ESTIMATING U.S. IMPORT PENETRATION INTO SUB-NATIONAL REGIONS

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Abstract

We develop an industry-specific model of import demand that takes into account the costs associated with international transport from the exporting country to the port of entry and also the costs associated with domestic transport from the port of entry to the consumer. The costs of domestic transport are usually not included in empirical models of international trade. We estimate these costs using an econometric specification derived from the structural model. We apply the model to 2013–7 import data for the U.S. electrical equipment industry. We use the structural equations and the econometric estimates of the parameter values to impute the flow of imports to U.S. consumers in five regions that cover the lower 48 states, and then we calculate industry-specific import penetration rates for each region. Finally, we simulate the exposure of consumers and industry employment in each region to changes in tariffs on U.S. imports from different countries.

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1 Introduction

Changes in tariffs lead to changes in the prices that U.S. consumers face. The effects of these price changes are unevenly distributed if consumers in different parts of the country face different import penetration rates. For example, if U.S. consumers on the West Coast spend a larger share of their budget on imports from Asia, then their cost of living will increase more when there is an increase in tariffs on these imports.

It is difficult to quantify the regional distribution of these consumer effects, because the penetration of imports into different parts of the country is not measured in official trade statistics. U.S. import data report the port districts where the imports clear customs, but they do not report the region of the country where the imported products are ultimately consumed. The Commodity Flow Survey measures the domestic shipment of goods that are manufactured within the United States, but it does not measure the domestic shipment of imports.

Still, the entry point of the imports provides useful information. It is suggestive of where import consumption is likely concentrated, since it is costly to ship imports across the vast United States. To go further and estimate how far the imports are shipped within the country, we develop a model of sub-national trade. We construct an industry-specific structural econometric model that links the value of imports that enter each U.S. region to the region's proximity to different consumer markets across the country.

First, we use the model to estimate the elasticity of substitution in the industry and the cost of shipping imports from the region where they enter the country to the region where they are consumed. We apply the model to 2013–7 import data for the U.S. electrical equipment sector. Our econometric analysis indicates that domestic distances matter and proximity to consumers is a significant determinant of the share of imports that enter each region of the country.

Second, we use the structural equations, our econometric estimates of transport costs between the regions, and data on the location of production and import entry to estimate the regional distribution of import consumption. We estimate that domestic transport costs result in significant differences in import penetration rates across regions. As we would expect, the consumption of imports is relatively concentrated in the regions where the imports enter. For example, imports from China are concentrated on the West Coast, and imports from Germany are concentrated on the East Coast.

The main contribution of this paper is its novel methodology for estimating the sub-national effects of changes in trade policy even when there are significant limits on the availability of sub-national data. Our estimates of the regional differences in import penetration help us to better understand how different consumers and workers are affected by tariffs on U.S. imports. For example, sub-national import penetration rates can be useful when analyzing the effects of tariffs and other trade shocks on local labor markets within the United States. The large and growing literature on this topic – which includes Autor, Dorn and Hanson (2013), Hakobyan and McLaren (2016), and Acemoglu, Autor, Dorn, Hanson and Price (2016) – adopts the simplifying assumption that the United States has a nationally integrated product market. This is equivalent to assuming a common import penetration rate across the country. These studies do not account for the effects of domestic distances on the penetration of the imports. In contrast, we demonstrate how information about the regional penetration of imports might improve estimates of the regional labor market effects of trade, and we also provide estimates of regional consumer effects.

The rest of the paper is organized as follows. Section 2 introduces the modeling framework. Section 3 describes the data sources and summary statistics. Section 4 presents econometric estimates of the model parameters. Section 5 introduces the methodology for estimating regional import penetration rates and reports the results of these calculations. Section 6 uses a simulation model to translate the import penetration rates into measures of consumers' exposure to tariff changes. Section 7 uses the simulation model to estimate how industry employment in each region responds to tariff changes. Section 8 concludes.

