# IMPACT OF RISING INTERNATIONAL TRADE COSTS ON U.S. WORKERS BY DEMOGRAPHIC GROUP

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**Abstract**

Riker (2023) provides a modeling framework for estimating the exposure of different groups of U.S. workers to international trade using employment-weighted averages of the trade intensities of U.S. manufacturing industries. In this paper, we reapply this model in a retrospective analysis. We estimate the short-run impact of rising international trade costs on U.S. manufacturing imports from 2021 to 2022 on the employment of U.S. workers in groups defined by their race, sex, age, and educational attainment. We also introduce two extensions to the model. First, we quantify the dilution of the employment effects in an all-worker average that includes non-manufacturing workers. Second, we model the effects of changes in trade costs on imported intermediate goods, as well as changes in trade costs on imported final goods.



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# 1 Introduction

Riker (2023) estimates the exposure of different groups of U.S. workers to international trade using the groups' industry employment-weighted averages of the trade intensities of U.S. manufacturing industries in 2021. The measures of trade exposure are based on publicly available data and can be applied to many different demographic aggregations of the workers. The estimates indicate that differences in the race and educational attainment of the workers have larger effects on the measures of their exposure to trade than differences in their sex, ethnicity, or occupation. The author estimates prospective exposure to potential future changes in international trade costs; however, the same method can be used in a retrospective analysis of the impact of past changes in international trade costs.

In this paper, we use the model to estimate the short-run impact of changes in international trade costs on the employment of U.S. manufacturing imports between 2021 and 2022. We estimated employment effects for 40 groups defined by the race, sex, age, and educational attainment of the workers. The estimated employment effects were positive for almost all of the groups, since higher trade costs on imported final goods increase labor demand within an import-competing manufacturing industry. The percent changes in the groups' employment within the manufacturing sector ranged from -0.08% to 0.28%. Workers who are college graduates experienced smaller positive (and in some cases negative) employment effects, while workers who were American Indian, Aleut, or Eskimo Only experienced larger positive employment effects. Overall, the signs and magnitudes of the group effects were not explained by a single demographic characteristic but instead reflected the combinations of the workers' characteristics. When we included non-manufacturing workers in the calculation of the average effect on each group, the employment effects were smaller in magnitude or diluted for all of the groups. They were less diluted for workers who are 40 or older, male, White Only or Asian, Hawaiian, or Pacific Islander Only. When we extended the model to include employment effects from changes in the trade costs on imported intermediate goods, these additional effects offset the effects from changes in the trade costs of the imported final goods for some groups and flipped the signs of the net employment effects for other groups. Workers who are female, White Only, American Indian, Aleut, or Eskimo Only, or have not graduated from college more frequently experienced positive net changes in employment due to the changes in international trade costs.

The rest of the paper is organized into five parts. Section 2 describes the data sources and reports summary statistics for the U.S. manufacturing industries. Section 3 reports the estimated employment effects for workers within these industries. Section 4 reports the dilution of average group effects when the averages include workers outside of the manufacturing sector. Section 5 extends the model to also include employment effects from changes in international trade costs on imported intermediate goods. Section 6 provides concluding remarks. The technical appendix provides a theoretical framework for the calculations based on the derivation in Riker (2023).

## 2 Data Sources and Summary Statistics

The model uses individual data on the demographic characteristics of U.S. workers. The data on the industry of the workers, as well as their race, sex, age, and educational attainment, are from public use micro-data files of the Annual Social and Economic (ASEC) supplement of the Current Population Survey.[1]

In addition to this worker-level information, the model uses data on shipments, payrolls, and costs of materials by NAICS three-digit U.S. manufacturing industry in 2021 from the U.S. Census Bureau's Annual Survey of Manufactures (ASM).[2] It uses data on the 2021 and

[1] These data are publicly available at `https://cps.ipums.org/cps/`.

