An Armington Model of U.S. Cotton Exports

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Abstract. *A multiregional Armington model of U.S. cotton exports is estimated inappropriately with ordinary least squares (OLS) and appropriately with seemingly unrelated regression (SUR). Trade elasticity estimates and out-of-sample forecast performance demonstrate the importance of using the correct econometric technique. The choice of estimator clearly influences the model's forecast accuracy out of sample, levels of trade parameter estimates, and degrees of coefficient estimate efficiency. Four shortcomings of the agricultural trade literature are addressed: (1) frequent neglect of trade theory, (2) excessively wide ranges of trade parameter estimates, (3) frequent misuse of OLS, and (4) failure to validate models out of sample.*

Keywords. *Armington theory, U.S. cotton trade, ordinary least squares (OLS), seemingly unrelated regression (SUR), forecast performance, price elasticities*

The agricultural trade literature appears deficient on at least four accounts, according to Chambers and Thompson. First, the literature has often ignored international economic theory and its advances (*4*, p. 2).[1] Second, the range of the estimates for U.S. policy relevant trade parameters such as the price elasticities of foreign demand for U.S. cotton is excessively wide (*24*). The profession, thus, has no consensus on a reasonable confidence interval for the true values of these parameters. Third, researchers have often not validated agricultural trade models beyond the sample (*24*). Fourth, researchers have too often ignored econometric problems and have inappropriately estimated agricultural trade models with ordinary least squares (OLS).

In this article, I address these criticisms in the context of the U.S. cotton trade. First, I apply Armington's theory of international demand for commodities differentiated by kind and origin (hereafter Armington theory) to a multiregion model of U.S. cotton exports. Armington theory is considered a theoretically powerful approach with substantial economic content—a promising approach for modeling issues in U.S. agricultural trade (*22, 24*). Yet the Armington approach is still new to U.S. agricultural trade modeling, particularly cotton (*24*).

Second, I estimate the Armington model with an inappropriate technique, OLS, and with the appropriate econometric estimator, Zellner's seemingly unrelated regression (SUR). A comparative analysis of the model estimated with these two techniques addresses Thompson's complaint that econometric problems are often not confronted.

Third, I calculate U.S. trade relevant parameters and compare them for the model's OLS and SUR "versions." An estimate range (OLS, SUR) is generated for each coefficient and, hence, trade parameter. The results address Thompson's criticism of the literature's wide range of trade parameter estimates.

Fourth, I test and compare forecast performances of the OLS and SUR versions of the Armington model out of sample. This procedure addresses Thompson's criticism that trade models are often not validated.

Addressing these criticisms with four objectives exposes several interrelationships. Ignoring econometric problems and inappropriately estimating the Armington cotton model with OLS introduces sizable deviations in parameter estimates from SUR-estimated levels. Furthermore, choosing between the appropriate econometric estimator and an inappropriate one noticeably influences the out-of-sample forecasts of the Armington model.

Armington's Theory

Armington provided an important insight in international trade theory. His theory provided a way to account for the fact that commodities in international trade are differentiated by place of origin as well as

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

by kind U S and Mexican cotton are therefore imperfect, rather than perfect, substitutes

However, no Armington study of U S cotton exports has yet appeared in major books or journals A concise presentation of the specifications and advantages of Armington theory will follow Detailed presentations of derivations and specifications appear in two of his earlier articles (*1, 2*) Grennes, Johnson, and Thursby (*10*) and Johnson, Grennes, and Thursby (*15, 16*) present detailed summaries of Armington's theory within the context of U S agriculture

Armington's theory (*2*) differentiates a commodity supply by kind and origin Following Armington (*2*, pp 159–60), we see that a "good" or "market" is a commodity differentiated by kind, as cotton is from corn, for example A "product" is differentiated by both kind and origin U S and Mexican cotton exports represent two imperfectly substituted products within an importing region's cotton market Importers are often observed as treating a good's supplies from different exporters as imperfect substitutes (*2*, p 159, *15, 16*) Thus, an importer performs a two-stage optimization In stage 1, the importer decides the total amount of cotton to import from all sources The importer then determines the optimal levels of *product* imports

Armington made three assumptions (*2*, p 161) First, importer preferences are homogeneously separable Armington realized two advantages of homogeneous separability Phlips (*21*, pp 72–76) demonstrated that weak separability, a condition implied by homogeneously separable preferences, is required to incorporate two-stage optimization Green (*9*, pp 150–54) has shown that homogeneous separability, a stronger condition than weak separability, is necessary both to endogenize two-stage optimization and to do so in a way that will generate the same demanded product quantities of the more conventional single stage process

