SUPPLIER SUBSTITUTABILITY BY IMPORTERS: IMPLICATIONS FOR ASSESSING THE 1980 U.S. GRAIN EMBARGO

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Abstract

The 1980 U.S. suspension of grain sales to the Soviet Union illustrates the importance of the choice of conceptual framework for empirical analysis of international trade problems. A spatial equilibrium model of wheat and coarse grains trade assumes perfect substitution among exporting nations' commoditites by importers and, thus, precludes the embargo from having a large impact. The imperfect substitutability assumption of an Armington model results in larger consequences from the embargo. For small shocks, the Armington model better captures the rigidities characteristic of international grain markets. The spatial model provides insights on adjustments to large shocks, but rigidities persist in actual markets.

Key words: grain embargo, spatial equilibrium, differentiated products, Armington models, Soviet Union.

In the fall of 1979, the United States agreed that the Soviet Union's 1979/80 purchases of grain could total 25 million tons—well above the 8-million-ton annual maximum specified under the 1975 U.S.—Soviet grain agreement. During December 1979, military forces of the Soviet Union invaded neighboring Afghanistan. In response, the United States prohibited sales above the levels agreed to under the 1975 accord. This partial embargo lasted until April 21, 1981. During the embargo, Argentina emerged as a major supplier of grain to the U.S.S.R., and those two nations signed a long-term supply agreement.

In the years following the embargo, U.S. agricultural export performance deteriorated. Exports in 1981 were at record levels in volume and value, but by 1986, both the value and volume of U.S. agricultural exports had declined to the levels of the early 1970's. Because of the timing of the decline in U.S. exports and recent policies to recover these markets, it is important to know the extent to which the U.S. sales suspension hurt U.S. agricultural exports.

Debate on this issue has formed into two opposing camps. Agricultural economists have generally argued that the embargo did not impose serious losses on U.S. farmers and is not an important factor in the overall dismal performance of U.S. exports. Although the embargo can be credited for a loss by the United States of the Soviet market, analysis by Shei and Thompson of a hypothetical partial trade embargo, using a spatial equilibrium model, shows minor effects on the United States. An extensive study by the U.S. Department of Agriculture argues that the 1980 embargo had little adverse impact on the United States. Rather, the weak trade performance in the 1980's largely resulted from changes in the macroeconomic environment (USDA/ERS). Paarlberg et al. discuss factors contributing to the poor U.S. export performance. Although several factors are mentioned, the embargo is not. In contrast, commodity groups and trade associations argue that the embargo resulted in serious short-run losses to U.S. producers and is *a* major—if not *the* major—reason for the decline in exports. Halow of the North American Export Grain Association writes,

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"... the United States imposed the 1980 embargo of grain on the Soviet Union, a factor which has cost the U.S. farmer millions of tons in exports and the Nation billions of dollars in export income. There is little said of this factor, one of the chief reasons for the current agricultural slump in the United States" (p. 287).

The remainder of this paper illustrates that the effects of an embargo differ according to contrasting assumptions about the behavior of world grain markets. These assumptions also affect analysis of other trade issues unrelated to an embargo. In the subsequent sections, two alternative models are used to analyze the U.S. sales suspension for wheat and coarse grains trade—a spatial equilibrium model and an Armington model. While both models utilize a common empirical base, they make contrasting assumptions about the substitutability of different exporting countries' grain for importers. The empirical results show that the different assumptions as to market behavior cause greatly different outcomes, given common behavioral parameters for comparable parts of the two models.

SPATIAL EQUILIBRIUM MODEL

The spatial equilibrium model is primarily concerned with explaining trade flows on the basis of differences in transportation costs (Schmitz and Bawden; Takayama and Judge). The model assumes the world market consists of m exporting regions and n importing regions separated by distance. The countries are assumed to behave competitively in the international market and trade homogeneous commodities; that is, the commodity, say wheat, exported by the United States is a perfect substitute for wheat exported by Canada. Policies and transportation costs are included in the model as exogenous variables. Net trade functions relating imports or exports by a country or region to its border price summarize trading behaviors, which may be subject to domestic and trade interventions. Border prices and trade flows are the solution variables for the spatial equilibrium model. For simplicity, all prices and transportation costs are quoted in U.S. dollars per ton.

The behavioral equations for internal demand, supply, and stocks-adjustment in a region can be expressed as a function of the internal price. As shown by Bredahl et al., internal prices can be written as a function of the border price. The result is a series of excess demand functions for importers and excess supply functions for exporting countries which give trade as dependent on the border price, P^*. The elasticity of the function is composed of the domestic demand, supply, and stocks-adjustment elasticities, as well as the elasticity of price transmission. For the n importers, the excess demand functions are given by:

$$(1)\ M_j = M_j(P_j^*);\ M_j' < 0,\ j = 1, ..., n.$$

For exporters, the excess supply functions are:

$$(2)\ X_i = X_i(P_i^*);\ X_i' > 0,\ i = 1, ..., m.$$

The trade flow from exporter i to importer j is denoted by X_{ij} and has an associated transportation cost of T_{ij} which separates border prices in the two regions. For each exporter, the sum of purchases by importers must equal total exports:

$$(3)\ X_i = \sum_{j=1}^{n} X_{ij},\ i = 1, ..., m.$$

Similarly, for each importing country, total purchases must equal the sum of purchases from all exporters:

$$(4)\ M_j = \sum_{i=1}^{m} X_{ij},\ j = 1, ..., n.$$

For a competitive international market, prices are linked across countries by transportation costs (T_{ij}) and exogenous, importer-specific trade policy interventions (S_{ij}):

$$(5)\ P_j^* \leq T_{ij} - S_{ij} + P_i^*, \text{ and}$$

$$(6)\ (P_j^* - T_{ij} + S_{ij} - P_i^*)\, X_{ij} = 0.$$

Equation (5) states that no cheaper source can be available to an importer than sources on which its price is based, and flows occur only from the cheapest exporter(s) to an importer. The inequality of equation (5) implies that exporting countries may not be competitive in some import markets—their prices after transport charges and policy interventions are added are too high. As shown by equation (6), exporters do not supply markets in which they are not competitive.

