The Production Theory Approach to Import Demand Analysis: A Comparison of the Rotterdam Model and the Differential Production Approach

Andrew A. Washington and Richard L. Kilmer

Results indicate that, when comparing the unconditional derived-demand elasticities to the unconditional consumer demand elasticities, significant differences emerge due to the differences in the first-stage estimation procedure between the differential production approach and the Rotterdam model. In comparing the consumer demand price/cross-price elasticities to the derived-demand price/cross-price elasticities, it is clear that use of the Rotterdam model when a production approach should be used can lead to overestimation, underestimation, and incorrect signs in deriving unconditional price effects.

Key Words: dairy, demand, imports, international, production. Rotterdam, trade

JEL Classifications: D12, D24, F10, F14, Q17

The Rotterdam model application to import demand has been accomplished by a number of studies (Lee, Seale, and Jierwiriyapant; Seale, Sparks, and Buxton; Zhang, Fletcher, and Carley). In past studies, imports are considered to be final goods that enter directly into the consumer's utility function and the resulting demand equations for imports are derived from utility maximization theory. However, given the nature of international trade, where traded goods are either used in other production processes or go through a number of do-

mestic channels before reaching the consumer, it is more appropriate to view imported goods as intermediate products than as final consumption goods even if no transformation takes place (Davis and Jensen). The primary objective of this article is to compare and contrast the use of the differential production approach with the Rotterdam model. Both approaches are applied to Japan's derived demand for imported whey differentiated by source country of production. Unconditional elasticities from both approaches are then compared.

The application of production theory to international trade is by no means a new concept. Past research that used a production theory approach to international trade include Burgess (1974a,b), Kohli (1978, 1991), Diewert and Morrison, and Truett and Truett. Each of these studies acknowledged that most goods entering into international trade require further processing before final demand delivery. They further acknowledged that, even when a traded

product is not physically altered, activities such as handling, insurance. transportation, storing, repackaging, and retailing still occur. This results in a significant amount of domestic value added when the final product reaches the consumer. Therefore, it is more appropriate to view imported products as inputs rather than as final goods even if goods are not transformed.

Davis and Jensen (pp. 410–12) meticulously discuss the advantages of the production theory approach over the utility approach to import demand estimation. Their first point is that most imported agricultural commodities are inputs and not final goods. Second. specifying the first-stage aggregates is more intuitive when using the production theory approach. Third, it is easier and more intuitive to estimate unconditional elasticities using production theory. Their last point is that the estimated parameters using production theory will be structural parameters.[1]

Kohli (1991) notes that viewing imports as intermediate goods not only has its merits in correctness but it also leads to substantial simplifications theoretically. One simplification is that the demand for imports can be derived from production theory and there is no need to model final demand. Second, this approach allows for the avoidance of the difficulties that arise when we aggregate over individual consumers. To expound on this point, data is typically reported in aggregate terms. Therefore, if we are estimating demand, we are estimating aggregate demand, and if we are estimating derived demand, it is aggregate or industry derived demand. The differences between aggregate demand and aggregate derived demand is that one is an aggregation over consumers and the latter is an aggregation over firms. When we consider optimizing behavior by both consumers and firms, do the properties derived from consumer and producer-maximizing behavior hold in the aggregate? Mas-Colell, Whinston, and Green indicate that, when consumer preferences and wealth effects

are identical across consumers, the aggregate demand function satisfies all of the properties of an individual demand function.[2] However, if there is the slightest difference in preferences and if these differences are independent across consumers (as one would expect), the property of symmetry, which is a common property tested in most empirical demand studies, will almost certainly not hold.[3]

When we aggregate across firms, there are no such conditions required for the properties of optimal firm behavior to hold in aggregation. This is because the aggregate profit obtained when each production unit maximizing profit separately. taking prices as given, is the same as that that would be obtained if they were to coordinate their actions in a joint profit-maximizing decision (Mas-Colell, Whinston, and Green).[4] This result implies that the profit-maximizing output arrived at if all firms coordinated their actions is the same as the sum of the individual output of each profit-maximizing firm. It further implies that the total cost of production for the coordinated output is the same as the sum of total cost for each individual firm if firms are price takers in the input market (Mas-Colell, Whinston, and Green). Therefore, if we estimate input demand functions and output supply functions using aggregate data, the properties of the demand and supply functions for each individual firm will theoretically hold in aggregation.[5]

---

[2] The properties of a system of demand equations for a utility maximizing consumer are adding up, homogeneity, and the symmetry and negative semidefiniteness of the matrix of price effects.