Second, Armington (*2*, p 161) assumed that an importer's substitution elasticities defined over product pairs are constant

Third, Armington (*2*, p 161) assumed a common substitution elasticity for each product pair within a particular market (for example, cotton) These assumptions suggest an importer utility function that is homogeneously separable, and has a constant elasticity of substitution (CES) (*2, 15*) An importer groups cotton exports into a cotton market quantity (or utility) index that is linearly homogeneous and that serves as a CES utility function argument (*2*, p 167) The importer first maximizes real national-income-constrained utility to determine a Marshallian total cotton demand (equation 1) Following Armington (*2*), the importer then minimizes expenditures on all cotton products subject to the first-stage demand or utility level Armington (*1, 2*) derived equation 2 as the importer's second-stage demand for a product, in this case, U S cotton Relation 3 is equation 2's natural logarithm form that is actually estimated Region-specific variables were added to equations 1 and 3 because Armington's theory was derived along the general lines of an arbitrarily selected commodity and importer Armington (*2*) also derived equation 4, the own-price elasticity of an importer's product demand (hereafter direct-price elasticity)

$$x_i = h^i(RLY, p_1, \ldots, p_i, \ldots, p_n) \quad (1)$$

$$x_{ij} = g^{ij}(x_i, p_{i1}, \ldots, p_{ij}, \ldots, p_{im}) = b_{ij}^{\sigma_i} x_i (p_{ij}/p_i)^{-\sigma_i} \quad (2)$$

$$\ln(x_{ij}) = \sigma_i \bullet \ln(b_{ij}) + \ln(x_i) - \sigma_i \bullet \ln(p_{ij}/p_i) \quad (3)$$

$$N_{iii} = -((1.0 - S_{ij}) \bullet \sigma_i + S_{ij} \bullet N_{i/i}) \quad (4)$$

For some importer, $i = 1, \ldots, n$ represents the goods or markets (for example, cotton), $j = 1, \ldots, m$ is the number of exporters (for example, the United States), x_i is the demand for the ith good from all sources, RLY is the importer's real income, x_{ij} is the ith good imported from the jth exporter (for example, cotton from the United States), p_{ij} is the real x_{ij} price in importer currency, p_i is the index of the market's p_{ij}, σ_i is the importer's ith market (cotton) substitution elasticity, b_{ij} is the intercept for x_{ij} demand, ln is the natural logarithm operator, N_{iii} is the importer's elasticity of x_{ij} demand with respect to p_{ij}, $N_{i/i}$ is the importer's elasticity of *market* demand with respect to p_i, and S_{ij} is the market expenditure's share spent on x_{ij}

Armington's assumptions were designed to accomplish three things First, two-stage importer optimization was endogenized because it is frequently observed in world trade (*2*, pp 159, 171) Second, two-stage optimization was theoretically justified without violating Hicksian consumer theory Armington (*2*, pp 164–66) clearly intended to incorporate two-stage importer optimization in which product demand optima are consistent with the single-stage process of the more traditional theory of buyers' behavior Third, "these assumptions yield a specific form for the relation between demand for a product, the size of the corresponding market and relative prices, the only price parameter in this function [equation 2] is the elasticity of substitution in that market " (*2*, p 161)

Armington's theory has four advantages First, the often observed two stage importer optimization procedure is endogenized in a manner consistent with the one-stage process and in a way which does not violate Hicksian consumer theory (*2*, p 171, *9*)

Second, reduced multicollinearity may arise from the model's weak separability Phlips (*21*, pp 72–74) demonstrated that weak separability permits product demands to be estimated with the product's *market-related* parameters rather than with those of the entire consumption set Nonmarket, and possibly collinear, arguments may be deleted

Third, further multicollinearity reductions may arise through indexing of collinear prices in both stages of two-stage importer optimization First-stage product prices are collapsed into a price index for each homogeneously separable market The m market-related prices are collapsed into the price ratio variable in the second-stage relation (equation 2) Deleting and indexing collinear variables are multicollinearity remedies suggested by econometric texts Yet such texts often caution the reader about the dangers of specification errors from misspecifications and omitted relevant variables (*18*, pp 150–56, *19*, pp 391–93) Researchers should note an important Armington model attribute specifications that implement these multicollinearity remedies with the luxury of theoretical justification

