Explaining Armington: what determines substitutability between home and foreign goods?

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Abstract. For decades trade economists have modelled imperfect substitution between home and foreign goods in consumption (often called the Armington assumption) with little analysis of what explains the wide variation in these substitution elasticities across sectors. Using a varying coefficients model, we estimate Armington elasticities between U.S. domestic and foreign goods across over 100 industrial sectors from 1980–88 and examine the role of product, industry, political, and 'home bias' factors as determinants. We find strong support that the presence of foreign-owned affiliates affects Armington elasticities in important ways, and some support that entry barriers and union presence have an effect. JEL Classification: F23, D12

Expliquer Armington: qu'est-ce qui détermine le degré de substituabilité entre les biens locaux et étrangers? Au cours des dernières décennies, les spécialistes du commerce international ont construit des modèles de consommation où les biens locaux et étrangers sont imparfaitement substituables (le postulat d'Armington) mais n'ont pas beaucoup analysé les facteurs qui expliquent la grande variation de ces élasticités de substitution d'un secteur à l'autre. A l'aide d'un modèle de coefficients variants, les auteurs établissent les élasticités d'Armington entre biens locaux américains et produits en provenance de l'étranger pour plus de 100 secteurs industriels au cours de la période 1980–88. Ils examinent des déterminants possibles de la taille de ces élasticités: la nature du produit et de l'industrie, certains facteurs politiques et la 'préférence pour les produits locaux.' Il appert que la présence de filiales d'entreprises étrangères affecte de manière importante la taille des élasticités d'Armington, et que la présence de barrières à l'entrée et de syndicats a un certain effet.

1. Introduction

The Armington assumption that home and foreign goods are differentiated purely

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because of their origin of production has been a workhorse of empirical studies in trade. It has routinely been used in both econometric and simulation models to model import demands and to assess the effects of various trade policy options. In a recent study, Trefler (1995) used an Armington assumption to account for home bias. He found that the Armington assumption helps to explain why trade across countries is so much lower than that predicted by traditional trade theory. That the Armington assumption helps to explain what Trefler calls 'the case of missing trade' opens up a number of questions concerning the determinants of consumer preferences that lead to lower trade volumes. Specifically, the degree of substitution between home and import goods may be due purely to economic reasons, such as product and industry characteristics, or it may be due, at least in part, to political variables and strategies that may strengthen home bias and increase the perceived product differentiation between home and foreign goods (e.g., 'buy American' campaigns). In this paper, we provide the first analysis of differences in Armington elasticities by examining the role of product, industry, and political characteristics in explaining the degree of substitutability in consumption between U.S. and foreign goods across 3-digit SIC industries.

A number of recent studies have estimated Armington elasticities at a fairly disaggregated level (e.g., Shiells, Stern, and Deardorff 1986, Reinert and Roland-Holst 1992; Shiells and Reinert 1993). These studies find significant differences in Armington elasticities across industries, but they do not explore the reasons for these differences.[1] We use similar data in our study to estimate Armington elasticities with a varying coefficients model, where we specify the Armington elasticities as a function of explanatory variables that differ across industrial sectors.

We are able to explain a significant amount of the variation in Armington elasticities across industries and find a number of factors that are important in explaining these cross-industry differences. First and foremost, we find that multinational corporations (MNCs) play an important role. Everything else equal, a higher degree of foreign ownership in the industry's industrial customers (i.e., the sectors downstream of the industry) leads to a greater elasticity of substitution between the home and the foreign good. This accords with our hypothesis that MNCs may be more open than domestic firms to foreign sources of intermediate inputs. This greater 'openness' may stem from simple informational advantages by MNCs (i.e., better knowledge of potential foreign sources of inputs). Thus, globalization of production may be blurring the distinction between home and foreign goods.

However, there is an important caveat attached to this result. When the presence of foreign-owned affiliates in the downstream industries is accompanied by high import ratios downstream, we find a significant negative effect on the degree of substitutability between the domestic and the foreign good. This suggests that an *import* bias, not a home bias, may be prevalent in some industries, that is, a bias by transplanted foreign firms for imported inputs from their own countries. This is

1 Stone (1979) found substantial differences in own price elasticities of demand across industries as well.

consistent with Swenson (1997), who finds that Japanese transplanted automakers are much less willing to substitute between U.S. and imported inputs.

We also find the presence of significant entry barriers in an industry lower the Armington elasticity of substitution between the home and the foreign good. Entry barriers limit competition and may discourage product differentiation, leading to lower elasticities of substitution. One politically oriented variable we investigate may affect substitutability as well: union presence in an industry. Unions represent organized political power that may be better able to influence (e.g., 'buy American' campaigns) domestic consumers to favour home goods, and their presence in an industry leads to statistically lower substitution elasticities between the home and the foreign good in some of our empirical specifications.

2. What determines substitution between home and foreign goods?

At a conceptual level, Armington models typically specify a constant elasticity of substitution (CES) utility function over the home and the import good with an associated consumer optimization problem. From this optimization problem a simple equation can be derived that relates relative market shares of domestic and foreign goods to the associated relative prices through an elasticity of substitution. In our case, we seek to explain the differences in these elasticities of substitution between the home and import good across industrial sectors. There are two general reasons to expect differing Armington elasticities of substitution across different sectors. First, the parameters of the underlying utility function in each sector may be different owing to differences in physical or perceived product differentiation. Second, there may be differences in the constraint facing consumers in different industrial sectors that may affect the degree of substitutability (e.g., protection). In the remainder of this section, we describe some of these possibilities in greater detail as a precursor to specifying an empirical framework that allows some of these effects to be observed and estimated.