[3] The property of negative semidefiniteness holds in aggregation under less strict conditions. If each individual demand function satisfies the uncompensated law of demand, then the aggregate demand function satisfies the weak axiom of revealed preference, which implies a negative semidefinite price effect matrix.

[4] Prices are assumed as given even with coordination.

[5] The properties of the input demand function are the same as the properties of the consumer demand function. The property of the supply function is that the matrix of price effects is symmetric and positive semidefinite. The authors assumed that firms are still price takers even with coordination. Production technology can vary over firms.

---

[1] For a more in-depth discussion of the conceptual and theoretical advantages of the production approach, see Davis and Jensen.

Overview of Theory

The differential approach to the theory of the firm is comparable with the differential approach to consumer theory proposed by Barten (1964) and Theil (1965). The empirical application of the differential approach to consumer demand resulted in the Rotterdam model, which has been used extensively in demand studies and to a lesser extent in import demand studies. The majority of import demand studies that used the Rotterdam model assumed that imported goods entered directly into the consumer's utility function and strong assumptions were made about how consumers view imported and domestic goods and how they grouped commodities. Furthermore, it was often assumed that these commodity groups were to some degree independent in terms of the consumer's utility function (e.g., see Lee, Seale, and Jierwiriyapant; Seale, Sparks, and Buxton; and Zhang, Fletcher, and Carley). In these studies, the intermediate nature of imports was not considered.

The Rotterdam Model

The estimation of import demand using the Rotterdam model is accomplished in two stages. First, consumers allocate total expenditures between product groups (first stage) and, second, consumers allocate total group expenditures among goods within the product group (second stage).[6] It is also assumed that product groups are blockwise dependent, i.e., the utility interactions among goods are a matter of the groups and not the individual goods.

The first stage of the consumer budgeting process results in a system of composite demand equations, where each equation is expressed as

---

[6] Given a common assumption that imports and domestics goods are independent, there is an additional stage before the two mentioned, where total expenditures are allocated between imports and domestic goods (Seale, Sparks, and Burton).

$$(1) \quad W_g d(\log Q_g) = \Theta_g d(\log Q)$$

$$+ \sum_{h=1}^{G} \Pi_{gh} d(\log P_h'),$$

where $d(\log Q_g)$ and $d(\log P_h')$ are the group Divisia volume and Frisch price indexes, respectively; W_g, Θ_g, and Π_g are the budget share, marginal share, and absolute price coefficient, respectively; and $d(\log Q)$ is the percentage change in real income (Theil, 1980, p. 101). Equation (1) states that the composite demand for the product group depends on real income and the Frisch price indexes for each group. The size of the system represented by equation (1) is equal to the total number of groups specified in the consumer's utility function. When estimating import demand, the total number of equations in the system can be as large as the total number of goods imported, which makes estimating equation (1) problematic.

The demand for individual goods within a group conditional on total group expenditures (second stage) results in a system of demand equations where each equation is expressed as

$$(2) \quad w_i d(\log q_i) = \theta_i d(\log Q_g) + \sum_{j=1}^{n} \pi_{ij} d(\log p_j),$$

where w_i represents the share of group expenditures allocated to good i and θ_i is the conditional marginal share; q_i and p_i are the quantities and prices, respectively; π_{ij}'s are the conditional Slutsky price coefficients; and n is the number of goods within the product group (Theil, 1980, p. 103).

