

TRADE ELASTICITIES, TRANSPORT COSTS, AND EMPLOYMENT IN U.S. MANUFACTURING

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Abstract

I update the estimates of the trade elasticity of substitution for specific manufacturing industries in Ahmad and Riker (2020) using post-pandemic data on industry profit margins from the 2022 Economic Census. Then I demonstrate how to use these elasticity estimates to simulate the U.S. employment effects of industry-specific changes in the international transport costs of imported final goods. The simulations indicate that a 20% increase in the international transport costs could increase U.S. employment in the manufacturing industries by up to 2.10% and by up to 4,953 workers, depending on the industry's trade elasticity, import penetration rate, export share, initial employment level, and initial international transport costs.

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1 Introduction

As an update to Ahmad and Riker (2020), I re-estimate the trade elasticity of substitution between domestic and imported varieties at the NAICS 4-digit industry level using recently released post-pandemic data from the 2022 Economic Census of the United States. Then I demonstrate how to use the elasticity estimates to simulate the U.S. employment effects of industry-specific changes in international transport costs of imported final goods.

Section 2 summarizes the theoretical framework underlying the simulations. The industry-specific model of trade in differentiated products implies an empirical relationship between the price-cost markup and the elasticity of substitution in industries operating under monopolistic competition. In this setting, constant returns to scale and unlimited factor supplies imply a simple reduced-form equation for the effects of an increase in international transport costs on industry employment in the United States. The model only requires industry-level data on the total value of shipments, production worker wages, total cost of materials, and employment that are publicly available from the U.S. Census Bureau and industry-level data on the values of U.S. imports and exports that are publicly available from the U.S. International Trade Commission.

I apply the method to 84 NAICS four-digit U.S. manufacturing industries. Section 3 describes the data sources and the approach to calibrating the elasticity of substitution. Section 4 reports the estimates of the trade elasticity of substitution and employment effects for each NAICS four-digit industry. The simulations indicate that a 20% increase in international transport costs of imported final goods could increase U.S. employment in the individual manufacturing industries by up to 2.10% and by up to 4,953 workers, depending on the industry's trade elasticity, import penetration rate, export share, initial employment level, and initial international transport costs. Section 5 concludes with a summary of findings and potential model extensions.

2 Theoretical Framework

2.1 Trade Elasticity of Substitution

Consumers have constant elasticity of substitution (CES) preferences with elasticity parameter σ . There is monopolistic competition, with a continuum of firms.¹ Each firm takes the industry price index as given, since its own contribution to this index is infinitesimal. Each firm perceives that the own-price elasticity of demand for its product is constant and equal to $-\sigma$.

The firm faces a constant marginal cost of production that is equal to its average variable cost. The mark-up of each firm, m , is defined as the difference between its price (p) and marginal cost (c) divided by its price.

$$m = \frac{p - c}{p} \quad (1)$$

At the firm's profit-maximizing price, this mark-up is equal to the reciprocal of the absolute value of the constant own-price elasticity.

$$\sigma = \frac{1}{m} = \frac{p}{p - c} \quad (2)$$

This inverse relationship between σ and m applies to the data for each firm in the industry and also to aggregated data for the industry as a whole.

2.2 Effects on Industry Employment

Given the CES demands and assuming constant returns to scale production technologies and perfectly elasticity factor supplies, equation (3) relates the percent change in the industry

¹The model is an adaptation of the models of monopolistic competition and trade in differentiated products in Krugman (1980), Melitz (2003), and the extensive literature that followed.

employment associated with the increase in domestic shipments ($\hat{L}$) to the percent change in the trade cost factor ($\hat{\tau}$).²

$$\hat{L} = (1 - \chi) (\sigma - 1) \mu \hat{\tau} \quad (3)$$

μ is the industry's initial import penetration rate, defined as the expenditure share of imports or equivalently the ratio of the value of imports to the sum of the value of imports and domestic shipments. χ is the industry's initial export share of the shipments of domestic producers in the industry, defined as the ratio of the value of exports to the sum of the value of exports and domestic shipments. This equation assumes that import supply is perfectly elastic, so there is complete pass-through of the change in transport costs into the delivered prices of imports.³ Finally, equation (4) is the resulting change in the number of workers in the domestic industry.

$$\Delta L = \hat{L} L_0 \quad (4)$$

L_0 is initial employment in the industry.