In general, the elasticity of substitution between two goods depends on the degree of product differentiation – consumers see goods as imperfect substitutes when there are obvious physical product differences. The greater are the differences, the lower is the elasticity of substitution between the products. However, product differentiation does not turn on actual physical differences between goods alone. Physical identical goods may be differentiated by availability in time, convenience of purchase, after-sales service bundled with the good, or even consumers' perceptions of inherent unobservable quality. In fact, consumers' perceptions of inherent quality have been shown to be rather strong in some instances, even when they are shown that they cannot distinguish between the two products when using them. For example, many people state strong preferences between Pepsi and Coke, even though these same people have trouble identifying their favourite brand in blind taste tests.[2] These factors not related to physical characteristics may play a par-

2 This textbook example is offered by Carlton and Perloff (1994, 283). They also suggest over-the-counter aspirin as a similar example, where even placebos do almost as well as any aspirin brand in human experiments.

ticularly strong role in product differentiation, and hence elasticity of substitution, between domestic and foreign goods.

In particular, a number of studies of international trade flows have found evidence that consumers may have a strong preference bias for the home good over the foreign good that, given the discussion above, increases product differentiation between the goods. Trefler (1995) carries out a detailed analysis of how and why the Heckscher-Ohlin-Vanek (HOV) theorem performs so poorly in predicting trade flows. After showing that trade flows between countries are generally at much smaller levels than predicted by the HOV theorem, he modifies the HOV theory to account for a home bias (à la the Armington assumption of differences between home and foreign goods purely because of origin of location) which is parameterized and estimated. Along with accounting for neutral technology differences between countries, Trefler finds that modelling an Armington home bias is statistically and economically significant in explaining trade flows between countries.

This preference for home goods does not seem to be an artefact of the HOV trade model – gravity trade models have shown similar effects as well. For example, McCallum (1995) uses a traditional gravity trade model to analyse trade flows between U.S. states and Canadian provinces. Despite fairly similar culture, language, and institutions between these two countries, McCallum finds a surprisingly large 'border' effect. Everything else equal, McCallum finds that province-to-province trade is over twenty times larger than trade between provinces and states, and this large border effect holds up under a variety of sensitivity tests. Helliwell (1996) largely confirms McCallum's results using similar data even when focusing specifically on Quebec. Wei (1996) uses a gravity trade model and finds home bias in trade flows among OECD countries from 1982–94.[3]

As Trefler (1995) points out, the home bias may be due not necessarily to consumers' 'primitive' preferences (similar to the Pepsi versus Coke example mentioned above), but to other economic factors that make consumers prefer the home good in general. Trefler performs a secondary regression of his estimated Armington home bias coefficients on tariffs and transport costs. While his analysis yields the expected direct relationship between the home bias and transport costs and tariffs, the low number of observations gives Trefler noisy estimates that are not statistically significant. The papers using gravity trade models find home bias despite controlling for transport costs through a distance variable.

However, there are a number of other economic factors that may be contributing besides tariffs and transport costs. As mentioned above, a number of factors, such as purchasing convenience, after-sales service, and external signals of unobservable quality, may affect the degree of product differentiation. The presence of these factors means greater product differentiation (reflected in the elasticity of substitution),

3 Wei (1996) looks at the degree to which countries import from themselves (defined as total production minus exports) versus imports from foreign countries. Although Wei's estimates of home bias among OECD countries is an order of magnitude smaller than the McCallum results, Wei finds that an average OECD country imports two and a half times more from itself than from an otherwise identical foreign country.

and if the domestic good systematically has an advantage over the import good in these factors, then there will be a greater degree of home bias (reflected in relative levels of the goods). One example is information and transactions cost differences associated with different suppliers. Purchase of imports necessarily brings additional transactions costs and risks from (1) customs paperwork to (2) exchange rate risk to (3) the possibility of protection and disruption of supplies to (4) delayed shipments because of extensive transportation to (5) possibly fewer resources for after-sales service on the part of the foreign supplier. These factors differentiate otherwise identical goods, as well as create a systematic home bias, because the domestic industry has advantages in these areas.

Location of foreign firms in a host market may affect these sources of 'home bias' in a number of dimensions and affect substitution patterns. A large literature has examined MNC activity and the effect on trade patterns.[4] There has been relatively less analysis, however, with respect to how product differentiation and substitution patterns between the home and import good are affected by location of foreign firms in a host country. With respect to product differentiation, consider the case where the domestic industry comprises only transplanted foreign firms. Is there a domestic 'good' in this context? Obviously, MNCs may blur the distinction between import and domestic goods and lead to lower product differentiation. With respect to substitution patterns, MNCs may have distinct effects in a sector as well. Location of some operations in the importing country by foreign firms may significantly reduce transactions costs of import purchases (such as the ability to get adequate after-sales service) and also increase the elasticity of substitution. For example, Yamawaki (1991) shows that location of distributional operations by Japanese MNCs in the United States had a significant positive impact on their exports to the United States. Finally, transplanted foreign firms may have strong preferences for imported inputs from their parent country that would affect substitution patterns. Safarian (1966), Graham and Krugman (1995), Zeile (1995), and Swenson (1997) find evidence for greater imported inputs by foreign affiliates than by comparable domestic firms for a number of different data samples involving foreign affiliates in the United States and Canada. These effects could create an import bias and lower elasticities of substitution.

In summary, while there may be a role for primitive consumer preferences, there are also a number of possible systematic factors that determine both home bias effects and the degree of imperfect substitution between the home and the foreign good. These economic factors affecting substitution patterns most likely differ substantially across industrial sectors. Thus, we use this cross-sectional variation to help us to identify the most important determinants of Armington elasticities.

4 In the theoretical literature, papers such as Helpman (1984, 1985) and Markusen (1984, 1995) have examined the relationship between the MNCs and trade patterns, while Lipsey and Weiss (1981, 1984), Grubert and Mutti (1991), and Head and Ries (1997) are examples of papers in which these relationships are empirically examined.

