Armington Elasticities for United States Manufacturing Sectors

Kenneth A. Reinert, *U.S. International Trade Commission and Wellesley College*, and David W. Roland-Holst, *Mills College*

1. INTRODUCTION

Most neoclassical trade models specify continuous substitution possibilities between imported and domestic goods in comparable product categories. A common form of this in practical work is based on a constant elasticity of substitution (CES) specification derived from Armington (1969). Although the Armington model has been widely adopted, little direct econometric estimation of CES elasticities has been undertaken, leaving modelers to rely on judgmental values and sensitivity analysis.[1] In this article, we provide Armington estimates for detailed mining and manufacturing sectors of the United States.

Using data from a number of government sources, we have developed time series on prices and quantities of imported and domestic goods (in domestic use) for 163 sectors. For most of these, we were able to specify an estimating equation that yielded statistically significant CES elasticities. In the next section, the CES specification of import demand is reviewed. Section 3 discusses the database that was assembled for the estimates presented in Section 4. Section 5 presents some concluding remarks.

Address correspondence to Kenneth A. Reinert, Research Division, Office of Economics, U.S. International Trade Commission, Washington, DC 20436.

Thanks to Charles Gilbert and Mark Planting for data, to Clinton Shiells and Jaime de Melo for helpful comments and suggestions, and to Andrew Parks for computer assistance. The views expressed in this article are those of the authors and should not be attributed to the U.S. International Trade Commission.

Received November 1990; final draft accepted November 1991.

[1]Three exceptions are estimates for Australia by Alaouze, Marsden, and Zeitsch (1977), for Portugal by Corado and de Melo (1986), and for Ecuador by Roland-Holst and Sadoulet (1989).

Journal of Policy Modeling 14(5):631–639 (1992)

0161-8938/92/$5.00

2. MODELING IMPORT BEHAVIOR WITH THE CES FUNCTIONAL FORM

Trade theory usually views import behavior from the perspective of the economy as a whole. This is equivalent to considering an aggregate agent who views imported and domestic goods in similar product categories as substitutes in consumption. If this representative consumer has a well-behaved utility function, then the consumption decision is amenable to neoclassical utility maximization or, in a dual formulation, expenditure minimization.

The hypothetical representative consumer obtains utility from a composite (Q) of imported (M) and domestic (D) goods, and we assume there are continuous substitution possibilities between the latter. The decision problem is then to choose a mix of M and D that minimizes expenditure, given respective prices p_M and p_D and the desired level of Q. In the Armington specification, a CES functional form is chosen for Q:

$$Q = \alpha[\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}, \qquad (1)$$

where α and β are calibrated parameters and σ is the (constant) elasticity of substitution between imports and domestic goods. The solution to the consumer's optimization problem will then be to choose imports and domestic goods whose ratio satisfies the first-order condition

$$M/D = [(\beta/(1-\beta))(p_D/p_M)]^{\sigma}, \qquad (2)$$

which is the familiar equivalence between rates of substitution and relative prices.[2] The parameter σ also can be interpreted as the compensated price elasticity of import demand.

Assuming that the utilities in composite consumption are weakly separable, Armington elasticities can be estimated for disaggregated commodity categories.[3] These can then used to determine import demand elasticities in multisectoral simulation models.[4]

[2]de Melo and Robinson (1989) give a more extended treatment of CES import behavior in a general equilibrium model.

[3]See Section 2 of Winters (1984) for a discussion of separability assumptions.

[4]See, for example, Dervis, de Melo, and Robinson (1982).