[2] These data are publicly available at `https://www.census.gov/programs-surveys/asm/data/tables.html`.

2022 free alongside value of domestic exports and the landed duty-paid value and customs value of imports for consumption by NAICS three-digit industry from the U.S. International Trade Commission's Trade Dataweb.[3] It also uses data on the 2021 cost shares of inter-industry inputs from a 71 Industries Direct Requirements table from the U.S. Bureau of Economic Analysis.[4] Finally, the model calibrates the elasticity of substitution parameter for each manufacturing industry using the approach in Ahmad and Riker (2019), based on data on the value of shipments, wage payments, and costs of materials of domestic producers in the industry in the 2021 ASM.

Table 1 reports the estimated elasticity of substitution, import penetration rate, and percent change in the trade cost factors between 2021 and 2022 for each of the NAICS three-digit manufacturing industries. The trade cost factor is defined as the ratio of the landed duty-paid and customs values of U.S. imports in each manufacturing industry in each year. It is increasing in tariffs, international transport costs, and any other barriers to trade.

There is significant variation in all three industry statistics. The elasticity of substitution values for 2021 ranged from 1.81 for beverage and tobacco products to 4.86 for petroleum and coal products. The import penetration rates in 2021 ranged from 8.15% for printing and related products to 95.23% for leather and allied products. The percent changes in international trade costs ranged from -1.18% for U.S. imports of electrical equipment to 1.99% for U.S. imports of wood products.[5]

[3] These data are publicly available at `https://dataweb.usitc.gov/`.
[4] These data are publicly available at `https://www.bea.gov/industry/input-output-accounts-data/`.
[5] The average percent change for all 21 manufacturing industries was 0.19%.

Table 1: Characteristics of the U.S. Manufacturing Industries

| Manufacturing Industry Name and NAICS Code | Elasticity of Substitution | Import Penetration (%) | Trade Cost Factor (% Δ) |
|---|---|---|---|
| Food manufacturing (311) | 3.33 | 10.08 | 0.99 |
| Beverage and tobacco products (312) | 1.81 | 16.90 | 0.25 |
| Textile mills (313) | 3.54 | 37.38 | 0.71 |
| Textile product mills (314) | 3.24 | 62.82 | 1.03 |
| Apparel (315) | 3.19 | 94.24 | -0.02 |
| Leather and allied products (316) | 3.44 | 95.33 | 0.32 |
| Wood products (321) | 2.74 | 20.00 | 1.99 |
| Paper manufacturing (322) | 2.96 | 12.46 | 0.30 |
| Printing and related products (323) | 2.91 | 8.15 | 0.71 |
| Petroleum and coal products (324) | 4.86 | 12.63 | -0.06 |
| Chemical manufacturing (325) | 2.08 | 34.99 | 0.45 |
| Plastic and rubber products (326) | 2.88 | 25.73 | 1.29 |
| Nonmetallic mineral products (327) | 2.56 | 9.81 | 1.49 |
| Primary metal products (331) | 2.90 | 39.04 | 0.81 |
| Fabricated metal products (332) | 2.97 | 21.82 | 0.10 |
| Machinery manufacturing (333) | 3.19 | 44.92 | -0.06 |
| Computers and electronics (334) | 2.88 | 69.48 | -0.12 |
| Electrical equipment et al. (335) | 2.92 | 62.94 | -1.18 |
| Transportation equipment (336) | 4.54 | 35.96 | 0.02 |
| Furniture (337) | 3.10 | 47.00 | 0.21 |
| Miscellaneous manufacturing (339) | 2.39 | 60.32 | 0.10 |

# 3 Estimated Effects on U.S. Manufacturing Workers

Equation (1) is the proportional (or percent) change in employment for workers within group $g$, $\hat{L}_g$, due to changes in the trade cost factors in all of the manufacturing industries, $\hat{\tau}_i$.[6]

$$\hat{L}_g = \sum_i \left(\frac{L_{gi}}{L_g}\right) \ (\sigma_i \ - \ 1) \ \left(\frac{V_i - E_i}{V_i}\right) \left(\frac{M_i}{V_i - E_i + M_i}\right) \ \hat{\tau}_i \qquad (1)$$