2 Modeling Framework

The model assumes that consumer demand for the products of the industry has the constant elasticity of substitution form in equation (1), with products differentiated by source: imports are differentiated by country of origin and region of import entry, and domestic products are differentiated by the sub-national region where they are produced.[1]

$$v_{jec} = Y_c \left(\frac{p_j \; f_{je} \; d_{ec}}{I_c} \right)^{1-\sigma} \frac{1}{d_{ec}} \tag{1}$$

v_{jec} represents the landed duty-paid value of industry imports from country of origin j that enter the United States in entry region e and are shipped to consumption region c.[2] v_{jec} is the value of these imports when they arrive at the region of import entry, before adding the costs of domestic transport to the region of consumption. Y_c is total expenditure on the products of the industry in region c. I_c is the CES industry price index for the region. p_j is the producer price of industry imports from country j. $f_{je} > 1$ is an international trade cost factor that includes freight charges from source country j to region of entry e and any tariffs on the imports. $d_{ec} > 1$ is a domestic transport cost factor for imports that enter region e and are shipped to consumers in region c. σ is the elasticity of substitution among the differentiated products in the industry. The value of imports consumed in region c depends

[1] Product differentiation by country or region of origin is the Armington assumption that is common in models of international trade. Additional product differentiation by region of import entry could reflect differences in the products that arrive at the various ports, as well as differences in the convenience of alternative distribution networks. While (1) assumes that demand has a CES form, this assumption does not require that individual consumers purchase from multiple sources: Anderson, de Palma and Thisse (1988) show that the CES demand structure can be derived from a specific logit model in which consumers face idiosyncratic extreme value-distributed costs associated with each source of supply and each individual chooses a single, preferred source of supply.

[2] Region c may be the same as region e or different.

on the size of the market in c (Y_c); the industry price index in c (I_c); the price of the imports when delivered to region c ($p_j\ f_{je}\ d_{ec}$); and the interchangeability of products from different sources of supply (σ).

Equation (2) is the CES industry price index.

$$I_c = \left(\sum_j \sum_e (p_j\ f_{je}\ d_{ec})^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{2}$$

Equation (3) is a log-linear transformation of (1).

$$ln\ v_{jec} = ln\ Y_c\ +\ (\sigma - 1)\ ln\ I_c\ + (1-\sigma)\,(ln\ p_j + ln\ f_{je})\ - \sigma\ ln\ d_{ec} \tag{3}$$

The domestic transport cost factor, d_{ec}, depends on whether the product is shipped within the same region, to an adjacent region of the country, or to a non-adjacent region farther away.[3]

$$ln\ d_{ec} = ln\ d_0 + \alpha\ adj_{ec}\ +\ \beta\ nonadj_{ec} \tag{4}$$

adj_{ec} is an indicator variable that is equal to one if e and c are different regions that are adjacent, and $nonadj_{ec}$ is an indicator variable that is equal to one if e and c are different regions that are not adjacent. For shipments within the same region, $ln\ d_{ec}$ is simply equal to $ln\ d_0$. We expect that $0 < \alpha < \beta$.

The total value of imports from country j entering region e, v_{je}, is the sum across the imports from j to e destined for each of the sub-national regions indexed by c.

$$v_{je} = \sum_c v_{jec} \tag{5}$$

[3]We use a specification of domestic transport costs with indicator variables rather than a continuous measure of distance because the regions in the model are large areas rather than precise locations.

We approximate (5) using a first-order log-linear Taylor series expansion around an equilibrium with symmetric domestic transport costs between and within the sub-national regions.[4]

$$ln\ v_{je} = \sum_c \theta_c\ ln\ v_{jec}\ +\ \gamma \tag{6}$$

θ_c represents region c's share of national expenditure on the products of the industry, and γ is a constant term. The log-linear approximation in (5) is very similar to the bonus vetus OLS approach in Baier and Bergstrand (2009).[5]

Finally, (7) substitutes (3) into (6).

$$ln\ v_{je} = \gamma\ +\ (1-\sigma)(ln\ p_j + ln\ f_{je}) + \sum_c \theta_c\,(ln\ Y_c + (\sigma-1)\ ln\ I_c - \sigma\ ln\ d_{ec}) \tag{7}$$

Equation (7) is the basis for the econometric specification below.

3 Data and Descriptive Statistics

The model consolidates the eight Bureau of Economic Analysis (BEA) regions of the United States into five roughly equal-sized regions that cover the lower 48 states.[6] The model's North Central region includes BEA's Great Lakes and Plains regions. North East includes BEA's New England and Mideast regions. West includes most of BEA's Far West region and all of BEA's Rocky Mountain region. South East and South West correspond to BEA's Southeast and Southwest regions. Table 1 lists the states and import districts included in

[4] Absent log-linearization, the system of non-linear equations will be intractable when there is a large number of source countries and several sub-national regions of entry and consumption.

[5] Baier and Bergstrand (2009) is a model of international trade, rather than sub-national trade, so their log-linear expansion is around an equilibrium with symmetric international trade costs, rather than symmetric domestic transport costs.