Schmitz and Bawden, Shei and Thompson, and others solve for the competitive international equilibrium corresponding to the solution of equations (1)-(6) through the use of a quadratic programming algorithm maximizing consumer plus producer surplus less transportation costs. Holland and Sharples have developed an alternative method based on the fixed point algorithm of McKinnon which directly solves equations (1)-(6).

These equations constitute the basic structure of the spatial equilibrium modeling framework. This framework is well designed to analyze the effects of a partial embargo such as occurred in 1980. That embargo restricted a particular trade flow to a maximum level and can be incorporated as a trade flow constraint of the form:

$$(7)\ X_{ij} \leq R_{ij}\ ,$$

where R_{ij} is the maximum level of U.S. (country i) sales to the Soviet Union (country j).

Since the spatial equilibrium model assumes that the grains exported by the various nations are perfect substitutes, its solutions are typically characterized by a few, specialized trade flows corresponding to trade across least-cost routes. Actual trade-flow patterns are considerably more diverse. The basis (solution) may be unaffected over a range of alternative scenarios, then may change drastically for a small change in the scenario. In the case of the U.S. partial embargo, removing the bilateral trade flow constraint (i.e., removing the embargo) is expected to cause large and rapid shifts in a small number of trade flows as variables enter or leave the basis.

Another feature of mathematical programming models is that they shift the basis values in an effort to circumvent the constraint. While the flow constraint potentially imposes costs on the United States and the Soviet Union by introducing inefficiencies in shipping, total U.S. trade and the U.S. border price are generally not greatly affected. Transportation cost differentials are small, so that trade can be rerouted with only a small impact on total costs. Thus, the spatial equilibrium model by design suggests that world trade flows adjust to largely offset the effects of a partial embargo. These characteristics of the spatial equilibrium model lie behind the conclusion by Shei and Thompson that a partial embargo is ineffective at denying the embargoed country access to world markets at prices similar to those prevailing prior to the action.

ARMINGTON MODEL

A model which recognizes that commodities may be imperfect substitutes was developed by Armington and has been used to analyze world grain trade (Grennes et al.; Figueroa; Patterson). The approach used by Armington is to treat the importer's utility function as separable and introduce a two-stage maximization process. In the first stage, the total level of imports of a commodity is determined. Subsequently, the total level of imports is allocated to specific exporting countries, where each trade flow is viewed as a separate, differentiated good. These exporter-specific commodities are treated as imperfect substitutes.

The exporter behavioral relations and market clearing identities (equations 2-4) are the same as discussed for the spatial equilibrium model and the price linkages (equation 5) are only slightly modified to calculate a separate price for each exporter at an importer's border:

$$(8)\ P_{ij} = P_i^* + T_{ij} + S_{ij}.$$

The major modifications in the model occur in importer behavior. Initially, the importer is assumed to have a utility function which is separable into branches of commodities, M_j^k, where j denotes the country and k denotes the branch. This function is maximized subject to a total income constraint. The result is to give demand for each branch as a function of indices of prices of goods in that branch and other branches:

$$(9)\ M_j^k = M_j^k(P_j^1, \ldots, P_j^s, Y_j),$$

where P_j^k is the price index for branch k, and Y_j is country j's total expenditure. This is essentially the excess demand function (equation [1]) used in the spatial equilibrium model, assuming that the resulting trading behavior in that model is the outcome of a utility maximization process, and replacing border prices for commodities with price indices.

The second stage maximizes the utility obtained from each branch subject to the total branch allocation given by equation (9). Compared to the spatial equilibrium model, the second-stage maximization provides an alternative rule for explaining trade-flow patterns consistent with an overall excess demand of M_j^k.

For a large number of exporting and importing countries, the equations explaining trade-flow allocations contain too many parameters for either successful estimation or construction of an operational model. To simplify the model, Armington introduced two assumptions. The elasticities of substitution in each market are assumed to be constant, and the elasticity of substitution between any two products in a particular market is identical to that between any other pair in that same market. These assumptions mean that constant elasticity of substitution functions are imposed on importers in the second stage. Hence, the specific form of the trade-flow functions used in the model is:

$$(10)\ X^k_{ij} = M^k_j\, b_{ij}\, (P^k_{ij} / P^k_j)^{-\sigma_j};\ j = 1, ..., n,$$

where σ_j is the constant elasticity of substitution in country j, and b_{ij} is a country and commodity (or source) specific constant. As σ_j approaches infinity, the goods approach the spatial equilibrium assumption of homogeneous products. The lower the elasticity of substitution, the more differentiated the products are. Furthermore, the branch price index, P^k_j, is specified according to the following relationship:

$$(11)\qquad P^k_j = \frac{\sum_i (X^k_{ij} P^k_{ij})}{\sum_i X^k_{ij}}.$$

Hence, the price index, P^k_j, is simply the average price paid for imports by country j.