$L_g$ is the total employment of workers in group $g$ in the manufacturing sector, and $L_{gi}$ is the workers in group $g$ who are employed in industry $i$. $\sigma_i$ is the elasticity of substitution between domestic and imported varieties within industry $i$. $V_i$ is the value of total shipments of domestic producers in industry $i$, $E_i$ is the value of industry exports, and $M_i$ is the value of industry imports.

Table 2 reports the estimated employment effects within 40 different groups of U.S. manufacturing workers defined by the workers' race, sex, age, and educational attainment. The table reports the average percent change in labor demand for workers within the groups defined by the rows and columns of the table. This is equal to the average percent change in their employment level when there is short-run wage rigidity.

Almost all of these domestic employment effects were positive, meaning that the changes in international trade costs from 2021 to 2022 had, on net, a positive effect on U.S. manufacturing employment in almost all of the 40 groups.[7] The effects were small, all less than 0.30% in absolute value. The estimated effects ranged from -0.08% for workers who are female, multiracial, younger than 40, and have not graduated from college, to 0.28% for workers who are male, American Indian, Aleut, and Eskimo Only, forty or older, and college graduates. The variation across the demographic groups reflects differences in the distribution of the groups' employment across the industries subject to the international trade cost shocks.

[6] The technical appendix provides a full derivation of this equation.

[7] If the trade cost factors had risen in *all* of the manufacturing industries, then the estimated employment effects would all have been positive, since $\sigma_i > 1$.

The values in Table 2 vary across the combinations of demographic characteristics in a complex way. To demonstrate this, we estimated a simple regression with the values in Table 2 as the dependent variable and a constant and race, sex, age, and education indicator variables as explanatory variables.

$$\hat{L}_g = \beta_0 + \beta_1\, I(American\ Indian...)_g + \beta_2\, I(Asian...)_g + \beta_3\, I(Black...)_g + \beta_4\, I(Multiracial)_g + \beta_5\, I(40\ or\ Older)_g + \beta_6\, I(Female)_g + \beta_7\, I(College\ Graduate)_g + \epsilon_g \quad (2)$$

$I(c)_g$ are indicator variables that is equal to one if workers in group $g$ have characteristic $c$ and is equal to zero otherwise. $\epsilon_g$ is the error term. This regression summarizes the independent contribution of each of these demographic indicators to the estimated employment effects. The estimation sample has 40 observations, one for each of the values reported in Table 2.

Table 3 reports the econometric estimates. The point estimates for the indicator variables for each demographic characteristic in isolation indicate that workers who are American Indian, Aleut, or Eskimo Only, Black Only, and multiracial had positive effects on the estimated change in employment (relative to workers who are White Only), while workers who are Asian, Hawaiian, or Pacific Islander Only had a negative effect (relative to workers who are White Only). Workers who are 40 or older and female tended to have a more positive employment effect, while workers who graduated from college had a negative effect on average. However, most of these effects are not precisely estimated. The effect for workers who are American Indian, Aleut, or Eskimo Only was negative and statistically significant at the 5% level, while the effect for college graduate was negative and statistically significant at the 10% level, but the rest of the estimated coefficients were not significantly different from zero.