3. DATA ON U.S. PRICES AND DEMAND FOR IMPORTED AND DOMESTIC GOODS

Applied multisectoral trade models increasingly rely on social-accounting matrices (SAMs) as their basic information structure.[5] Since the data source of the interindustry component of U.S. SAMs is the input–output table of the U.S. Bureau of Economic Analysis (BEA), our estimates of Armington elasticities are based on a set of 163 sectors that are directly conformable to BEA sectors.[6]

The estimation of Armington elasticities requires data on both import prices and real-valued imports. To generate these series, quarterly import data for the years 1980–1988 were extracted from U.S. Department of Commerce data tapes by seven-digit TSUSA item. These data then were concorded to the 163 sectors. Laspeyres price indices were computed for each sector as

$$P_M(t) = \sum_i \phi_i(P_i^m(t)/P_i^m(o)), \tag{3}$$

where ϕ_i is the base-period import share of TSUSA item i, $P_i^m(t)$ is the unit value of TSUSA item i in quarter t, and $P_i^m(0)$ is the unit value of TSUSA item i in the base period. The base period was chosen as the second quarter of 1987 for mining sectors and the second quarter of 1986 for manufacturing sectors. These import price indices were used to deflate imports to obtain real import series.

The Armington estimation also requires data on prices of the corresponding domestic goods and real values of domestic sales of domestic goods. Producer price indices (PPI) were used as a proxy for the prices of the domestic goods. These were obtained from U.S. Department of Labor data tapes on a four-digit SIC basis and were concorded to the 163 estimating sectors. In cases in which more than one producer price series concorded with a sector, the series were aggregated using domestic output weights (1986 for manufacturing, 1987 for mining). Domestic output for these base periods was obtained from U.S. Department of Commerce data tapes for manufacturing sectors and the Census of Mining for mining sectors. The PPI are

[5]The U.S. International Trade Commission, for example, has constructed a highly disaggregated SAM to calibrate a computable general equilibrium model for trade policy analysis. See Reinert and Roland-Holst (1992).

[6]A table detailing the concordance between the 163 estimating sectors and the corresponding BEA and SIC sectors is available from the authors.

monthly data, and an average of the PPI over the 3 months of each quarter was used.

The core data for the development of a domestic output series are the Federal Reserve Bank's Indices of Industrial Production (IIP).[7] The IIP classification was concorded to the 163 sectors. In cases in which more than one IIP concorded with a sector, the series were aggregated using IIP series weights. The IIP series are monthly, and a 3-month average was taken as the quarterly value.

The IIP data provide series for domestic production. However, to estimate the Armington functions, we require data on domestic sales of domestic goods, that is, domestic production less exports. To do this, we first rescaled the IIP series so that they express domestic production as a proportion of the base-year average quarterly production. Again, the base years are 1987 for mining and 1986 for manufacturing. Next, we applied base-year output to these series to generate series of real output. Finally, we subtracted real export series to obtain series of real domestic sales. To generate the real export series, quarterly export data for the years 1980–1988 were extracted from U.S. Department of Commerce data tapes by seven-digit Schedule B item. These data then were concorded to the 163 estimating sectors. In order to deflate the exports, Laspeyres price indices were computed in a manner equivalent to Equation 3.

4. EMPIRICAL ESTIMATES OF ARMINGTON ELASTICITIES

To estimate the CES elasticities of substitution between imports and domestic goods, we take a logarithmic form of the first-order conditions of Equation 2 above, that is,

$$\log[M/D] = \sigma \log[\beta/(1 - \beta)] + \sigma \log[p_D/p_M] \tag{4}$$

and supplement this with quarterly dummy variables (d_i) to specify the estimating equation

$$y = b_0 + b_1 x + b_2 d_2 + b_3 d_3 + b_4 d_4, \tag{5}$$

where $x = \log(p_D/p_M)$ and $b_1 = \sigma$ is the Armington elasticity.

We compared this relatively parsimonious model with more complex specifications, including trends, lagged dependent variables, and gamma-distributed lag models, and found that Equation 5 performed

[7]These indices are described in Board of Governors of the Federal Reserve System (1986) and in Hosley and Kennedy (1985).

best. Shiells (1985) in particular has proposed a model with both distributed lag adjustments and simultaneous equations to determine domestic supply and demand.[8] While it might be of independent interest to elucidate the dynamic adjustment process, elaborate lag specifications did not improve our estimates, which in any case are intended primarily for use in comparative static simulation work. It also may be of independent interest to study empirical linkages between domestic supply, demand, and import behavior, but for this purpose we encourage reliance upon a fully specified CGE simulation rather than a two-equation, partial equilibrium specification.