3. Estimation procedure

To examine the potential sources of differences in elasticities of substitution across industries, we first estimate elasticities of substitution between the home and foreign good for over 100 industries using a simple Armington model specification. We then examine explanations for variations in these Armington elasticities in a second-stage regression. The Armington model assumes that products are differentiated solely by origin of the good. Thus, following Armington (1969) and much of the ensuing literature, we assume that consumer utility for goods in an industry are separable from consumption of other products and postulate a simple CES subutility function to model demand for a home and import good in that industry:

$$U(M, D) = [\beta M^{(\sigma-1)/\sigma} + (1-\beta)D^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}, \tag{1}$$

where $U(.)$ is subutility over the home and foreign good, M is the quantity of the import good, D is the quantity of the domestic good, β is a parameter that weights the import good relative to the home good, and σ is the constant elasticity of substitution between the domestic and the imported good. From this, the first-order condition is

$$\frac{M}{D} = \left[\left(\frac{\beta}{1-\beta}\right)\frac{P_D}{P_M}\right]^{\sigma}, \tag{2}$$

where P_D and P_M are the price of the domestic and the imported good, respectively. Taking logs yields the familiar model typically estimated:

$$\ln\left[\frac{M}{D}\right] = \sigma \ln\left[\frac{\beta}{1-\beta}\right] + \sigma \ln\left[\frac{P_D}{P_M}\right]. \tag{3}$$

To the extent that the home and import goods are not perfect substitutes, σ will take some finite value, so that a lower estimated σ means less substitution between the two goods. The greater the degree of product differentiation, then the smaller the elasticity of substitution between the products.

As a first step in our testing strategy, we follow Reinert and Roland-Holst (1992) and use quarterly data from 1980–88 to estimate separate Armington elasticities for 151 different U.S. industrial sectors using the following equation based on (3) above:

$$\ln\left[\frac{M}{D}\right] = \alpha + \sigma \ln\left[\frac{P_D}{P_M}\right] + \beta_1 d_2 + \beta_2 d_3 + \beta_3 d_4 + \epsilon, \tag{4}$$

where α is an intercept coefficient; d_2, d_3, and d_4 are dummy variables for quarters 2, 3, and 4; and ϵ is a normally distributed error term. In the preceding section we argued that the variation in these elasticities across sectors is potentially explainable. Thus, we next extend Reinert and Roland-Holst's analysis by modelling the variation of the Armington elasticity (σ) across these separate regressions as a linear function of a set of regressors, X_i:

$$\sigma_i = X_i\gamma. \tag{5}$$

Thus, our second step in the estimation is to regress the estimated Armington elasticities on appropriate explanatory variables. Because our second-stage dependent variable is estimated in the first stage, we have an estimate of the variance of each dependent variable, which leads to a heteroscedasticity problem (i.e., the disturbance variance is not constant across observations) in the second stage and yields inefficient estimates of the γ parameter vector. Thus, following Saxonhouse (1976) we correct for this heteroscedasticity by weighting all second-stage variables by the inverse of the estimated standard error of the dependent variable for each observation.[5]

4. First-stage estimation: Armington elasticities

We estimate equation (4) for each sector using ordinary least squares with an iterative Cochrane-Orcutt procedure to correct for autocorrelation. The data come from Reinert and Roland-Holst (1992), who constructed the data set for sectors that are directly conformable to U.S. Bureau of Economic Analysis (BEA) sectors and are roughly at the 3-digit SIC level. Import data are taken from U.S. Department of Commerce tapes, concorded to the sectors and deflated into real terms using constructed Laspeyres import price indices. These price indices are also used for the import price data. The domestic price series is taken from U.S. Department of Labor producer price indices and concorded to the 151 sectors. Finally, quarterly domestic output series were constructed from the Federal Reserve Bank's Indices of Industrial Production.[6]

Our estimates of Armington elasticities by sector are listed in an appendix available from the authors. A number of the sectors had too many missing values for estimation and, in a few cases, we estimated significant negative values for the Armington coefficient. Taking these sectors out leaves 146 sectors, of which 110 had estimates that were positive and statistically significant at the 5 per cent level or better.[7] Table 1 gives summary statistics for the estimated Armington elasticities. The average elasticity is 0.81 with standard deviation across the 146 observations of 0.63. Thus, there is a great deal of variation in the estimated elasticities across our sectors.

5 We note that, while we have argued that sources of home bias may affect substitution patterns, the parameter β in equation (1) reflects home bias as well to the extent that $(1-\beta)$ is the relative weight placed on the home good in the subutility function. After our analysis of the determinants of the Armington elasticities, we will turn briefly to an analysis of factors determining the relative weight on the home good in section 7 of the paper.

6 For more detail on construction of the variables, see Reinert and Roland-Holst (1992, 633–4).

7 Our results in the second stage are qualitatively identical when all Armington elasticities are included, but estimation is slightly less precise as one would expect.

TABLE 1
Summary statistics of estimated Armington elasticities

	Histogram	
	Range	Number
Number of observations = 146	Less than 0	14
Average = 0.81	0–0.5	25
Standard deviation = 0.63	0.5–1.0	58
Minimum = −0.96	1.0–1.5	35
Maximum = 3.52	1.5–2.0	10
	Above 2.0	4

5. Second-stage estimation: Explaining Armington elasticities

The second step in our estimation is to regress the Armington elasticities on explanatory variables as in equation (5) and correct for heteroscedasticity as described above. Our choice of regressors for the auxiliary regression explaining differences in Armington coefficients across industries falls into three general categories: (1) variables that should reflect actual product differentiation; (2) variables that capture integration of foreign firms in the U.S. market; and (3) both political and economic variables that potentially capture home bias effects. Table 2 lists descriptive statistics of the regressors explained below.

We attempt to control for differences in actual product differentiation across industries in a couple of ways. First, we postulate that the greater the level of imported goods that come from a developing country, the more does product differentiation exist between the U.S. domestic good and the import good. Linder (1961) first suggested that countries with similar per capita income levels may trade more with each other, ceteris paribus, since their consumers have similar tastes, and thus the type of goods produced by each country better matches the tastes of the other country. Linder uses this logic to argue why more trade occurs between industrialized countries and Francois and Kaplan (1996) provide recent empirical evidence that is consistent with the Linder hypothesis. In our context here, the Linder hypothesis suggests that, for an industrialized country such as the United States, import goods from developing countries may be much more different from the domestic goods in a sector than would be true for imports from similar industrialized countries. Thus, we include the ratio of a sector's imports that come from developing countries as an explanatory variable and expect a negative coefficient. Of note, this variable may also capture home bias effects, which could strengthen this negative coefficient. U.S. consumers may use country of origin as a signal of quality with respect to the actual product, after sales service, or consistency of supplies. Our prior is that even if the home good was identical in physical features to the import good, U.S. consumers may be more likely to perceive differences if the import is from a developing country as opposed to an industrialized country.

