WHITHER ARMINGTON TRADE MODELS?

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ABSTRACT

The Armington trade model distinguishes commodities by country of origin and import demand is determined in a separable two-step procedure. This framework has been applied to numerous international agricultural markets with the objective of modeling import demand. In addition, computable general equilibrium (CGE) models commonly employ the Armington formulation in the trade linkage equations.

The purpose of this paper is to test the Armington assumptions of homotheticity and separability with data from the international cotton and wheat markets. Both parametric and nonparametric tests were performed and the empirical results reject the Armington assumptions. This has important implications for international trade modeling and CGE modeling.

Key Words: Armington, separability, homotheticity, nonparametric tests, wheat, and cotton.

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The responsiveness of import demand to international price changes is an important topic in applied international agricultural trade research. Elasticities of import demand are used commonly to estimate the effects of trade barriers and to examine trade policy options. There was renewed interest in the topic during the 1985 debate over the U.S. Food Security Act. In fact, the price responsiveness of import demand for U.S. agricultural sales became the single most important issue in the policy debate (Thompson, 1988). Ultimately, the U.S. government decided that the import demand for U.S. agricultural exports (such as cotton and wheat) was price responsive. Foreign import demand elasticities in excess of unity were then used to justify lowering U.S. loan rates (i.e., floor prices) as a means of attempting to regain market shares in the international markets (FAPRI; Myers).

Empirical estimates of import demand elasticities are predicated on the specification chosen for the trade model. A number of different model specifications have appeared in the literature and these are well documented in two separate surveys by Sarris (1981) and Thompson (1981). The Armington model is one specification which has been very popular. It is a disaggregate model which distinguishes commodities by country of origin with import demand being determined in a separable two-step procedure. The Armington approach permits the calculation of cross-price elasticities between imports from all sources using estimates of the aggregate price elasticity of demand for imports, a single elasticity of substitution and trade shares. The ease of use and flexibility are two reasons why the Armington model has been applied so often to international agricultural markets. Of course, another important reason is that the Armington model often gives results which are judged to be successful because of both plausible parameter estimates and statistical significance. The Armington approach has been applied to modeling agricultural trade by Abbott and Paarlberg; Babula; Figueroa and Webb; Grennes, Johnson and Thursby; Johnson, Grennes, and Thursby; Penson and Babula; Sarris (1983); and Suryana. In addition, it has been accepted as the appropriate way in which to model trade flows in a computable general equilibrium (GGE) model (de Melo and Robinson, 1981 and 1985) and has been used extensively in CGE models of international trade in agricultural products (e.g., Adelman and Robinson). The Armington model assumes that import demands are homothetic and separable among import sources. Thus, within a market, trade patterns change only with relative price changes and the elasticities of substitution between all pairs of products (e.g., between United States and Canadian wheat) are identical and constant. These are strong restrictions on demand. In this paper we test these restrictions using data from the international cotton and wheat markets.

Three approaches are used in our empirical work. All three approaches test restrictions on a country's system of import demand equations for a product (cotton or wheat) from different sources. The maintained hypothesis is that imports of the product from different countries comprise a weakly separable group so that we are considering restrictions on the second stage of a two-stage budgeting process.

First, nonparametric methods (from Varian 1982, 1983) are used to test (a) whether the data are consistent with a stable system of well-behaved import demand equations and (b) whether Armington restrictions hold. The appeal of this approach is that it provides a complete test of the hypothesis in question with no additional assumptions concerning functional form (Varian 1983, p. 100). The principal drawback is the unknown power of the tests and the possibility of false rejections due to measurement error (Varian 1985, Chalfant and Alston).

Second, the Armington model is estimated and tested as a nested model defined by a set of parametric restrictions on a double-log import demand model incorporating the complete set of relative prices. This provides a direct test of the Armington model but the drawback is that we are testing against an alternative that cannot be fully compatible with the adding-up restrictions from demand theory unless preferences are restricted to be homothetic (e. g., see Deaton and Muellbauer 1980b, pp. 17–18).

Our third approach follows Winters. The Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980a) is used to estimate the parameters of the import demand equations and Armington restrictions are tested parametrically. As with the nonparametric approach, this approach tests necessary conditions for Armington restrictions to hold in a model in which other theoretical restrictions (symmetry and adding up) can be imposed; it does not test the complete set of restrictions (including functional forms for demand) that make up the Armington model. This approach avoids the drawbacks of the nonparametric approach (unknown power) and that of the direct approach with the ad hoc double-log model. However, it does involve the imposition of the AIDS functional form to be tested as a joint hypothesis with the Armington restrictions. That is, it tests whether import demand equations are separable and homothetic under the maintained hypothesis that they are of the AIDS form.

The three approaches are complementary. The alternate methods yield different results on particular restrictions but we find that all three approaches comprehensively reject the Armington model. In every country each approach rejects the restrictions implied by the necessary conditions that the demand equations are both homothetic and separable. Thus, we conclude that the Armington trade model is inappropriate for cotton and wheat.