Equation 5 was estimated with ordinary least squares and an iterative Cochrane–Orcutt scheme to correct for autocorrelation. The results are summarized in Table 1. Of the 163 sectors estimated, 104 had positive Armington estimates that were significant at the 5 percent level. In addition to these, 14 had significant residual serial correlation, 15 had insufficient data, and the remainder of the estimated coefficients were insignificant. The residually autocorrelated sectors are indicated with an asterisk next to their respective Durbin–Watson statistics in Table 1, and the sectors with insufficient data, as well as those with negative coefficients, are omitted from the table.

5. CONCLUDING REMARKS

This article matched the Armington specification of substitution between imports and domestic goods with U.S. trade data to obtain econometric estimates of the Armington elasticities for 163 mining and manufacturing sectors. In about two-thirds of the cases, positive and statistically significant estimates were obtained. Individually, or in weighted aggregations, these estimates can be used to sharpen the behavioral specification of applied trade models.

Our general results indicate that substitution possibilities between U.S. domestic goods and importables are indeed limited, with significant elasticities ranging between a low of 0.14 and a high of 3.49. This implies, among other things, that commodities at this level of aggregation are far from perfect substitutes, and there is ample scope for price differences and distortions without complete specialization in trade. Imperfect substitutability calls into question a variety of effective protection and welfare measures that impose the law of one price on domestic and imported commodities.

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[8]See also Shiells, Stern, and Deardorff (1986).

Table 1: Estimated Armington Elasticities

Sect	Elast	t	R^2	DW	DOF	Description
1	1.22	1.63	.64	1.93	10	Iron and ferroalloy ores mining
4	0.16	0.23	.21	2.12	30	Coal mining
5	0.31	2.30*	.50	2.13	24	Crude petroleum and natural gas
6	0.97	17.84*	.96	1.83	10	Stone, sand, and gravel
8	1.13	1.78	.40	1.87	10	Chemical and fertilizer mineral mining
9	1.68	3.30*	.28	1.06*	30	Meat packing plants and prepared meats
11	1.00	33.92*	.99	2.23	12	Creamery butter
12	1.99	6.74*	.88	1.80	30	Cheese, natural and processed
15	0.67	3.10*	.79	1.75	18	Fluid milk
17	1.16	2.84*	.32	2.32	30	Flour and other grain mill products
18	0.35	8.04*	.70	1.19	30	Cereals and flour
19	1.88	7.90*	.90	1.30	6	Dog, cat, and other pet food
20	1.26	6.24*	.56	1.29	30	Prepared feeds, n.e.c.
21	0.59	1.67	.56	1.41	8	Wet corn milling
22	1.11	7.68*	.76	1.51	28	Bread, cake, cookies, and crackers
24	0.13	6.57*	.56	1.29	30	Chocolate and other confectionary products
25	0.02	0.80	.72	2.22	30	Malt and malt beverages
26	3.49	6.95*	.75	2.08	14	Wine, brandy, and brandy spirits
27	0.15	8.46*	.86	2.76	30	Distilled liquor, except brandy
28	1.49	4.75*	.65	0.95*	24	Soft drinks, flavorings, and syrups
29	0.93	2.82*	.40	2.51	30	Vegetable oil mills
30	0.06	0.14	.05	2.77	30	Animal and marine fats and oils
32	1.85	4.12*	.45	2.70	22	Shortening and cooking oils
33	0.27	5.16*	.47	1.74	30	Sea foods, ice, and pasta
34	0.69	1.52	.45	1.97	26	Cigarettes
35	0.15	3.28*	.57	2.23	30	Cigars
36	0.99	6.21*	.54	1.62	30	Tobacco
37	0.54	3.96*	.54	1.89	30	Yarn, thread, and broadwoven fabric mills
38	0.82	7.41*	.88	1.22	12	Narrow fabric mills
39	1.21	2.55*	.77	1.32	8	Floor coverings
40	0.57	1.91	.44	1.43	6	Felt, lace, and other textile goods
41	2.53	9.80*	.75	1.12*	30	Hosiery
43	0.45	3.55*	.38	1.80	30	Apparel made from purchased materials
44	2.18	3.74*	.74	1.19	6	House furnishings, textile bags, canvas
45	0.64	2.60*	.55	1.47	22	Logging camps and logging contractors
46	0.58	0.64	.13	2.92	26	Sawmills
47	1.73	8.53*	.84	0.83	12	Hardwood dimension and flooring mills
48	0.06	2.10*	.22	2.01	30	Millwork, wood kitchens and cabinets
50	1.02	20.13*	.96	2.14	30	Wood pallets, skids, and containers
52	0.49	9.92*	.77	1.45	30	Wood preserving and particleboard
53	0.05	0.91	.15	1.71	30	Household furniture
56	0.97	16.60*	.86	2.65	30	Paper mills, except building papers
57	1.50	6.92*	.62	1.50	30	Paperboard mills
59	1.42	8.19*	.68	2.27	30	Sanitary paper products
60	0.97	1.00	.39	1.30	6	Building paper and board mills