The $R^2$ statistic for this simple regression was 0.2411. This means that more than three-

Table 2: Estimated Average Effects on U.S. Manufacturing Workers

| Race and Sex | Age $<$ 40 College Graduate (% $\Delta$) | Age $<$ 40 Not a Graduate (% $\Delta$) | Age $\geq$ 40 College Graduate (% $\Delta$) | Age $\geq$ 40 Not a Graduate (% $\Delta$) |
|---|---|---|---|---|
| American Indian, Aleut, or Eskimo Only | | | | |
| Female | -0.06 | 0.25 | 0.11 | 0.12 |
| Male | -0.04 | 0.19 | 0.28 | 0.18 |
| Asian, Hawaiian, or Pacific Islander Only | | | | |
| Female | 0.06 | 0.04 | 0.05 | 0.05 |
| Male | 0.01 | 0.13 | 0.02 | 0.02 |
| Black Only | | | | |
| Female | 0.04 | 0.13 | 0.13 | 0.11 |
| Male | 0.05 | 0.15 | -0.01 | 0.12 |
| Multiracial | | | | |
| Female | 0.26 | -0.08 | 0.24 | 0.19 |
| Male | 0.04 | 0.17 | 0.05 | 0.19 |
| White Only | | | | |
| Female | 0.07 | 0.12 | 0.09 | 0.11 |
| Male | 0.05 | 0.11 | 0.04 | 0.12 |

Table 3: Regression with Table 2 Values as the Dependent Variable

| Explanatory Variables | Point Estimate | Robust Standard Error |
|---|---|---|
| American Indian, Aleut, or Eskimo Only | 0.040 | (0.041) |
| Asian, Hawaiian, or Pacific Islander Only | -0.041 | (0.018) |
| Black Only | 0.001 | (0.018) |
| Multiracial | 0.044 | (0.045) |
| 40 or Older | 0.026 | (0.026) |
| Female | 0.008 | (0.026) |
| College Graduate | -0.047 | (0.026) |
| Constant | 0.095 | (0.020) |

fourths of the variation in the Table 2 values was not explained by the simple regression model. They reflect "within" variation associated with combinations of the characteristics and were not explained by any of the demographic characteristics in isolation. This result indicates that it is important to consider a worker's combination of demographic characteristics rather than relying on simpler single-factor analysis.

# 4 Dilution in an All-Worker Average Group Effect

Next, we estimated average employment effects *over all* of the U.S. workers within each of the 40 demographic groups, rather than the average effects only over workers in the manufacturing sector (as in Table 2). Equation (1) still represents the employment effects on group $g$, but in this extension of the model $L_g$ is defined more broadly to include non-manufacturing as well as manufacturing workers. Because we added into the average workers who were employed in non-manufacturing industries not directly subject to the changes in trade costs of imported manufactured goods that we were analyzing, the average effects that include all workers are necessarily smaller in absolute value than the manufacturing-specific effects reported in Table 2.

Table 4 reports the manufacturing shares of employment in the 40 groups. These shares determine the dilution in the average group employment effects when non-manufacturing workers were added. The share of each group's U.S. workers employed in the manufacturing sector is generally larger for workers who are 40 or older, White Only, Asian, Hawaiian, or Pacific Islander Only, or male, though there is considerable variation across all four demographic dimensions in the table.

Table 4: Average Manufacturing Share of Employment by Group

| Race and Sex | Age $<$ 40 College Graduate (%) | Age $<$ 40 Not a Graduate (%) | Age $\geq$ 40 College Graduate (%) | Age $\geq$ 40 Not a Graduate (%) |
|---|---|---|---|---|
| American Indian, Aleut, or Eskimo Only | | | | |
| Female | 9.5 | 4.2 | 6.3 | 12.4 |
| Male | 7.9 | 8.5 | 6.5 | 10.6 |
| Asian, Hawaiian, or Pacific Islander Only | | | | |
| Female | 8.6 | 5.2 | 5.4 | 8.5 |
| Male | 11.5 | 10.9 | 14.3 | 14.5 |
| Black Only | | | | |
| Female | 2.2 | 4.8 | 2.8 | 6.9 |
| Male | 6.2 | 11.3 | 7.1 | 13.6 |
| Multiracial | | | | |
| Female | 3.2 | 4.1 | 2.6 | 10.2 |
| Male | 15.0 | 10.7 | 6.4 | 14.0 |
| White Only | | | | |
| Female | 4.6 | 5.6 | 4.7 | 7.4 |
| Male | 10.4 | 11.6 | 10.4 | 15.2 |

Table 5 reports the estimated all-worker average employment effects for each of the 40 groups. These all-worker averages were calculated as the product of the effects on each group within the manufacturing sector (in Table 2) and the manufacturing share of group employment (in Table 4).

