$$dL_{jr} = L_{0jr} (1 - \chi_{jr}) (\sigma_j - 1) s_{jcr} \hat{\tau}_{jcr} \quad (10)$$

The variable L_{0jr} represents the industry j employment in region r before the reduction in import costs.

Finally, equation (11) represents the percent change in the industry-specific consumer price index in region r .

$$\hat{P}_{jr} = s_{jcr} \hat{\tau}_{jcr} \quad (11)$$

This equation for the price effects is greatly simplified by the model's assumptions that wages, foreign producer prices, and markups do not change. The effect on the overall consumer price index in region r is the product of the percent change in the industry price index in equation (11) and the industry's share of the region's aggregate consumer expenditures, so the percent change in the overall consumer price index should be very small in all of the regions.

3. Data on the Household Appliance Manufacturing Industry

We apply the U.S. regional model to a specific four-digit manufacturing industry: household appliance manufacturing (NAICS 3352). Table 1 reports the value of the industry's total

⁶ The relative size of the industry, only 0.4 percent of U.S. manufacturing employment in 2014 and 0.03 percent of total U.S. employment in the same year, supports the assumption that labor supply to the industry is very elastic, as long as workers can move freely across industries.

⁷ In the extreme case with no inter-industry and inter-regional labor mobility, there would be no employment effects but potentially large wage effects. For these reasons, assumptions about labor mobility are an essential ingredient of the model that needs further research.

employment and shipments of U.S. producers in 2014.⁸ The table also reports U.S. exports of the industry to all countries, U.S. imports from all countries, U.S. imports from China, and average U.S. tariff rates on imports from China.⁹ In the final row, the table reports an estimate of nationwide consumption of the products of the industry, based on the domestic shipments and international trade data. The U.S. industry accounts for less than half of total consumption in the U.S. market, and imports from China play a large role in the market. U.S. tariff rates on imports of this product from China were relatively low in 2014, averaging 2.41 percent.

Table 1: Nationwide Statistics for U.S. Household Appliances Manufacturing (NAICS 3352)

Economic Measure	Value in 2014	Source
Total U.S. Employees	46,434	ASM
Total Value of Sales by U.S. Producers	\$20,292,488,000	ASM
U.S. Imports	\$24,395,906,698	Trade Dataweb
U.S. Imports from China	\$13,570,146,742	Trade Dataweb
U.S. Exports	\$4,249,723,545	Trade Dataweb
Average Tariff on Imports from China	2.41%	Trade Dataweb
U.S. Consumption	\$40,438,671,153	Both

Our analysis requires trade data that identify the customs districts of the U.S. imports and exports. A district is a collection of neighboring U.S. ports (land and air ports, as well as sea ports). The district-level trade data indicate transit points where the imports enter the United States and where the exports leave, but they do not indicate where the imports are consumed or where the exports are produced. While the data do not reveal the regional origins and destinations for the international trade flows, they can still be informative if we adopt specific assumptions about the geographic segmentation of the product markets, as we demonstrate below.

Table 2 is a concordance that assigns the districts in the international trade data to the eight BEA regions for our estimation of regional imports and exports. We aggregate several of the adjacent BEA regions to simplify the analysis.¹⁰ We use BEA regional data on personal consumption expenditures to approximate the regional consumption of the products of the industry in 2014, assuming that the expenditure share of a particular product is identical across the BEA regions.¹¹

⁸ The source of these data is the Census Bureau's *Annual Survey of Manufactures*.

⁹ The source of these data is the USITC's *Trade Dataweb*.

¹⁰ Specifically, we combine BEA's New England and Mideast regions into an East region, and we combine the BEA's Rocky Mountain and Far West regions into a West region.

¹¹ For example, there will be identical, fixed expenditure shares if consumers have a unit elasticity of substitution between composites of the products of each industry. This assumption of Cobb-Douglas preferences at the level of industries or sectors is common in multi-sector models of international trade.