(Table 1 continues)

Table 1: Estimated Armington Elasticities

Sect	Elast	*t*	R^2	*DW*	DOF	Description
61	1.68	10.15*	.84	1.43	18	Paper coating and glazing
62	1.48	4.57*	.64	3.44	10	Paperboard containers and boxes
63	0.98	9.26*	.80	3.00	30	Newspapers
64	1.00	43.12*	.79	1.19	30	Periodicals, books, and greeting cards
65	0.80	11.48*	.85	1.98	20	Printing
66	0.48	4.17*	.50	1.39	18	Industrial inorganic and organic chemicals
67	0.31	3.62*	.43	1.39	30	Agricultural chemicals
68	0.96	18.73*	.94	0.86	8	Chemical preparations
69	1.71	11.55*	.82	1.36	30	Plastics materials and resins
70	0.87	4.47*	.52	2.81	30	Synthetic rubber
71	0.66	2.31*	.29	2.17	30	Organic fibers
72	1.09	6.49*	.91	2.50	10	Drugs
73	0.58	1.44	.35	1.77	10	Soap, detergents, and sanitation goods
76	0.40	1.53	.88	1.15	10	Paving mixtures, blocks, asphalt felts
77	0.02	0.34	.27	1.66	30	Tires and inner tubes
78	0.29	4.32*	.56	2.42	26	Rubber and plastics footwear
79	0.01	0.14	.68	2.39	22	Other rubber products
80	1.46	1.71*	.10	0.94*	30	Miscellaneous plastics products
81	1.07	1.89*	.31	2.90	30	Leather tanning and finishing
83	1.27	14.85*	.98	1.68	10	Other leather goods
84	0.36	11.95*	.80	1.14*	30	Glass and glass products, except containers
85	0.23	1.13	.06	0.76*	30	Glass containers
86	1.09	12.73*	.86	0.67*	30	Cement, hydraulic
87	1.04	28.48*	.97	1.89	30	Brick and structural clay tile
88	0.88	24.13*	.46	2.12	30	Ceramic wall and floor tile
90	0.84	8.94*	.74	1.03*	30	Ceramic plumbing and electrical supplies
91	1.45	7.38*	.77	2.12	30	China and earthenware products
93	0.82	16.13*	.88	2.13	30	Stone and nonmetalic mineral products
94	0.76	7.75*	.87	1.71	10	Primary steel
95	3.08	4.06*	.70	2.35	10	Iron and steel foundries
96	0.69	2.17*	.53	1.08	8	Metal heat treating and primary metal
97	0.91	0.98	.12	1.46	28	Primary copper
103	0.16	1.30	.29	2.68	20	Other nonferrous rolling, drawing, insulating
106	1.03	2.76*	.57	1.16	16	Metal barrels, drums and pails
107	0.45	1.47	.45	1.71	10	Metal plumbing fixtures, heating equipment
108	0.74	6.26*	.75	0.91*	30	Fabricated metal work
109	1.07	2.34*	.25	1.57	29	Fabricated plate work (boiler shops)
110	0.22	2.34*	.63	1.86	10	Screw machine products and bolts, etc.
111	1.17	23.65*	.98	1.79	10	Forgings and stampings
112	0.20	0.48	.53	2.23	14	Cutlery
113	0.22	8.87*	.71	1.77	30	Hand tools
115	0.24	2.75*	.22	0.75*	30	Other fabricated metal products
116	0.30	1.25	.29	2.10	30	Pipe, valves, and pipe fittings
117	0.99	21.77*	.96	2.37	20	Turbines and turbine generator sets
118	0.30	17.75*	.91	2.04	30	Internal combustion engines, n.e.c.

