UPDATED ESTIMATES OF THE TRADE ELASTICITY OF SUBSTITUTION

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Abstract

We update estimates of the trade elasticity of substitution for specific manufacturing industries in Ahmad and Riker (2019) using data on industry profit margins from the 2017 Economic Census. The methodology is derived from a model of international trade in differentiated products and monopolistic competition. We compare the elasticity estimates using 2017 data to earlier estimates using 2012 data.

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1 Introduction

The elasticity of substitution between domestic and imported varieties of a particular good is one of the key parameters in models of the impact of international trade policy. Within a Constant Elasticity of Substitution (CES) demand framework, the elasticity of substitution determines the magnitudes of changes in trade patterns in response to changes in tariff rates and other trade policies. There is a large econometric literature devoted to estimating the elasticity of substitution for different industries. Within this literature, there is considerable variation in estimates, reflecting differences in data sources and estimation techniques. Ahmad, Montgomery and Schreiber (2020) provides a useful review of the different approachs and estimates of the trade elasticity, also known as the Armington elasticity, including the approach in Ahmad and Riker (2019).

In this paper, we focus on updating our earlier estimates, which were based on data from the 2012 Economic Census of the United States. Section 2 presents the theoretical framework. 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. We re-apply our methodolgy to more recent data from the 2017 Economic Census. The data sources and limitations are described in Section 3. Section 4 reports our updated estimates of the elasticity of substitution at the level of four-digit NAICS manufacturing industries, and Section 5 concludes.

2 Theoretical Framework for Estimating the Elasticity

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 assume that consumers have constant elasticity of substitution (CES) preferences with elasticity parameter σ. In these models, there is a continuum of firms, each with monopoly power in the unique variety that it produces. The assumption of a continuum of varieties simplifies the pricing decision of the firms. Each firm takes the industry price index as given, since its own contribution to this index is infinitesimal. Each firm perceives the own-price elasticity of demand for its product to be a constant that is equal to $-\sigma$.

These trade models also assume that each 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.

$$m = \frac{p - c}{p} \tag{1}$$

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. Given the relationship between the own-price elasticity and the elasticity of substitution in the model, σ is equal to the reciprocal of this mark-up.

$$\sigma = \frac{1}{m} = \frac{p}{p - c} \tag{2}$$

Within the model, 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. This remains true even in Melitz-Chaney models where firms in the same industry face different marginal costs and charge different prices.[1]

The monopolistic competition models of Krugman and Melitz assume a non-nested CES

[1] Suppose there are n firms in the industry with constant but heterogeneous marginal costs c_i for $i = 1, ..., n$. Then the aggregation for the entire industry is simply given as:

$$\sum_{i=1}^{n} p_i \; q_i = \frac{\sigma}{\sigma - 1} \sum_{i=1}^{n} c_i \; q_i$$

demand structure with the same elasticity of substitution between domestic products and imports from difference countries. However, it is common in computable general equilibrium models of trade and other types of trade policy simulation models to assume a nested CES demand structure, with a higher elasticity of substitution between import from different countries than between domestic products and a composite of imports. If preferences are nested in this way, then the σ parameter that we estimate from the price-cost margins of the domestic producers will be the elasticity of substitution in the *upper tier* (between domestic products and a composite of the imports) rather than the elasticity of substitution in the lower tier (between imports from different countries).

3 Data Sources and Limitations

We use data from the 2017 Economic Census of the United States to calculate industry mark-ups.[2] In this paper, we analyze industries at the level of four-digit NAICS industries. 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 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.