Armington's fourth advantage is that it permits the price elasticities to be estimated indirectly with equation 4 with nothing more than some share information, the N_{ih}, and the price ration coefficient (substitution elasticity estimate)

Note that Armington's framework is a theory of demand Armington states that his theory of "ex ante demand requires no particular assumptions about supply" (*2*, p 163) I, therefore, concentrate on the demand side of the U S cotton export market

Estimated Demand Model

An annual multiregional Armington model of U S cotton exports was estimated with OLS and SUR for 1960–81 Total U S cotton exports were delineated into demands by Japan, South Korea (Korea), the European Community (EC10—first 10 members), and a residual rest of the world (RESROW) Two-stage Armington behavior was not modeled for Korea In line with previous work, one-stage Korean optimization was modeled (*3*, p 133) Korea purchased cotton nearly exclusively from the United States throughout the estimation period (*8*) Therefore, Korean optimization was not expanded to two stages because the United States was virtually Korea's sole cotton supplier during the sample period (*3*, *8*) Thus, equations 1 and 3 for non-Korean regions and Korea's Marshallian demand for U S cotton were estimated with OLS and SUR Trade parameter estimates and forecast accuracy levels of the model's two versions were then compared

Considerations on Econometric Technique

Armington's approach first determines the importer's cotton market demand, which subsequently serves as a predetermined second-stage argument (*1*, *2*) For a single importer, OLS would be the appropriate econometric technique The client region's total and U S cotton import demands constitute a recursive system (*19*, p 586) Without simultaneity of the second-stage equation's market demand variable, two-stage least squares (2SLS) is not necessary OLS estimates are consistent, unbiased, and efficient in the absence of serial correlation, contemporaneous correlation, and lagged endogenous regressors (*18*, p 138, *19*, p 586)

In a multi-importer framework, however, problems with contemporaneous correlation may arise, OLS estimates would be unbiased but inefficient (*18*, *19*) Despite nonidentical sets of regressors, regional import demands may be contemporaneously correlated through the error, that is, "seemingly unrelated" (*19*, p 518) Kmenta (*19*, p 518) notes that contemporaneous correlation often confronts commodity demands across demanding agents In light of differences in real incomes, for example, first-stage demands may be correlated through the error Second-stage demands may be seemingly unrelated despite different logged first-stage arguments Without serial correlation and lagged endogenous variables, SUR would be the appropriate econometric estimator for the first-stage equations as one seemingly unrelated system, and for the second-stage equations as another SUR estimates would be unbiased, asymptotically consistent, and efficient (*18*, p 141, *19*, p 518) Kmenta (19, p 525) suggests that such estimates have similar small sample properties

Three-stage least squares (3SLS), a technique handling the combined problems of simultaneous equations and contemporaneous correlation, is not necessary for the multiregion Armington cotton model Although contemporaneous correlation may be a problem, coefficient bias from simultaneous equations is precluded because of the recursive nature of each importer's system of first- and second-stage demands

Comments on the Data

A few comments about the data are necessary before presenting the estimated model U S cotton exports are analyzed in nonlogged terms CIF, FOB, and GDP denote cost-in-freight, free-on-board, and gross domestic product, respectively Real or deflated 1967 currency levels are analyzed The U S dollar (dollar) serves as a proxy for RESROW currency Price indexes and deflators have a 1967 base Exchange rates reflect foreign currency per dollar The appendix details variable definitions and data sources in an effort to reconcile the Armington model's theoretically dictated variables with sources of available data

Equation 5 shows Longmire and Morey's relationship between deflated U S /deflated non-U S pecuniary terms For importer K

$$(PK/CPIK) = (P\$/USDEFL)*(NOMXRT(K,US) *(USDEFL/CPIK)) \quad (5)$$

where PK is the pecuniary variable in nominal kth region currency, CPIK is the kth region's consumer price index or CPI, P$ is the pecuniary variable in nominal dollars, NOMXRT(K,US) is the nominal currency K/dollar exchange rate, and USDEFL is the U S GNP implicit price deflator (U S deflator) The final two right-side terms constitute the real K/U S exchange rate embodying the nominal rate and the relative inflation factor (*20*)