We calculate the value of national consumption expenditure on the products of industry j as the value of shipments of the U.S. industry minus exports plus imports. We calculate the import penetration ratio for each region as the ratio of regional expenditure on imports of the products to regional total expenditure on the products.

We estimate each region's 2014 employment level as the product of the region's share of national manufacturing employment and the industry's share of national manufacturing employment. We estimate the geographic distribution of industry employment in this way because published employment statistics for American states are often not available at the level of specific industries due to non-disclosure rules. The national export share is the ratio of exports to the total value of shipments. To estimate export shares at the regional level, we allocate the total value of shipments of the U.S. industry among the regions based on estimated regional employment in the industry, and we use the value of exports from each region based on the district-level data on international trade.

Table 2: BEA Regions and Assigned U.S. Customs Districts

BEA Region	States and DC	Customs Districts
New England	CT, ME, MA, NH, RI, VT	Boston MA, Portland ME, Providence RI, St. Albans VT
Mideast	DE, DC, MD, NJ, NY, PA	Baltimore MD, Buffalo NY, New York NY, Ogdensburg NY, Philadelphia PA, Washington DC
Great Lakes	IL, IN, MI, OH, WI	Chicago IL, Cleveland OH, Detroit MI, Milwaukee WI
Plains	IA, KS, MN, MO, ND, NE, SD	Duluth MN, Minneapolis MN, Pembina ND, St. Louis MO
Southeast	AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV	Charleston SC, Charlotte NC, Miami FL, Mobile AL, New Orleans LA, Norfolk VA, Savannah GA, Tampa FL
Southwest	AZ, NM, OK, TX	Dallas TX, El Paso TX, Houston TX, Laredo TX, Nogales AZ
Rocky Mountain	CO, ID, MT, UT, WY	Great Falls MT
Far West *	CA, NV, OR, WA	Columbia-Snake OR, Los Angeles CA, San Diego CA, San Francisco CA, Seattle WA

*Note: Alaska and Hawaii are included in BEA's Far West region but are not included in our model, because our model is limited to markets in the contiguous states.

Table 3 reports each region’s estimated penetration ratio for imports from China, its export shares, and its employment levels in the household appliances industry in 2014. The penetration ratio for imports from China is much higher in the West region (76.11 percent) than in the East region (14.47 percent). The national average is 33.56 percent. There is much less dispersion in the industry’s export shares, which are not China-specific. The regional export shares range from 15.20 percent to 25.37 percent, with an average of 20.04 percent. The two regions with the most employment in the household appliance industry are the Southeast and the Great Lakes.

Table 3: Regional Import Penetration, Export Shares, and Employment in 2014

Region	Import Penetration Ratio for Imports from China (percentage)	Export Shares (percentage)	Estimated Industry Employment (head count)
All 48 Contiguous States Combined	33.56	20.04	57,699
East	14.47	21.72	9,716
Great Lakes	33.02	25.37	13,675
Plains	19.71	15.20	5,441
Southeast	28.44	15.32	14,232
Southwest	14.41	22.42	5,919
West	76.11	18.91	8,716

Note: The East region is a combination of the BEA’s New England and Mideast regions.
The West region is a combination of the BEA’s Rocky Mountain and Far West regions.

Table 4 summarizes the data requirements for estimating the effects on U.S. industry employment and consumer prices. The rows of the table correspond to the different data inputs of the model, none perfectly observed and all approximated. Calculating the price effects requires the least data, while calculating the number of jobs lost requires the most.

Table 4: Data Requirements of the PE Model

Model Input	Estimated Percentage Change in Employment	Estimated Number of Jobs Lost	Estimated Percentage Change in Prices
Import Penetration Ratio	Required	Required	Required
Export Share	Required	Required	Not Required
Initial Employment Level	Not Required	Required	Not Required
Elasticity of Substitution	Required	Required	Not Required

4. Estimating the Elasticity of Substitution

The elasticity of substitution, σ_j , is not directly observed in the data. We estimate this parameter using an econometric model that relates the industry's import values to import costs. Equation (12) represents the specification in the econometric analysis.¹²

$$\ln(E_{jfdt}) = \gamma_{jdt} + \delta_{jft} + (1 - \sigma_j) \ln(X_{jfdt}) + \epsilon_{jfdt} \quad (12)$$

