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A DISCUSSION ON ARMINGTON TRADE SUBSTITUTION ELASTICITIES

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A Discussion on Armington Trade Substitution Elasticities

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Abstract:
Applied partial and general equilibrium models used to examine trade policy are almost universally sensitive to trade elasticities. Indeed, the Armington elasticity, the degree of substitution between domestic and imported goods, is a key behavioral parameter that drives the quantitative, and sometimes the qualitative, results that policymakers use. While standard transparent approaches to econometric estimation of these elasticities have been offered for the last 30 years, the estimates are viewed as too small by many trade economists. A few robust findings emerge from the econometric literature: (1) more disaggregate analyses find higher elasticities, (2) long-run estimates are higher than short-run estimates, and (3) time series analyses generally find lower elasticities relative to cross-sectional studies. We offer simulation results to illustrate the sensitivity of general equilibrium models to Armington elasticites. We conclude with remarks on the current challenges that remain in determining these important parameters.

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I. Introduction

Using economic models to evaluate changes in trade policy generally requires the conversion of policy changes into price effects. Model analyses use these price shifts to determine how policy is expected to affect output, employment, trade flows, economic welfare, and other variables of interest. The direction and magnitude of a trade policy change on individual variables depends on the size of the shock as well as the behavioral relationships present in the economy. When evaluating policy shifts within an economic model, these behavioral relationships largely take the form of elasticities reflecting the responsiveness of one set of variables to a change in a second set. For example, trade policy changes the effective price of traded goods relative to domestically produced goods. As a result, a key relationship for model analysis is the degree of substitution between imported and domestic goods. This key relationship is commonly identified as the Armington elasticity.[1]

In general, knowledge of elasticities is important for policy considerations. Changes in tariffs and taxes will affect a country's trade opportunities, level of income, and employment. The size of these impacts will largely depend on the magnitude of elasticities. The Armington elasticity is an essential component of trade policy analysis. Partial and general equilibrium models that rely on the Armington structure are universally sensitive to these elasticities. Indeed, a modeler's central Armington choice will drive key quantitative, and sometimes qualitative, results that policymakers use.

In the following section we review literature estimates of Armington elasticities. We point out some of the key differences and robust findings in these studies. In section III we

[1]The constant elasticity of substitution (CES) specification for the trade substitution elasticity is derived from Armington (1969).

exemplify the importance of the elasticity estimates by offering results from a stylized policy analysis. We make concluding remarks in section IV.

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II. Econometric Estimates

Comprehensive industry-level estimates of Armington elasticities have appeared intermittently over the last few decades. The five main studies available for U.S. imports include Stern, Francis, and Schumacher (1976), Shiells, Stern, and Deardorff (1986), Reinert and Roland-Holst (1992), and Shiells and Reinert (1993), and most recently, Gallaway, McDaniel and Rivera (2000). These studies employ standard, transparent approaches to Armington estimation. Many trade economists, however, view these elasticity estimates with skepticism and believe that domestic and imported goods are much more substitutable than the estimates suggest. We highlight specification and identification issues with these single equation techniques.

One of the first systematic studies to provide import-demand elasticities for the U.S. was carried out by Stern, Francis, and Schumacher (1976). This study offers "best estimates" of U.S. import-demand elasticities for 28 industries at the 3-digit ISIC level. Interestingly, rubber products, wearing apparel, metal products excluding machinery and transport equipment were among the sectors found to be "extremely import sensitive," while food, beverages, textiles, tobacco, machinery including electrical machinery, and iron and steel were classified as "moderately import sensitive." The wood and paper products industries were considered "import inelastic."

Shiells, Stern, and Deardorff (1986) estimated trade substitution elasticities using a simple stock-adjustment model with annual data from 1962-1978 for 163 disaggregated industries. The authors obtained statistically significant Armington elasticities for 122 of 163 sectors estimated. Their estimates compared adequately with previous estimates from Stern et al. (1976).

Reinert and Shiells (1993) disaggregated U.S. imports into those from the NAFTA members and those from the rest of the world (ROW). Using quarterly data over 1980-1988, they obtained estimates for 128 mining and manufacturing sectors. Elasticities were estimated using three specifications: (i) generalized least squares estimation technique, based on a Cobb-Douglas price aggregator; (ii) maximum likelihood estimation using a CES price aggregator; and, (iii) a simultaneous equation estimator that uses a Cobb Douglas price aggregator and employs a distributed lag model. Reinert and Shiells found the estimates to be relatively insensitive across the three alternative estimation procedures.