TABLE 2
Descriptive statistics of auxiliary regression explanatory variables

Variable	Mean	Standard deviation	Minimum	Maximum
1. Ratio of industry imports from developing countries	0.32	0.25	0	1.00
2. Ratio of industry shipments for final counsumption	0.25	0.31	0	1.00
3. Ratio of industry owned by foreign parent	0.12	0.13	0	0.67
4. Ratio of downstream inputs that are imported × (1 − Variable 2)	0.08	0.08	0	0.50
5. Ratio of domestic downstream industrial users owned by foreign parents × (1 − Variable 2)	0.06	0.05	0	0.22
6. Downstream importers × downstream foreign owned	0.0073	0.0091	0	0.047
7. Median firm size	9.47	34.93	0.14	282.37
8. Dummy variable for whether industry subject to protection or protectionist threat	0.45	0.49	0	1.00
9. Ratio of union workers in industry	0.50	0.15	0.09	0.87

We include a second variable to control potentially for product differentiation: the ratio of a sector's goods that are for final consumption. Products are demanded by two major groups of consumers – households for final consumption and downstream industries as intermediate inputs. To the extent that product differentiation is systematically more common for one group than the other, there should be an explainable difference in the elasticities of substitution. Like the ratio of imports from developing country variable, home bias could also determine the coefficient for this variable. If the bias for home goods is systematically larger for one group as opposed to the other, then the ratio of industry shipments that go for final consumption will have explanatory power for differences in Armington coefficients. Thus, we have no strong prior on the expected sign.

As discussed in section 2, the presence of MNCs may have a significant impact on consumption and substitution patterns between the home and the import good. The percentage of domestic firms owned by foreign parents *within* the industry varies significantly across our sectors. A higher presence of foreign firms in the sector may decrease certain factors that lead to home bias, suggesting a higher Armington elasticity. Specifically, production in the home country by foreign firms is most likely correlated with these foreign firms' setting up better distribution networks in the home country for both their home country production and exports to the home country. More efficient distribution of the import good makes it easier for the consumer to substitute to these products. Finally, the presence of foreign firms in the industry also may lower information costs for domestic consumers and increase substitution between domestic and foreign goods. For all these reasons we expect a greater foreign presence in the sector to increase substitutability between the home and the foreign good.

The percentage of an industry's domestic downstream industrial users that are owned by foreign parents varies significantly across our sectors as well. Presumably, a firm with a foreign parent would be more open to sourcing from foreign sources, and there should be less of a home bias in their purchasing patterns. Thus, we construct a ratio of consumers that are downstream industrial users owned by foreign parents and expect it to have a positive coefficient.

We also have data on the overall importing behaviour of industrial sectors that use a sector's output as intermediate inputs (i.e., the downstream industrial users). This may provide information on how 'open' a sector's downstream industrial consumers are to imports, and thus how willing a sector's industrial consumers are to substituting between domestic and imported inputs. Thus, we create a variable to capture this for each sector by calculating the average percentage of imported inputs by the industrial consumers downstream to the sector times how much of the sector's output goes to these industrial users (as opposed to households for final consumption). The higher this indicator of import behaviour by downstream industries, the greater the Armington elasticity we expect for the sector.

The presence of foreign-owned affiliates in the downstream sector is also potentially important for this issue. Downstream industries may see a relatively large import ratio because of heavy sourcing by foreign-owned affiliates from their home country. Graham and Krugman (1995) find that imports per worker by foreign-owned affiliates in the United States is almost twice that of U.S. MNCs, while Swenson (1997) finds that foreign-owned automobile manufacturers in the United States source one-third of their inputs from abroad, compared with only 10 per cent by U.S.-owned producers in 1993. Safarian (1966) goes one step further by providing evidence that the sourcing from abroad by foreign-owned affiliates is primarily from the MNC's home country.[8] This suggests that there may be a 'foreign' bias, in that the foreign-owned affiliates are sourcing from abroad because they are unwilling to substitute from the more familiar foreign sources to inputs in the United States. This behaviour would tend to lessen the substitutability we observe between the home and the import good. To control for this possibility we interact the import ratio of downstream industries with the ratio of foreign-owned affiliates and expect a negative coefficient.

Finally, we include political-economic variables that may affect home bias and explain cross-industry differences in the Armington elasticities. First, one simple economic explanation for low levels of substitution may be high entry barriers for exporters. To control for this effect, we include median firm size in the industry, since larger median firm size suggests larger entry barriers and, thus, fewer alternatives for substitution possibilities. We expect a negative coefficient.

Second, some imports were subject to import investigations and/or protection during the time period of our data. To the extent that the protection is in the form of a tariff, it is not clear that substitution patterns should be affected, though market shares

8 Safarian (1966) finds that 42 per cent of U.S.-owned affiliates in Canada 'acquired all of their imports from the United States and another 32 per cent took 70 per cent or more of their imports from that source' (151).

should change through resulting price changes. Antidumping and countervailing duty (AD/CVD) protection, however, has a number of features that may make it less desirable to use the protected foreign good independent of price changes, that is, create a greater likelihood of home bias. Specifically, domestic importers, not the foreign firms, are liable for AD and CVD duties. This is problematic because there is a great deal of uncertainty in the determination of these duties. The AD duty rate paid by the importer at the time of import is not necessarily the ultimate duty the importer must pay, because the U.S. Department of Commerce often conducts administrative reviews of these duties from previous periods, re-estimates the duty, and collects further duties if a larger duty is found for the period of study. The result of this is that domestic importers may become quite unwilling to import products with AD/CVD duties, owing to the almost open future liability. Likewise, quotas may make supplies of the import good less certain and increase the home bias. Thus, we include a dummy variable for AD/CVD or quota protection in an industry and expect it should result in a lower Armington elasticity.