Dividing equation (1) by W_g and substituting into equation (2) yields the unconditional demand equation

$$(3) \quad w_i d(\log q_i)$$

$$= \theta_i \left[\frac{\Theta_g}{W_g} d(\log Q) + \sum_{h=1}^{G} \frac{\Pi_{gh}}{W_g} d(\log P_h') \right]$$

$$+ \sum_{j=1}^{n} \pi_{ij} d(\log p_j).$$

From equation (3), we get the unconditional income elasticity

(4) $\eta_i = \dfrac{d(\log q_i)}{d(\log Q)} = \dfrac{\theta_i}{w_i} \dfrac{\Theta_g}{W_g},$

which is the product of the conditional expenditure elasticity θ_i/w_i and the expenditure elasticity for the group Θ_g/W_g. We also get the unconditional price elasticity

(5) $\eta_{ij} = \dfrac{d(\log q_i)}{d(\log p_j)} = \dfrac{\theta_i}{w_i} \dfrac{\Pi_{gh}}{W_g} + \dfrac{\pi_{ij}}{w_i},$

where Π_{gh}/W_g is the own-price elasticity for the group and π_{ij}/w_i is the conditional price elasticity for the ith good.

The Differential Production Approach

Using the methodology of Laitinen and Theil, Laitinen, and Theil (1980), the differential production model will also be used to estimate the import demand. The differential production model is derived from the differential approach to the theory of the firm where firms maximize profit in a two-stage procedure. In the first stage, firms determine the profit-maximizing level of output to produce, and in the second stage, firms minimize the cost of producing the profit-maximizing level of output. According to Laitinen and Theil and to Davis and Jensen, this procedure is consistent with a one-step or direct profit-maximization procedure. In the first stage, the output supply equation is obtained, and the conditional factor demand system is obtained in the second stage. Using the results of both stages, a system of unconditional derived-demand equations is derived.

In the first stage, a competitive firm seeks to identify the profit-maximizing level of output by equating marginal cost with marginal revenue. This procedure yields the differential output supply equation

(6) $d(\log Q^*) = \varphi d(\log p^*) + \displaystyle\sum_{j=1}^{N} \pi_j d(\log w_j),$

where Q^*, p^*, and w_i represent the output, output price, and the price of inputs, respectively, and φ and π are the price elasticity of supply and the elasticity of supply with respect to in-

put prices, respectively. N is the total number of inputs used in production.

In the second stage, the differential factor demand model is derived, which will be used to estimate the system of source-specific derived-demand equations. This model is specified as

(7) $f_i d(\log x_i) = \theta_i^* d(\log X) + \displaystyle\sum_{j=1}^{n} \pi_{ij}^* d(\log w_j),$

where f_i is the factor share of imported good x from source country i in total input cost; x_i and w_i represent the quantity and price of inputs that include the price of each imported good from source country i;

$$d(\log X) = \sum_{i=1}^{n} f_{it} d(\log x_t),$$

where $d(\log X)$ is the Divisia volume input index; θ_i^* is the mean share of the ith input in the marginal cost of the firm; π_{ij}^* is the conditional price coefficient between the ith and jth importing sources or inputs; and n is the number of inputs in the system, $n \in N$.[7]

The differential factor demand model requires that the following parameter restrictions be met in order for the model to conform to theoretical considerations

$$\sum_{j} \pi_{ij}^* = 0 \quad \text{(homogeneity)}$$

and $\pi_{ij}^* = \pi_{ji}^*$ (symmetry). The second-stage procedure results in the conditional own-price/cross-price elasticity

(8) $\varepsilon_{xw}^c = \dfrac{d(\log x_i)}{d(\log w_j)} = \dfrac{\pi_{ij}^*}{f_i},$

and the conditional Divisia volume input elasticity,

(9) $\varepsilon_{xX} = \dfrac{d(\log x_i)}{d(\log X)} = \dfrac{\theta_i^*}{f_i}.$

Using the relationship between the Divisia volume input index and output, $d(\log X) =$

---

[7] The derivation of equations (6) and (7) are found in Laitinen and Theil.