As in the case of the spatial equilibrium model, solutions to the Armington model have special features. Because of the assumption of imperfect substitutability, the Armington model is less able to adjust trade flows to circumvent the embargo. That is, there are rigidities on rerouting flows imposed on the model via the elasticities of substitution. Compared to the spatial equilibrium model, an exporting country's total exports and border price will show greater adjustment in the Armington model since the trade elasticity facing a particular exporter is lower. Whereas the spatial equilibrium model predicts a small number of large trade-flow adjustments, the Armington model predicts a large number of small trade-flow adjustments.

The country-specific constants, b_{ij}'s, also play a critical role in the Armington model. For example, in the extreme case where there is no trade flow, then $b_{ij} = 0$ on that flow. With the embargo, the constant remains equal to zero, and there is still no trade flow. Thus, unlike the spatial equilibrium model, the Armington model will not allow development of new trade flows in response to the embargo. In the less extreme case where the constant is low, an extremely large relative price change may be needed to cause a noticeable change in trade flows. Thus, flows tend to be rigid, and the embargo has a correspondingly larger effect on total U.S. exports.

Introduction of trade-flow constraints are also more difficult in the Armington framework than for the spatial equilibrium model. If a trade-flow constraint is assumed binding, the Armington model then represents determination of unconstrained trade flows. Hence, equation (10) becomes

$$(12)\quad X^k_{ij} = R^k_{ij} + (M^k_j - \sum_i R^k_{ij})\, b_{ij}\, (P^k_{ij}/P^k_j)^{-\sigma_j},\ j = 1, ..., n,$$

where R^k_{ij} is the constrained flow of commodity k from exporter i to importer j. That is, trade flows from i to j are composed of two parts. Some flows are forced by constraint (R^k_{ij}'s), while the remainder are determined according to the Armington formula. It can be shown that this is equivalent to the standard Armington two-stage utility maximization, subject to the trade-flow constraint, $X^k_{ij} \geq R^k_{ij}$.

Obviously, the b_{ij}'s will differ for a model incorporating constraints and one with no constraints. The greatest difficulty in implementing a relaxation of the embargo in the Armington model will be in determining the b_{ij}'s which would apply in each situation.

OPERATIONALIZING THE MODELS

To facilitate comparisons of the results of the two models, it is assumed that the first stage determination of total imports of branch k in the Armington model and the excess demand functions of the spatial equilibrium model are identical. The differences in the two models then are solely in the treatment of trade-flow patterns. In the spatial equilibrium model, trade flows are supplied by the cheapest source according to transportation costs. In the Armington framework, each trade flow is explained by a behavioral function which includes the imperfect substitutability of the goods supplied by competing exporters. As the elasticity of substitution (σ_j) increases, the goods tend toward becoming more perfect substitutes and the Armington model approaches the spatial equilibrium model behavior.

The empirical models are based on calendar year 1980 data because that year is the only year for which the embargo was in effect over the course of the whole year. Calendar year wheat trade-flow data are available in Mackie et al. For coarse grains, calendar year trade-flow data compiled by the U.S. Department of Agriculture are used. Since each model is short run (for one year only), production and beginning stocks are held fixed. Trade behavior reflects adjustments to world prices by consumption, feed use, and ending stocks.

To operationalize the models, estimates for the behavioral parameters are required. There is disagreement in the profession on the magnitudes of these parameters (Gardiner and Dixit). Consequently, the elasticities adopted in the USDA Trade Embargo/Competitiveness study are used to establish parameter values for this model. The steering committee of the USDA study and USDA experts compiled existing econometric estimates of demand, stocks adjustment, and international price transmission elasticities for the major grain trading regions. These were discussed and a set of consensus elasticity assumptions were determined based on the group's judgment (USDA/ERS). While these elasticities are not always the result of direct econometric estimation, they are based on considerable experience and prior research.

Given the assumed parameters, a linear net trade equation for each region is synthesized by calculating the appropriate slope and constant for each equation. Base model solutions are benchmarked to 1980 outcomes. With this procedure, the base solutions of the models yield the aggregate quantities traded by each country. Furthermore, it is possible to set trade flows for the Armington model equal to actual 1980 flows. The spatial model framework permits benchmarking of exporter prices and total trade by country or region, but not the individual trade flows or importer border prices. Observed trade flows deviated substantially from cost-minimizing patterns. Table 1 reports net trade elasticities, net trade (imports or exports) for 1980, and 1980 border prices.

The spatial equilibrium model allocates trade flows on the basis of transportation costs. A matrix of such costs for the appropriate regions is presented by Holland and Sharples. The data used by Holland and Sharples are from Harrer and Binkley. They examine the transportation of commodities overseas and in the process compile transportation rates on most of the world's major shipping routes.

The Armington model allocates trade flows according to the elasticity of substitution and the country-specific constant. Thus, the values of these parameters are critical. Previous use of Armington models in research on agricultural commodity markets is limited. A major study using this framework is by Grennes et al., who estimate a world wheat trade model in which the elasticity of substitution is assumed to equal 3.0 for all countries. Their research has been criticized because this assumption appears to have little empirical support (Thompson). Figueroa has recently estimated a quarterly Armington model for wheat and corn. Because his estimates are obtained from quarterly data, countries can substitute grain across quarters as well as between suppliers. Consequently, many of Figueroa's estimates are high, especially in East Asian markets. Patterson estimated annual elasticities of substitution for wheat and coarse grains. In general, Patterson's estimates for comparable regions/nations are lower than those obtained by Figueroa. Patterson's estimates of the elasticity of substitution are used to construct the Armington model for 1980. His estimated elasticities of substitution vary greatly among nations and by commodity as shown in Table 2. The lowest substitutability in the wheat market occurs for several Asian markets—a value of zero. For these nations, the commodities exported by the major exporting countries do not substitute for one another. The other extreme—that of high substitutability among wheats—is given by 4.7 in Other Western Europe. The elasticities of substitution for coarse grains are similar, ranging from zero in Indonesia, India, Nigeria, and Other South Asia to a high of 4.1 in the Southeast Asian countries. Individual estimates vary greatly between these extremes. None of the estimates is close to the high level that Patterson suggests effectively yields the spatial equilibrium results.