Table 5: Estimated Average Employment Effects in Each Group

| Race and Sex | Age < 40 College Graduate (% Δ) | Age < 40 Not a Graduate (% Δ) | Age ≥ 40 College Graduate (% Δ) | Age ≥ 40 Not a Graduate (% Δ) |
|---|---|---|---|---|
| American Indian, Aleut, or Eskimo Only | | | | |
| Female | -0.006 | 0.011 | 0.007 | 0.015 |
| Male | -0.003 | 0.016 | 0.018 | 0.019 |
| Asian, Hawaiian, or Pacific Islander Only | | | | |
| Female | 0.005 | 0.002 | 0.003 | 0.004 |
| Male | 0.001 | 0.014 | 0.003 | 0.003 |
| Black Only | | | | |
| Female | 0.001 | 0.006 | 0.004 | 0.008 |
| Male | 0.003 | 0.017 | -0.001 | 0.016 |
| Multiracial | | | | |
| Female | 0.008 | -0.003 | 0.006 | 0.019 |
| Male | 0.006 | 0.018 | 0.003 | 0.027 |
| White Only | | | | |
| Female | 0.003 | 0.007 | 0.004 | 0.008 |
| Male | 0.005 | 0.013 | 0.004 | 0.018 |

# 5 Including Imported Intermediate Goods

To simplify the model, we have assumed that the effects of changes in international trade costs on labor demand are industry-specific, and that is why shocks to trade costs on the manufacturing industries do not spillover to non-manufacturing industries. The model can be generalized by incorporating inter-industry input-output linkages. In this case, trade cost shocks in one industry spill over to other industries, and estimated employment effects are not a simple weighted average based on a group's industry shares of employment.

In this section, we extend the modeling framework to include employment effects from changes in international trade costs on imported intermediate goods (as well as imported final goods). Equation (3) generalizes the expression in equation (1) for the percent change in employment in group $g$.

$$\hat{L}_g = \sum_i \left(\frac{L_{gi}}{L_g}\right) (\sigma_i - 1) \left(\frac{V_i - E_i}{V_i}\right) \left(\frac{M_i}{V_i - E_i + M_i}\right) \hat{\tau}_i + \sum_i \left(\frac{L_{gi}}{L_g}\right) (1 - \sigma_i) \left(\frac{V_i - E_i}{V_i}\right) \left(\frac{V_i - E_i}{V_i - E_i + M_i}\right) \sum_k \left(\frac{M_k}{V_k - E_k + M_k}\right) D_{ik} \hat{\tau}_k \quad (3)$$

$D_{ik}$ is the direct requirements cost share of products from industry $k$ in production in industry $i$. The first sum in equation (2) is the generally positive effect on employment of the historical changes in trade costs on imported final products in industry $i$, and the second sum is the generally negative effect on employment of the historical changes in trade costs on imported intermediate goods from all of the manufacturing industries (indexed by $i$ and $k$).[8]

Table 6 reports both types of effects on employment within the U.S. manufacturing sector, for the same 40 demographic groups.

[8]If trade costs increased for both types of imports in all of the manufacturing industries, then the first type of effects would always be positive and the second type would always be negative, since $\sigma_i > 1$.