[6] The model focuses on the lower 48 states plus the District of Columbia. It does not include Alaska, Hawaii, or the U.S. territories.

each of the five U.S. regions.[7]

Table 1: Definitions of the Five Regions in the Model

Sub-National Regions	States	Import Districts
North Central	IA, IL, IN, KS, MI, MN, MO, ND, NE OH, SD, WI	Chicago, Cleveland, Detroit, Duluth Milwaukee, Minneapolis, Pembina, St. Louis
North East	CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT	Baltimore, Boston, Buffalo DC, New York, Ogdensburg Philadelphia, Portland Providence, St. Albans
South East	AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV	Charleston, Charlotte Miami, Mobile New Orleans, Norfolk Savannah, Tampa
South West	AZ, NM OK, TX	Dallas, El Paso, Houston, Port Arthur, Laredo, Nogales
West	CA, CO, ID, MT, NV, OR, UT, WA, WY	Columbia-Snake, Great Falls Los Angeles, San Diego San Francisco, Seattle

Our analysis of sub-national import penetration focuses on data for the electrical equipment industry, NAICS code 335.[8] In 2016, 15.0% of the value of U.S. imports in this industry were residential and industrial electrical lighting equipment (NAICS code 3351), 26.7% were small and major household appliances (NAICS code 3352), 28.9% were electrical equipment like transformers, motors, and generators (NAICS code 3353), and the remaining 29.4% were other electrical equipment like batteries, communication and energy wire, and wiring devices.

We analyze U.S. import data for this industry at the level of country, region of entry, and

[7] An import district is an aggregate of neighboring ports of entry.

[8] While it would be interesting to fit the model to more finely disaggregated product categories, we apply the model to NAICS three-digit industry to ensure that the state-level data on the shipments of domestic producers are complete in the public datasets that we use.

year.[9] Table 2 reports the countries that accounted for the largest share of U.S. imports in the industry in 2016, based on the landed duty-paid value of the imports. Table 3 reports the share of industry imports that entered each of the five regions from these major import sources. As we would expect, imports from China, Japan, and Korea were concentrated in the West region, imports from the NAFTA countries were concentrated in the South West, West, North East, and North Central regions, and imports from Germany were concentrated in the North East, South East, and North Central regions.

Table 2: Major Import Sources in 2016 (%)

Country Source	Share of Total Imports
China	40.289
Mexico	24.646
Japan	4.782
Germany	4.107
Korea	3.984
Canada	3.531

Table 3: Region Shares of Import Entry by Source Country in 2016 (%)

Regions	Imports from China	Imports from NAFTA	Imports from Germany	Imports from Japan	Imports from Korea
North Central	17.347	6.535	24.002	29.542	11.899
North East	10.842	4.727	25.597	6.641	10.890
South East	14.078	1.601	24.438	16.958	7.430
South West	15.891	75.322	14.614	12.993	18.198
West	41.842	11.815	11.349	33.867	51.583

We use BEA's data on private consumer expenditures in each region as a measure of regional aggregate expenditures.[10] We estimate the value of the domestic shipments of U.S.

[9] The source for the import data are the U.S. International Trade Commission's Dataweb at `https://dataweb.usitc.gov/`

[10] The source for the expenditure data is the regional private consumption expenditure database published by the Bureau of Economic Analysis at `https://www.bea.gov/data/consumer-spending/state` Accord to this source, the regional shares of aggregate expenditure range from 21% to 23% each for the North Central, North East, South East and West regions and 11% for the South West region.

regional producers by subtracting the value of their U.S. exports from the value of their total shipments.[11] Table 4 reports each region's shares of domestic supply (regional production net of the region's U.S. exports). The region with the smallest share of domestic supply in the industry was South West, and the regions with the largest shares were South East and North Central.

Table 4: Domestic Supply in the Industry in 2016 (%)

Sub-National Region	Share of Domestic Supply
North Central	34.289
North East	18.316
South East	29.257
South West	5.975
West	12.163

The model also includes international and domestic transport costs. The international trade cost factor, f_{je}, is the ratio of the landed duty-paid value of the imports to their customs value. (The numerator includes international freight costs and tariffs.) The domestic transport cost factor d_{ec} is not directly measured; it is estimated in the econometric model discussed in the next section.

4 Econometric Estimates

We estimate domestic transport costs and the elasticity of substitution using a panel of U.S. import values for the industry in 2013–7.[12] The econometric specification in (8) is based on (4) and (7), with the addition of a time subscript t and a normally distributed error term ϵ_{jet}.

[11]The value of shipments for each industry comes from the 2016 Annual Survey of Manufactures, at `https://www.census.gov/programs-surveys/asm.htm`. The free along side value of exports and the landed duty-paid value of imports in the industry comes from the USITC's Dataweb.