The estimation uses a panel dataset that includes U.S. imports classified in NAICS 3352 by country, district, and year between 2010 and 2014.¹³ The variable E_{jfdt} is the landed duty-paid value of the industry j imports from country f into district d in year t , and γ_{jdt} and δ_{jft} are industry-district-year and industry-country-year fixed effects. We consider two alternative measures of import costs, X_{jfdt} : one that includes freight costs and tariffs (the ratio of the difference between landed duty-paid value of the imports and their customs value to their customs value), and one based only on freight costs (the ratio of the difference between CIF value of the imports and their customs value to their customs value). The variable ϵ_{jfdt} is the error term of the model.

¹² Anderson and van Wincoop (2003, 2004) and Head and Mayer (2014) discuss fixed effects estimation of gravity models.

¹³ The source for the import and trade cost data is the USITC's *Trade Dataweb*.

The specification in equation (12) does not include many explanatory variables, but the fixed effects control for many factors that we would otherwise include as explanatory variables. The industry-country-year fixed effects δ_{jft} absorb producer prices in the industry in exporting country f in year t . The industry-district-year fixed effect γ_{jdt} absorb the industry price index and aggregate expenditure level in the local market in year t .

Table 5 reports estimates of σ_j for the two alternative measures of import costs. In both specifications, the estimate of σ_j for NAICS 3352 is positive and statistically significant. The first specification, with a point estimate of 5.484, has slightly better overall fit, but the two estimates are very similar.

Table 5: Econometric Estimates for Household Appliances for 2010-2014

	Trade Costs Including Duties	Trade Costs Excluding Duties
Elasticity of Substitution σ	5.484 (4.601 - 6.367)	5.302 (4.430 - 6.174)
Country Fixed Effects	Included	Included
District Fixed Effects	Included	Included
Number of Observations	5,884	5,884
R Squared	0.5621	0.5603

Note: 95 percent confidence intervals are reported in parentheses.

5. Simulated Effects of Reductions in Import Costs

In this section, we use the calibrated model in equations (9), (10), and (11) to estimate the regional employment effects of an illustrative ten percent reduction in the cost of importing household appliances from China ($\hat{\tau}_{jcr} = -0.10$). In the first of the extreme market integration scenarios, the product market is perfectly nationally integrated. In this case, the import penetration ratio for household appliances from China is the same for all regions. The point estimates and confidence intervals for this scenario are reported at the top of Table 6.¹⁴ The estimated reduction in U.S.

¹⁴ The only uncertainty reflected in these confidence intervals is the variance of the econometric estimate of the elasticity of substitution in Table 5. Other model inputs are not known with certainty, but the uncertainty about them is not quantified in the reported confidence intervals. The estimated price effects do not include confidence intervals because they do not include the econometric estimate of the elasticity of substitution.

employment is 12.03 percent or 6,943 jobs. The model estimates a 3.36 percent reduction in the household appliance prices faced by U.S. consumers.

Table 6: Estimated Employment Effects and Consumer Price Effects

Scenario	Region	Estimated Percentage Change in Employment	Estimated Number of Jobs Lost	Estimated Percentage Reduction in Prices
Integrated	All 48 Contiguous States Combined	12.03 (9.66-14.40)	6,943 (5,576-8,310)	3.36
Segmented	East	5.08 (4.08-6.08)	493 (396-591)	1.45
Segmented	Great Lakes	11.05 (8.87-13.23)	1,511 (1,214-1,809)	3.30
Segmented	Plains	7.49 (6.02-8.97)	408 (327-488)	1.97
Segmented	Southeast	10.80 (8.67-12.93)	1,537 (1,234-1,840)	2.84
Segmented	Southwest	5.01 (4.03-6.00)	297 (238-355)	1.44
Segmented	West	27.68 (22.23-33.13)	2,412 (1,937-2,887)	7.61

Note: The table reports 95 percent confidence intervals in parentheses.