Whenever possible, pecuniary variables for the multination EC10 are expressed in dollars, a common denominator into which pecuniary variables of the 10-member nations may be converted and aggregated For example, real EC10 GDP is the deflated sum of national GDP's converted to dollars via the exchange rates

For the multicountry EC10, I was unable to convert member nation exchange rates and CPI's to a common measurement unit for the sample period and consequently adopted Longmire and Morey's technique of import share-weighted indexing Each EC10 nation's nominal exchange rate was converted to a unitless 1967 index and then weighted by that nation's share of the EC10's imported metric tonnage of wheat, corn, cotton, and soybeans These weighted indexes were summed into a regional EC10 exchange rate index The EC10 national CPI's were converted to a 1967 base, weighted in the same manner as the national exchange rate indexes above, and summed into an import-share-weighted regional consumer price index

Equation Estimates

Tables 1 and 2 provide first- and second-stage econometric results with brief descriptions of the variables The appendix collates detailed variable definitions and sources of available data

First-Stage Estimates

Real EC10 GDP was deleted because of a negative and insignificant coefficient Perhaps the variable's explanation of real regional income was hindered by aggregation of the real GDP's of heterogeneous nations such as small, affluent Denmark and larger, less affuent Italy The real EC10 GDP was replaced with a "negative income" proxy, a real crude petroleum price index

The equation for Korea represents the only market demand without a real polyester price or price proxy A real U S polyester price valued in own-foreign currency was initially included in each market demand For Japan and Korea, the real U S polyester price generated altogether insignificant coefficients Perhaps Japan and Korea use non-U S polyester Yet previous work (*3, 7*) suggests that real polyester price is important Because polyester is a petroleum-based substance, the real crude petroleum price was included in the Japanese and Korean first-stage demands as a real polyester price proxy For Korea, the proxy was also insignificant and was deleted Results for Korea support Dyck and Siller's contention that "growth in South Korean agricultural imports depend heavily on growth in real income " (*8*, p 19) (see table 1)

The lag of the real cotton world average price (cotton WAP) was included in the RESROW market demand because the lagged specification generated a more significant coefficient than the current variable The lagged fit may be better because much of the RESROW region is in the Southern Hemisphere, which has seasons and crop cycles that are 6 months out of phase with those of the seven Northern Hemisphere exporters whose prices are incorporated into the cotton WAP Thompson has stressed such time aggregation problems when a model spans agents in both the Northern and Southern Hemispheres A lagged real cotton price was included in the Korean demand because it, too, fit with greater significance than current values Perhaps the stronger lagged price's fit for Korea may have arisen from a delayed price response resulting from protectionist barriers, whereas the overall own-price variable's persisting insignificance may have arisen because Korea benefited from substantial P L 480 cotton shipments during much of the sample period (*8*)

Second-Stage Estimates

Several region-specific variables were included X73 accounts for the post-1972 era of nonfixed exchange rates and high OPEC petroleum prices X73 may also capture the impact of the entry of Britain, Ireland, and Denmark into the EC X80 reflects the EC's admission of Greece in 1980 X7172 is intended to account for the dollar devaluations (1971–72) during the Nixon Administration and the initial stages of breakdown in the Bretton-Woods system of fixed exchange rates X73 and X7172 were included in the relation for Japan

Table 1—First-stage demands, econometric estimates

Variable	Explanation	OLS	SUR
		Estimates	
TLCTEC	EC10 cotton market import demand		
INT	Intercept	4,815 590	4,925 430
t value		12 700	13 560
RLPETPR	Negative income proxy	-137 010	-135 300
t-value		-5 740	-5 730
CTWAPEC	Real cotton WAP, EC10 currency	-3 271	-4 072
t-value		-1 600	-2 110
POLYPEC	Real polyester price, EC10 currency	1,056 760	1,078 960
t-value		6 480	6 770
R square		905	903
d	Durbin-Watson	2 192	2 138
TLCTJP	Japan cotton market import demand		
INT	Intercept	3,615 320	3,582 920
t-value		8 730	9 130
RLGDPJP	Real GDP, Japan	008	009
t-value		2 140	2 340
CTWAPJP	Real cotton WAP, yen	- 017	- 017
t value		-2 170	-2 180
RLPETPR	Real crude oil price	-82 586	-84 270
t-value		-3 400	-3 490
WTWAPJP	Real wheat WAP, yen	015	014
t-value		850	830
R-square		488	487
d	Durbin-Watson	1 702	1 682
USCTKO	Korean demand, U S cotton		
INT	Intercept	134 260	149 850
t-value		2 500	2 840
RLGDPKO	Real GDP, Korea	224	225
t-value		30 190	30 510
PUSCTKO1	Lagged real U S cotton price, won	001	- 002
t-value		-1 120	-1 500
R-square		982	982
d	Durbin Watson	3 333	3 219
TLCTRSRW	RESROW cotton market import demand		
INT	Intercept	10,492 990	10,689 300
t value		1 870	1 930
RROWGDCT	Real GDP, RESROW	4 946	5 125
t-value		1 200	1 260
RLCTWAP1	Lagged real cotton WAP	-14 139	-13 826
t-value		-2 680	-2 630
RLPOLYP	Real polyester price	-1,575 150	-1,659 750
t-value		- 720	- 770
TREND	Time trend	-63 267	-79 755
t value		- 180	- 230
R-square		861	861
d	Durbin-Watson	1 831	1 842