$\gamma d(\log Q^*)$,[8] equation (6) can be substituted into equation (7) to yield the unconditional derived-demand system

(10) $f_i d(\log x_i)$

$$= \theta_i^* \gamma \left[\varphi d(\log p^*) + \sum_{j=1}^{n} \pi_j d(\log w_j) \right]$$

$$+ \sum_{j=1}^{n} \pi_{ij}^* d(\log w_j).$$

Dividing through equation (10) by f_i and using equations (8) and (9), we get the unconditional derived-demand elasticities. The unconditional elasticity of input demand with respect to output price is

(11) $\varepsilon_{xp} = \dfrac{d(\log x_i)}{d(\log p^*)} = \gamma \varepsilon_{xx} \varphi,$

And the unconditional own-price/cross-price elasticity of input demand is

(12) $\varepsilon_{xw} = \dfrac{d(\log x_i)}{d(\log w_j)} = \gamma \varepsilon_{xx} \pi_j + \varepsilon_{xw}^c.$

Last, we get the unconditional elasticity of derived demand with respect to the price of an input contained in N but not in n:

(13) $\varepsilon_{xu} = \dfrac{d(\log x_i)}{d(\log w_j)} = \gamma \varepsilon_{xx} \pi_j.$

Inputs contained in N but not in n include labor and other inputs that are not part of the imported whey group.

The second-stage procedures in the consumer and production approaches yield empirically identical demand systems, equation (2) and equation (7), resulting in identical conditional elasticities. Davis and Jensen note that this similarity explains the empirical success of consumer-based conditional demand sys-

tems even though they may be conceptually flawed. However, given the differences in the first stage, equation (1) and equation (6), unconditional elasticities differ between the two approaches. Also, the production approach results in the unconditional elasticity of derived demand with respect to output price whereas the Rotterdam model results in the unconditional income elasticity. This suggests that the use of the Rotterdam model, when a production approach is more appropriate, not only leads to biased unconditional own-price/cross-price elasticity estimates but also leads to the reporting of unconditional income elasticities when the concern should be the unconditional elasticity of derived demand with respect to output price.

Application to the Derived Demand for Imported Whey in Japan

This study assesses the competitiveness of whey imports into Japan from the United States compared with whey imported from other countries such as the European Union (E.U.), Australia, and New Zealand. Following Armington, similar imported dairy products such as E.U. whey and U.S. whey are both individual goods that are part of the product group whey but they are different based on their source country of production. There are a number of reasons why similar products are viewed as different based on their source country of origin. Dairy products from different sources may actually be physically different. Physical differences include quality, protein, fat content, and taste. There may also be perceived differences, such as a country's reputation for a quality product, trade history, reliability, and consistency, and political issues tied to trade (Zhou and Novakovic). The crux of this assumption is that within an importing country, a particular dairy product imported from a given source is considered a substitute for that same product from another source. However, because of the physical and perceived differences attributed to the product due to its origin, these products are imperfect substitutes.

In this article, it is assumed that dairy prod-

[8] γ is the elasticity of cost with respect to a proportionate output increase. According to Laitinen (p. 113), γ is also the ratio of revenue to cost. When calculating elasticities, the average of the geometric mean of γ for periods t and $t - 1$ is used, where $\gamma_t = [(R_i R_{i-1})/C_i C_{i-1}]^{1/2}$ is the two-period geometric mean and $\bar{\gamma} = \sum_{t=1}^{T} (\gamma_t / T)$ is the average of γ_t across all observations.

ucts are imported through firms that exclusively import. Although there are firms within Japan that import whey as well as transform whey into other products, it is assumed that there is a separate entity within the firm that deals primarily with the procurement of imported dairy products. Also, dairy imports through this type of firm make up a smaller percentage of imports in Japan. In addition to providing imported products to other firms, these firms also provide the services that are associated with importing. These services include search and acquisition, transportation, logistics, and storing. A major characteristic of this firm type is that it deals primarily in imported goods. This suggests that the procurement of imported goods by firms is a unique process separate from the procurement of similar products produced domestically. Even if the firm is a subsidiary or branch of a larger firm that purchases domestic and foreign-produced inputs, it is not unlikely that the subsidiary that is responsible for imported inputs deals primarily in this activity. This is because the acquisition of foreign-produced goods is more involved than purchasing domestically produced goods.