[12]We pool over the most recent five years for a more precise estimate.

$$ln\ v_{jet} \ = \ h_{jt} \ + \ (1-\sigma)\ ln\ f_{jet} \ - \sigma \sum_c \ \theta_{ct}\ (\alpha\ adj_{ec} \ + \ \beta\ nonadj_{ec}) \ + \epsilon_{jet} \qquad (8)$$

The third term on the right-hand side of (8) measures the proximity of entry region e to consumer markets in the different regions indexed by c: it is a regional expenditure-weighted average of the costs of domestic transport from the region of import entry to the region of consumption. All of the terms in (7) that do not vary according to the entry region of the imports are absorbed in the country-year fixed effects in (8), and this greatly reduces the data requirements of the econometric model.[13] This specification is a practical solution to the problem that we do not observe the domestic shipments of imports from e to c; if we had reliable data on inter-regional shipments of imports, we could estimate domestic transport costs using a standard gravity model of e-to-c bilateral trade.

We estimate the parameters in (8) using ordinary least squares (OLS), with a sample that includes the 3,315 country-region-year combinations with U.S. imports in 2013-7 data set. There are two alternative specifications, a more restricted one that assumes that $\alpha = \beta$ and a less restricted one that does not impose this restriction.[14]

Table 5 reports the parameter estimates, with robust standard errors in parentheses. The values of σ, α, and β implied by the estimated econometric coefficients are all significantly different from zero at the one percent level, and we clearly reject the restrictions that $\alpha = \beta$ and that the country-year fixed effects are jointly zero.[15] The point estimate of σ is 7.365.

[13] The country-year fixed effects include five terms from the right-hand side of equation (8): the constant γ, the source-specific price term $(1-\sigma)\ ln\ p_{jt}$, the aggregate expenditure term $\sum_c \theta_{ct}\ ln\ Y_{ct}$, and the price index term $(\sigma - 1)\ \sum_c \theta_{ct}\ ln\ I_{ct}$. This specification is also consistent with an alternative nested CES model with imports from each country within a nest with an elasticity of substitution that is higher than the elasticity of substitution between domestic products and the import nest. With nested CES demand, there would be additional price index terms, but they would also be absorbed in the country-year fixed effects.

[14] If all imports were consumed in the same region where they enter the country, then α and β would be prohibitively large. The estimates for the less restricted specification reject that case.

[15] The F statistic for the hypothesis that $\alpha = \beta$ has a p-value of 0.0000. The F statistic for the hypothesis that all of the country-year fixed effects are jointly zero has a p-value of 0.0000.

The point estimate of α and β imply that transport costs between regions are more than 200% greater, on average, than transport costs within a region. The estimates suggest that there is a moderate amount of import penetration beyond the region where the imports enter the country: we can reject the assumption that domestic transport costs are zero, a common simplification in empirical models of international trade.[16]

As a sensitivity analysis, we re-estimated the less restricted version of the econometric model with alternative data inputs. The additional estimated coefficients, the implied parameter values, and their standard errors are reported in Table 6. The first variant re-estimates the model excluding imports from Canada and Mexico. NAFTA imports typically involve a different mode of transportation than imports from outside of North America, and we wanted to ensure that NAFTA trade is not driving the estimates of the parameter values in the model. The estimates of the model parameters from the more limited sample are similar to the less restricted estimates reported in Table 5. The estimate of σ is lower, and the estimates of α and β are slightly higher, but they are close. The second variant uses a different measure of expenditure to calculate the θ_{ct} weights in (8). The models in Table 5 use total private consumer expenditure in each region, while the second variant in Table 6 focuses on expenditure on durable goods. The estimate of σ is very similar. The estimates of α and β are higher.

5 Regional Import Penetration Rates

To calculate regional import penetration rates, we need an estimate of the value of industry imports at a finer level – by source country, region of import entry, and region of consumption. Since this disaggregation of import flows is not reported in official trade statistics, we impute these trade flows using the structural equations and the estimated parameter values from the

[16] See, for example, Autor et al. (2013) and the related studies discussed in the Introduction and Section 7.