Reinert and Roland-Holst (1992) estimated Armington elasticities for 163 U.S. mining and manufacturing sectors. They obtained significant estimates for approximately two-thirds of the 3-digit SIC industries estimated using quarterly data from 1980-1988. Their statistically significant estimates range from 0.14 to 3.49

Gallaway, McDaniel and Rivera (2000) offer the most comprehensive, disaggregated, and up-to-date set of Armington elasticity estimates. The authors consider explicitly the long-run aspect that is applicable to applied partial and general equilibrium modeling. They provide estimates for 311 industries at the 4-digit SIC level over the period 1989 to 1995. Significant long-run estimates range from 0.53 to 4.83. Long-run estimates are up to five times as large as short-run estimates, and on average twice as large as the short-run estimates. This is important since long-run estimates are more appropriate for most trade policy analysis than short-run estimates. A comparison of the Gallaway, McDaniel and Rivera 4-digit estimates to Reinert's and Roland-Holst's 3-digit provides further insight to the well-known aggregation bias: the more detailed commodity level, the greater the ease of substitutability.

Hummels (1999) departs from the above literature. Using a multi-sector model of trade to isolate channels through which trade cost or resistance affects trade volume across countries or regions he is able to solve for the implied substitution elasticity. Assuming that all distance related trade resistance is a freight charge he computes a range for the substitution elasticity of 2 to 5.3. More compelling are Hummels' direct substitution elasticity estimates in a framework that includes a more general interpretation of trade resistance. His average estimates are 4.8, 5.6, and 6.9 for aggregation at the 1-digit, 2-digit, and 3-digit levels respectively.

The cross-sectional estimates presented by Hummels are much higher than the central values obtained in the time-series studies of U.S. data. The average of 6.9 reported by Hummels at the 3-digit level is well above the average long-run estimate of 1.6 reported by Gallaway, McDaniel and Rivera at the 4-digit level. The large divergence in these estimates indicates misspecification.

Although Riedel (1988) and Riedel and Athukorala (1994) do not directly estimate Armington elasticities, their estimations of Hong Kong's export demand elasticity have been cited as evidence that Armington elasticities are likely higher than the estimates reviewed above.[2] Riedel (1988) and Riedel and Athukorala (1994) argue that direct estimation of export demand for a small economy perform poorly because observed quantities are determined by price and supply conditions (export demand is perfectly elastic). They identified the system by inverting the demand function and considering the export supply function. Under this

[2] Specifically Harrison, Rutherford and Tarr (2001) make this argument. In their "low elasticities" case an Armington of 4 and a lower-level elasticity of substitution between imports from different regions of 8 is assumed. Although high this assumption is generally consistent the direct econometric estimates. In their central case,

specification they present compelling evidence that Hong Kong is a price-taker.[3] The indication is that the world market does not distinguish between Hong Kong goods and those of other countries and that the Armington elasticity is very high. This is important evidence that researchers need to consider when disaggregating small economies, because the optimal tariff is inversely related to the Armington elasticity.

One of the most useful aspects of econometric estimates is that they offer guidance on relative ease of substitutability *across sectors*. For example, in reviewing the econometric estimates reported in the papers mentioned above, plastic materials and resins, photographic equipment, paperboard boxes and malt beverages are sectors with some of the highest Armington estimates. On the other side, military weapons (ordnance), games and toys, nonrubber footwear, gray iron foundries, and cereal breakfast foods are sectors with some of the lowest Armington estimates (Gallaway, McDaniel, and Rivera, 2000).

What explains the wide variation in these substitution elasticities across sectors? In an attempt to explain such variation, Blonigen and Wilson (1999) find that increased multinational presence in the downstream industries increases the elasticity of substitution unless importing behavior in the downstream industries is unusually high as well. This finding suggests an import bias by foreign transplant firms. Their results also offer some evidence that home bias variables, such as, entry barriers and union presence, may lower the Armington elasticity.

The reviewed papers that offer econometric estimates are useful to modelers in that they provide a starting point for specifying key behavioral parameters. However, the lack of consensus on point estimates reflects the sensitivity of the estimation results to the technique

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however, they assume an Armington of 15 and a lower-level elasticity of 30. They contend that these higher elasticities are similar to the point estimates obtained by Riedel (1988).

employed. There are, however, a few robust findings. First, long-run estimates are much higher than short-run. Researchers using short-run estimates should be concerned about understating trade response. Second, the level of aggregation is important; the more disaggregate the sample the higher the estimated substitution elasticity. In light of this, it is important to question common practices in flexible aggregation models. These include: applying aggregate estimates to individual sectors that are the focus of study, and applying the average elasticity from disaggregate estimates to an aggregated commodity. We feel that it is important for modelers to consider these known biases and not to adopt econometric point estimates indiscriminately.