The country-specific constants for the

TABLE 1. NET TRADE ELASTICITIES AND 1980 NET IMPORTS AND BORDER PRICES

Region	Net Trade Elasticities		Net Imports (million metric tons)		Border Prices ($/metric ton)	
	Wheat	Coarse Grains	Wheat	Coarse Grains	Wheat	Coarse Grains
United States	1.00	1.55	−36.127	−63.348	175.00	130.00
Canada	0.43	2.64	−18.082	− 4.159	178.60	134.59
European Community	0.17	− 0.25	− 9.113	11.984	177.50	142.30
Western Europe[a]	−0.53	− 2.01	1.760	7.787	179.00	144.40
Japan	−0.04	− 0.53	5.682	18.282	194.46	146.95
Australia	0.14	0.26	−12.372	− 3.868	180.10	130.16
South Africa	−2.99	0.94	0.010	− 1.324	200.00	132.36
Eastern Europe	−0.55	− 0.86	5.149	9.079	195.20	151.00
U.S.S.R.	−0.51	− 1.40	13.885	10.759	196.64	150.01
China	−0.54	0.00	11.834	1.733	203.39	155.63
Mexico	−1.07	− 0.92	0.736	7.176	190.97	145.05
Central America	−0.11	− 0.66	2.112	0.843	191.23	145.90
Brazil	−0.08	− 0.70	4.755	1.905	193.25	143.26
Argentina	0.12	0.68	− 4.944	− 3.673	180.50	125.76
Venezuela	−0.35	− 0.71	0.729	1.175	190.69	145.69
South America[a]	−0.30	− 1.05	3.054	1.605	193.59	145.46
SubSahara[a]	−0.24	− 1.69	2.270	1.223	209.66	154.26
Nigeria	−0.04	− 4.79	1.003	0.223	209.66	154.26
Egypt	−0.18	− 0.74	5.231	0.967	203.10	152.46
North Africa[a]	−0.37	−10.61	4.383	1.003	191.58	153.76
India	−4.51	0.00	0.054	0.274	208.19	150.86
South Asia[a]	−0.67	0.00	2.643	0.018	207.19	150.86
Indonesia	−0.26	0.00	1.482	0.050	202.59	152.66
Thailand	−0.26	0.21	0.174	− 2.247	202.59	127.46
Southeast Asia[a]	−0.40	− 2.13	1.333	0.961	199.49	150.56
East Asia[a]	−0.37	− 1.30	2.364	3.021	203.21	153.53

[a]Each of these aggregate regions excludes those individual countries modeled separately and included on the above list. Hence, these regions are the "other" countries in the region.

model are calculated in a manner similar to that used for the trade equations using 1980 data. Given the observed trade levels and prices, and the assumed elasticities of substitution, the Armington trade-flow equations (9) can be benchmarked to 1980 outcomes as well. This procedure permits the model to match observed 1980 total trade by country and exporter prices.

The final step in operationalizing the models is the incorporation of the embargo. The actual data for 1980 include the effects of the embargo; hence, to determine the impact, the embargo must be removed. In the spatial equilibrium model the embargo is represented by a trade-flow constraint which is relaxed in the no-embargo scenario. In addition, the U.S. action resulted in the signing of a bilateral trade agreement between Argentina and the Soviet Union. The no-embargo scenario also removes this trade-flow restriction.

Analyzing the U.S. sales suspension in the Armington model is somewhat more difficult than is the case for the spatial equilibrium model. The partial embargo is incorporated into the base Armington model by assuming the Soviet objective in 1980 is to minimize import costs subject to constraints on U.S.-Soviet trade and Soviet-Argentine trade. In effect, this constraint removes 1980 Soviet imports from the U.S. and Argentina from their cost minimization problem. The Soviets allocate the trade flows of the remaining imports on the basis of cost minimization and their elasticity of substitution, as given in equation (12).

As before, the actual 1980 data include the embargo. These are the data to which the base solution is benchmarked. The effects of the embargo are determined by removing the constraint on U.S.-Soviet trade and the Argentine-Soviet bilateral grains agreement. Thus, the model predicts changes from actual outcomes. For counterfactual simulation of a

TABLE 2. ELASTICITY OF SUBSTITUTION USED IN THE ARMINGTON MODEL[a]

Region	Elasticity of Substitution	
	Wheat	Coarse Grains
European Community	3.29	0.71
Western Europe[b]	4.70	2.19
Japan	0.00	2.11
South Africa	0.00	NA[c]
U.S.S.R.	3.67	0.15
China	0.00	0.98
Eastern Europe	2.08	0.84
Mexico	0.24	2.20
Central America	1.03	1.65
Brazil	0.80	1.48
Venezuela	0.00	3.77
South America[b]	2.31	0.67
Egypt	1.55	3.75
North Africa[b]	3.20	3.22
SubSahara[b]	1.67	1.74
Nigeria	1.62	0.00
India	3.99	0.00
South Asia[b]	0.77	0.00
Indonesia	1.40	0.00
Thailand	0.00	NA[c]
Southeast Asia[b]	0.00	4.14
East Asia[b]	2.59	3.75
Middle East	0.86	0.73
Other	0.00	0.00

[a]Source: Patterson.