Two-Stage Theoretical Models

In general, a two-stage budgeting procedure assumes that consumers allocate their total expenditures in two stages (Deaton and Muellbauer, 1980b). In the first stage, total expenditure is allocated over broad groups of goods, while in the second stage group expenditures are allocated over individual commodities. It is well known that weak separability of the direct utility function over broad groups of goods is a necessary and sufficient condition for the second stage of a two-stage budgeting procedure. However, weak separability imposes restrictions on consumer behavior. First, the marginal rate of substitution between two goods from the same group is independent of the consumption of goods in other groups. Second, the substitution effects between goods in different groups are limited. A price change of a commodity in one group affects the demand for a commodity in another group only through the group income effect. Third, separability implies a restrictive relationship between price and income effects. More specifically,

$$S_{ij} = \mu_{GH} \frac{\partial qi}{\partial x} \cdot \frac{\partial q_j}{\partial x} \qquad (1)$$

where S_{ij} is the compensated cross-price affect, μ_{GH} is a constant depending on groups G and H, q_i and q_j are quantities of the i^{th} and j^{th} goods where i and j belong to different groups and x is total expenditure.

In the context of a trade allocation model, the two-stage budgeting procedure can be explained as follows. In the first stage an importer's total imports of a particular commodity can be expressed as:

$$M = M(Y, P, P_o, Z_1) \qquad (2)$$

where M is total imports of the commodity (e.g., cotton), Y is the importer's national income; P is an index of the import price of cotton, P_o is a vector of the prices of all other goods, and Z_1 is a vector of other explanatory variables.

In the second stage, total imports of the commodity are divided up amongst the various suppliers of the product to yield:

$$M_i = M_i(M, P_1,\ldots,P_n, Z_2), \quad i=1,\ldots,n \tag{3}$$

where M_i represents the imports of cotton from country i (i = 1,...,n), P_j represents the import price of cotton supplied by the jth export nation and Z_2 is a vector of other exogenous variables.

How does Armington's model relate to the above two-stage budgeting procedure? The first two stages of Armington's framework are, in general, equivalent to those described above. That is, in the first stage the importer decides how much of a particular commodity to import (equation (2)). In the second stage (equation (3)), given the total amount imported, the importer decides how much to import from each supplier. Thus, the implications of weak separability apply to the possible substitution effects among commodity groups. In addition, the Armington model uses a CES within-group specification. That is,

$$w_i = b_i^{\sigma}\left(\frac{P_i}{P}\right)^{(1-\sigma)} \tag{4}$$

where w_i is the market share of imports from source i, b_i is a constant, P_i is the price of the commodity from the i^{th} source, P is the import price index depending only on the within-group prices and σ is the constant elasticity of substitution parameter. The CES specification implies weak separability between different import sources.[1]

Further, as is clear in the CES specification of equation (4), the Armington approach assumes homotheticity of the sub-utility or within-group utility functions. This implies that an importer's market shares are independent of group expenditures. Consequently, all expenditure elasticities within a group are equal and unitary and import market shares change only in response to relative price changes. Thus, the Armington framework implies that in the second stage (within-group allocations) market shares do not vary with expenditures and that different import sources are separable. To test the Armington model, we focus on the properties of the second stage and test the implied restrictions of homotheticity and separability.[2]

Data

Wheat imports were analyzed for five importing nations: China, Brazil, Egypt, U.S.S.R. and Japan. These countries accounted for approximately 51 percent of world wheat imports in 1984/85. Annual data for prices and trade flows were obtained from the International Wheat Council, World Wheat Statistics. Prices were f.o.b. quotations, basis the exporting country. The number of observations for each of the importing regions varied based on the availability of data and import developments for that particular country. For Japan, the estimation period covered the years 1960/61-1984/85. Brazil imports wheat from three sources: Argentina, Canada and the United States. However, Brazil started importing wheat from Canada only in 1970/71 and therefore the estimation period for Brazil included the years 1970/71-1984/85. Egypt has three primary import sources: Australia, the EEC, and the United States. The data included the period 1971/72-1984/85. Imports of wheat by the Soviet Union varied dramatically over the years. The United States became a major source for the Soviets during the 1972/73 marketing year. Argentina, Australia and the EEC became major wheat exporters to the Soviet Union during the early 1980s. Canada has been the only major foreign source of wheat supply to the Soviet Union since the 1960s, although the quantity imported varied considerably from year to year. The data used for the U.S.S.R. included the period of 1972/73-1984/85. The same period of analysis was used for the People's Republic of China (PRC). Although Australia and Canada have been exporting wheat to the PRC since the 1960s, the United States did not export wheat to China until the early 1970s.

Cotton imports were analyzed for five leading importing nations: France, Italy, Japan, Taiwan and Hong Kong. In 1983/84 these five countries accounted for 37 percent of total cotton imports. Annual data for prices and trade flows were obtained from World Cotton Statistics published by the International Cotton Advisory Committee. Prices were c.i.f. Liverpool, England. As with wheat, the number of cotton observations varied for each importing region. For Italy, Hong Kong and France the time period studied was 1969/70 - 1983/84. Data for Japan and Taiwan were not available for 1983/84 and thus the equations were estimated using data from the 1969/70 - 1982/83 period.