Table 5: Econometric Estimates of the Model Parameters

Dependant Variable: Log of the Value of Imports	More Restricted Point Estimates (St. Errors)	Less Restricted Point Estimates (St. Errors)
Econometric Coefficients		
Log of International Trade Cost Factor	-6.459	-6.365
	(0.748)	(0.750)
Expenditure Shares in Adjacent Regions		-5.949
		(0.566)
Expenditure Shares in Non-Adjacent Regions		-6.960
		(0.596)
Expenditure Shares in All Other	-5.678	
	(0.565)	
(Country-Year Fixed Effects and Constant Included)		
Implied Values of the Model Parameters		
Elasticity of Substitution (σ)	7.459	7.365
	(0.748)	(0.750)
Domestic Transport Cost to Adjacent Regions (α)		2.243
		(0.253)
Domestic Transport Cost to Non-Adjacent Regions (β)		2.573
		(0.322)
Domestic Transport Cost to All Other Regions	2.141	
	(0.231)	
R-Squared Statistic	0.924	0.925
Number of Observations	3,315	3,315

Table 6: Sensitivity Analysis, with Standard Errors

Dependant Variable: Log of the Value of Imports	Less Restricted in Table 5	Without NAFTA Countries	Durable Goods Measure
Econometric Coefficients			
Log of International Trade Cost Factor	-6.355	-6.170	-6.392
	(0.750)	(0.721)	(0.746)
Expenditure Shares in Adjacent Regions	-5.949	-6.185	-7.120
	(0.566)	(1.060)	(0.614)
Expenditure Shares in Non-Adjacent Regions	-6.960	-7.233	-7.922
	(0.596)	(1.267)	(0.634)
(Country-Year Fixed Effects and Constant Included)			
Implied Values of the Model Parameters			
Elasticity of Substitution (σ)	7.365	7.170	7.392
	(0.750)	(0.721)	(0.746)
Domestic Transport Cost to Adjacent Regions (α)	2.243	2.369	2.620
	(0.253)	(0.372)	(0.336)
Domestic Transport Cost to Non-Adjacent Regions (β)	2.573	2.742	2.921
	(0.322)	(0.488)	(0.402)
R-Squared Statistic	0.925	0.925	0.927
Number of Observations	3,315	3,265	3,315

less restricted specification in Table 5. The data requirements for this imputation include several observed variables (regional expenditure levels, international trade costs, and the adjacency of the regions) and several variables that are not directly observable (regional price indices for the industry, prices for imports, and prices for domestic products).[17] We calibrate the model to data for 2016, which is the most recent year with Annual Survey of Manufactures data on the value of the shipments of the domestic producers in the industry.

Equation (9) is the import penetration rate for industry imports from country j that enter region e and are consumed in region c in year t.

$$\lambda_{ject} = \frac{\phi_{jet}\ \omega_{ject}\ d_{ec}}{\sum_{j'} \sum_{e'} \phi_{j'e't}\ \omega_{j'e'ct}\ d_{e'c}} \tag{9}$$

The variable j' indexes all countries of origin, including the United States, and e' indexes all regions of domestic production or import entry. $\phi_{j'e't}$, the share of national industry supply from source $j'e'$ in year t.

$$\phi_{jct} = \frac{\sum_c v_{ject}}{\sum_{j'} \sum_{e'} \sum_c v_{j'e'ct}} \tag{10}$$

We directly observe $\phi_{j'e't}$. $\omega_{j'e'ct}$ is the share of $j'e'$ supply that is shipped to region c in year t.

$$\omega_{jct} = \frac{v_{ject}}{\sum_{c'} v_{jec't}} \tag{11}$$

We do not directly observe $\omega_{j'e'ct}$, so we need to model it. Equation (12) is the value of shipments from source je that are consumed in region c in year t, before adding the cost of domestic shipping from region e to region c.

[17] We calculate ϕ_{jet} and θ_{ct} using available data on domestic shipments and the aggregate expenditures. The elasticity of substitution σ and the domestic transport costs between regions d_{ec} are based on the econometric estimates in Table 5.

$$ln\ v_{ject} = ln\ Y_{ct} + (\sigma - 1) \sum_{j'} \sum_{e'} \phi_{j'e't}\ ln\ (p_{j't}\ f_{j'e't}\ d_{e'c}) + (1 - \sigma)\ ln\ (p_{jt}\ f_{jet}) - \sigma\ ln\ (d_{ec}) \quad (12)$$

Like (7), this equation is based on a log-linearization around the equilibrium associated with symmetric domestic transport costs.

Substituting the shipment values in (12) into (11), we can derive the following reduced form for ω_{ject} :

$$\omega_{ject} = \frac{\theta_{ct} \left(\prod_k (d_{kc})^{\phi_{kt}(\sigma-1)}\right) (d_{ec})^{-\sigma}}{\sum_{c'} \theta_{c't} \left(\prod_k (d_{kc'})^{\phi_{kt}(\sigma-1)}\right) (d_{ec'})^{-\sigma}} \quad (13)$$

The variable k is an index over all of the sources of supply to the domestic market, ϕ_{kt} and θ_{ct} are observable, and the parameters of d_{ec} are based on the econometric estimates for the less restricted model in Table 5.