Table 6: Estimated Average Effects, with Imported Intermediate Goods

| Race and Sex | Age < 40 College Graduate (% Δ) | Age < 40 Not a Graduate (% Δ) | Age ≥ 40 College Graduate (% Δ) | Age ≥ 40 Not a Graduate (% Δ) |
|---|---|---|---|---|
| American Indian, Aleut, or Eskimo Only | | | | |
| Female | | | | |
| Imported Final Goods | -0.06 | 0.25 | 0.11 | 0.12 |
| Imported Intermediate Goods | -0.05 | -0.07 | -0.06 | -0.04 |
| Male | | | | |
| Imported Final Goods | -0.04 | 0.19 | 0.28 | 0.18 |
| Imported Intermediate Goods | -0.01 | -0.06 | -0.05 | -0.06 |
| Asian, Hawaiian, or Pacific Islander Only | | | | |
| Female | | | | |
| Imported Final Goods | 0.06 | 0.04 | 0.05 | 0.05 |
| Imported Intermediate Goods | -0.02 | -0.03 | -0.03 | -0.03 |
| Male | | | | |
| Imported Final Goods | 0.01 | 0.13 | 0.02 | 0.02 |
| Imported Intermediate Goods | -0.02 | -0.05 | -0.02 | -0.04 |
| Black Only | | | | |
| Female | | | | |
| Imported Final Goods | 0.04 | 0.13 | 0.13 | 0.11 |
| Imported Intermediate Goods | -0.04 | -0.06 | -0.04 | -0.05 |
| Male | | | | |
| Imported Final Goods | 0.05 | 0.15 | -0.01 | 0.12 |
| Imported Intermediate Goods | -0.02 | -0.05 | -0.02 | -0.04 |
| Multiracial | | | | |
| Female | | | | |
| Imported Final Goods | 0.26 | -0.08 | 0.24 | 0.19 |
| Imported Intermediate Goods | -0.07 | -0.04 | -0.09 | -0.05 |
| Male | | | | |
| Imported Final Goods | 0.04 | 0.17 | 0.05 | 0.19 |
| Imported Intermediate Goods | -0.03 | -0.05 | -0.05 | -0.05 |
| White Only | | | | |
| Female | | | | |
| Imported Final Goods | 0.07 | 0.12 | 0.09 | 0.11 |
| Imported Intermediate Goods | -0.04 | -0.05 | -0.04 | -0.05 |
| Male | | | | |
| Imported Final Goods | 0.05 | 0.11 | 0.04 | 0.12 |
| Imported Intermediate Goods | -0.04 | -0.05 | -0.04 | -0.05 |

The effects from imports of intermediate goods offset the effects from imports of final goods for 3 of the 40 groups, and more than offset them (and flipped the sign of the change in group employment) for 4 of the 40.

Table 7 reports each group's net employment effect based on equation (2), combining the effects of changes in the trade costs on imported intermediate and final goods. The net effects are generally positive. (Positive values are highlighted in bold type in the table). The net effects ranged from -0.12% for workers who are female, multiracial, younger than 40, and have not graduated from college to 0.23% for workers who are male, American Indian, Aleut, or Eskimo Only, forty or older, and college graduates.

Table 7: Estimated Net Average Effects, with Imported Intermediate Goods

| Race and Sex | Age $<$ 40 College Graduate (% $\Delta$) | Age $<$ 40 Not a Graduate (% $\Delta$) | Age $\geq$ 40 College Graduate (% $\Delta$) | Age $\geq$ 40 Not a Graduate (% $\Delta$) |
|---|---|---|---|---|
| American Indian, Aleut, or Eskimo Only | | | | |
| Female | -0.11 | **0.18** | **0.05** | **0.08** |
| Male | -0.05 | **0.13** | **0.23** | **0.12** |
| Asian, Hawaiian, or Pacific Islander Only | | | | |
| Female | -0.04 | **0.01** | **0.02** | **0.02** |
| Male | -0.01 | **0.08** | 0.00 | -0.02 |
| Black Only | | | | |
| Female | 0.00 | **0.07** | **0.09** | **0.06** |
| Male | -0.01 | **0.10** | -0.04 | **0.07** |
| Multiracial | | | | |
| Female | **0.19** | -0.12 | **0.15** | **0.14** |
| Male | **0.01** | **0.12** | 0.00 | **0.14** |
| White Only | | | | |
| Female | **0.03** | **0.07** | **0.05** | **0.06** |
| Male | **0.01** | **0.06** | 0.00 | **0.07** |

There is not a simple pattern in Table 7: none of the rows or columns of the table have all positive values. However, groups of workers who are female, White Only, American

Indian, Aleut, or Eskimo Only, or college graduates more frequently experienced positive net employment effects.