Nonparametric Tests

The nonparametric approach to demand analysis uses the results of revealed preference analysis to derive algebraic conditions on demand functions (Varian 1983). We can use these conditions to test for the compatibility of data with the existence of a utility function that "rationalizes the data", to use Varian's terminology. We can also test for the compatibility of data with the existence of a utility function that is homothetic, separable, or both homothetic and separable (as is implied by the Armington model).

Varian spells out the relevant conditions succinctly. First, compatibility of the data with the existence of a utility function is necessary if we are to conduct demand analysis and the required condition is that the data satisfy the Generalized Axiom of

Revealed Preference (GARP). When this condition is not violated the data are consistent with having been generated by the maximization of a utility function by a representative consumer.[3] Second, for data sets that satisfy GARP we can proceed to test compatibility of the data with restrictions on the utility function.

Satisfaction of the Homothetic Axiom of Revealed Preference (HARP) implies the existence of a homothetic utility function that rationalizes the data. Thus, to test the Armington restriction of homotheticity, we check whether the data satisfy HARP. A necessary condition for (weak) separability of a subgroup (of a group of goods that satisfies GARP) is that the subgroup also satisfies GARP. This is only a necessary condition, the sufficient conditions require that the data satisfy both GARP and the Afriat inequalities (Varian, p. 105); however, Barnett and Choi (also see Belongia and Chalfant) suggest that the use of the sufficient condition biases the non-parametric test towards rejection of separability. Thus, a conservative approach (erring in favor of the Armington model) is to use only the necessary conditions. Finally, for data that satisfy separability we can test for "homothetic separability" which holds when demands for goods within a separable group are homothetic.

Varian has developed computer programs to test these conditions. Our testing procedure uses these programs as follows. First, we test each data set with GARP. Next, for data that satisfy GARP, we apply HARP to test for homotheticity, and we test for separability of each import source from the rest. Then, for any data set that satisfies all of these tests, the homothetic separability test is applied. Only sets of import data (prices and quantities by source) that satisfy all of these tests are completely compatible with the Armington assumptions.

The results of the nonparametric tests are summarized in Table 1. First, most of the data sets satisfy GARP. The exceptions were Brazil's wheat imports, Hong Kong's cotton imports, and Taiwan's cotton imports. Of course these violations might be due to measurement error. Following Chalfant and Alston, we checked to see how much of a measurement error would be needed to have caused the violations of GARP that we observed. In the case of Brazil's wheat, only a very small measurement error (about one percent of prices or quantities) in one year (1977/78) could have accounted for the violation. Similarly, a very small measurement error in 1983/84 may have caused the violation of GARP in the case of Hong Kong's cotton imports. In the case of Taiwan's cotton, larger measurement errors (say 5 percent in 1970/71 and in 1976/77) would be required to account for the violations. To conduct other nonparametric tests using these data sets that violated GARP we eliminated one observation from the Brazilian wheat data (1977/78) and the Hong Kong cotton data (1977/78) and two observations from the Taiwanese cotton data (1970/71 and 1976/77). With these observations eliminated, the remaining data satisfy GARP. This procedure is justified if we believe the violations were caused by measurement errors. An alternative procedure would be to experiment with adjustments to the data until GARP was satisfied. To the extent that they satisfy GARP we may treat imports as a separable group and proceed to test homotheticity and separability as within-group restrictions.[4]

(Table 1 about here)

The second test was for homotheticity. All ten of the data sets violated HARP at every observation. Thus, homotheticity is rejected for every system of import demand equations being studied.

Third, we tested for separability among import sources by excluding each source of imports in turn and testing whether the remaining sources make up a separable group by applying the necessary condition, GARP. In the case of China's wheat imports and Taiwan's cotton imports, separability was not rejected for any source country. However, for the other four wheat importers and the other four cotton importers separability was rejected for one or more of the source countries. For example, for France's cotton imports, the United States was not separable from the other sources although each of the other sources was separable from the group comprising the rest including the United States.

Finally, because all of the data violate HARP, the test for homothetic separability is redundant. None of the data satisfy the necessary conditions of the Armington model, homothetic separability.

Armington Estimates

Consider the following double-log specification of the "within-group" allocation of expenditures among n sources (i) of imports within a country:

$$\ln M_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln \frac{P_j}{P^*} + \beta_i \ln \frac{M}{P^*} \tag{5}$$

where M_i is the quantity imported from source i, P_j is the price of imports from source j, M is total expenditure on imports of the good from all sources, and P^* is Stone's (geometric) price index for imports of this good.

$$\ln P^* = \sum_{k=1}^{n} w_k \ln P_k \tag{6}$$

where w_k is the expenditure share of source k in total imports.[5]

This model is homogeneous of degree zero in all prices and total expenditure. However, it is not possible in general to impose the theoretical restrictions of symmetry and adding up (e.g. see Deaton and Muellbauer, 1980b). The Armington model of equation (4) is nested within this model under the restrictions that $\gamma_{ij} = 0 \ \forall \ j \neq i$ (i.e., weak separability means that only the own-price and group price are included), $\beta_i = 1 \; \forall \; i$ (demands are homothetic), and $\gamma_{ii} = \gamma_{jj} = -\sigma \; \forall \; i,j$ (i.e., equality of the own-price coefficients). Under these restrictions the system of demands does satisfy the theoretical restrictions of symmetry and adding up and $\gamma_{ii} = -\sigma$ is the elasticity of substitution for the system.