In the second of the extreme scenarios, the product markets are completely segmented into regions, and the import penetration ratio for household appliances from China and the export shares of U.S. employment in the industry vary by region.¹⁵ The lower rows in Table 6 report point estimates and confidence intervals for this second case. The largest impacts are in the West, Great Lakes, and Southeast regions, and the smallest impacts are in the Southwest and Plains regions. The percentage reductions in regional employment range from 5.01 percent to 27.68 percent, and the regional numbers of lost jobs range from 297 to 2,412. The percentage reductions in regional prices range from 1.44 percent to 7.61 percent.

¹⁵ The econometric analysis of micro-data from the Commodity Flow Survey in Hillberry and Hummels (2008) suggests that this is probably the more realistic of the two scenarios.

6. Inter-Regional Shipments Based on an Industry-Specific Gravity Model

Clearly neither of the extreme market integration scenarios – no inter-regional shipments or completely unrestricted inter-regional shipments – are completely realistic, and so we construct an intermediate scenario with some inter-regional shipping, though the actual extent of inter-regional shipping is not directly observable and is challenging to estimate. We extend the model to allow for inter-regional shipments of domestic production, though we still assume that there is no cross-hauling of international trade between the sub-national regions. In this case, the reductions in import costs affect labor demand in each region through an additional, less direct channel: they reduce domestic shipments to other regions due to a reduction in the other region's industry price index, which is proportional to the other region's penetration ratio for industry imports from China.

We again define $E_{jrr'}$ as the value of inter-regional shipment of the production of U.S. region r to U.S. region $r' \neq r$. Equation (13) is based on the log-linearized reduced-form gravity model of trade flows in Baier and Bergstrand (2009).¹⁶

$$E_{jrr'} = \frac{(Y_{jr} - X_{jr})(C_{jr'} - M_{jr'})}{Y_j - X_j} \left(\frac{t_{jrr'}}{\left(\prod_k (t_{jrk})^{\lambda_k} \right) \left(\prod_k (t_{jkr'})^{\psi_k} \right) / \left(\prod_k \prod_{k'} (t_{jkk'})^{\lambda_k \psi_{k'}} \right)} \right)^{1-\sigma_j} \quad (13)$$

where

$$\lambda_{jk} = \frac{C_{jk} - M_{jk}}{C_j - M_j} \quad (14)$$

$$\psi_{jk} = \frac{Y_{jk} - X_{jk}}{Y_j - X_j} \quad (15)$$

The variables C_j , M_j , X_j , and Y_j represent the national values (the sums over all of the U.S. regions) of consumption, imports, exports, and domestic production in industry j , and k is an

¹⁶ This is comparable to equation (22) in Baier and Bergstrand (2009). By using the econometric estimate of σ_j from Table 5 in this calculation, we are assuming that the elasticity of substitution between the varieties produced by the different U.S. regions is the same as the elasticity of substitution between the varieties produced by the different countries.

index of the regions. We assume that $t_{jrr'} = 1$ when $r = r'$ and that inter-regional shipping costs have a constant elasticity with respect to inter-regional distance, β_j .

$$t_{jrr'} = \mu_j (\text{dist}_{rr'})^{\beta_j} > 1 \quad (16)$$

In equations (13) through (16), the inter-regional shipments of industry j are determined by the magnitude of supply (net of exports) and consumption (net of imports) in each region and the distance between the regions. We calibrate β_j by matching the modeled ratio of total inter-

regional shipments to total production net of exports, $\left(\sum_r \sum_{r'} E_{jrr'}(\beta_j) \right) / (Y_j - X_j)$, to aggregate statistics on long distance shipments of household appliances in the U.S. Commodity Flow Survey (CFS).

Table 7 reports data from the 2012 CFS for NAICS 335, the electric equipment sector that includes, but is not limited to, household appliances. According to the CFS, 45.1 percent of shipments by value and 53.0 percent of shipments by weight were delivered within 500 miles of the U.S. manufacturer.