## 6 Conclusions

The retrospective application of the model focuses on the relatively small change in international trade costs on U.S. manufacturing imports between 2021 and 2022, but the model could be easily applied to any historical shocks in import or export costs. The analysis indicates that the distribution of employment effects cannot be simply summarized along a single demographic dimension and is better characterized by a worker's combination of demographic characteristics. We demonstrated two useful extensions to the model. We quantified the dilution of the employment effects in an all-worker average that includes non-manufacturing workers, and we added employment effects from changes in international trade costs on imported intermediate goods. In future research, another useful extension would be to allow for variation in labor supply elasticity values across the demographic groups.

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# Technical Appendix

This technical appendix derives the measure of the effects of changes in international trade costs on labor demand and employment based on an industry-specific partial equilibrium model of international trade with conventional functional forms. The derivation follows Riker (2023). It is abbreviated in this case, because we are focusing on exposure to import shocks and are not also estimating exposure to export shocks.

The value of domestic shipments of industry $i$ has the constant elasticity of substitution (CES) form in equation (4).

$$v_i = \theta_i \; Y \; (P_i)^{\;\sigma_i \; - \; 1} \; (p_i)^{\;1 \; - \; \sigma_i} \tag{4}$$

$v_i$ is value of shipments of each domestic producer in the industry, and $p_i$ is their price. $Y$ is aggregate expenditure in the domestic market, and $\theta_i$ is the expenditure share of products in industry $i$. $P_i$ is the CES industry price index in equation (5), and $\sigma_i$ is the elasticity of substitution between domestic and imported varieties.

$$P_i = \left( \; n_i \; (p_i)^{\;1 \; - \; \sigma_i} \; + n_i^* \; (p_i^* \; \tau_i)^{\;1 \; - \; \sigma_i} \; \right)^{\frac{1}{1 \; - \; \sigma_i}} \tag{5}$$

$n_i$ and $n_i^*$ are the numbers of domestic and foreign varieties in the industry, $p_i^*$ is the price of foreign varieties, and $\tau_i > 1$ is an international trade cost factor on imports that is increasing in tariffs, transport costs, and any other barriers to trade.

The model assumes that production in industry $i$ has a Leontief technology that combines labor and materials in fixed proportions. $w$ is the marginal cost of labor, and $c$ is the marginal cost of materials. $a_{wi}$ and $a_{ci}$ are industry-specific unit factor requirements.

Finally, the model assumes that there is monopolistic competition in the domestic market.[9] There is a continuum of firms, and each has monopoly power in the unique variety that it produces. Each firm perceives that the own-price elasticity of demand for its variety is a constant, so its price is a constant mark-up over its marginal cost of production.

$$p_i = \left( \frac{\sigma_i}{\sigma_i \; - \; 1} \right) \; (a_{wi} \; w \; + \; a_{ci} \; c) \tag{6}$$

Using the approach to calibrating $\sigma_i$ from Ahmad and Riker (2019), equation (6) implies equation (7):

$$\sigma_i = \frac{p_i}{p_i - a_{wi} \; w - a_{ci} \; c} = \frac{V_i}{V_i - W_i - C_i} \tag{7}$$

$V_i$ is the value of total shipments of domestic producers in industry $i$, $W_i$ is total domestic wage payments in the industry, and $C_i$ is the total cost of materials in the industry.