3 Data Sources and Calibration

I use data from the 2022 Economic Census of the United States to calculate industry mark-ups at the level of NAICS four-digit manufacturing industries.⁴ The total value of shipments (TVS) is a measure of net selling value at the factory gate. Production worker annual wages (PWW) includes all compensation for workers up through the line-supervisor who engaged

²The trade cost factor, τ , is equal to one plus the tariff rate and the international transport cost rate.

³This "small country" assumption is common in models of international trade. The assumption is most appropriate when the industry's U.S. market is small relative to the industry's global market.

⁴These data are publicly available at <https://www.census.gov/data/tables/2022/econ/economic-census/naics-sector-31-33.html>.

in fabricating, processing, assembling, and related production activities. The total cost of materials (TCM) are the direct charges for materials consumed, including parts, fuel, power, resales, and contract work.

Following Ahmad and Riker (2020), I calculate the mark-ups assuming that the wage payments to production workers (PWW) are the only part of payroll that is a variable cost. This calculation assumes that wage payments to non-production workers are all fixed costs, and that the cost of materials are all variable costs. The calculation assumes that all other expenses of the industry are fixed costs.⁵

$$m = \frac{TVS - (PWW + TCM)}{TVS} \quad (5)$$

Next, I estimate the trade elasticity of substitution for each industry based on equation (6):

$$\sigma = \frac{TVS}{TVS - (PWW + TCM)} \quad (6)$$

This relationship between σ and these industry-level measures of the values of shipments and costs holds whether all firms have the same costs, as in Krugman (1980), or there is firm heterogeneity in costs, as in Melitz (2003).

I use this estimate of σ , along with data on the landed duty-paid values of imports ($LDPV$), the Free Along Side value of exports (FAS), and the total value of shipments of domestic producers (TVS), to substitute for μ and χ in equation (3).⁶

$$\hat{L} = \left(1 - \frac{FAS}{TVS}\right) (\sigma - 1) \frac{LDPV}{TVS - FAS + LDPV} \hat{\tau} \quad (7)$$

Equations (4) and (7) imply the following reduced-form expression for the change in industry

⁵As noted in Ahmad and Riker (2020), the greatest limitation of this methodology is that the calculation of marginal costs is only approximate, since industry costs are not clearly disaggregated into variable and fixed components in the Census data.

⁶The import and export data are publicly available at <https://dataweb.usitc.gov/>.

employment:

$$\Delta L = L_0 \left(1 - \frac{FAS}{TVS} \right) (\sigma - 1) \frac{LDPV}{TVS - FAS + LDPV} \hat{\tau} \quad (8)$$

4 Elasticity and Simulation Results

The NAICS four-digit estimates of σ based on post-pandemic 2022 data from the 2022 Economic Census are close to the pre-pandemic 2017 estimates in Ahmad and Riker (2020). The simple average value of σ in the 84 industries rose slightly, from 2.74 to 2.78. The estimates rose in 51 of the industries, stayed the same in one, and declined in 32. The changes in the estimates of σ were less than 0.5 in absolute value for 78 of the 84 industries.

I used the updated estimates of σ in simulations of the effects of an industry-specific 20% increase in the international transport costs of imported final goods. The percent change in the trade cost factor, $\hat{\tau}$, is equal to $\frac{0.20}{\tau_0} \frac{f_0}{\tau_0}$, where τ_0 is the initial international trade cost factor and f_0 is the initial transport cost rate. I estimated employment effects in each industry separately, and the results are organized in four tables that group similar industries.