Table 7: Data on NAICS 335 Shipments from the 2012 U.S. Commodity Flow Survey

Distance	Cumulative Share Value of Shipments (percentage)	Cumulative Share Tons of Shipments (percentage)
Less than 50 miles	9.4	11.6
50 - 99 miles	14.3	17.4
100-249 miles	26.1	32.7
250-499 miles	45.1	53.0
500-749 miles	61.9	70.4
750-999 miles	73.6	80.5
1,000-1,499 miles	86.1	90.7
1,500-1,999 miles	93.9	96.8
2,000 miles or more	100.0	100.0

Based on these data, we assume that approximately 55 percent of domestic production is shipped between U.S. regions. Setting the modeled ratio of total inter-regional shipments to total production net of exports equal to 0.55, we estimate that β_j is equal to 0.22855. We use this parameter value

to calculate the inter-regional shipments $E_{jrr'}$ in equation (13), and then we estimate the $\theta_{jrr'}$ shares that determine the magnitude of the employment effects in equations (17) and (18).

$$\hat{L}_{jr} = (\sigma_j - 1) \left(\sum_k \theta_{jrk} s_{jck} \hat{\tau}_{jck} \right) \quad (17)$$

$$dL_{jr} = L_{0jr} (\sigma_j - 1) \left(\sum_k \theta_{jrk} s_{jck} \hat{\tau}_{jck} \right) \quad (18)$$

In these equations, the variable k indexes all sub-national regions within the United States.

Table 8 reports the estimated regional employment effects based on the inter-regional shipments implied by the gravity model. The employment effects range from an estimated 6.28 percent reduction in industry employment in the East to an estimated 24.46 percent reduction in the West. The employment effects are generally close to the segmented scenario in Table 6. They are slightly larger in the East and Southeast regions but are much larger in the Southwest and Plains, regions that ship a larger share of their production to the West according to the gravity model. The employment effects are slightly smaller in the West and Great Lakes regions. The price effects are the same as the segmented scenario in Table 6, since they do not depend on the magnitude of inter-regional shipments of the domestic producers.

Table 8: Estimated Employment Effects and Consumer Price Effects

Region	Estimated Percentage Change in Employment	Estimated Number of Jobs Lost	Estimated Percentage Reduction in Prices
East	6.28 (5.59-7.00)	610 (543-680)	1.45
Great Lakes	9.88 (8.12-11.63)	1,351 (1,110-1,590)	3.30
Plains	13.22 (11.10-15.16)	719 (604-825)	1.97
Southeast	11.17 (9.27-13.03)	1,589 (1,319-1,854)	2.84
Southwest	11.23 (9.66-12.62)	665 (572-747)	1.44
West	24.46 (18.42-30.50)	2,132 (1,605-2,659)	7.61

Note: The table reports 95 percent confidence intervals in parentheses.

7. Conclusions

The industry-specific regional model establishes that there can be significant differences in employment and price effects across regions of the United States that depend on differences in import penetration into the regions and the pattern of inter-regional shipments. When inter-regional shipments are estimated based on the industry-specific gravity model, the employment effects range from an estimated 6.28 percent reduction in industry employment in the East to an estimated 24.46 percent reduction in the West. The estimated reduction in consumer prices range from 1.45 percent in the East to 7.61 percent in the West.

The model demonstrates the importance of finding a way to reasonably estimate inter-regional shipments. They are a key input to the model that needs additional study. For example, a useful direction for future research might be to apply the method for approximating inter-regional shipments in Section 6 to Canadian data and then compare the gravity-based estimates to actual inter-regional shipments reported in Canada's inter-provincial trade data as a test of the approximation that we have used in our analysis of U.S. data. The method for estimating inter-

regional shipments might also be improved by taking into account the contiguity of regions and other gravity factors.

Another significant limitation of the model is that employment in each region in the household appliance industry is roughly estimated in Section 3, and this is an area that could benefit from additional research.

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