We estimated this model for the 10 cotton or wheat importers and tested the Armington restrictions of separability ($\gamma_{ij} = 0 \; \forall \; j \neq i$), homotheticity ($\beta_i = 1 \; \forall \; i$), and equality of own price coefficients ($\gamma_{ii} = \gamma_{jj} \; \forall \; i,j$). The estimates were obtained using iterative seemingly unrelated regressions (SUR) techniques and the parametric restrictions were tested using the likelihood ratio procedure for which the test statistic is:

$$2\,[\lambda_u - \lambda_r] \sim \chi^2(J) \qquad (7)$$

where λ_u is the log-likelihood for the unrestricted model and λ_r is the log-likelihood for the model with J parametric restrictions imposed.[6]

The results of these estimations and tests are summarized in Table 2. The Armington model does seem to fit the data reasonably well and the estimates are plausible with the exception of Egypt's wheat imports for which the elasticity of substitution is negative and significant.[7] Outcomes such as those in Table 2 help to explain the popularity of the Armington approach. However, the Armington restrictions are comprehensively rejected with the chi-square tests. While we could not reject homotheticity in four of the cases, separability, homothetic separability, and the Armington model were rejected in all ten cases. The full Armington restrictions were rejected in all ten cases when the models were corrected for first order autocorrelation as well as in the OLS estimation.

(Table 2 about here)

The drawback here is that we have rejected the Armington model in favor of a model that we cannot require to satisfy the theoretical restrictions that we would like to impose (and which the nonparametric tests indicate can be imposed) on the data. These restrictions can be imposed in the AIDS model and we can test separability and homotheticity restrictions subject to symmetry and adding up as maintained hypotheses.

AIDS Model Estimates

In an AIDS specification (Deaton and Muellbauer 1980a, 1980b) of import demand, the budget share of imports from source i is given by:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln(M/P), \quad i = 1,\ldots,n \tag{8}$$

where the log of the price deflator is

$$\ln P = \alpha_0 + \sum_k \alpha_k \ln p_k + \frac{1}{2} \sum_j \sum_k \gamma_{kj} \ln p_k \ln p_j , \tag{9}$$

M is total expenditure on imports and p_j are prices of imports from source j. Adding-up, homogeneity, and symmetry respectively require that

$$\sum_i \alpha_i = 1, \ \sum_i \gamma_{ij} = 0 \text{ and } \sum_i \beta_i = 0; \ \sum_j \gamma_{ij} = 0; \text{ and } \gamma_{ij} = \gamma_{ji}. \tag{10}$$

The aggregate price deflator in (9) can be approximated by Stone's index from equation (6).[8] Having made this substitution, the AIDS model can be seen to be identical to the double-log specification in equation (5) except that expenditure shares replace logarithms of quantities as the dependent variables.

The test for homotheticity in the AIDS import share equations is equivalent to testing that all the β_i are zero. This implies that the import shares are independent of the total import level (see equation (8)). To test for separability between import sources, we follow Winters and test whether the price from a particular import source contributes anything to the otherwise complete allocation model. This condition is a necessary consequence of separability. In general, one of the implications of separability over groups is that the within-group demand functions contain only prices of commodities within that group. Thus, for each import source we estimated an AIDS excluding it and then tested whether its price had any influence on the included import shares.[9]

The import demand models of equation (8) were estimated by iterative SUR techniques with symmetry and homogeneity restrictions imposed. Due to the adding-up condition, the contemporaneous covariance matrix is singular.. Thus, the standard procedure of arbitrarily deleting an equation was employed. The SUR estimators have the same asymptotic properties as maximum likelihood estimators. The estimates are invariant to the equation deleted (Barten). Since the primary focus of the paper is to examine the usefulness of the Armington model, only the tests of separability and homotheticity are reported.

In half of the cases analyzed imports are supplied by only three sources (wheat into Brazil, Egypt and Japan and cotton into Hong Kong and Taiwan). In these cases, when we exclude one source to test for separability, and then delete a further equation for estimation because of the singular residual covariance matrix, we are left with a single equation model to be estimated by OLS. The single equation for the expenditure share of imports from source k represents the demand for imports from two sources (k and j) as a function of their prices and total expenditure on imports from the two sources. To test for separability of a third source (i) we use a t-test on the coefficient of the logarithm of the price of imports from that source (δ_{ki}) in the share equation for source k. To test homotheticity in the reduced model (including only two of three sources) we use a t-test on the coefficient of the logarithm of real expenditures in the share equation of source k (β_k). To test the joint restriction of separability of source i and homotheticity within the reduced model ($\delta_{ki} = 0$ and $\beta_k = 0$) we use a standard F-test. In all cases we estimate a system of equations to obtain unrestricted estimates, and to test for homotheticity alone, using iterative SUR. In these multiple equation models we use likelihood ratio tests of the various parametric restrictions implied by homotheticity, separability, or homotheticity and separability. The test statistic is the χ^2 defined in equation (7).