To better understand the formulas, consider the extreme case where domestic transport costs are not increasing in domestic distance, and $\alpha = \beta = 0$). In this case, shipments are distributed exactly in proportion to expenditure share ($\omega_{ject} = \theta_{ct}$), and national supply shares determine the expenditure shares in each region ($\lambda_{ject} = \phi_{jet}$ for all ct). Domestic transport costs that increase in domestic distance move the shares away from this integrated national product market benchmark, and this adjustment is captured in (9) and (13).

Table 7 presents the estimated import penetration rates in 2016 for each of the five regions, for U.S. imports from China, the NAFTA countries, Japan, Germany, and Korea. The table reports the point estimates with standard errors in parentheses. The standard errors on the estimates of the regional import penetration rates were calculated from the variance-covariance matrix of the econometric estimates in Table 5, using a bootstrapping procedure. First, we used the point estimates and variance-covariance matrix of the estimated coefficients in Table 5 to draw 1,000 multivariate normally distributed values for these coefficients, resampling with replacement. Second, we calculated the implied values of σ, α, and β for each of the draws. Third, we calculated the regional import penetration rates for each draw. Finally, we calculated the mean and standard errors for the resulting import penetration rates across the 1,000 draws.

The estimated import penetration rates vary significantly across regions since domestic transport costs increase with the distance from region e to region c ($0 < \alpha < \beta$). If there were a nationally integrated product market ($\alpha = \beta = 0$), then import penetration rates in each region would be equal to the nation-wide import penetration rates at the bottom of Table 7.

Import penetration rates from China and Korea (and to a lesser extent Japan) were concentrated in the West. This is the region where a majority of these imports entered, and it is relatively isolated from the centers of U.S. production in the industry located in the North East and North Central regions.

The high penetration rates for the NAFTA imports in the South West and West regions reflect both the importance of Mexico as a source for imports in this industry and the very small share of competing U.S. production in the South West region. There were also moderate import penetration rates in the regions that border Canada. The smallest import penetration rate for NAFTA imports was in the South East, the only region that does not border Mexico or Canada.

Penetration rates for imports from Germany were highest in the North East, North Central, and South East regions, again reflecting the geographic concentration of import entry. However, these import penetration rates were less than five percent even in these regions, because these regions also accounted for the largest shares of competing domestic production.

Table 7: Import Penetration Rates by Region in 2016 (%)

Sub-National Region of Consumption	Imports from China	Imports from NAFTA	Imports from Japan	Imports from Germany	Imports from Korea
North Central	16.845	4.815	3.334	2.333	1.150
	(0.059)	(0.217)	(0.008)	(0.003)	(0.012)
North East	17.791	6.318	1.367	4.035	1.747
	(0.215)	(0.614)	(0.045)	(0.059)	(0.038)
South East	16.977	2.277	2.388	2.908	0.921
	(0.169)	(0.478)	(0.010)	(0.016)	(0.029)
South West	17.401	56.287	1.684	2.908	1.949
	(0.040)	(0.309)	(0.010)	(0.016)	(0.002)
West	44.091	9.320	4.220	1.260	5.314
	(0.418)	(0.345)	(0.028)	(0.014)	(0.058)
Nation-wide	23.011	15.959	2.708	2.326	2.256

6 Consumer Exposure to Changes in Tariffs

Next, we construct a partial equilibrium model and simulate the impact on consumers of a change in the tariff on industry imports from each of the major import sources. The regional import penetration rates are an important determinant of regional consumers' exposure to the tariff changes; under restrictive assumptions, the regional import penetration rates are the sole determinant. This is the case, for example, if we assume that the supply from each source has a Cobb-Douglas production function with constant returns to scale in all factor inputs, the supply of factor inputs from the rest of the economy is perfectly elastic, total industry expenditures are fixed, and domestic and international transport costs as fixed.[18] Under these partial equilibrium assumptions, producer prices do not change in response to the tariff changes and there is complete pass-through of the tariff changes into the landed prices of the imports.[19]

We simulate the effect of a hypothetical increase in tariffs on imports from country j that increases international trade costs on these imports by 10 percent, holding constant producer prices, international and domestic transport costs, and tariffs on imports from all sources other than j, so $\hat{f}_{je} = 0.10$ for all e. Equation (14) is the percent change in the industry price index in (2) resulting from the 10 percent increase in international trade costs for imports from j.[20]

$$\hat{I}_c = 0.10 \sum_{e} \lambda_{jec} \tag{14}$$

[18]The assumption of fixed total industry expenditures is equivalent to assuming that the industry receives a constant share of aggregate expenditures and aggregate expenditures do not change in response to changes in industry-specific tariffs. These assumptions greatly simplify the partial equilibrium modeling of consumer exposure to the tariff changes, but they do not restrict the econometric model in Section 4 or the calculation of regional import penetration rates in Section 5.