[b]Each of these aggregate regions excludes those individual countries modeled separately and included on the above list. Hence, these regions are the "other" countries in the region.

[c]NA = Not applicable.

no-embargo scenario, b_{ij}'s for Soviet trade must be calculated. This is accomplished by using pre-embargo Soviet trade flows during 1978 and 1979 to synthesize equation (10) and using that revised equation in the no-embargo scenario.

COMPARISON OF THE EFFECTS OF THE U.S. EMBARGO GIVEN DIFFERENCES IN SUBSTITUTABILITY

This section contrasts the effects of the 1980 U.S. sales suspension in the spatial equilibrium and Armington models. The scenarios examined assume that while the U.S. action does constrain a bilateral trade flow, the Soviet excess demand function is not affected by the embargo. As expected from the previous discussion, the results obtained are sensitive to the framework used in the analysis. Thus, conclusions of the embargo's effects are conditional on the assumption of substitutability.

Prices

The effects of the embargo on prices for major regions in the two models are reported in Table 3. The assumption of imperfect substitutability in the Armington model causes greater price adjustments as the market is less able to circumvent the U.S. action.

The spatial equilibrium model predicts that the U.S. sales suspension lowered the U.S. border price of wheat by 0.54 percent and the border price of coarse grains by 0.15 percent. These small declines are a result of transportation inefficiencies introduced as world trade adjusts to offset the embargo. As observed earlier, the less efficient transportation routes followed are only slightly more costly than those found in the base solution. The assumption of imperfect substitutability in the Armington model means that the U.S. must cut prices more drastically to find alternative markets for embargoed grain. That model predicts declines in the U.S. border prices of wheat and coarse grains of 4.77 and 2.81 percent, respectively.

The two models also suggest much different price adjustments for major competitors. In the spatial equilibrium model, the only significant price increase by competitors is for Argentina. Argentina increases its border price of wheat by 4.09 percent and coarse grains by 1.47 percent. The Armington model results suggest that the Argentine price increases are larger—24.14 percent and 82.40 percent. These large increases occur because the low elasticities of substitution in markets supplied by Argentina prevent those nations from rapidly adjusting (by seeking alternative sources) as Argentine grain is diverted to the Soviet Union. Further, the spatial equilibrium model predicts that the increase in the Argentine wheat price exceeds the rise in the coarse grains price. The Armington model reverses this pattern because Argentina is a relatively larger supplier in the coarse grains market than in the wheat market.

Because of the trade-flow adjustments in the spatial equilibrium model, some exporters are shipping grain on more costly routes following the embargo. Hence, their border prices fall. The Armington model precludes this result. Therefore, the border prices of all competitors rise. For example, the spatial

TABLE 3. COMPARISONS OF PRICE CHANGES FOR GRAIN DUE TO THE U.S. SALES SUSPENSION BETWEEN THE SPATIAL EQUILIBRIUM AND ARMINGTON MODELS

Region	Wheat		Coarse Grains	
	Spatial	Armington	Spatial	Armington
	-----percent change[a]-----			
United States	−0.54	−4.77	−0.15	−2.81
Canada	0.70	4.69	−0.14	9.10
Australia	−0.08	24.01	0.69	22.04
Argentina	4.09	24.14	1.47	82.40
European Community	1.18	0.45	−0.14	1.08
Western Europe[b]	1.40	−0.97	−0.14	−1.71
Thailand	−0.07	2.43	0.70	7.65
Japan	−0.16	1.04	−0.13	0.34
Eastern Europe	0.15	1.83	−0.15	−0.01
U.S.S.R.	1.53	5.60	0.90	3.74
China	−0.05	2.54	0.59	−1.45
Mexico	−0.37	−3.28	−0.13	−2.55
Brazil	−0.37	4.41	1.29	3.78
Egypt	0.17	9.07	−0.12	−0.46

[a]Results reported here are percent changes from base solution results, which correspond to the observed 1980 prices for the Armington model and exporters in the spatial model.

[b]Each of these aggregate regions excludes those individual countries modeled separately and included on the above list. Hence, these regions are the "other" countries in the region.

equilibrium model predicts a 0.08 percent decline in the Australian border price of wheat as that nation is forced to adjust shipments in Asian markets, since the U.S. expands sales of embargoed grain in that region. Because of the low elasticities of substitution in Asian markets, the ability of U.S. sales to displace those of Australia is limited in the Armington model, and the Australian border price for wheat rises by 24.01 percent. Similar differences are obtained for Canada and Australia in the coarse grains market.

Comparison of the price changes for importers in the two models suggests similar conclusions. The Armington model usually shows the largest price adjustments. In many cases, the introduction of imperfect substitutability changes the direction of price adjustment. The spatial equilibrium model predicts that several importers benefit from the embargo by purchasing U.S. grain embargoed from the U.S.S.R. at reduced prices. The Armington model reduces the ability of importers to adjust trade flows to reap such benefits. For example, the spatial model predicts a decline in the Brazilian import price for wheat. The elasticity of substitution for Brazil is 0.8, and Argentina is a major supplier. Thus, as Argentina's export price rises due to the embargo, Brazil's price also rises. In contrast, Mexico's price is linked closely to the U.S. price because of the large U.S. market share and Mexico's low elasticity of substitution. Hence, Mexico benefits from the fall in the U.S. price.