In the interests of brevity not all of the test statistics are reported here. Instead, only the values for Japan are reported in detail and those for all other importers are tabulated and reported in summary form. All of the values for all countries are available from the authors. Japan was singled out because it is a major importer of both cotton and wheat. Tables 3 and 4 report the detailed Japanese test results for wheat and cotton, respectively. In every case, the first column of each table contains the import source which is being tested to determine whether it is separable from the other (included) import sources.

(Tables 3 and 4 about here)

First, consider the homotheticity constraint. Initially we test this restriction alone without any separability restrictions on sources of imports within the group. The last entry in the second column of Tables 3 and 4 reports the test statistic. For

Japan the restriction is rejected for both wheat and cotton in the full model including all sources. Consider Tables 5 and 6 which summarize results for all countries. In the last column of Table 5 (for wheat) it can be seen that homotheticity is rejected at the 5 percent level of significance in two countries (Japan and USSR) and is not rejected for the others (China, Brazil, and Egypt) when all sources are included. The homotheticity constraint in cotton (see Table 6) is not rejected in Taiwan and Italy but is rejected for the other three countries (Hong Kong, France and Japan). The other entries under "homotheticity" in Tables 3, 4, 5 and 6 refer to tests for homotheticity within a reduced model where one of the sources has been excluded to test for separability. This restriction is rejected in 2 of 3 cases for Japanese wheat imports (Table 3) and 1 of 3 cases for Japanese cotton imports (Table 4). Looking at all of the countries studied, the restriction is rejected in 12 of 18 cases for wheat (Table 5) and 5 of 20 cases for cotton (Table 6).

(Tables 5 and 6 about here)

With respect to separability over import sources, consider the third column in Tables 3 and 4. The coefficient, δ_{ki}, is the log price coefficient on the import source (i) being tested in the share equation for an included source (k). For each import source being tested the AIDS was estimated excluding it and then tested to determine whether its price had any influence on the remaining import shares. For Japanese wheat imports (Table 3), in all three cases, separability is not rejected. For wheat in total (Table 5) separability is rejected in 9 of 18 cases, in 4 of the 5 countries. Turning to cotton, separability was comprehensively rejected for Japanese imports (Table 4). As shown in Table 6, overall, separability was rejected in 16 of 20 cases, and at least once in each of the 5 countries.

Finally, in the last column of Tables 3 and 4, homotheticity and separability were tested jointly. The joint test is the critical test of the Armington assumptions. In every importing country these joint constraints were rejected at least once. In Tables 5 and 6 it is found that the joint constraints were rejected in 14 of 18 cases for wheat and in 17 of 20 cases for cotton.

Synthesis of Results

Table 7 summarizes the results from the three alternative approaches to testing Armington restrictions on import demand equations for cotton and wheat, A "+" indicates the restriction is not rejected while a "–" indicates the restriction is rejected. Homotheticity was rejected in 10 of 10 countries by the nonparametric method 6 of 10 countries in the double-log approach, and in 5 of 10 countries using the AIDS model, 21 of 30 times in total. Separability was rejected in 8 of 10 countries using the nonparametric approach, all 10 countries using the double-log model, and in 9 of 10 countries using the AIDS model. That is, the necessary conditions were rejected in 27 out of 30 cases. These necessary conditions are relatively weak restrictions compared to the Armington separability restrictions. In the nonparametric and AIDS tests we consider whether each source in turn is separable from the rest. The Armington model requires that all sources of imports are jointly separable. This restriction was rejected in all countries using the double-log model.

(Table 7 about here)

The joint test of homotheticity and separability is the critical test of the Armington model. On this criterion the results are quite unequivocal. With all three approaches and in each country the Armington restrictions were comprehensively rejected.

Implications

Armington model estimates are commonly used in counterfactual policy simulations. In such contexts, the acid test might not be whether the Armington restrictions are rejected by the data but, rather, whether the resulting elasticity estimates are significantly biased. That is, how important is the finding that Armington restrictions do not hold in terms of the practical problems for which the estimates are being made?

We can provide a partial answer to this question. In the context of the double-log model, the application of the Armington separability restriction when it is inappropriate amounts to omitting relevant explanatory variables. The omitted explanatory variables are prices of substitutes which are likely to be positively correlated with the own price variable that is included. When the omitted prices are prices of substitutes (positive cross-elasticities), the own-price parameter estimate will be positively biased so that the own-price elasticities will be underestimated (i.e. less negative).[10] This argument is relatively straightforward in the context of the double-log model about which we have already expressed our reservations. Intuitively, it would seem reasonable to extrapolate to other functional forms but that might not be appropriate. To illustrate the potential importance of these specification biases we computed own-price elasticities for imports of U.S. cotton in the five countries using the three models (Armington, double-log, and AIDS). The results are in Table 8.