If we assume a production function for these firms, then the output of these firms is the imported goods that are sold to other firms and the inputs are the imported goods from the various exporting countries. If we minimize cost subject to this production function, the system of input demand equations resulting from the optimization procedure will be a system of import demand equations. If we assume product differentiation across source countries, then each import demand equation represents the demand for a product from a particular source.

In the first stage, the importing firm seeks to maximize profit by equating marginal cost with marginal revenue. This procedure yields the differential output supply equation (expressed in finite log changes)

(14) $\Delta Q_i^* = \varphi \Delta p_i^* + \sum_{j=1}^{N} \pi_j \Delta w_{jt} + \varepsilon_{it}$,

where $\Delta Q_t = \log(Q_t/Q_{t-1})$, $\Delta p_t = \log(p_t/p_{t-1})$, and $\Delta w_{it} = \log(w_{it}/w_{it-1})$ and where q, p, and

w_i's represent the output, output price, and input prices, respectively; φ and π are the parameters to be estimated, which are also the own-price elasticity of supply and the elasticity of supply with respect to input prices, respectively; ε_{it} is the disturbance term. Q^* represents Japan's total imports of whey that are to be supplied. p is the price at which firms in Japan sell whey, and the w_i's are the prices paid for whey imports from each of the exporting countries, the price of labor (wages), and the price of other inputs used. N is the total number of inputs used in production.

In the second stage, the differential factor demand model is derived, which is used to estimate the system of derived-demand equations where each equation is the derived demand for imported whey from a particular source. This model is specified as follows (expressed in finite log changes):

(15) $\bar{f}_{it} \Delta x_{it} = \theta_i^* \Delta X_t + \sum_{j=1}^{n} \pi_{ij}^* \Delta w_{jt} + \varepsilon_{it}$,

where $\bar{f}_{it} = (f_{it} + f_{it-1})/2$; $\Delta x_{it} = \log(x_{it}/x_{it-1})$, and $\Delta w_{it} = \log(x_{it}/w_{it}/w_{it-1})$; x_i and w_i represent the quantity and price, respectively, of imported whey from source country i;

$$\Delta X_t = \sum_{i=1}^{n} \bar{f}_{it} \Delta x_{it},$$

where ΔX_t is the finite version Divisia volume input index; θ_i^* and π_{ij}^* are parameters to be estimated; n is the number of inputs in the system; and ε_{it} is the disturbance term.

In addition to the imports from each individual source country, labor and other inputs are used in the production process. The labor demand and demand for other inputs are expressed in general terms as

(16)   labor
         = $f(output, wages, input price index)$

(17)   other inputs
         = $f(output, wages, input price index)$.

Equations (16) and (17) represent the system of derived-demand equations for labor and other inputs where these inputs are a function

Table 1. Likelihood Ratio (LR) Test Results for Autocorrelation in the Derived Demand and Consumer Demand Models

Country/Product	Model	Log-Likelihood Value	LR	$P[\chi^2_{(i)} \leq LR] = .95$
Japan/whey	AR (1)	55.125		
	No AR (1)	48.729	12.7927	3.84 (1)[a]

[a] Number of restrictions are in parentheses.

of the total amount to be supplied, wages, and an input price index that represents the price of all inputs except labor and whey imports. Here we assume that labor and other inputs are independent of the source-specific whey imports. This is to say that, although labor and other inputs affect the total to be imported, these inputs do not directly affect the amount imported from an individual source country.

Empirical Results

Using United Nations Commodity Trade Statistics, the derived demand for imported whey into Japan was estimated. The exporting countries considered were the United States, European Union, Oceania (aggregation of Australia and New Zealand), and rest of the world (ROW), which is an aggregation of all other countries. The time period for the data set was 1976–1998. During this period, the United States on average accounted for 35% of all whey exports to Japan, while Oceania, the European Union, and ROW accounted for 17, 19, and 27%, respectively. All values and quantities were reported through Japanese customs. Values were on a cost, insurance, and freight basis. According to FAO statistics, Japan primarily imports dry whey, which is used as both cattle feed and an ingredient in infant formula. In the last decade, imports of dry whey have accounted for 100% of all whey imports.