OLS = Ordinary least squares
SUR = Zellner's seemingly unrelated regression
WAP = World average price

Table 2—Second-stage demands, econometric estimates

Variable	Explanation	OLS	SUR
		Estimates	
USCTECLN	Logged EC10 imports, U S cotton		
INT	Intercept	-16 018	1 203
t-value		- 810	080
TLCTECLN	Logged total EC10 cotton imports	3 098	1 199
t-value		1 490	810
X73	Indicator variable	751	524
t-value		1 710	1 300
X80	Indicator variable	908	180
t-value		2 020	570
TRENDLN	Logged time trend	-1 323	-1 701
t-value		-1 450	-2 230
ARMCTLN	Logged Armington price ratio	-4 748	-3 182
t-value		-2 010	-1 410
R square		639	578
d	Durbin-Watson	1 972	1 499
USCTJPLN	Logged Japanese imports, U S cotton		
INT	Intercept	-10 104	-3 907
t-value		-1 530	-1 060
TLCTJPLN	Logged total Japanese cotton imports	2 438	1 615
t-value		2 880	3 500
X73	Indicator variable	715	599
t-value		3 000	2 940
X7172	Indicator variable	- 071	- 111
t-value		- 290	- 860
ARMCTLN	Logged Armington price ratio	-1 133	-1 327
t value		- 960	-1 150
TRENDLN	Logged time trend	- 989	- 810
t-value		-2 720	-2 540
R-square		499	464
d	Durbin-Watson	1 278	1 315
t value	t-value of lagged residual coefficient when OLS estimated residuals regressed with OLS on own lag and equation explanatory variables	1 379	1 379
USCTRWLN	Logged RESROW imports, U S cotton		
INT	Intercept	-13 847	-7 488
t-value		-2 660	-2 300
ARMCTLN	Logged Armington price ratio, cotton	- 790	- 984
t-value		- 770	- 960
TRENDLN	Logged time trend	-1 526	-1 115
t-value		-3 580	-3 320
TLCTRWLN	Logged RESROW cotton imports	2 831	2 004
t value		4 230	4 870
X73	Indicator variable	415	426
t-value		2 480	2 540
R-square		688	660
d	Durbin Watson	2 178	1 976

OLS = Ordinary least squares
SUR = Zellner's seemingly unrelated regression

to capture real exchange influences from the break down and disappearance of the Bretton-Woods system Coefficients conform to expectation as the real yen/dollar exchange rate rose during 1971–72 and then dropped for a considerable time thereafter

I modified Armington's second-stage price ratio because of low statistical significance levels and positive price coefficient estimates That is, I replaced Armington's (2) price ratio specification, the U S price over a cotton WAP that included the U S price, with Sirhan and Johnson's (23) specification The latter specification places U S price over the world average of competing non-U S prices The poor initial results with Armington's ratio specification may have two explanations First, the price ratio's denominator, the cotton WAP, may poorly reflect the world average price, so as to undermine the Armington ratio's explanation of relative U S /world cotton export price Second, the insignificance of the Armington price ratio coefficients may suggest weak sample evidence in support of Armington's assumptions about the substitution elasticity, estimated by the coefficient Therefore, I used Sirhan and Johnson's price ratio specification

Despite a Durbin-Watson statistic far into the inconclusive range, I did not correct Japan's second-stage data for first-order serial correlation The t-value of the coefficient on the lagged residuals was insignificant when the OLS residuals were regressed against their lag and the equation's explanatory variables Following Judge and others (*17*, p 219), I made no corrections for serial correlation