Assuming constant marginal costs, the mark-up in (2) can be expressed in terms of sales (TVS) and total variable costs (TVC):

$$m = \frac{p\ q\ -\ c\ q}{p\ q} = \frac{TVS\ -\ TVC}{TVS} \tag{3}$$

We calculate mark-ups assuming that the wage payments to production workers (PWW)

[2] These data are available at `https://www.census.gov/data/tables/2017/econ/economic-census/naics-sector-31-33.html`.

are the only part of payroll that is a variable cost.[3] 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.

$$m = \frac{TVS - (PWW + TCM)}{TVS} \tag{4}$$

Finally, we use m to estimate the elasticity of substitution for each industry:

$$\sigma = \frac{1}{m} \tag{5}$$

One advantage of this approach to estimating the elasticity of substitution is that the calculations generate a full set of σ estimates for detailed manufacturing industries. A second advantage is that the data are from a reliable and recent Census data. As noted in Ahmad and Riker (2019), the greatest limitation of our approach is that the calculation of marginal costs is only approximate, since industry costs are not more disaggregated into variable and fixed components in the Census data.

4 Estimates for 2017 and 2012

Table 1 reports estimates of the elasticity of substitution for 22 four-digit industries in the food, beverages, tobacco, textile, apparel, and leather product sectors within U.S. manufacturing. The estimates are similar in absolute and relative magnitude between the two Census years, though they are estimated independently, using different years of data. The Pearson correlation coefficient is 0.97 and the Spearman coefficient is 0.95. The stability of the estimates is a strength of the approach.[4] The 2017 estimates are higher for 10 of the 22

[3]This corresponds to the high end estimate m_1 in Ahmad and Riker (2019).

[4]In contrast, econometric estimates of trade elasticities are often sensitive to the estimation period.

industries and lower for 12. The estimates for 2017 range from 1.22 to 5.22.

Table 1: Estimates of σ for NAICS 311-316

Industry (NAICS code)	2017	2012
Animal food manufacturing (3111)	3.45	4.12
Grain and oilseed milling (3112)	4.10	4.03
Sugar product manufacturing (3113)	2.68	2.57
Fruit and vegetable preserving (3114)	2.57	2.60
Dairy product manufacturing (3115)	3.78	4.11
Animal slaughtering (3116)	4.36	4.96
Seafood product preparation (3117)	3.57	3.34
Bakeries (3118)	2.10	2.21
Other food manufacturing (3119)	2.30	2.25
Beverage manufacturing (3121)	1.99	2.12
Tobacco manufacturing (3122)	1.22	1.29
Fiber, yarn, and thread mills (3131)	4.11	4.46
Fabric mills (3132)	2.77	2.68
Textile and fabric finishing (3133)	3.35	3.25
Textile furnishings (3141)	2.96	3.42
Other textile product mills (3149)	2.48	2.71
Apparel knitting mills (3151)	3.13	2.98
Cut and sew apparel (3152)	2.56	2.62
Apparel accessories (3159)	2.32	2.28
Leather and hide tanning (3161)	5.52	6.25
Footwear manufacturing (3162)	3.09	2.66
Other leather and allied products (3169)	2.50	2.36

Table 2 reports estimates of the elasticity of substitution for 21 four-digit industries in the wood, paper, printing, petroleum, chemical, rubber, plastic and non-metallic mineral product sectors. The Pearson and Spearman correlation coefficients are again high (0.98 and 0.96). The 2017 estimates are lower for 18 of the 21 industries and are only higher for 3. The estimates for 2017 range from 1.78 to 5.69.

Table 2: Estimates of $\sigma$for NAICS 321-327

Industry (NAICS code)	2017	2012
Sawmills and wood preservation (3211)	3.39	4.04
Veneer, plywood, and engineered wood (3212)	2.90	3.31
Other wood products (3219)	3.02	3.21
Pulp, paper, and paperboard (3221)	2.25	2.19
Converted paper products (3222)	3.17	3.01
Printing and related support (3231)	2.29	2.22
Petroleum and coal products (3241)	5.69	6.75
Basic chemical manufacturing (3251)	2.46	2.95
Resin and synthetic rubber products (3252)	3.15	3.68
Pesticides and fertilizers (3253)	2.09	2.32
Pharmaceuticals and medicines (3254)	1.52	1.53
Paint, coating, and adhesives (3255)	2.29	2.55
Soap and cleaning compounds (3256)	1.78	1.97
Other chemical products (3259)	2.39	2.56
Plastic products (3261)	2.52	2.63
Rubber products (3262)	2.80	3.35
Clay products, refractory (3271)	1.97	2.17
Glass and glass products (3272)	2.18	2.32
Cement and concrete products (3273)	2.38	2.50
Lime and gypsum products (3274)	2.25	2.45
Other nonmetallic mineral products (3279)	2.07	1.97