Table 1 reports estimates for 22 four-digit industries in the food, beverages, tobacco, textile, apparel, and leather products within U.S. manufacturing (NAICS codes 3111 through 3169). The estimated trade elasticities in Table 1 range from 1.18 to 4.57, and the estimated employment changes range from 0.00 to 1.90%. The estimated increase in the number of workers in an industry ranges from 0 to 848 workers.

Table 1: Estimates for Food, Textiles, and Related Industries

Industry (NAICS code)	σ	μ (%)	χ (%)	f_0 (%)	$\hat{L}$ (%)	ΔL
Animal food manufacturing (3111)	3.49	4.68	5.95	9.12	0.18	111
Grain and oilseed milling (3112)	4.47	15.35	11.52	5.70	0.50	294
Sugar product manufacturing (3113)	2.86	22.65	7.08	4.32	0.32	273
Fruit and vegetable preserving (3114)	2.65	18.39	6.99	9.98	0.49	833
Dairy product manufacturing (3115)	4.24	3.80	6.20	5.47	0.11	183
Animal slaughtering (3116)	4.10	6.07	9.64	2.19	0.07	387
Seafood product preparation (3117)	4.04	28.05	3.37	5.89	0.88	274
Bakeries (3118)	2.28	11.29	3.16	5.34	0.14	416
Other food manufacturing (3119)	2.37	13.15	8.15	5.12	0.16	393
Beverage manufacturing (3121)	2.16	21.89	7.02	4.95	0.22	570
Tobacco manufacturing (3122)	1.18	3.25	0.39	3.00	0.00	0
Fiber, yarn, and thread mills (3131)	4.57	17.33	33.38	7.85	0.56	107
Fabric mills (3132)	2.73	52.05	38.36	8.32	0.80	324
Textile and fabric finishing (3133)	3.32	22.23	15.30	7.07	0.54	115
Textile furnishings (3141)	2.97	63.96	9.84	9.91	1.90	848
Other textile product mills (3149)	2.53	57.19	14.87	10.33	1.28	708
Apparel knitting mills (3151)	2.93	78.88	8.09	7.19	1.65	145
Cut and sew apparel (3152)	2.52	96.04	37.75	4.96	0.75	388
Apparel accessories (3159)	2.43	90.10	38.93	5.43	0.72	57
Leather and hide tanning (3161)	3.59	51.85	54.39	3.71	0.43	13
Footwear manufacturing (3162)	2.95	97.48	33.08	5.70	1.22	109
Other leather and allied products (3169)	2.36	95.71	60.47	7.00	0.60	74

Table 2 reports estimates for 21 four-digit industries in the wood, paper, printing, petroleum, chemical, rubber, plastic and non-metallic mineral products (NAICS codes 3211 through 3279). The estimated trade elasticities for this group range from 1.50 to 5.29, and the estimated employment changes range from 0.02 to 1.21%. The estimated increase in the number of workers in an industry ranges from 11 to 3,425 workers.