First-stage estimation required the domestic wholesale price of whey in Japan. This price series was not available. However, a proxy was used that was the per unit wholesale price of all milk powders, which is reported by the Statistic Bureau Management and Coordination Agency for the Government of Japan. To account for the labor requirement in the importation of whey, an index of Japan's

hourly wages was included in the estimation (U.S. Department of Labor). To account for other inputs, an industry input price index was also included (Economagic.com).

Second-Stage Estimation and Conditional Elasticities

Table 1 presents the log-likelihood values, the likelihood ratio (LR) statistics, and the critical value for the LR test for autocorrelation. A likelihood ratio test indicated that first-order autocorrelation could not be rejected at the .05 significance level; thus, all results presented have the AR(1) error structure imposed.[9]

LR tests were also used to test if the data satisfied the economic properties of homogeneity and symmetry. The results of these tests are summarized in Table 2. LR tests indicate that the property of homogeneity could be rejected. However, Laitinen's test for homogeneity, which is a more precise test, indicated that homogeneity could not be rejected. Given the homogeneity constraint, symmetry could not be rejected. The property of negative semidefiniteness was verified by inspection of the eigenvalues of the price coefficient matrix. This property is validated when all of the eigenvalues are less than or equal to zero. All eigenvalues were nonpositive in the Japan whey system.

Table 3 presents the conditional parameter estimates for the derived demand and consumer demand for imports of whey into Japan. With the exception of the ROW, all own-price coefficients are negative and all are significant by at least the .05 significance level. The condition marginal factor share estimates indicate

---

[9] The AR(1) process is the same for all equations in the system.

Table 2. Likelihood Ratio (LR) Test Results for Economic Constraints and Laitinen's Test for Homogeneity in the Derived Demand and Consumer Demand Models

Country/ Product	Model	Log-Likelihood Value	LR	$P[\chi^2_{(i)} \leq LR]$ = .95	Laitinen's Test	
					W^{*a}	$P[T^2 \leq W^*]$ = .95[b]
Japan/whey	Unrestricted	55.541				
	Homogeneity	51.179	8.726	7.81 (3)[c]	9.217	11.186
	Symmetry	48.998	4.362	7.81 (3)		

[a] W^* is the Wald statistic for the homogeneity constraint.
[b] T^2 is Hotelling's T^2-statistic.
[c] Number of restrictions are in parentheses.

a positive relationship between the Divisia volume index of all imports and the imports from the individual sources except for the ROW.[10] In the consumer demand (Rotterdam) model, the conditional marginal factor shares are interpreted as the conditional marginal expenditure share. Cross-price parameter estimates indicate that the U.S. and Oceania whey imports, Oceania and E.U. imports, and E.U. and ROW imports are substitutes.

Table 4 presents the conditional elasticities for the derived demand and consumer demand

of imported whey.[11] The Divisia index elasticities for imports of whey into Japan are 0.914, 2.295, 2.336 and −0.500 for the United States, Oceania, the European Union, and the ROW, respectively. These indicate that, as the Divisia volume index increases, imports from the United States will increase proportionately while imports from Oceania and the European Union will increase by more than twice as much. In the consumer demand model, these are interpreted as conditional expenditure elasticities. The own-price elasticities are −1.031, −2.930, −1.574, and −0.296 for the United

[10] Homogeneity and symmetry are imposed on the parameters. AR(1) is also imposed.

[11] All elasticities are evaluated at the mean.