Table 3 reports estimates of the elasticity of substitution for 27 four-digit industries in the metal, machinery, and computer sectors. The correlations are 0.96 and 0.87. The 2017 estimates are lower for 18 of the 27 industries, higher for 7, and unchanged for 2. The estimates for 2017 range from 1.71 to 3.87.

Table 3: Estimates of σ for NAICS 331-334

Industry (NAICS code)	2017	2012
Iron and steel mills (3311)	3.51	4.21
Steel products from purchased steel (3312)	3.46	3.54
Alumina and aluminum production (3313)	3.87	4.71
Nonferrous metal products, ex. alum., (3314)	3.59	4.10
Foundries (3315)	2.45	2.44
Forging and stamping (3321)	2.78	3.03
Cutlery and handtools (3322)	1.88	1.83
Architectural and structural metals (3323)	2.63	2.78
Boilers and tanks (3324)	3.26	3.09
Hardware (3325)	2.18	2.24
Spring and wire products (3326)	2.47	2.78
Machine shops (3327)	2.41	2.33
Coating and engraving (3328)	2.14	2.14
Other fabricated metal (3329)	2.15	2.27
Agriculture and construction machinery (3331)	2.80	2.84
Industrial machinery (3332)	2.16	2.16
Commercial and service machinery (3333)	2.13	2.28
Ventilation, heating, and air conditioning equipment (3334)	2.33	2.46
Metalworking machinery (3335)	2.34	2.39
Engines and turbines (3336)	2.80	2.90
Other general purpose machinery (3339)	2.38	2.44
Computers and peripherals (3341)	2.43	2.24
Communications equipment (3342)	2.09	2.44
Audio and video equipment (3343)	2.03	1.95
Semiconductors and components (3344)	2.25	2.09
Navigational and other instruments (3345)	1.71	1.73
Magnetic and optical media (3346)	2.37	1.90

Finally, Table 4 reports estimates of the elasticity of substitution in 16 four-digit industries in the electrical equipment, transportation equipment, furniture, and miscellaneous manufacturing sectors. The correlations are 0.97 and 0.85. The 2017 estimates are higher for 9 of the 16 industries and lower for 7. The estimates for 2017 range from 1.75 to 5.02.

Table 4: Estimates of σ for NAICS 335-339

Industry (NAICS code)	2017	2012
Electric lighting equipment (3351)	2.02	2.28
Household appliances (3352)	2.63	2.30
Electrical equipment (3353)	2.51	2.50
Other electrical equipment (3359)	2.45	2.43
Motor vehicles (3361)	5.02	5.21
Motor vehicle bodies and trailers (3362)	4.02	4.23
Motor vehicle parts (3363)	4.01	4.03
Aerospace products and parts (3364)	2.14	2.29
Railroad rolling stock (3365)	3.95	3.93
Ship and boat building (3366)	2.06	2.05
Other transportation equipment (3369)	2.62	2.79
Household and institutional furniture (3371)	2.57	2.69
Office furniture and fixtures (3372)	2.25	2.18
Other furniture related products (3379)	2.93	2.24
Medical equipment and supplies (3391)	1.75	1.66
Other miscellaneous manufacturing (3399)	2.08	2.07

5 Conclusions

Our approach to estimating the elasticity of substitution for detailed manufacturing industries has practical data requirements, and it is easy to update as new data are released. A limitation to keep in mind, howver, it that this estimation approach is based on a structural relationship between elasticity of substitution and the markup in a CES monopolistic competition model, and it may not be appropriate for industries that are characterized by concentrated market shares or even a single large firm with significant market power.

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