[Table 8 about here]

The Armington estimates are mostly smaller than both the double-log and AIDS estimates. One exception is Italy's elasticity of demand for U.S. cotton where the double-log estimate is not statistically significant. With this one exception the Armington model estimates are less elastic than the double-log estimates. This result is consistent with our argument above about the consequences of omitting relevant explanatory variables. The other exception is Taiwan's imports of U.S. cotton where the Armington model resulted in a demand elasticity slightly more elastic than that from the AIDS — though both were much less elastic than the estimate from the double-log model. If we were to take the AIDS model as representing truth, we would say that the Armington model understates the true elasticities substantially (say 50 percent) in most cases. If the double-log estimates were correct, the biases are more important.

Conclusions

This paper tested the assumptions of the Armington trade model in the context of the international cotton and wheat markets. The Armington model is comprehensively rejected with data from the five leading importing countries for each good, using three alternative testing approaches. This leads us to conclude that the Armington restrictions should not be applied as a matter of course in the analysis of import demand for these goods. By analogy doubt is raised as to whether the Armington restrictions are appropriate for other goods and in other applications such as CGE modeling. At a minimum, where possible, commodity trade data should be tested for consistency with the restrictions, perhaps using tests such as we have used in this study. In general, it will be desirable and appropriate to use a less severely restrictive set of assumptions about demand relationships than those of the Armington model.

The main advantage of the Armington approach is its parsimony with respect to parameters to be estimated while retaining compatibility with demand theory. This advantage is often important in international trade studies where data are very limited; but it comes at a cost. When the restrictions are inappropriate the parameters will be biased, possibly in important ways. When we use a parametrically more generous specification (such as the AIDS model), we lose the main advantage of the Armington model in exchange for reducing the risk of this specification bias. At the same time, as occurred in our estimates, we increase our risk of getting wrong signs. Clearly, given our nonparametric results that support the existence of a well-behaved system of demands; the AIDS model can be a misspecified model, too. And, as with the Armington approach, data limitations restrict our options for specification searches to find the "true" model. Our tests comprehensively reject the Armington model for cotton and wheat. This leads us to be concerned that similar conclusions may apply to other trade models in the literature based upon (untested) Armington restrictions.

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FOOTNOTES

[1]The Armington model imposes the CES functional form on equation (3). This is the typical approach followed by those who have estimated Armington models (e.g., Sarris, Grennes et al., Abbott and Paarlberg, and Figueroa and Webb) and it is the one which we are concerned with in this paper. Alternatively, others (e. g., Goddard) have modified the Armington model by using a different functional form. Goddard used a generalized Box-Cox functional form.

[2]These tests are conditional on some general assumptions. First, general separability assumptions are implicitly made in our approach. For example, both cotton and wheat are assumed to be weakly separable from all other commodities. In addition, leisure (labor supply decisions) is assumed to be separable from all other commodities and our approach assumes intertemporal separability. In order to make consumer models tractable these separability assumptions are frequently made. Finally, in every case, in order to make the models tractable, we abstract from the problem of aggregation over consumers and over different varieties of wheat and cotton. These general assumptions are usually made in applications of Armington models.

[3]Chalfant and Alston provide a more intuitive explanation of GARP which they use to test for structural change in demand for meats.

[4]The Armington model has been applied sometimes to a group comprising imports plus the domestically produced good (e.g., Grennes, Johnson and Thursby). Alternatively, others have dealt only with import (excess) demand, without explicit treatment of domestic supply and demand (e.g., Sarris, 1983). None of the importers being studied in this paper produce significant amounts of cotton, but several of the wheat importing countries (especially the Soviet Union and China) produce most of

the wheat that they consume. We are therefore assuming that domestic wheat is a differentiated product within the "wheat group" in these countries. The Armington restrictions imply that any sub-group is separable so that a test of Armington restrictions on a sub-group tests necessary conditions for the Armington model.

[5]Armington used a CES price index (see, also, Sarris, 1983). However, he expressed the model in percentage change form which is equivalent to first differencing the logarithmic form. Taking first differences of equation (6) in the logarithms of prices (i.e., holding shares constant) results in the price index used by Armington.

[6]Autocorrelation was present in many of these models both with and without the Armington restrictions. While this does not lead to biased parameter estimates, it might lead to biased standard errors and biased test results. Given our nonparametric results, supporting the existence of a well-behaved static system of demand equations, it is probably appropriate to interpret this autocorrelation as evidence of model mis-specification. In any event, our main results are not sensitive to autocorrelation corrections.

[7]This result could easily be rationalized as being due, for example, to the extensive involvement of the Egyptian government in the wheat market. However, it does imply positive own price elasticities of demand, a result that is not implied by the data alone because the data satisfy GARP.

[8]For a discussion of the effects of this substitution on the properties of the subsequent estimators, see Blanciforti and Green. Green and Alston discuss implications for computation of elasticities.

[9]The spirit of this approach is directly analogous to that used in the non-parametric test for separability where we tested source-by-source whether the demand system was sensitive to the exclusion of a source. This is a test of a

necessary condition for the Armington model's assumption that all sources are separable. It is not as strong as the condition that all sources be jointly separable which is required by the Armington model.

[10]This point was first suggested to us by Mike Wohlgenant (personal communication). Kmenta (pp. 443-44) proves the relevant arguments about the effect of omitting relevant explanatory variables.