Trade Elasticity Estimates

Equation 4, the direct-price elasticity, was calculated for Japan, the EC10, and RESROW Korea's own-price elasticity of demand for U S cotton was calculated directly from the singly modeled equation's price coefficient Table 3 presents elasticity estimates for the OLS and SUR model versions Worldwide elasticities are sums of regional elasticities weighted by the importer's share of U S cotton exports

Table 3—Direct-price elasticities of foreign demand for U S cotton

Region	OLS-estimated model	SUR-estimated model	SUR difference from OLS
	Elasticities		*Percent*
EC10	4 0856	2 7475	-32 75
Japan	9820	9780	- 41
Korea	0921	1201	30 40
RESROW	6637	8110	22 19
World	1 1433	1 0282	-10 06

The choice of estimator affected regional estimates of direct-price elasticity more than world estimates The elasticity estimates of the SUR and OLS model versions were nearly equal for Japan The SUR-estimated model elasticities exceeded OLS-estimated levels for two of the three non Japanese regions The SUR version's elasticity of world demand for U S cotton was 10 06 percent less than that of the OLS version

Theoretically, the OLS and SUR coefficient estimates are unbiased and have the same expected values (*18, 19*) SUR estimates are efficient, but OLS estimates are not (*18, 19*) (see tables 1 and 2) The *point estimates* of the inappropriately OLS-estimated coefficients and the appropriately SUR-estimated coefficients vary enough to generate noticeable differences in the policy-relevant direct-price elasticity estimates of the Armington model Such differences range up to nearly 33 percent regionally and more than 10 percent aggregately The proper choice of econometric technique is, therefore, an important consideration for Armington modelers who intend to estimate trade elasticities affecting U S policy Two of Thompson's criticisms are clearly related the trade parameter estimate range is too wide, and the OLS technique is often inappropriately employed That is, ignoring the econometric problem of contemporaneous correlation and employing the inappropriate OLS estimator to the Armington cotton model have generated differences of up to nearly 33 percent in trade elasticity estimates Such differences are partly responsible for the wide estimate range that Thompson criticized

Forecast Errors Beyond the Sample

The mean absolute percent errors (MAPE's) were calculated for 1982–84, 3 years beyond the sample for the OLS and SUR model versions Because of a lack of validation results from other Armington cotton models, I used the naive model's forecast statistics for comparison The naive prediction is the previous period's actual value Table 4 provides MAPE information Note that the 1982–84 validation period spans a time of great market uncertainty over the parameters of the then imminent 1985 U S farm bill This situation may partly explain the rather high MAPE's of the three models, including the naive model

World levels of U S cotton were most accurately predicted by the OLS-estimated model The SUR-estimated and the naive models predicted world levels of U S cotton exports with nearly the same degree of accuracy Naive regional forecasts were most accurate in three of the four cases Regionally,

Table 4—Mean absolute percent errors (MAPE's): Foreign demand for U.S cotton, 1982-84

Region	SUR-estimated model	OLS-estimated model	Naive model
	Percent		
EEC10	55 99	27 08	17 40
Japan	32 36	33 05	24 19
Korea	31 89	31 24	3 98
RESROW	19 52	26 02	36 38
World	19 96	14 15	19 54

the OLS and SUR versions "tied" in terms of forecast accuracy, with OLS MAPE's exceeding SUR MAPE's in two of the four cases Furthermore, the SUR version out-performed both the OLS version and the naive model in predicting the RESROW's imports of U S cotton RESROW was the single largest region, accounting for about half of U S cotton exports

Again recall that SUR and OLS coefficients are unbiased with equal expected values (*18, 19*) Yet policymakers should note that OLS-SUR coefficient *point-estimates* varied sufficiently to generate noticeable differences in forecast performance Thompson has criticized trade modelers who have failed to validate models beyond the sample and to employ the proper econometric estimator In light of his criticisms, my findings — that the appropriately estimated SUR version fared as well as the OLS version did with regional forecasts and worse than the OLS version did with the aggregate world forecasts — are important to policymakers who may consider the Armington approach in modelling U S crop exports Choice of the appropriate econometric estimator appears more critical when one is analyzing region-specific policy These findings suggest a relationship between the Armington model's forecast performance and proper econometric technique