Table 3. Conditional Derived Demand (Consumer Demand) Parameter Estimates for Japanese Imports of Whey

Exporting Country	Price Coefficients, π^*_{ij} and (π_{ij})				Marginal Factor Shares, θ^*_i and (θ_i)
	United States	Oceania[a]	European Union	ROW[b]	
United States	−.3653***	.3556***	.1032	−.0935	.3239**
	(.1254)[c]	(.0686)	(.0739)	(.0884)	(.1729)
Oceania		−.4947***	.0744**	.0647	.3874***
		(.0973)	(.0426)	(.0836)	(.0948)
European Union			−.2926**	.1150*	.4341***
			(.0628)	(.0649)	(.1166)
ROW				−.0862	−.1454
				(.1286)	(.1228)
System R^2 = .79					

[a] Australia and New Zealand aggregation.
[b] ROW is rest of the world.
[c] Asymptotic standard errors are in parentheses.
*** Significance level = .01.
** Significance level = .05.
* Significance level = .10.

Table 4. Conditional Divisia and Price Elasticities of the Derived Demand and Consumer Demand for Imported Whey

			Elasticities			
				Conditional Cross-Price		
Exporting Country	Divisia Index	Conditional Own-Price	United States	Oceania[a]	European Union	ROW[b]
United States	0.914*	−1.031***		1.003***	0.291	−0.264
	(0.488)[c]	(0.354)		(0.193)	(0.209)	(0.249)
Oceania	2.295***	−2.930***	2.106***		0.441*	0.383
	(0.562)	(0.577)	(0.406)		(0.252)	(0.495)
European Union	2.336***	−1.574***	0.555	0.401*		0.618*
	(0.627)	(0.338)	(0.397)	(0.229)		(0.349)
ROW	−0.500	−0.296	−0.321	0.222	0.395*	
	(0.422)	(0.442)	(0.303)	(0.287)	(0.222)	

Note: A Wald statistic was used, which has a χ^2 distribution.
[a] Australia and New Zealand aggregation.
[b] ROW is rest of the world.
[c] Asymptotic standard errors are in parentheses.
*** Significance level = .01.
** Significance level = .05.
* Significance level = .10.

States, Oceania, the European Union, and ROW, respectively. With the exception of the ROW, all are significant at the .10 significance level. Conditional cross-price elasticities of derived demand for whey in Japan indicate significant substitutional relationships between whey imports from the exporting sources. The U.S./Oceania cross-price elasticity is 1.003, while the Oceania/U.S. elasticity is 2.106, reflecting the higher value placed on U.S. whey. The Oceania/E.U. and the E.U./Oceania elasticities are 0.441 and 0.401, respectively, indicating fairly equal substitutability between the two sources. E.U. whey imports are the only imports that were substitutes for whey from the ROW.

First-Stage Estimation and Unconditional Elasticities

First-stage estimation required the estimation of equation (14), which is the output supply equation. Results are presented in Table 5. The output price parameter estimate (1.2963) is positive as expected and significant at the .01 significance level. This estimate is also the price elasticity of supply, which indicates that the supply of whey in Japan is price elastic.

Table 5. Parameter Estimates for the Supply of Whey in Japan

Input Price Coefficients, π_{ij}						
United States	Oceania[a]	European Union	ROW[b]	Wage	Input Price Index	Output Price Coefficient
−0.0322	0.1638	0.0001	0.0575	−0.4888***	−3.3351**	1.2963***
(0.0974)[c]	(0.1477)	(0.0670)	(0.1890)	(0.4143)	(1.6403)	(0.3709)
R^2 = .57						

[a] Australia and New Zealand aggregation.
[b] ROW is rest of the world.
[c] Asymptotic standard errors are in parentheses.
*** Significance level = .01.
** Significance level = .05.

Table 6. Unconditional Elasticities of the Consumer Demand Model (Rotterdam Model)

| | | | | Elasticities | | |
| | | | | Cross-Price | | |
Exporting Country	Income	Own-Price	United States	Oceania[a]	European Union	ROW[b]
United States	0.914*	−1.396***		0.638***	−0.074	−0.629***
	(0.488)[c]	(0.195)		(0.195)	(0.195)	(0.195)
Oceania	2.295***	−3.848***	1.188***		0.477**	−0.535**
	(0.562)	(0.225)	(0.225)		(0.225)	(0.225)
European Union	2.336***	−2.509***	−0.379	−0.534**		−0.316
	(0.627)	(0.251)	(0.251)	(0.251)		(0.251)
ROW	−0.500	−0.096	−0.121	0.422**	0.595***	
	(0.422)	(0.169)	(0.169)	(0.169)	(0.222)	

Note: A Wald statistic was used, which has a χ^2 distribution.
[a] Australia and New Zealand aggregation.
[b] ROW is rest of the world.
[c] Asymptotic standard errors are in parentheses.
*** Significance level = .01.
** Significance level = .05.
* Significance level = .10.