A final variable we include is the domestic union presence in the industry. Domestic unions have an interest in consumers' buying domestic products rather than imports. At the same time, they also have the ability to organize politically to encourage consumers to buy domestic products. For example, a look at the United Auto Workers (UAW) union in the early 1980s demonstrates a number of ways that the union tried to affect consumption patterns of U.S. consumers. Such activities by the UAW during this time period include (1) supporting domestic content legislation, (2) supporting legislation giving tax benefits to consumers who purchase U.S.-made automobiles, (3) picketing foreign dealers to tell consumers to 'buy American,' and (4) using resources to develop advertising jingles informing consumers that U.S. cars are built 'better'.[9] For these reasons we expect a stronger union presence in the industry to correlate with a lower Armington coefficient.

The results from the second-stage regression are shown in the first column of table 3. The adjusted R-squared is 0.32 and an F-test rejects the null that the coefficients are jointly zero at the 99 per cent confidence level, suggesting that there are systematic differences in the elasticity of substitution across industrial sectors that can be explained by our model. All variables have the expected sign, except for the ratio of downstream inputs that are imported, and a number of variables are statistically significant at standard confidence levels. A larger percentage of industry imports from a developing country correlates with lower Armington elasticities. This may not be surprising, since the United States is an industrialized nation and its mix of products may therefore be quite different from that of developing countries. This is an interpretation in the spirit of Linder (1961), in the sense that the goods countries produce and trade are determined in part by the country's own income level. However, the negative coefficient may also reflect a larger home bias when imports are from developing countries.

9 These examples of union behaviour were reported in the following *Wall Street Journal* articles: (1) domestic content: 16 September 1982, 37; (2) tax benefits: 6 May 1980, 1; (3) pickets: 1 March 1980, 1; (4) advertising jingles: 28 October 1980, 3.

TABLE 3
Weighted ordinary least squares results of Armington elasticities of substitution on explanatory variables.

Variables	Hyp. sign	OLS	'Best' OLS model	Shiells et al. model	AIDS model
Constant		1.240***	1.174***	−15.800***	−0.846
		(0.135)	(0.124)	(2.805)	(0.743)
1. Ratio of industry imports from developing countries	−	−0.279*	−0.154	10.667***	1.179
		(0.154)	(0.144)	(2.160)	(0.743)
2. Ratio of industry shipments for final consumption	?	0.023	−0.143	−5.295***	−0.622
		(0.143)	(0.140)	(2.539)	(0.800)
3. Ratio of industry owned by foreign parent	+	0.214	0.380	7.319	−2.652
		(0.250)	(0.241)	(5.830)	(1.791)
4. Ratio of domestic downstream industrial users owned by foreign parents* (1 − Variable 2)	+	3.600**	3.517**	47.875**	18.372**
		(1.485)	(1.486)	(22.686)	(7.765)
5. Ratio of downstream inputs that are imported* (1 − Variable 2)	+	−0.811	−0.545	84.637***	3.691
		(0.599)	(0.559)	(10.942)	(4.330)
6. Downstream importers* downstream foreign-owned	−	−28.863***	−32.966***	−711.98***	−98.446*
		(9.605)	(9.422)	(134.36)	(49.234)
7. Median firm size	−	−0.004***	−0.005***	−0.049***	0.006
		(0.001)	(0.001)	(0.012)	(0.004)
8. Dummy variable for whether industry subject to protection or threat of protection	−	−0.012	0.038	2.462**	−0.468
		(0.058)	(0.055)	(0.978)	(0.334)
9. Ratio of union workers in the industry	−	−0.664***	−0.612***	12.572***	2.486**
		(0.195)	(0.192)	(3.862)	(1.137)
Observations		146	140	136	142
Adjusted R^2		0.35	0.43	0.58	0.05
F-test		9.68***	12.80***	21.38***	1.87*

NOTES
Standard errors are in parentheses.
***, **, and * denote statistical confidence at the 99, 95 and 90 per cent levels, respectively.

Foreign presence in the downstream industry also has a large estimated positive correlation with the size of the Armington elasticity, as expected, while its interaction with importing behaviour in the downstream industry is negative. Our estimates show that the presence of multinationals in the U.S. economy may increase substitution patterns between the home and the foreign good at the means of the data. For example, a 10 percentage point increase in the ratio of foreign-owned affiliates in the downstream sector would lead to a 0.13 increase in the Armington coefficient. If the increase in foreign-owned affiliates is accompanied by a 10 percentage point increase in the ratio of imported inputs by the downstream industry, however, the Armington coefficient drops by 0.41. Thus, internationalization of production may increase trade levels, since the foreign-owned affiliates import inputs from abroad, while lowering the observed substitution between the domestic and import good.

These results accord well with the nature of foreign direct investment into the United States during the period of our data. Specifically, a substantial amount of foreign direct investment flowed into the United States during this period and thus represented relatively new production presence by foreign-owned affiliates. As discussed earlier, a number of authors have shown that new foreign-owned affiliates often source a substantial amount of inputs from abroad. For example, Swenson (1997) shows that Japanese automakers in the United States sourced a significant amount of their inputs from abroad during the period 1984–93. In addition, the elasticity of substitution between imported and domestic inputs was significantly lower for the Japanese transplant firms than for their U.S. domestic counterparts. Our results support the notion that Swenson's results can be generalized across all of U.S. manufacturing.

Variables that we expected to capture purely home bias effects performed fairly well. A larger median firm size in the industry means lower elasticities of substitution, ceteris paribus, which accords with our hypothesis that entry barriers should affect consumers' alternatives and abilities to substitute. Union presence in the industry also has a significant negative effect on the elasticity of substitution. This was expected, since unions represent political power and have resources to fund efforts to persuade consumers of the industry's products to purchase the home goods in favour of the foreign good. These efforts may strengthen consumers' perceived differences between the home and the foreign good and lead to lower Armington elasticities.

6. Alternative specifications

Our explanations for Armington elasticities depend on the accuracy of the elasticity estimates themselves, and there are a number of issues that the literature has stressed with respect to estimating elasticities of substitution. First, Deaton and Muellbauer (1980) find that not accounting for the time series properties of aggregate demand data seems to lead to rejection in the data of common utility maximization assumptions, such as homogeneity, in estimation of demand models. Thus, elasticity estimates may be biased by omission of time trends and possibly lagged dependent variables.