The value of modeling with the OLS- and SUR-estimated structures over the naive model is apparent First, the estimated structures provided aggregate U S cotton export predictions that were nearly as accurate as, or more accurate than, naive forecasts Second, although the naive model more accurately predicted U S cotton exports in some regional cases, the OLS and SUR versions did provide an array of explicit and theoretically based economic relationships that one may use to analyze the impacts of specific U S policies on cotton Naive forecasts fail to provide such economic intelligence

Conclusions

This article has uncovered relationships among the four major criticisms of the agricultural trade literature I addressed Chambers' criticism that international economic theory has been ignored or underemployed by applying the Armington model to the U S cotton trade Thompson criticized the agricultural literature for failing to provide a consensus range for trade parameter estimates, for failing to test models out of sample, and for ignoring remediable econometric problems by inappropriately employing OLS I have addressed these criticisms (1) by applying Armington theory to the U S cotton trade, (2) by alternatively estimating the model inappropriately with OLS and appropriately with SUR, (3) by calculating and comparing trade parameter estimates of the model's OLS and SUR versions, and (4) by testing and comparing the OLS and SUR versions' forecast performances out of sample

Two relationships between these criticisms became apparent First, the choice of econometric estimator for the Armington model generated a noticeable part of the trade parameter estimate range about which Thompson complained Second, the choice of econometric estimator substantially affected the forecast performance of the Armington model beyond the sample period That is, because readily remedied econometric problems were ignored through inappropriate OLS estimation, noticeable differences from the SUR version's parameter estimates and forecast performance were generated

Several findings emerged from the multiregion Armington model First, the OLS and SUR versions showed a price elasticity of world demand for U S cotton greater than unity Second, the model provided a set of region-specific price elasticities of demand for U S cotton No comparable trade parameter estimates from an Armington model of U S cotton exports have been published in a major book or journal Third, the choice of econometric estimator influenced trade parameter point estimates across model versions Fourth, econometric technique did influence the Armington model's out-of-sample forecast performance The appropriately SUR-estimated structure generally predicted region-specific imports of U S cotton as well as the inappropriately OLS-estimated structure The OLS version's world forecasts of U S cotton exports, however, were more accurate than the SUR version's counterparts

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Appendix: Variable Definitions and Data Sources

TLCTEC, TLCTJP, TLCTRSRW = total cotton imports, EC10, Japan, RESROW, respectively, 1,000 bales of 480 lbs, Aug /July year Sources *(5), (11), (25)*

TLCTECLN, TLCTJPLN, TLCTRWLN = natural logarithms (logs) of TLCTEC, TLCTJP, TLCTRSRW

USCTKO = U S cotton imported by South Korea, 1,000 MT, Aug /July year Sources *(5), (25)*

RLPETPR = 1967-based index of real Saudi Arabian crude light petroleum price Constructed from nominal dollar-valued Saudi crude price and U S deflator Sources crude prices from *(13)*, U S deflator from *(6)*

CTWAPEC = CTWAP*(NOMXRT(EC,US)/CPIEC) = cotton world average price (U S price included) in deflated EC10 currency, per 480-lb bale, CIF Liverpool, where

- CTWAP = weighted average of nominal dollar CIF Liverpool prices of following U S Memphis territory cotton (SM 1-1/16), Brazilian Sao Paolo Type 5 cotton, Mexican cotton (SM 1-1/16), Iranian cotton (SM 1 1/16), Soviet cotton (SM 1-1/16), Turkish Izmir cotton (SM 1-1/16), Syrian Izmar cotton (SM 1-1/16) Each price is weighted by exporter's share of the exports totalled over United States, Brazil, Mexico, Iran, USSR, Turkey, Syria
- NOMXRT(EC,US) = nominal regional EC10 exchange rate index A regional crop import-share weighted average of 10-member nation nominal ex change rates (non U S currency/dollar) converted to 1967 indexes Each national index weighted by national share of EC10's imported metric tonnage of corn, wheat, cotton, and soybeans
- CPIEC = regional EC10 CPI A regional crop import-share-weighted average of 10 member nations' CPI's National CPI's weighted as the national exchange rate indexes are in NOMXRT(EC,US)

Sources national nominal rf exchange rates and CPI's in *(13)*, wheat trade data in *(14)*, corn and soybean trade data from *(26)*

POLYPEC = PPLY*(NOMXRT(EC,US)/CPIEC) = polyester price in deflated EC10 currency, where