[19]The estimated regional import penetration rates could also be incorporated into a more complex, less restricted models to estimate consumer exposure to the tariff changes. However, a more complex model requires additional sub-national data and is beyond the scope of this paper.

[20]We omit the time subscript again, since we are calculating hypothetical changes.

The price effects vary by region as long as domestic transport costs increase with the distance from region e to region c $(0 < \alpha < \beta)$. If there were a single nationally integrated product market $(\alpha = \beta = 0)$, then the price effects would be equal across all of the regions.

Table 8 reports the simulated percent change in the industry price index in each region resulting from the increase in the tariff on imports. For example, if there were a 10% increase in international trade costs that was specific to imports from China, it would increase the industry price index by 4.4% in the West region but by only 1.7% in the South East and North Central regions, due to the differences in the penetration of imports from China across the regions. If the 10% increase in international trade costs were specific to imports from Japan, it would increase the industry price index by 0.4% in the West region, 0.3% in the North Central region, and 0.1% in the North East region. If the increase in international trade costs were specific to NAFTA imports, it would increase the industry price index by 5.6% in the South West region but by less than 1.0% in all other regions. The asymmetry in price effects in the simulation matches the differences in our estimated regional import penetration rates: tariffs on imports from China, Japan, and Korea have the largest effects on prices in the West region; tariffs on imports from the NAFTA countries have the largest effects on prices in the South West region; and tariffs on imports from Germany have the largest effects on prices in the North East region.

7 Industry Employment Effects of Changes in Tariffs

Finally, we use the partial equilibrium model – with its assumption of perfectly elastic labor supply to the industry from the rest of the economy – to estimate the effects of a tariff change on industry employment in each region. Equation (15) is implied by the Cobb-Douglas production technology and the CES demands in (1).

Table 8: Effects on the Industry Consumer Price Index (%)

Sub-National Region of Consumption	Imports from China	Imports from NAFTA	Imports from Japan	Imports from Germany	Imports from Korea
North Central	1.685	0.481	0.333	0.233	0.115
	(0.006)	(0.022)	(0.001)	(0.000)	(0.001)
North East	1.779	0.632	0.137	0.404	0.175
	(0.022)	(0.061)	(0.005)	(0.006)	(0.004)
South East	1.698	0.228	0.239	0.291	0.092
	(0.017)	(0.048)	(0.001)	(0.002)	(0.003)
South West	1.740	5.629	0.168	0.162	0.195
	(0.004)	(0.031)	(0.001)	(0.000)	(0.000)
West	4.409	0.932	0.422	0.126	0.531
	(0.042)	(0.035)	(0.003)	(0.001)	(0.006)

$$\hat{w}_k + \hat{L}_k = \sum_{k \in DOM} \sum_c \omega_{kc} \left(\hat{Y}_c + (\sigma - 1)\ \hat{I}_c + (1 - \sigma)\ \hat{p}_k \right) \tag{15}$$

The variable $k \in DOM$ indexes the domestic supply sources in the five regions. $\hat{w}_k$ is the percent change in industry wages in region k, and $\hat{L}_k$ is the percent change in industry employment that serves the domestic market from region k. Equation (16) simplifies (15) based on the partial equilibrium assumptions that wages, producer prices, domestic transport costs, and aggregate expenditures remain constant when the tariff changes, and then solves for the percent change in industry employment from a 10 percent increase in the international trade costs of imports from source j.

$$\hat{L}_k = 0.10\ (\sigma - 1) \sum_{k \in DOM} \sum_c \omega_{kc} \sum_e \lambda_{jec} \tag{16}$$

The percent change in industry employment depends on the relevant import penetration rate

(λ_{jec}) and the share of domestic supply from k that is shipped to c (ω_{kc}).

Table 9 reports the simulated percent change in industry employment from the increase in the tariff on imports for each of the countries.