To explore this issue further, we ran a variety of specifications for each Armington elasticity estimate to take into account possible dynamic behaviour in the data, including first differences, a lagged dependent variable estimated via two-stage least squares, a linear time trend, a quadratic time trend, and various combinations of these specifications. We then examined the results from each sector individually and chose the 'best' estimates based on simple statistical criterion.[10] In all but four cases, at least one specification was found where the autoregression coefficient was either insignificant or the null could be rejected that its absolute value was one at

10 For example, time trends and lagged dependent variables were included if their t-statistic rejected the null hypothesis that their coefficient is zero at the 90 per cent confidence level or higher.

the 95 per cent confidence level. Our best estimates of the Armington elasticities and the specification used for each sector are reported in an appendix available from the authors. The simple correlation between the original Armington estimates and the 'best' estimates is 0.86, and, in general, the original estimates are quite robust to dynamic specifications for most sectors.

We next ran these 'best' estimates and their associated standard errors in our second-stage regression and report these results in column 3 of table 3. Qualitatively, the results are quite similar to our OLS results, and the evidence is that the fit of the second-stage regression is slightly better. All statistically significant coefficients discussed above are still significant with the exception of the ratio of industry imports from developing countries, which was only marginally significant before. Thus, our results are generally robust to accounting for potential dynamic demand behaviour.

A second concern is that authors of a number of studies, including Winters (1984), Shiells, Stern, and Deardorff (1986), Alston et al. (1990), and Davis and Kruse (1993), have pointed out that the simple Armington model assumes a number of restrictive assumptions on consumer utility maximization behaviour. First of all, the Armington model assumes that utility over the domestic and foreign good in each industry is weakly separable from total utility. This means that the marginal rate of substitution between the home and the foreign good is independent of consumption of goods in other industries. Second, the constant-elasticity-of-substitution (CES) functional form further assumes weak separability between the home and the foreign good within the subutility group. Finally, demands are assumed homothetic, which is seen in the fact that relative market shares are independent of total expenditures on the import and the domestic good (i.e., group expenditures are not an explanatory variable for relative market shares).

In response, we ran our first-stage regression using two alternative specifications of demand suggested by the literature, which allow for more flexible assumptions and yield estimates of elasticities of substitution between the home and foreign good. First, Shiells, Stern, and Deardorff (1986) derive from a general utility maximization problem a flexible loglinear model of import demand that depends on the log of both import and domestic prices, the log of total expenditures on both goods (i.e., their specification does not assume homotheticity), and a lagged dependent variable to control for partial adjustment. Thus, following Shiells et al., we test for each industry the following equation:

$$\ln M = \alpha + \beta_0 \ln P_M + \beta_1 \ln P_D + \beta_2 \ln E + \beta_3 \log M_{-1} + \epsilon, \qquad (6)$$

where E is total expenditures on both goods and the other variables are defined as above. We include quarterly dummies as before and also perform two-stage least squares to control for endogeneity of the prices, expenditures and the lagged dependent variable.[11]

11 As noted in Scheills, Stern, and Deardorff (1986). The elasticity of substitution in their model is derived as $\beta_1/\theta_H + \beta_2$, where θ_H is the domestic good budget share, which we take at the mean.

Second, we ran an almost ideal demand system (AIDS) specification for each industry,

$$w_M = \alpha + \beta_0 \ln P_M + \beta_1 \ln P_D + \beta_2 \ln (E/P) + \epsilon. \tag{7}$$

where w_M is the budget share of the import good in total expenditures and P is the price deflator for expenditures approximated by Stone's price index.[12] The AIDS model for each industry also includes a similar equation for the budget share of the domestic good, but because of the adding-up condition, estimation of both equations in a SUR system leads to a singular covariance matrix. Thus, following standard practice, we drop one equation (the domestic budget share equation) and estimate the import equation.[13]

In an appendix available from the authors, the estimates of substitution elasticities from the Shiells, Stern, and Deardorff (1986) model and the standard AIDS model are reported. The estimates are quite different from the traditional Armington estimates, with much higher means and variances in general, as well as a many more estimates that are significantly negative or likely outliers. These results seem to be consistent with the previous literature. Shiells et al. estimate elasticities of substitution for industries that are quite similar to those of Reinert and Roland-Holst (1992) and report estimates in which the average absolute value of the estimates is much higher in general. Shiells et al. use yearly data from 1962–1978, however, while Reinert and Roland-Holst use quarterly data from 1980–88. Our estimates, using the Reinert and Roland-Holst data with the Shiells et al. specification, show that the model specification is likely the driving factor behind the significant differences.

Our next step is to run the secondary regression to explain these new estimates of substitution elasticities from the Shiells et al. and AIDS models.[14] The last two columns of table 3 report these results. We first note that the regression using the Shiells et al. estimates seems to fit the data better than the AIDS model does,[15] so we place more confidence in these estimates. Despite the large differences between the alternative first-stage estimates and those of the simple Armington specification, the second-stage regressions show that there are quite similar systematic factors explaining the cross-sectional differences in elasticities of substitution. First, and

12 Stone's price index is $\ln P = \Sigma_{k=1}^{n} w_k \ln P_k$, where $k = M, D$.

13 The elasticity of substitution in the AIDS model when a Stone price index is used can be expressed (using our notation) as $1 + \beta_1/(w_M * w_D)$, where w_M and w_D are the import and the domestic budget shares, respectively, taken at their means. See Chalfant, Gray, and White (1991) for details.

14 For these models we could not get expenditure data for non-manufacturing sectors 1–8. Additionally, we eliminated elasticity estimates greater than 50 and less than −50 as outliers. This left 136 and 142 separate industry estimates for the Shiells et al. and AIDS models, respectively. The Armington and AIDS model results were qualitatively robust to various formal and informal methods of eliminating outliers; the Shiells et al. estimates were less robust to these types of sensitivity tests.