- NOMXRT(EC,US), CPIEC = EC10's nominal exchange rate index and CPI defined above in CTWAPEC and
- PPLY = nominal polyester price, dollars/lb

Sources PPLY in *(25)*

RLGDPJP, RLGDPKO = real Japanese and Korean GDP's, respectively, in own currencies Source *(12)*

CTWAPJP = CTWAP*(NOMXRT(J,US)/CPIJP) = cotton world average price in deflated yen, where

- CTWAP = nominal cotton world average price (dollars) defined above,
- NOMXRT(J,US) = nominal yen/dollar rf ex change rate,
- CPIJP = Japanese CPI

Sources exchange rate, CPI from *(13)*

WTWAPJP = WTWAP*(NOMXRT(J,US)/CPIJP) = wheat world average price, CIF Rotterdam, in real yen, where

- NOMXRT(J,US), CPIJP = Japan's nominal rf yen/dollar exchange rate and CPI,
- WTWAP = nominal dollar CIF Rotterdam world average wheat price A weighted average of the nominal, dollar, CIF Rotterdam prices of Argentine trigo pan wheat, Canadian No 2 Maritime North Atlantic wheat, and U S wheat (average wheat price) Each price weighted by nation's share of total exports of the United States, Argentina, and Canada The U S average wheat price is an average of the following (1) simple mean price of prices of U S No 2 dark hard winter wheat (13 5%) and No 2 hard winter ordinary wheat This simple mean is weighted by the U S hard red winter wheat share of USWT3X, (2) U S No 2 soft red winter wheat price weighted by U S soft red winter wheat share of USWT3X, (3) No 2 U S dark northern spring wheat (14%) weighted by U S hard red spring wheat share of USWT3X
- USWT3X = total U S exports of hard red winter, soft red winter, and hard red spring wheat

Sources wheat trade, wheat class, and all wheat price data in *(14)*

PUSCTKO1 = PUSCT*(NOMXRT(K,US)/CPIKO), lagged 1 year = CIF Liverpool price of U S Memphis territory (SM 1-1/16) cotton in real won, where

- NOMXRT(K,US), CPIKO are defined as Korea's nominal rf exchange rate and CPI,
- PUSCT = nominal dollar price, CIF Liverpool, U S Memphis territory cotton (SM 1-1/16)

Source PUSCT in *(5)*, Korean exchange rate, CPI in *(13)*

RROWGDCT = deflated dollar-valued RESROW GDP net of the United States, Korea, Japan, and EC10 Source *(12)*

RLCTWAP1 = (CTWAP/USDEFL) lagged 1 year = cotton world average price (lagged) in deflated dollars, where

- CTWAP = above-defined nominal cotton WAP
- USDEFL = U S GNP implicit price deflator (U S deflator) Source USDEFL in *(6)*

RLPOLYP = PPLY/USDEFL = polyester price/lb , deflated dollars, where

- PPLY = nominal dollar polyester price/lb defined above in POLYPEC,
- USDEFL = U S deflator

ARMCTLN = natural log of (PUSCT/CTWAPNUS) = logged Armington price ratio for cotton The ratio of PUSCT defined above in PUSCTKO1 over CTWAPNUS, where

- CTWAPNUS = nominal dollar-valued, CIF Liverpool world average price defined in CTWAPEC, but exclusive of U S price

ARMCTLN1 = ARMCTLN above lagged one period

X73 = indicator variable 1 0 for post-1972, 0 for pre-1973

X80 = indicator variable 1 0 for post-1979, 0 for pre-1980

X7172 = indicator variable 1 0 for 1971–1972, 0 otherwise

TREND = time trend 1960 = 11 0 1981 = 32 0

TRENDLN = natural logarithm of TREND above

USCTJPLN,USCTECLN, USCTRWLN = natural logs of U S cotton exports of Japan, EC10, and RESROW, respectively 1,000 MT values, Aug /July year Sources *(5)*, *(25)*

Pathologies of the Market and Their Cure

Government is a kind of social agriculture, distorting the market system in the direction of higher human valuations without destroying it and always accommodating to its principles The "invisible hand" is a necessary partner of the visible hand of conscious intervention Without understanding their properties and limitations, both the visible and the invisible hands easily turn into fists which are destructive This does not mean to say, however, that we should never turn woods into farms or never have a government to produce favorable distortions in the market

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Market Process, Vol 4, No 1, Spring 1986