Finally, model misspecification is particularly problematic when estimated parameters are exogenous inputs to an entirely independent structural trade model. The specifications of Stern, Francis, and Schumacher (1976), Shiells, Stern, and Deardorff (1986), Reinert and Roland-Holst (1992), and Shiells and Reinert (1993), and Gallaway, McDaniel and Rivera (2000) all suffer from the general critique that they are structurally inconsistent with the general equilibrium because they do not consider the supply side of the market. The negative estimates commonly found in these studies may, at least in part, be attributed to model misspecification. Even the work by Hummels (1999), which is consistent with a general equilibrium, is not necessarily consistent with the structure of most applied computational models.[4] In sum, sensitivity to estimation technique and misspecification are reasons that prudence is in order when adopting estimates from the literature.

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[3] Riedel and Athukorala (1993) use similar methodology and show that Korea is a price-taker in the market for machinery.

[4] Large scale applied models often assume constant returns and perfect competition. Hummels (1999) motivates his empirical trade model with a richer general equilibrium theory that includes monopolistic competition.

III. The Sensitivity of Policy Analysis to Armington Estimates

To illustrate the importance of the Armington elasticity in applied general equilibrium models we compute examples in which the quantitative and qualitative results vary across assumed elasticities, which are within the range of the cited literature. The model is a direct extension of the widely available GTAPinGAMS system.[5] The multi-region social accounts are based on an aggregation of GTAP version 4, which uses 1997 as a base year. The accounts are projected onto a steady-state expansion from 1997 to 2050. The dynamic structure is one of neo-classical capital accumulation driven by exogenous population growth. Agents are assumed to be forward looking and accumulate capital to maximize intertemporal utility.[6]

For these illustrative experiments we simply use the steady-state equilibrium as the baseline.[7] The model is also greatly simplified by aggregating up to include only three goods (agricultural products, manufactured products, and services), and four regions (Columbia, NAFTA members, other Latin American countries, and the rest of the world).

We focus on Columbia to illustrate an important implication of the Armington trade structure. It is typical to find applied models with a regional aggregation that explicitly breaks out focus countries of interest but most of the rest of the world is captured in residual aggregates. An implication of this is that relatively small countries (Columbia in our example) are assigned a unique variety in the demand system of their trade partners. The Armington structure results in a great deal of market power, and relatively high optimal tariffs, even for small countries (each country is a monopoly suppliers of its variety).

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[5] The GTAPinGAMS system is maintained by Tom Rutherford, University of Colorado. Documentation is available in Rutherford and Paltsev (2000).

[6] We consider the dynamic equilibrium because we are interested in exploring the dependency of trade responses on capital flows. In the central case we assume perfect international intertemporal capital markets over the computed horizon (2005 to 2050). Lau, Pahlke,and Rutherford (1997) present a practical method for representing the neo-classical dynamic equilibrium for computation.

Using the simulation model we compute welfare for the representative Columbian agent under various levels of protection holding the response of the other regions constant. Figure 1 presents these results for a range of Armington elasticities. With low Armington elasticities, 1 or 3, (which are roughly consistent with the long-run time-series econometric estimates of Gallaway, McDaniel, and Rivera, 2000) unilateral liberalization from the benchmark rate of protection is harmful to Columbia. Adopting a higher estimate, 5, (roughly consistent with Hummels, 1999) indicates that marginal liberalization is beneficial to Columbia. Only when we adopt an elasticity of 8 is total liberalization superior to the benchmark, and even then the optimal for Columbia is at a rate of protection that is about 40% of the current level. In this example, both the qualitative and quantitative effects of liberalization are sensitive to our choice of elasticity.

[7] In actual policy analysis a more credible baseline might be considered that includes, at least, medium-run differential growth rates across countries.

Figure 1.