Table 2: Estimates for Wood, Chemicals, Minerals, and Related Industries

Industry (NAICS code)	σ	μ (%)	χ (%)	f_0 (%)	$\hat{L}$ (%)	ΔL
Sawmills and wood preservation (3211)	2.64	22.00	7.77	5.63	0.35	321
Veneer and plywood (3212)	2.54	26.08	4.38	8.78	0.61	512
Other wood products (3219)	2.73	13.72	3.49	11.10	0.44	1,155
Pulp, paper, and paperboard (3221)	2.22	19.35	19.95	6.22	0.22	197
Converted paper products (3222)	3.20	10.44	7.61	8.42	0.32	816
Printing and related support (3231)	2.23	7.47	5.34	7.85	0.12	471
Petroleum and coal products (3241)	5.29	12.08	17.00	3.09	0.26	255
Basic chemical manufacturing (3251)	2.49	25.98	26.00	4.86	0.26	418
Resin and synthetic rubber products (3252)	2.92	28.20	38.54	8.26	0.49	562
Pesticides and fertilizers (3253)	1.93	35.46	27.06	4.46	0.20	76
Pharmaceuticals and medicines (3254)	1.50	56.11	34.70	0.63	0.02	70
Paint, coating, and adhesives (3255)	2.59	6.37	11.73	5.04	0.08	62
Soap and cleaning compounds (3256)	1.94	22.30	19.51	4.29	0.14	147
Other chemical products (3259)	2.43	40.28	26.48	3.94	0.31	273
Plastic products (3261)	2.53	20.81	9.84	10.17	0.50	3,425
Rubber products (3262)	2.65	46.20	21.70	10.99	1.14	1,618
Clay products, refractory (3271)	2.06	60.17	26.48	15.88	1.21	445
Glass and glass products (3272)	2.24	30.45	16.12	12.01	0.63	589
Cement and concrete products (3273)	2.42	3.43	0.29	22.81	0.18	345
Lime and gypsum products (3274)	2.31	3.57	2.60	8.32	0.07	11
Other nonmetallic mineral products (3279)	2.08	29.96	9.61	12.07	0.61	531

Table 3 reports estimates for 25 four-digit industries in the metal, machinery, and computers (NAICS codes 3311 through 3345). The estimated trade elasticities for this group range from 1.84 to 3.61, and the estimated employment changes range from 0.02 to 0.76%. The estimated increase in the number of workers in an industry ranges from 7 to 1,167 workers.

Table 3: Estimates for Metals, Machinery, and Related Industries

Industry (NAICS code)	σ	μ (%)	χ (%)	f_0 (%)	$\hat{L}$ (%)	ΔL
Iron and steel mills (3311)	2.99	31.50	11.25	5.89	0.60	449
Steel products from purchased steel (3312)	3.13	11.90	2.66	9.82	0.41	220
Alumina and aluminum production (3313)	3.61	37.53	12.64	3.75	0.60	352
Nonferrous metal, ex. alum., (3314)	3.39	78.63	68.57	0.66	0.08	42
Foundries (3315)	2.72	5.80	1.79	13.77	0.21	229
Forging and stamping (3321)	3.05	6.28	3.50	3.65	0.08	75
Cutlery and hand tools (3322)	2.04	61.65	22.18	6.93	0.60	185
Architectural and structural metals (3323)	2.54	7.20	1.26	6.30	0.13	535
Boilers and tanks (3324)	3.05	20.04	10.20	9.53	0.62	508
Hardware (3325)	2.18	60.53	28.33	5.52	0.50	142
Spring and wire products (3326)	2.63	36.80	15.50	8.54	0.76	263
Machine shops (3327)	2.48	11.58	6.76	9.50	0.26	965
Other fabricated metal (3329)	2.23	43.04	27.81	5.10	0.35	857
Ag. and construction machinery (3331)	2.81	37.42	22.01	3.96	0.39	724
Industrial machinery (3332)	2.45	77.49	73.55	3.86	0.22	220
Commercial and service machinery (3333)	2.29	44.15	33.84	3.02	0.21	175
Ventilation, heating, and air cond. (3334)	2.55	35.31	13.63	4.29	0.37	566
Metalworking machinery (3335)	2.44	38.04	16.76	3.74	0.31	421
Engines and turbines (3336)	2.84	52.67	48.82	3.57	0.33	322
Other general purpose machinery (3339)	2.57	45.25	28.89	3.89	0.37	1,167
Computers and peripherals (3341)	2.96	99.46	96.23	1.58	0.02	7
Communications equipment (3342)	2.34	82.73	32.48	1.81	0.26	220
Audio and video equipment (3343)	2.37	95.52	60.08	2.16	0.22	28
Semiconductors and components (3344)	2.45	59.68	32.04	1.97	0.22	603
Navigational and other instruments (3345)	1.84	36.92	25.99	1.87	0.08	347

Finally, Table 4 reports estimates for 16 four-digit industries in the electrical equipment, transportation equipment, furniture, and miscellaneous manufacturing (NAICS codes 3351 through 3399). The estimated trade elasticities for this group range from 1.83 to 6.44, and the estimated employment changes range from 0.05 to 2.10%. The estimated increase in the number of workers in an industry ranges from 70 to 4,953 workers.