Table 9: Effects on Industry Employment in 2016 (%)

Sub-National Region of Consumption	Imports from China	Imports from NAFTA	Imports from Japan	Imports from Germany	Imports from Korea
North Central	10.807	3.139	2.112	1.491	0.747
	(1.250)	(0.373)	(0.244)	(0.175)	(0.087)
North East	11.336	4.000	0.875	2.567	1.112
	(1.181)	(0.124)	(0.095)	(0.324)	(0.108)
South East	10.833	1.510	1.520	1.852	0.593
	(1.152)	(0.361)	(0.170)	(0.221)	(0.053)
South West	11.184	35.117	1.089	1.046	1.247
	(1.299)	(4.241)	(0.128)	(0.115)	(0.145)
West	27.931	5.959	2.676	0.812	3.363
	(3.360)	(0.764)	(0.321)	(0.084)	(0.408)

The employment effects within each column vary by region since domestic transport costs increase with the distance from region k to region c ($0 < \alpha < \beta$). If there were a nationally integrated product market ($\alpha = \beta = 0$), then the percent changes in employment would be equal across the regions.

The ratio of the maximum regional employment effect to the minimum effect is slightly smaller than the ratio for the price effects, because the employment effects average the price effects across the regions that are served by production in region k. For example, in the case of imports from China, the max-min ratio for the price effects is 2.61, while the max-min ratio for the employment effects is 2.58.

Equation (17) defines ΔL_k, the change in the number of production workers in the industry in region k as a result of the tariff change.

$$\Delta L_k = \hat{L}_k \; L_{k0} \tag{17}$$

The employment change combines the percent change in in industry employment in (16) with data on initial employment levels, L_{k0}.

Table 10 reports the simulated changes in the number of production workers resulting from each tariff increase. The pattern in the changes in employment levels is quite different from the pattern in the percent changes. For example, for imports from Japan, the largest change in the number of production workers is in the North Central region, where a large share of industry employment currently resides, and the change in the number of workers in the West region is less than half as large.

Table 10: Change in the Number of Production Workers

Sub-National Region of Consumption	Imports from China	Imports from NAFTA	Imports from Japan	Imports from Germany	Imports from Korea
North Central	5,083	1,476	993	701	351
	(588)	(176)	(115)	(82)	(41)
North East	3,103	1,095	239	703	304
	(323)	(34)	(26)	(89)	(30)
South East	4,713	657	661	806	258
	(501)	(157)	(74)	(96)	(23)
South West	1,086	3,409	106	102	121
	(126)	(412)	(12)	(11)	(14)
West	4,535	967	434	132	546
	(546)	(124)	(52)	(14)	(66)

The variation in regional employment effects within the electrical equipment industry reflects geographic segmentation of the product market that is usually not addressed in the literature on trade and local labor market effects, and our model suggests that it should be considered. As we discussed in the Introduction, this literature finds significant variation in employment effects across locations, but the variation is due to differences in the local composition of employment. It is not within-industry variation. The models in this literature assume, at least implicitly, that the United States has a nationally integrated product market with a common nation-wide import penetration ratio.[21]

8 Conclusions

Our estimated regional import penetration rates are indicators of the exposure of consumers and workers in different parts of the country to changes in the costs of U.S. imports of electrical equipment from different countries. Although it is usually not feasible to directly observe where imports are consumed and how much is paid for the domestic transport of imports, we observe where the imports enter the country. By measuring the covariation between the location of import entry and the location of consumer expenditures, while

[21] Autor et al. (2013) and Hakobyan and McLaren (2016) both recognize that labor markets in the United States are segmented locally, and they find that differences in an industry's share of employment across locations will translate into differences in workers' exposure to imports and, ultimately, in differences in the effects of trade on labor market outcomes in different parts of the country. Autor et al. (2013) calculates 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 from China enter the United States. For example, if local labor markets in California and Massachusetts had the same industry composition of local employment, then the model in Autor et al. (2013) views the two local labor markets as equally exposed to imports from China, even though imports from China are more likely to arrive on the West Coast and are costly to transship 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 without taking into account where the imports enter the United States. The econometric model of wages in Hakobyan and McLaren (2016) does include a dummy variable for locations that are close to the U.S.-Mexican border, but the measure of distance to the border is not part of the authors' measure of each location's exposure to the NAFTA tariff reductions.

controlling for international trade costs and country-year effects, we generate estimates of domestic transport costs. We use the calibrated model to map U.S. imports of electrical equipment that enter each region to consumers in five regions that cover the lower 48 states. We show that taking domestic transport costs into account can improve estimates of the effects of tariff changes on consumers and workers in different parts of the country.

It would be straightforward to reapply this modeling framework to other products or to more disaggregated geographic areas if finer data were available. Another direction for future research is to relax some of the partial equilibrium restrictions on the simulations of price and employment effects, though a more complex model of domestic supply responses will require much more detailed sub-national data.

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