While comparison of pre- and post-embargo outcomes is hazardous, due to changes in other factors, it sheds some light on the relative performance of these two modeling frameworks in capturing the actual embargo impacts. Price data for this period show Argentina was able to extract price premiums for its grain as a result of the embargo (USDA/ERS). Both U.S. and Canadian wheat normally sell at a premium to Argentine wheat, but this pattern was reversed during the embargo. The Argentine premium relative to Canadian prices was short lived, disappearing in the third quarter of 1980 when the Canadians began to ship the Soviets larger quantities of grain, but the premium relative to U.S. wheat lasted throughout the embargo period. A similar pattern is found for corn. December 1979 prices of U.S. and Argentine corn were roughly the same. Following the embargo, the Argentine price rose quickly, yielding a 25 percent advantage over the U.S. price. This premium gradually eroded over 1980, and by early 1981, the U.S. corn price was above the Argentine price once again.

Both models show these price movements, but the very small premiums of the spatial model understate observed premiums, while Armington model predictions overstate premiums. The Armington result approximates the outcome immediately after the introduction of the embargo but is too large for the entire year.

The Canadian premiums relative to U.S. prices exhibit similar patterns. The actual Canadian premium rose once the Canadians reentered the Soviet market. The spatial model grossly understates these changes, while the Armington model overstates them somewhat, although the error is not as great as for Argentina. Changes relative to traditional behavior were more drastic for Argentina, due to the bilateral agreement with the Soviet Union which resulted from the embargo.

U.S. Grain Exports

The changes in U.S. trade flows and total exports due to the sales suspension in the two models are compared in Table 4. In the spatial equilibrium model, the U.S. action causes a large shift of U.S. exports from the Soviet Union to Eastern Europe, while total U.S. wheat and coarse grains exports fall slightly. The embargo causes U.S. exports of wheat to the Soviet Union to fall 5.4 million tons. Of that decline, 3.2 million tons is diverted to Eastern Europe. Brazil and China receive an additional 900 thousand tons of the embargoed wheat, while Other Southeast Asian countries expand purchases 178 thousand tons. The remaining adjustments consist of several extremely small changes.

Total U.S. coarse grain exports are predicted to be 143 thousand tons lower in the spatial equilibrium model despite the 3.2 million-ton reduction of U.S.-Soviet trade. Although Eastern Europe expands purchases by 304 thousand tons, the largest increases in U.S. trade flows occur in Brazil—1.1 million tons—and Other South America—1.6 million

TABLE 4. COMPARISON OF CHANGES IN U.S. GRAIN EXPORTS DUE TO THE EMBARGO IN THE SPATIAL EQUILIBRIUM AND ARMINGTON MODELS

Region	Wheat		Coarse Grains	
	Spatial	Armington	Spatial	Armington
	-----million metric tons[a]-----			
European Community	—[b]	0.260	0.004	0.258
Western Europe[c]	0.005	0.197	0.020	0.325
Japan	0.001	−0.002	0.012	0.823
Eastern Europe	3.153	0.257	0.304	0.155
U.S.S.R.	−5.380	−3.998	−3.161	−5.131
China	0.894	0.084	—	0.015
Mexico	—	0.025	0.008	0.171
Central America	0.002	0.056	0.001	0.018
Brazil	0.947	0.117	1.100	0.107
Venezuela	0.002	0.011	0.001	0.046
South America[c]	0.004	0.289	1.567	0.017
SubSahara[c]	—	0.107	—	0.026
Nigeria	—	0.012	—	0.012
Egypt	—	0.240	—	0.044
North Africa[c]	—	0.298	—	—
India	—	0.010	—	—
South Asia[c]	—	0.057	—	—
Indonesia	—	0.109	—	—
Southeast Asia[c]	0.178	−0.012	—	0.039
East Asia[c]	—	0.183	—	0.247
Middle East	—	0.073	—	0.004
Other	0.002	0.001	—	—
Total	−0.194	−1.796	−0.143	−2.825

[a]Results reported here are deviations from base solution results, which correspond to the observed 1980 trade flows for the Armington model.

[b]Indicates no change in the trade flow.

[c]Each of these aggregate regions excludes those individual countries modeled separately and included on the above list. Hence, these regions are the "other" countries in the region.

tons. Sales to these markets are increased as Argentina diverts coarse grain trade to the Soviet Union.

The results for the Armington model shown in Table 4 indicate a large number of small adjustments that produce a relatively large decline in total U.S. grain exports. For wheat, the Armington model predicts a decline in U.S.-Soviet trade of 4.0 million tons. Unlike the spatial equilibrium results, the loss of the Soviet market in the Armington model is offset by expanding U.S. wheat exports by 50-300 thousand tons to several markets with a total net export loss of 1.8 million tons. North Africa increases purchases the most—298 thousand tons—followed by markets in Other South America and Europe. Whereas Eastern Europe greatly increased purchases in the spatial equilibrium model—3.2 million tons, in the Armington model the increase is only 257 thousand tons.

Similar results are obtained for coarse grains. The decline in U.S.-Soviet trade in the Armington model is 5.1 million tons. The largest increase in U.S. trade is with Japan—823 thousand tons. U.S. coarse grain exports to all other markets increase, but the increases are 325 thousand tons or less. The total loss in U.S. coarse grains exports is 2.8 million tons in the Armington model, in contrast to a decline of only 143 thousand tons in the spatial equilibrium model.

Given the differences in price and total trade adjustment between the models discussed above, the impact of the U.S. embargo on export earnings should also differ. The spatial equilibrium model predicts little change in prices and total trade. Consequently, U.S. export earnings for wheat and coarse grains are only 98.3 million dollars lower. Because of the larger price and export changes in the Armington model, that model suggests that the United States lost 1.251 billion dollars in export revenue for wheat and coarse grains.