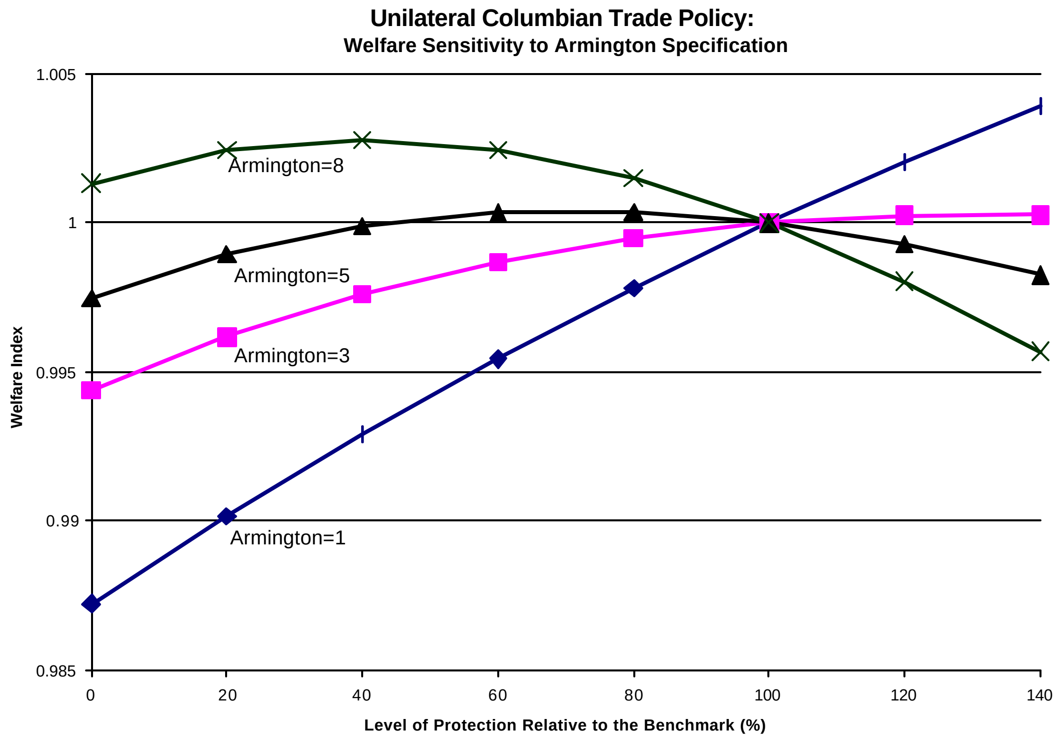
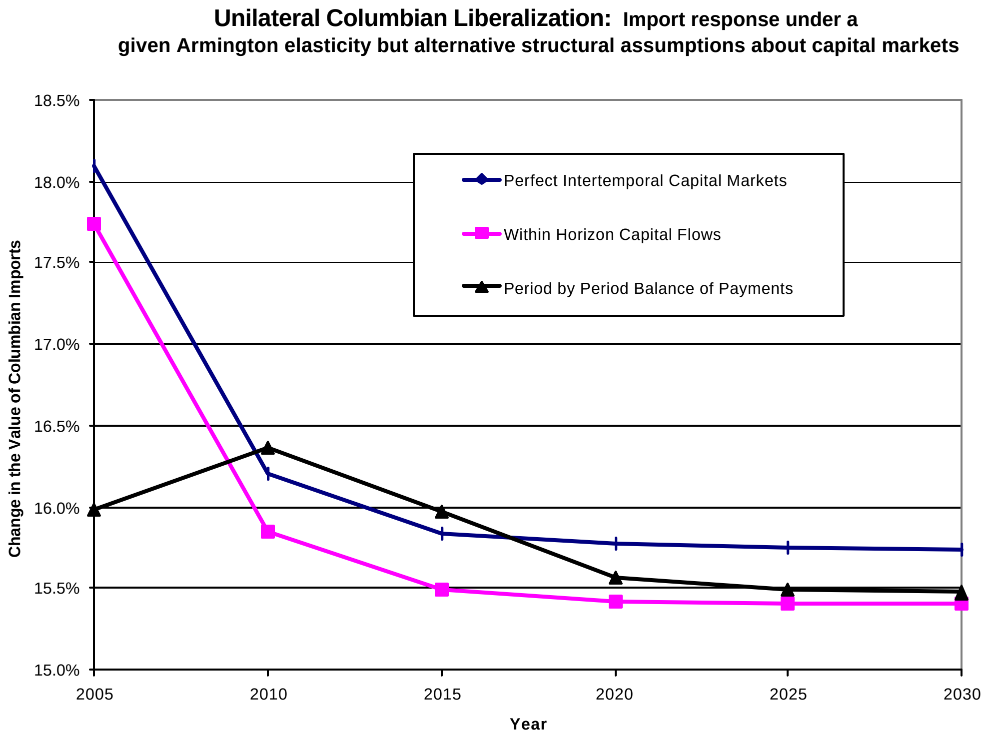


Figure 1 illustrates that the Armington parameter not only determines the sign and magnitude of liberalization, but that it also might be used to mitigate some of the undesirable features of the Armington structure. If we believe that Columbia, the country of focus, is generally a price taker on world markets, but the Armington structure is chosen for its tractability, then assuming a high elasticity compensates for the implicit market power granted when Columbia produces a unique variety. Obviously, a more satisfying solution would be to get rigorous proof that Columbia is truly a price taker (estimate the trade elasticities in an econometric model that includes the Columbian variety). Unfortunately, compromises and simplifying assumptions must be made in applied work. Given the infeasibility of a full structural estimation of the applied computational model, a researcher might identify the sensitivity and offer an argument for the chosen elasticities. The professional audience can then make an informed judgment about the validity of the results.