Table 4: Estimates for Vehicles, Equipment, and Related Industries

Industry (NAICS code)	σ	μ (%)	χ (%)	f_0 (%)	$\hat{L}$ (%)	ΔL
Electric lighting equipment (3351)	2.19	56.12	9.93	7.08	0.71	270
Household appliances (3352)	2.45	68.32	15.68	7.87	1.17	677
Electrical equipment (3353)	2.56	58.29	30.28	2.59	0.31	367
Other electrical equipment (3359)	2.31	56.94	30.28	3.02	0.29	456
Motor vehicles (3361)	4.94	40.83	18.12	1.30	0.33	842
Motor vehicle bodies and trailers (3362)	3.90	7.66	14.12	1.71	0.06	111
Motor vehicle parts (3363)	4.12	38.10	17.00	3.66	0.68	3,885
Aerospace products and parts (3364)	2.66	28.56	45.17	1.10	0.06	235
Railroad rolling stock (3365)	6.44	14.82	22.76	3.30	0.39	116
Ship and boat building (3366)	2.54	8.47	4.71	1.96	0.05	70
Other transportation equipment (3369)	2.55	43.50	13.99	4.74	0.50	187
Household and institutional furniture (3371)	2.56	52.47	6.01	16.93	2.10	4,953
Office furniture and fixtures (3372)	2.34	26.39	2.40	11.03	0.64	697
Other furniture related products (3379)	2.46	26.21	2.03	7.78	0.52	176
Medical equipment and supplies (3391)	1.83	44.71	30.13	2.69	0.13	389
Other miscellaneous manufacturing (3399)	2.29	74.37	29.92	5.18	0.60	1,443

The estimated employment increases in all 84 industries sum to 43,418 workers. In theory, summing the employment effects from the separate, industry-specific models can overstate the net aggregate effect on manufacturing employment, since increased labor demand in each industry could increase wages faced by other manufacturing industries, and this could dampen employment increases. However, Riker (2024) demonstrates that these general equilibrium feedback effects of import costs on U.S. manufacturing imports are not likely to be significant in practice as long as the transport cost shocks are industry-specific and specific

to imports of final goods.⁷

5 Conclusions and Extensions

Both the estimates of the trade elasticity and the simulated employment effects of increases in international transport costs are easy to calculate using the modeling equations in this paper and publicly available industry data. These estimates provide first cut approximations that could be further refined by expanding the model and collecting additional data for industries of interest.

The estimated employment effects sum to an additional 43,418 U.S. manufacturing workers in the hypothetical simulations. This includes 6,625 workers in food, textiles, and related industries, 12,298 in wood, chemicals, minerals, and related industries, 9,622 in metals, machinery, and related industries, and 14,872 in the vehicles, equipment, and related industries.

The modeling framework could be extended, and the estimates of employment effects refined, by relaxing some of the restrictive modeling assumptions and collecting additional data. The following is a list of potential model extensions that are probably practical to implement:

1. Relax the assumption of complete pass-through of changes in international transport costs into the delivered prices of imports.
2. Allow wages to rise due to tightening in the labor market.
3. Add labor market frictions that impede employment changes.
4. Allow for decreasing returns to scale due to capacity constraints.
5. Allow for multiple, linked stages of production, with transport cost shocks in upstream and downstream stages.

⁷On the other hand, if the cost shocks occur broadly across industries due to interlinked supply chains then general equilibrium feedback effects could be more significant.

All of these extensions of the model tend to *reduce* the estimated positive employment effects of an increase in international transport costs.

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