Soviet Grain Imports

Table 5 shows the model's predictions of the changes in Soviet purchase patterns in response to the U.S. embargo. Again, the characteristics which distinguish the two models are reflected in the outcomes reported in Table 5.

The spatial equilibrium model predicts that Soviet imports of wheat are only 0.045 million tons lower, while coarse grain imports are only 0.093 million tons lower. Despite the stability of overall trade, trade flows to the Soviet Union show large adjustments by a few key exporting countries. The spatial equilibrium model shows a loss of U.S. wheat exports of 5.38 million tons. Of this loss in U.S. trade, Canada replaces 2.835 million by diverting wheat from other markets, principally Eastern Europe. The remainder of the loss in wheat imports from the U.S. is offset by Argentine supplies under the Argentine-

TABLE 5. CHANGES IN SOVIET IMPORTS OF WHEAT AND COARSE GRAINS DUE TO THE U.S. SALES SUSPENSION IN THE SPATIAL EQUILIBRIUM AND ARMINGTON MODELS

Region	Wheat		Coarse Grains	
	Spatial	Armington	Spatial	Armington
	-----million metric tons[a]-----			
United States	−5.380	−3.998	−3.161	−5.131
Canada	2.835	0.802	0.263	1.173
Australia	—[b]	1.323	−0.195	1.207
Argentina	2.500	0.664	3.000	1.538
European Community	—	1.002	—	0.089
Western Europe[c]	—	—	—	0.295
Thailand	NA[d]	NA	—	0.268
South Africa	NA	NA	—	—
Total	−0.045	−0.247	−0.093	−0.561

[a]Results reported here are deviations from base solution results, which correspond to the observed 1980 trade flows for the Armington model.

[b]Indicates no change in the trade flow.

[c]Each of these aggregate regions excludes those individual countries modeled separately and included on the above list. Hence, these regions are the "other" countries in the region.

[d]NA = Not applicable.

Soviet grain agreement which resulted from the U.S. action. To obtain these supplies, Argentina reroutes wheat originally intended for South American markets. This trade diversion allows U.S. sales in those nations to expand.

In the coarse grains market, the spatial equilibrium model results show a 3.161 million-ton reduction in U.S.-Soviet trade. The major beneficiary of this trade flow disruption is Argentina, which increases sales to the U.S.S.R. under the bilateral agreement. Canada also reroutes 0.263 million tons of coarse grains from Eastern Europe to the Soviet Union. The spatial equilibrium model results predict that Australia reduces sales to the U.S.S.R. slightly. This result conflicts with *a priori* hypotheses that competitors would expand sales to offset the U.S. withdrawal from the Soviet market. For Argentina and Canada to fill the void in the Soviet market caused by the U.S. action, sales to other markets are reduced. Further, border prices for most importers fall. Thus, in response to lower prices, East Asia expands purchases slightly. Because Australia has a shipping cost advantage to those markets over the United States, Australia expands sales to East Asia to compensate for the withdrawal of other suppliers. To accomplish the expansion in sales to East Asia, coarse grain must be rerouted from the Soviet Union.

The changes in Soviet purchase patterns in response to the U.S. sales suspension in the Armington model are much different. Compared to the spatial equilibrium model results, the Armington model predicts a smaller U.S. loss in U.S.-Soviet wheat trade, but a larger loss in U.S.-Soviet coarse grain trade. The declines in total Soviet imports in the Armington model of 247 thousand tons for wheat and 561 thousand tons for coarse grains are larger than predicted by the spatial equilibrium model. The loss of U.S. exports to the Soviet Union estimated by the Armington model are 3.998 million tons of wheat and 5.131 million tons for coarse grains.

Unlike the spatial equilibrium results, the increased exports by competitors to the Soviet Union in the Armington model are diversified among more countries. For wheat, the Armington model results show Canada and Argentina expanding sales by 802 and 624 thousand tons, in contrast to increases of 2.835 and 2.5 million tons in the spatial equilibrium model. Whereas the spatial equilibrium model showed no increases for other wheat exporters, the Armington model predicts increased sales by Australia (1.323 million tons) and the European Community (1.002 million tons).

While the spatial equilibrium model predicts that the Argentines largely replaced the U.S. coarse grains denied the Soviets, the Armington model shows a much smaller increase for Argentina (1.538 million tons) and a greater pattern of diversification. The increase in Canadian coarse grains sales to the U.S.S.R. is much greater in the Armington model—1.173 million tons compared to 263 thousand tons. Unlike the spatial equilibrium model results, in the Armington model the European Community, Other Western Europe, and Thailand expand coarse grains sales to the Soviet Union. The spatial equilibrium model predicted that Australia diverts coarse grain away from the Soviet market toward East Asian markets in response to the U.S. embargo. The Armington model with its assumption of imperfect substitutability suggests that this diversion does not occur. Rather, Australia expands exports to the Soviet Union by 1.207 million tons.

Comparison of trade-flow patterns before the embargo to those during the embargo shows both significant shifts in export destinations and changes in tonnages (USDA/ERS). These effects are reflected in the model results, but neither model alone captures both effects. Unlike the spatial model, actual data suggest that all wheat competitors increased sales to the Soviet Union. Nor do the data suggest an Australian withdrawal in the coarse grains market as shown in Table 5. The Armington model underestimates the ability of the Argentines to gain access to the Soviet market and overstates the gain in that market by the European Community.