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Table 1. Nonparametric Test Results

Importer	GARP[a]	Separability of Wheat Source Country Aust.	Arg.	Can.	U.S.	E.C.
China	0	+	+	+	+	
Brazil	2		+	–	–	
Egypt	0	+			–	+
U.S.S.R.	0	–	–	+	+	+
Japan	0	+		+	+	

Importer	GARP[a]	Separability of Cotton Source Country USSR	Egpt.	Mex.	Turk.	Sud.	U.S.	Pak.	Braz.	Nic.
Italy	0	–	–	–	+	+	+			
Hong Kong	2	–					+	+		
Taiwan	7			+			+		+	
France	0	+	+		+		–			
Japan	0	–	–				+			–

Notes:

[a]Entries under "GARP" denote the number of observations that violated the generalized axiom of revealed preference. Observations that caused the violations of GARP for those countries were deleted to allow tests for separability to be carried out. These were #7 (1977/78) for Brazil's wheat, #15 (1983/84) for Hong Kong's cotton, and #2 (1970/71) and #7 (1976/77) for Taiwan's cotton.

[b]Entries denoted "+" indicate that imports from that country are separable from imports from the alternative sources. Entries denoted "–" indicate that imports from that country are not separable from other sources. Blanks indicate that data were not available for that supplier.

[c]The wheat sources are Australia, Argentina, Canada, the United States, and the European Community. The cotton sources are the Soviet Union (USSR), Egypt, Mexico, Turkey, Sudan, United States, Pakistan, Brazil and Nicaragua.

Table 2. Armington Model Estimates for Wheat and Cotton

Commodity[a] Importer	Estimates[b] σ	R^2	<------ χ^2 Statistics for Hypothesis Tests[c] ------> S	H	H&S	Armington OLS	Auto[d]
Wheat							
Brazil (n=3)	2.42 (1.70)	0.90	13.96*	7.56	20.28*	24.54*	30.60*
China (n=4)	6.96* (3.65)	0.55	29.30*	26.74*	55.90*	66.10*	101.64*
Egypt (n=3)	-1.91* (-3.78)	0.98	19.62*	4.68	27.48*	33.60*	28.32*
Japan (n=3)	0.75* (3.35)	0.99	40.52*	8.66*	76.76*	87.04*	74.88*
U.S.S.R. (n=5)	3.45* (4.55)	0.97	89.30*	61.82*	138.24*	160.60*	227.64*
Cotton							
France (n=4)	2.04* (4.22)	0.88	51.86*	21.56*	78.06*	81.42*	102.36*
Hong Kong (n=3)	4.10* (3.04)	0.82	22.18*	6.28	29.58*	41.18*	47.02*
Italy (n=6)	0.76* (4.00)	0.95	163.22*	32.24*	166.28*	173.28*	230.18*
Japan (n=4)	1.26* (3.34)	0.95	54.80*	10.52*	63.22*	76.56*	72.16*
Taiwan (n=3)	5.04* (6.85)	0.96	20.98*	1.82	23.42*	30.24*	23.12*

Notes:

[a] n is the number of import sources analyzed.

[b] These are OLS estimates from the model with the full set of Armington restrictions; t-values are in parentheses.

[c] These statistics refer to the restrictions $\gamma_{ij} = 0 \ \forall \ j \neq i$ (S=separability) and $\beta_i = 1 \ \forall \ i$ (H=homotheticity). H&S denotes the joint restriction of homothetic separability. "Armington" denotes the full set of Armington restrictions – homotheticity, separability, and equality ($\gamma_{ii} = \gamma_{jj} \ \forall \ i,j$). The degrees of freedom for the χ^2 equal the number of restrictions which are $n^2 - n$ (separability), n (homotheticity), n^2 (homothetic separability) and $n^2 + n - 1$ (Armington), where n is the number of import sources. * indicates significant at $p = 0.05$.

[d] Auto refers to results after correcting for first-order autocorrelation.

Table 3. AIDS Model Test Results for Japanese Wheat Imports

Separable County (i)	Homotheticity $\beta_k=0$ (t, d.f.=21)	Separability $\delta_{ki}=0$ (t,d.f.=21)	Homotheticity and Separability $\delta_{ki}=0, \beta_k=0$ (F,d.f.=2,21)
Canada	-0.79	1.47	1.08
Australia	-6.94*	2.01	32.36*
U.S.	4.15*	-0.86	10.08*
Complete System	$\chi^2(2)=37.23$*	–	–

Notes:

The critical values of these statistics for p=0.05 are $t_{21}=2.08$, $F_{2,21}=3.47$, $\chi^2_2=5.99$.

* denotes significance at p=0.05.

The F-test statistic is calculated as:

$$\frac{\left[\frac{SSE_u - SSE_r}{J}\right]}{\left[\frac{SSE_u}{N-K}\right]} \sim F_{J,N-K}$$

where N is the number of observations, K is the number of parameters being estimated in the unrestricted model (K=5), J is the number of restrictions being tested (J=2), SSE_u and SSE_r are the sums of squares of residuals from the unrestricted and restricted models, respectively (e.g. see Judge, et. al.).