(Table 1 continues)

Table 1: Estimated Armington Elasticities

Sect	Elast	t	R^2	DW	DOF	Description
119	1.06	11.08*	.96	1.52	10	Farm and garden machinery and equipment
120	0.97	7.60*	.65	1.42	30	Construction, mining, oil field machinery
121	0.94	10.79*	.79	2.37	30	Elevators, conveyors, cranes
122	0.79	8.01*	.91	2.17	8	Machine tools and power driven hand tools
123	0.69	7.05*	.53	0.91*	30	Special industry machinery
124	0.26	2.77*	.39	2.72	24	Pumps, compressors, blowers, fans, furnaces
125	0.83	10.89*	.86	1.02*	30	Ball and roller bearings, transmiss. equip.
127	0.85	5.60*	.49	1.07*	30	Electrical computing equipment
128	1.22	9.67*	.90	1.84	10	Service industry machines
129	0.20	2.13*	16	2.23	30	Transformers, switchgear and switchboard
130	0.72	3.30*	.58	1.28	8	Electrical industrial apparatus
131	2.69	2.60*	.18	2.10	30	Household cooking equipment
132	1.13	5.91*	.64	1.45	30	Household refrigerator and freezers
133	1.01	19.66*	.93	2.08	30	Household laundry equipment
134	1.97	11.77*	.86	1.75	18	Electric housewares and fans
135	1.99	3.92*	.72	1.13	4	Household vacuum cleaners
136	0.09	1.12	.30	2.16	30	Sewing machines, household appliances
137	0.82	3.59*	.67	2.63	10	Electric lamps, lighting, wiring devices
138	1.41	3.52*	.63	1.33	10	Radio, TV, phonograph records and tapes
139	0.63	4.18*	.75	0.47	6	Telephone and telegraph apparatus
140	1.42	16.54*	.97	1.47	6	Radio and TV communication equipment
141	0.62	9.80*	.75	2.48	30	Electron tubes
143	2.65	11.60*	.92	1.82	10	Storage batteries
144	0.36	5.99*	.59	1.47	26	Electrical equipment and supplies
145	1.16	12.02*	.92	1.39	10	Motor vehicles parts and accessories
146	0.76	3.30*	.68	1.09	6	Aircraft
147	0.62	3.24*	.55	1.60	8	Aircraft and missile equipment, n.e.c.
149	0.30	2.47*	.26	1.64	22	Boat building and repairing
150	0.92	5.07*	.67	0.98	12	Railroad equipment
151	1.73	6.30*	.91	1.98	10	Motorcycles, bicycles, and parts
153	0.65	2.31*	.93	1.17	8	Transportation equipment, n.e.c.
155	0.89	1.64	.45	1.65	5	Ordnance and accessories
157	0.89	22.52*	.98	1.95	6	Engineering, scientific, optical equipment
158	1.05	18.18*	.96	1.48	10	Measuring devices, environmental controls
159	0.66	2.61*	.86	0.65	10	Surgical, medical, and dental equipment
160	0.28	2.26*	.43	2.80	16	Watches, clocks, and ophthalmic goods
162	0.14	4.13*	.40	1.14*	30	Jewelry, musical instruments, toys

Note: Elast is estimated Armington elasticity of substitution. t is the t statistic; an asterisk next to this number indicates the estimated elasticity is statistically significant at the 5 percent level. R^2 is the R-squared value. DW is the Durbin-Watson statistic; an asterisk next to the latter value indicates significant residual serial correlation. DOF is the degrees of freedom for the estimation.

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