15 While these models are obviously not directly comparable, we note that the adjusted R^2 for the Shiells et al. specification is 0.58 versus 0.05 for the AIDS model.

most obvious, variables 4, 5, and 6, which account for downstream foreign affiliates, downstream importing behaviour and their interaction, are estimated precisely and tell a similar story in terms of relative magnitude effects on the elasticity of substitution. In fact, in contrast to the OLS specification, variable 5 is now precisely estimated and its coefficient is the hypothesized sign. Thus, the effect of MNCs on the Armington elasticities seems quite robust. The other variable that is robust across the OLS and Shiells et al. specifications is firm size, indicating that entry barriers reduce the elasticity of substitution between home and foreign goods.

However, there are some differences. First, the Shiells, Stern, and Deardoff (1986) estimates find that sectors where a large share of goods are for final consumption have lower elasticities of substitution between the home and import good, whereas the OLS specifications showed no statistically significant relationship. Second, the Shiells et al. estimates find positive correlations between the Armington elasticities and the level of protection, union presence, and share of developing country imports in a sector. These results are not consistent with our hypotheses or the OLS estimates.

7. A closer look at home bias

In this paper we are primarily concerned with explaining variation in Armington elasticities across manufacturing sectors. As we have discussed, one motivation for doing this is the recent interest in home bias, and we have argued that bias of any sort (home or foreign) should lead to a lower elasticity of substitution between the home and the import good. It is clear from equation (3) and (4), however, that it is possible to estimate a home bias more directly, as it is reflected in the relative weight, β, consumers put on the import good. From estimation of (4), we can derive an estimate of home bias as

$$1 - \beta = \frac{1}{1 + \exp(\alpha/\sigma)}, \qquad (8)$$

where α is the estimated intercept in equation (4) and σ is the estimated Armington elasticity. We find that for 124 of the 151 sectors (82 per cent) $1 - \beta$ takes a value higher than 0.5, suggesting a higher relative weight on the home good. In fact, 100 of the sectors (66 per cent) take a value of 0.85 or higher. These results suggest a significant amount of home bias. Explaining how and why this home bias occurs across sectors, as we did for the Armington elasticity above, appears to be the logical next step. Because of the involved non-linearities in the parameters, however, it is difficult to calculate standard errors on these estimates of home bias.[16] Thus, the procedure we used to control for statistical concerns surrounding the generated dependent variable in the analysis of the Armington elasticity above is not applicable, since it requires a consistent estimate of the standard errors. A

16 One way of dealing with this would be to use bootstrap methods to estimate standard errors. However, the limited number of observations for each sector's estimates (thirty-six or less) makes this infeasible.

second concern is that we are not able to estimate a home bias parameter in other models of demand we considered above, as is true with the Armington elasticity. Thus, there is no room for sensitivity checks using specifications that are less restrictive than a CES functional form.

Despite these concerns, we run second-stage regressions of the estimated home bias on regressors we argued earlier may affect home bias and, hence, the Armington elasticity. Table 4 presents these results for three common specifications used when the form of heteroscedasticity is unknown. These specifications are (1) White's correction for heteroscedasticity; (2) a specification that assumes the heteroscedasticity takes the form Var $[\epsilon_i] = \sigma^2(\alpha'\mathbf{z}_i)^2$, where ϵ_i is the true disturbance on observation i and $\mathbf{z}_i$ is a set of independent variables that determine the heteroscedasticity; and (3) a specification where we assume Var $[\epsilon_i] = \sigma^2\exp(\alpha'\mathbf{z}_i)$. The coefficient estimates are generally of correct sign and quite uniform across specifications, but as expected, given the discussion above, there is a significant amount of imprecision, owing to not being able to model the exact heteroscedasticity present in the data. However, while the F-test for the White's correction fails to reject the null hypothesis that all coefficients are jointly insignificant, models 1 and 2, which assume a specific form of heteroscedasticity, perform much better. All three specifications identify three statistically important determinants of home bias. First, as hypothesized, home bias is larger in sectors with a greater share of imports from developing countries. This could stem from actual or perceived quality differences. Second, we find that home bias is lower for goods that are more likely destined for final consumption than as intermediate inputs. Finally, there is some evidence that the presence of foreign MNCs in the sector reduce home bias. This is consistent with our hypothesis that the presence of MNCs in the sector blurs the distinction between the home and the import good and corresponds to our results from analysing determinants of the Armington elasticities.

8. Conclusion

The main goal of this paper was to determine if there are systematic reasons why Armington elasticities of substitution between the domestic and import good vary across U.S. manufacturing industries. As we have argued, variations should be due not only to physical product differentiation, but to factors affecting home bias and the presence of foreign-owned affiliates in the focus sector and its downstream industrial consumers. Robust to a number of specifications for estimating the elasticity of substitution, we find strong support that the presence of foreign-owned affiliates affects substitution patterns between the domestic and the import good in important ways. In general, increased multinational presence in the downstream industries increases the elasticity of substitution unless importing behaviour in the downstream industries is unusually high as well, suggesting an import bias by foreign transplant firms. We also find some evidence that home bias variables, such as unions and entry barriers, may lower the Armington elasticity in our initial specifications, but these results are less robust to alternative estimates of the elasticity of substitution.

TABLE 4
Weighted ordinary least squares results of home bias estimates on explanatory variables

Variables	Hyp. sign	White's correction	Model 1	Model 2
Constant		0.763***	0.722***	0.712***
		(0.129)	(0.112)	(0.126)
1. Ratio of industry imports from developing countries	+	0.198*	0.272***	0.284***
		(0.101)	(0.065)	(0.078)
2. Ratio of industry shipments for final consumption	?	−0.214*	−0.240**	−0.284***
		(0.117)	(0.104)	(0.108)
3. Ratio of industry owned by foreign parent	−	−0.349	−0.430*	−0.463*
		(0.289)	(0.258)	(0.253)
4. Ratio of domestic downstream industrial users owned by foreign parents × (1 − Variable 2)	−	0.688	1.074	1.266
		(1.140)	(0.878)	(0.962)
5. Ratio of downstream inputs that are imported × (1 − Variable 2)	−	0.303	0.439	0.655
		(0.448)	(0.478)	(0.433)
6. Downstream importers × downstream foreign-owned	−	−4.611	−8.787	−11.131
		(7.458)	(6.574)	(6.963)
7. Median firm size	+	0.000	0.001	0.001
		(0.001)	(0.001)	(0.001)
8. Dummy variable for whether industry subject to pretection or threat of protection	+	0.027	0.007	0.005
		(0.052)	(0.043)	(0.045)
9. Ratio of union workers in the industry	+	−0.043	0.012	−0.002
		(0.171)	(0.139)	(0.151)
Observation		151	151	151
Adjusted R^2		0.01	0.17	0.10
F-test		1.18	4.43***	2.92***