Table 4. AIDS Model χ^2 Test Results for Japanese Cotton Imports

Separable Country (i)	Homotheticity $\beta_k=0\ \forall_k$ (d.f.=2)	Separability $\delta_{ki}=0\ \forall_k$ (d.f.=2)	Homotheticity and Separability $\delta_{ki}=0$ and $\beta_k=0\ \forall_k$ (d.f.=4)
Egypt	2.12	6.74*	19.60*
Nicaragua	8.76*	16.26*	17.84*
U.S.S.R.	4.34	8.54*	20.28*
U.S.	5.14	11.34*	17.24*
Complete System	$\chi^2(3)=10.70$*	–	–

Notes:
The critical values of the χ^2 distribution for p=0.05 are 5.99 (d.f.=2), 7.81 (d.f.=3) and 9.49 (d.f.=4).
* denotes significance at p=0.05.

Table 5. Summary of AIDS Significance Tests for Wheat

		<--- Separable Country --->					Complete
Importer	Test	Aus.	Arg.	Can.	U.S.	E.C.	System
<u>China</u>							
	H[a]	–	+	+	–		+
	S[b]	–	–	+	+		
	H&S[c]	–	–	+	–		
<u>Brazil</u>							
	H		–	+	–		+
	S		+	–	–		
	H&S		+	–	–		
<u>Egypt</u>							
	H	+			+	–	+
	S	+			–	+	
	H&S	+			–	–	
<u>U.S.S.R.</u>							
	H	–	–	–	–	–	–
	S	–	–	–	+		
	H&S	–	–	–	–	–	
<u>Japan</u>							
	H	–		+	–		–
	S	+		+	+		
	H&S	–		+	–		

Notes:
Statistical significance is measured at the 5 percent level. "+" indicates failure to reject the restriction. "–" indicates the restriction is rejected. Blanks indicate the test was not applied to that source.
[a]Homotheticity
[b]Separability
[c]Homotheticity and Separability

Table 6. Summary of AIDS Significance Tests for Cotton

		<------------------------------ Separable Country ------------------------------>									Complete
Importer	Test	U.S.S.R.	Egypt	Mex.	Tur.	Sud.	U.S.	Pak.	Braz.	Nic.	System
<u>Italy</u>											
	H[a]	+	+	+	+	+	+				+
	S[b]	+	–	+	–	–	–				
	H&S[c]	–	–	+	–	–	–				
<u>Hong Kong</u>											
	H	+					+	–			–
	S	–					–	–			
	H&S	–					–	–			
<u>Taiwan</u>											
	H			+			–		+		+
	S			–			–		+		
	H&S			–			–		+		
<u>France</u>											
	H	+	–		+		–				–
	S	–	–		+		–				
	H&S	–	–		+		–				
<u>Japan</u>											
	H	+	+				+			–	–
	S	–	–				–			–	
	H&S	–	–				–			–	

Notes:
Statistical significance is measured at the 5 percent level. "+" indicates failure to reject the restriction. "–" indicates the restriction is rejected. Blanks indicate tests were not applied.
[a]Homotheticity
[b]Separability
[c]Homotheticity and Separability

Table 7. Summary of Nonparametric, Double-Log, and AIDS Model Test Results

Commodity	Importer	Homotheticity 1	Homotheticity 2	Homotheticity 3	Within Group Separability 1	Within Group Separability 2	Within Group Separability 3	Homotheticity and Separability 1	Homotheticity and Separability 2	Homotheticity and Separability 3
Wheat	China	–	+	+	+	–	–	–	–	–
	Brazil	–	–	+	–	–	–	–	–	–
	Egypt	–	+	+	–	–	–	–	–	–
	U.S.S.R.	–	–	–	–	–	–	–	–	–
	Japan	–	–	–	–	–	+	–	–	–
Cotton	Italy	–	–	+	–	–	–	–	–	–
	Hong Kong	–	+	–	–	–	–	–	–	–
	Taiwan	–	–	+	+	–	–	–	–	–
	France	–	–	–	–	–	–	–	–	–
	Japan	–	+	–	–	–	–	–	–	–

Notes:
(1) Nonparametric, (2) Double-log, (3) AIDS
"+" indicates the restriction is not rejected; "–" indicates the restriction is rejected (at p=0.05 for parametric tests).

Table 8. Uncompensated Own-Price Elasticities of Demand for Imports of U.S. Cotton[a]

	Elasticities at Sample Means[b]		
Importer	Armington[c] Model	Double-log Model	AIDS Model
France	-1.85* (-4.22)	-10.39* (-2.55)	-8.75
Japan	-1.12* (-3.34)	-3.98* (-2.30)	-2.92
Italy	-0.82* (-4.00)	-0.37 (-0.19)	-2.80
Hong Kong	-2.35* (-3.04)	-7.75* (-4.44)	-3.82
Taiwan	-1.76* (-6.85)	-11.26* (-7.89)	-1.40

Notes:
[a]All elasticities are uncompensated "within-group" measures for second stage allocations.
[b]t-values in parentheses; for the Armington model these are t-values for $\hat{\sigma}$ which apply if shares are treated as exogenous.
[c]Armington elasticities computed according to $\eta_{ijj} = -(1-w_{ij})\,\sigma_i - w_{ij}$ where i denotes the importing country and j denotes U.S.