Another important point to recognize is that, although many simulation models adopt the Armington structure, other structural assumptions play an important roll in determining the trade response independent of the chosen elasticity value. For example, an important structural assumption in dynamic models is the extent that international capital markets are available. In general, changes in trade policy will generate incentives for countries to adjust their capital position to take advantage of the best rates of return.

To illustrate the impact of structural assumptions about capital flows on trade response, we again simulate liberalization by Columbia. The Armington elasticity is held fixed at 5 across scenarios, and we model a complete liberalization of tariffs. In the central case we make an assumption that within the model horizon there can be no change in net indebtedness. Within horizon international capital flows are unrestricted, but any net accumulations of debt have to be paid back before the terminal period (2050). In the most restrictive scenario we make an assumption that there is no change in Columbia's capital flows (period by period balance of payments). In the least restrictive case we approximate the infinite horizon solution with perfect capital markets. In this case net accumulated debt need only be serviced, but never retired. Figure 2 presents the effect of these alternative assumptions on the change in Columbian imports.

Figure 2.



When the model is simply closed by maintaining no change in net indebtedness the trade response is very similar to the perfect capital markets case. In the period-by-period balance of payments case, however, the initial response is significantly less. This is because, when capital markets are available, Columbia can borrow against future exports and take advantage of lower import prices in the short-run. All of the models converge to approximately the same response in the long run. So, although the Armington elasticity largely determines the ultimate response, the structure of international capital markets interacts with the Armington to determine the adjustment dynamics. We highlight this because dynamic models are gaining influence in policy arenas, and adjustment dynamics are often of central importance.

IV. Concluding Remarks

There is no question that measurement of Armington elasticities is of fundamental importance in determining the response of trade models to policy experiments. There is equally little doubt that measurement of these elasticities is very difficult. The estimates from the literature provide little guidance on the correct point estimate to apply to a given commodity in a given model for a given aggregation. Most of the controversy surrounding Armington elasticities reduces to a general structural inconsistency between the econometric models used to measure the response and the simulation models used to evaluate policy.

Three robust findings emerge from the econometric literature. First, long-run estimates of Armington elasticities greatly exceed short-run estimates. Second, aggregation matters and interacts with the Armington specification. Finally, single equation time-series approaches identify smaller responses relative to cross-sectional estimation that includes a consideration of supply conditions.

Given the sensitivity of econometric estimates many modelers turn to sensitivity analysis of simulation results, which is quite useful to economists but has had limited impact in policy arenas. Quantitative impacts from simulation models are often used in a way that is at odds with the notion of comparative welfare analysis that acknowledges simplifying assumptions and uncertainty over key parameter values. Policymakers often utilize single figures to support policy positions. Unfortunately, acknowledging the existence of second moments in policy forums may weaken the same argument that it strengthens in academic review.

The consumers of simulation results, thus, demand a definitive literature point estimate of key parameters to further their cause. However, all estimated parameters are conditional upon the structure under which they were estimated. Structurally different simulation models need to maintain the flexibility to adjust and reject estimated parameters that produce unrealistic responses. The responsibility, of course, falls on the researcher to define and identify a range of responses. Once sensitivity analysis reveals the problem, adjustments away from econometric estimates are warranted. Ironically, when dealing with models that do not maintain the same structure, rejection of econometric estimates might be necessary to produce simulation responses consistent with the data used to estimate the econometric model.

Structural inconsistency across simulation models is also important to consider when adopting a given set of elasticities. Obviously, the same parameter set will produce different responses across different models, and even across different aggregations of the same model. Thus, the adoption of parameter sets used in previous studies or standard models does not abdicate the researcher's responsibility to think carefully about and defend the estimates.

Structurally consistent estimation/calibration of computational models is an area of promising research. Following the lead of the real business cycle literature and a philosophical acceptance of calibration as a method of estimation (Dawkins, Srinivasan, and Whalley (2001)), there is a new direction in the literature that combines aspects of stochastic estimation in structural general equilibrium models (Liu, Arndt, and Hertel (2001), and Francois (2001)). These ideas are in their infancy, but appear encouraging in their useful approach to solve a very difficult measurement problem.

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