Equations (8) and (9) are percent changes in industry labor demand (and equivalently employment) and the value of imports in industry $i$ resulting from changes in the international trade cost factors on imports of final goods in industry $i$.[10] They are first-order log-linear approximations evaluated at the initial equilibrium in the domestic market.

$$\hat{L}_i = \left( \frac{L_i \; - \; L_i^*}{L_i} \right) \hat{M}_i \; - \; \hat{p}_i \tag{8}$$

$L_i$ is total employment of domestic manufacturers in industry $i$, and $L_i^*$ is their employment associated with exports, so $\frac{L_i^*}{L_i} = \frac{E_i}{V_i}$, where $E_i$ is the value of the industry's exports. $\hat{L}_i$ is the proportional (or percent) change in employment in the domestic industry, $\frac{dL_i}{L_i}$, and $\hat{\tau}_i$ is the proportional change in the trade cost factors. $L_i$ and $M_i$ are endogenous variables that

[9]The models of monopolistic competition and trade in differentiated products in Krugman (1980), Melitz (2003), Chaney (2008), Helpman, Melitz and Rubinstein (2008), and subsequent studies also assume that consumers have CES preferences.

[10]Alternative assumptions about labor supply would break the equivalence between the percent changes and the percent changes in domestic industry employment. For example, differences in adjustment costs across the demographic groups would result in additional differences in employment effects.

change in response to changes in trade costs. $p_i$ is an endogenous variable that does not change, because it is fixed according to equation (6).

$$\hat{M}_i = (\sigma_i \; - \; 1) \, \mu_i \; \hat{\tau}_i \tag{9}$$

$\mu_i$ is the industry's import penetration rate, $\frac{M_i}{V_i - E_i + M_i}$. To simplify these expressions, we hold all other economic fundamentals constant, including $Y$, $w$, $c$, $a_{wi}$, $a_{ci}$, $\theta_i$, and $\sigma_i$. We also hold the foreign producer price ($p_i^*$) constant. The delivered price in the domestic market ($\tau_i \; p_i^*$) is not constant when $\tau_i$ changes. We assume that $n_i$ and $n_i^*$ remain fixed in the short run.

Equations (10) is the reduced-form expression for the percent change in domestic industry employment in response to the change in trade costs. It is derived by substituting equations (9) into equation (8), since $\hat{p}_i = 0$.

$$\hat{L}_i = \left( \frac{L_i \; - \; L_i^*}{L_i} \right) (\sigma_i \; - \; 1) \, \mu_i \; \hat{\tau}_i \tag{10}$$

This is the labor demand and employment effect of the changes in the trade cost factor on industry imports of final goods.

Equation (11) is an accounting identity that links the percent change in total employment for domestic workers in group $g$ to the industry-specific shifts in labor demand in equation (10).

$$\hat{L}_g = \sum_i \left( \frac{L_{gi}}{L_g} \right) \; \hat{L}_i \tag{11}$$

$L_g = \sum_i L_{gi}$ is total domestic employment of workers in group $g$ across all manufacturing industries, and $L_{gi}$ is domestic employment of group $g$ workers in industry $i$.

Equation (12), which is identical to equation (1) above, is the percent change in the employment of workers in group $g$ due to changes in the trade cost factors in all of the manufacturing industries.

$$\hat{L}_g = \sum_i \left(\frac{L_{gi}}{L_g}\right) \ (\sigma_i \ - \ 1) \ \left(\frac{V_i - E_i}{V_i}\right) \left(\frac{M_i}{V_i - E_i + M_i}\right) \ \hat{\tau}_i \tag{12}$$

According to equation (10), the exposure of an industry's employment to changes in international trade costs depends on the industry's import penetration rate and the extent of substitution between its domestic and imported varieties. According to equations (12), the impact on a specific group of workers depends on these factors and also on the distribution of the employment of group members across the manufacturing industries.