NOTES
Standard errors are in parentheses.
* * *, **, and * denote statistical confidence at the 99, 95 and 90 per cent levels, respectively.
Model 1 corrects for heteroscedasticity, assumed to take the form $\text{Var}[\epsilon_i] = \sigma^2(\alpha'\mathbf{z}_i)^2$, where ϵ_i is the true disturbance on observation i and $\mathbf{z}_i$ is a set of independent variables that determine the heteroscedasticity, whereas model 2 corrects for heteroscedasticity, assumed to take the form $\text{Var}\,[\epsilon_i] = \sigma^2 \exp\,(\alpha'\mathbf{z}_i)$.

Data Appendix

Construction of the variables for the initial Armington elasticity estimates are described by Reinert and Roland-Holst (1992), as mentioned in the text. In this appendix we describe construction of the variables used to test differences in the Armington elasticity across industries. The *ratio of U.S. imports from developing countries* was constructed by first concording our sectors to Standard International Trade Classification (SITC) sectors and then using U.S. import statistics reported at the SITC level in United Nations Statistical Office, *Commodity Trade Statistics According to Standard International Trade Classification: 1984*, Statistical Papers, Series D, Vol. XXXIV, No. 1-3, New York: United Nations, 1985, to calculate the ratio for the appropriate sector. We used 1984 data, since this year was the midpoint for the data series used to estimate the Armington elasticities. We used 1987 U.S. benchmark input-output tables constructed by the U.S. Bureau of Economic Analysis (BEA), as documented by Ann M. Lawson and D.A. Teske, 'Benchmark input-output accounts for the U.S. economy, 1987,' *Survey of Current Business*, April 1994, 73–115, to construct the *ratio of industry shipments for final consumption*. While the authors report more aggregated data on the U.S. input-output relationships, we used the fully disaggregated 6-digit BEA sector input-output tables available from the BEA. The data we used comprise the more disaggregated analog of table 2.1 reported in the Lawson and Teske article. This variable (ratio of industry shipments for final consumption) is the ratio of industry shipments that went for final consumption divided by total shipments by the industry (including to other industrial sectors downstream as intermediate inputs). Because the sectors in our study are based on BEA sectors, constructing variables based on the BEA input-output tables was less difficult than would otherwise be the case. The *ratio of the sector owned by a foreign parent* was constructed from data in Ned G. Howenstein and William J. Zeile, 'Foreign Direct Investment in the United States: Establishment Data for 1987,' *Survey of Current Business*, October 1992, 44–78. In this article the percentage of U.S. domestic shipments attributable to U.S. affiliates of foreign parents at 4-digit Standard Industrial Classification (SIC) level are listed. We used a concordance constructed by Reinert and Roland-Holst (and available from the authors) that maps the paper's sectors into 4-digit SIC categories to construct this variable for our sectors. When more than one 4-digit SIC industry was mapped into our sector, we constructed an average of the variable weighted by shipments in each SIC industry. There were numerous instances when the percentage of shipments by foreign-owned affiliates was suppressed to avoid disclosing proprietary data. In all instances, however, the percentage of establishments in the industry owned by a foreign parent was listed and we used this to infer the percentage of shipments by foreign affiliates. Specifically, in these cases we went to the next level of aggregation (usually 3-digit SIC), where both the number of establishments and the shipment data were reported, and we assumed that the linear relationship between the percentage of foreign-owned shipments and the percentage of foreign-owned establishments existing at the 3-digit industry is valid for all the 4-digit industries covered by that 3-digit industry. This linear relationship then was used to derive the percentage of shipments by foreign-owned affiliates given only the percentage of foreign-owned establishments in that industry. The *ratio of downstream inputs that are imported* was constructed by first calculating the percentage of imported intermediate inputs for all sectors using the BEA input-output tables. Then, to create the variable, for each sector i we took the average of these import percentages for all sectors downstream to sector i weighted by the input-output coefficient (i.e., weighted by how large a purchaser the downstream sector is relative to the other downstream sectors). Because this variable applies only to the sector's downstream users and each sector varies in how much of its consumption is by downstream industrial users versus final consumption, we multiplied the weighted average ratio of downstream imported inputs by the (1

– ratio of the sector's shipments that goes to industrial downstream consumers). The *ratio of downstream industrial users owned by foreign parents* was created similarly to the ratio of imported downstream inputs. First, we already calculated the ratio of foreign ownership for all sectors as described above. We then took the average of these ratios for all sector *i*'s downstream industrial users (weighted by the input-output coefficient) and multiplied by (1 – the ratio of industry shipments for final consumption). *Firm size* is median firm assets in millions from Dun and Bradstreet Credit Services, *Industry Norms and Key Business Ratios, 1984/85*, New York: Dun and Bradstreet, 1984. These are often reported at the 4-digit SIC level, which were mapped into our sectors. The *protection variables* were derived by the authors using various issues of the U.S. International Trade Commission (USITC) publication, *The Year in Trade*, corresponding to the years of our Armington elasticity estimation, 1980–88. This USITC publication gives annual comprehensive listings of current U.S. protection, ongoing protectionist investigations, and their outcomes. Finally, the *ratio of union workers in an industry* is the percentage of unionized production workers reported in table 2 of Richard B. Freeman and James L. Medoff, 'New estimates of private sector unionism in the United States,' *Industrial and Labor Relations Review* 32(2), 143–74, 1979. As Freeman and Medoff explain, these estimates were derived from the 1973, 1974, and 1975 May Current Population Surveys.

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