SENSITIVITY OF RESULTS TO THE EXCESS DEMAND ELASTICITY AND THE ELASTICITY OF SUBSTITUTION

The central thesis of this article is that different conclusions about the effects of the 1980 U.S. suspension of grain sales to the Soviet Union reflect differing assumptions about the conduct of world grain trade, and that the conduct assumption is more critical to the results than the other parameters used in the model. The previous section shows the importance of the conduct assumption. What remains to be accomplished is to determine the role of the empirical parameters used in the model.

Of greatest concern in this analysis are the net trade elasticities of the Soviet Union and Canada. The Soviet wheat net trade elasticity is varied from −0.25 to −0.75. Canadian wheat stocks adjustment ranges from −0.4 to −1.0. Similar wide ranges are assigned for coarse grains.

These ranges are used to provide upper and lower bounds for the excess demand functions of the Soviet Union and Canada. They may also be used to determine the net excess demand function implicitly facing the United States. In the spatial equilibrium model reported above, the excess demand elasticity faced by the United States in the wheat market is −1.15 and that for coarse grains is −1.65. When these parameters are set at the high side of the range, the net excess demand elasticities become −1.328 for wheat and −1.745 for coarse grains, which constitute changes of 15.5 percent and 5.9 percent, respectively. The lower bounds of these parameters cause the excess demand elasticities to become −0.971 for wheat and −1.545 for coarse grains.

Comparison of the spatial equilibrium results for the 1980 embargo with the high, midpoint, and low excess demand elasticities showed no significant difference. For example, the changes in U.S. border prices for wheat are 8 cents per ton different than with the midpoint estimate, and the coarse grains price differs by 1-2 cents per ton. In the case of U.S. exports, the differences between the model solutions are 13 thousand tons for wheat and 12 thousand tons for coarse grains.

To test the sensitivity of the Armington model results to the elasticity of substitution, the estimates obtained by Figueroa were used. Because Figueroa's estimates tended to be higher, especially in developing country markets and Japan, the price changes are smaller than those reported here. For example, the U.S. wheat price falls 2.88 percent rather than 4.77 percent as reported here. With smaller price changes, the adjustments in trade flows are not as large. Using Figueroa's estimates predicts that U.S. wheat exports fall 1.031 million tons and U.S. coarse grains exports are 1.841 million tons lower. The results reported in Table 4 show declines in U.S. wheat and coarse grains exports of 1.796 and 2.825 million tons, respectively.

Despite changes in the implicit export demand elasticity facing the U.S. and in the elasticities of substitution, the pattern of differences between solutions from these two models remains the same. These results suggest that for analysis of the embargo, the assumption of modeling framework is more critical to the results obtained than the parameter values used.

CONCLUSIONS

Differences of opinion as to the impact of the 1980 suspension of U.S. grain sales to the Soviet Union may reflect different views of the conduct of world markets. The choice of a conceptual framework upon which empirical analysis of the embargo is based largely predetermines outcomes obtained.

The spatial equilibrium model assumes that homogeneous commodities are traded in highly flexible markets where trade flows are determined on the basis of minimum transportation costs. The perfect substitutability assumption allows trade flows to instantaneously adjust to circumvent the distortion introduced by the embargo. Thus, the model predicts that there are a few, large adjustments in trade flows between the U.S., Canada, and Argentina, but total exports and imports by nations and border prices are not greatly affected. For example, the spatial equilibrium model suggests U.S. wheat and coarse grains prices are $0.94 and $0.19 per ton lower, respectively. U.S. wheat and coarse grains exports are 0.194 and 0.143 million tons lower. With these small changes in price and U.S. exports, U.S. export earnings are not significantly affected.

The Armington model assumes that there are rigidities in trade flows because commodities exported by different nations are imperfect substitutes. Comparison of the Armington solutions to those of the spatial equilibrium model suggests that assumptions about substitutability are critical. Whereas the spatial equilibrium predicts little impact from the embargo, the Armington model solutions suggest that the U.S. wheat price falls $8.68 per ton and U.S. wheat exports decline 1.796 million tons. The Armington model predicts that the U.S. coarse grains price is $3.74 per ton lower, while export volume is 2.825 million tons lower. The loss in U.S. export revenue in the Armington model is 1.251 billion dollars versus a loss of 98.3 million dollars in the spatial equilibrium model.

Taken in aggregate, these scenarios suggest that the empirical assessment of the impacts of the 1980 U.S. embargo are largely conditional on the conceptual framework. Regardless of the parameter values used, a spatial equilibrium model will show little impact from a trade-flow disruption. In contrast, introduction of imperfect substitutability will increase the effects.

Which framework most accurately captures the effect of the embargo is difficult to answer. Actual trade-flow data suggest while both models capture important impacts, neither is completely satisfactory. The spatial equilibrium model likely overstates the adjustments in trade flows due to the embargo, while the Armington model understates them. The embargo did not cause a few large changes in trade flows as suggested by the spatial equilibrium model. Because the embargo was a major shock to the system, it caused significant changes in trade-flow patterns, and this behavior is constrained in the Armington model. For small shocks and in the short run, where importers adjust the magnitude of purchases but do not seek alternative sources of supply, the Armington model is most likely preferred. This is because that model reflects the rigidities inherent in actual world trade flows. Econometric estimation clearly shows these rigidities (Figueroa; Patterson). For large shocks, the spatial equilibrium model solution is a necessary complement to the Armington results. It suggests new trade flows which may emerge based on minimizing transport costs. Examination of trade flows shows that large, persistent shocks cause adjustments which are precluded by assumption in an Armington model, but some rigidities persist in the longer run. A fruitful area for future research is the development of a modeling framework between these extremes which captures short-run rigidities as well as the flexibilities in trade-flow patterns in the longer run or in the face of large shocks to the system.

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