Parameter estimates for all import prices are insignificant. The parameter estimate for the price of labor and the price of other inputs (−1.4888 and −3.3351, respectively) are negative and significant, indicating that wages and other input prices are inversely related to the output supplied, which is to be expected. These are also the elasticity of output supply with respect to the price labor and with respect to the input price index. These indicate that the supply of imported whey in Japan is relatively sensitive to wages and other input prices. First-stage estimation in the differential production model is possible, and correct estimates could be used to derive unconditional derived-demand elasticities.

Unconditional elasticities for the Rotterdam model and the unconditional derived-demand elasticities are presented in Tables 6 and 7, respectively. To derive the unconditional income elasticities for the consumer demand (Rotterdam) model (equation (4)), the income elasticity for the product group whey was estimated to be one.[12] For the unconditional

own-price/cross-price elasticities (equation (5)), it is assumed that the price elasticity of the demand for the product group is −0.40 (Zhu, Cox, and Chavas). Unconditional derived-demand elasticities were derived using equations (11), (12), and (13).

In comparing the unconditional Rotterdam elasticity estimates in Table 6 to the unconditional derived-demand elasticities in Table 7, the biasedness due to the inappropriate application of consumer theory to import demand analysis becomes clear. First, the elasticity of derived demand with respect to output prices, the elasticity of derived demand with respect to wages, and the elasticity of derived demand with respect to other input prices would not be considered if the consumer demand model were applied. These derived-demand elasticities suggest that the derived demand for whey is highly responsive to these factors.

In addition to not reporting some of the derived-demand elasticities, the Rotterdam model leads to substantial differences in the unconditional own-price/cross-price elasticities. In the case of the own-price elasticities, the Oceania and E.U. elasticities derived using the Rotterdam model are substantially larger in absolute terms than the derived-demand

[12] The income elasticity for the group whey was estimated using the Workings Model (Theil and Clements, p. 14). The income elasticity for the group whey was equal to one.

Table 7. Unconditional Elasticities of Derived-Demand Model

Exporting Country	Elasticities							
	Output Price	Wage	Input Price Index	Own-Price	Cross-Price			
					United States	Oceania[a]	European Union	ROW[b]
United States	2.209*	−2.537*	−5.684*	−1.085***		1.283***	0.291***	−0.165***
	(1.179)[c]	(1.355)	(3.034)	(0.029)		(0.149)	(0.000)	(0.052)
Oceania	5.547***	−6.371***	−14.272***	−2.229***	1.968***		0.442***	0.629***
	(1.358)	(1.660)	(3.494)	(0.172)	(0.034)		(0.000)	(0.060)
European Union	5.646***	−6.484***	−14.526***	−1.574***	0.415***	1.114***		0.869***
	(1.516)	(1.742)	(3.901)	(0.000)	(0.038)	(0.192)		(0.067)
ROW	−1.208	1.387	3.109	−0.349***	−0.291***	0.070	0.395**	
	(1.021)	(1.172)	(2.626)	(0.045)	(0.025)	(0.129)	(0.000)	

Note: A Wald statistic was used, which has a χ^2 distribution.

[a] Australia and New Zealand aggregation.

[b] ROW is rest of the world.

[c] Asymptotic standard errors are in parentheses.

*** Significance level = .01.

** Significance level = .05.

* Significance level = .10.

elasticities. In the case of the own-price elasticity of demand for Oceania whey, the Rotterdam model overstates the own-price effect by 1.6 percentage points.

Unconditional cross-price elasticities differ between the approaches as well. Of the 12 unconditional cross-price elasticities, 11 are significant in the derived-demand model while 8 are significant when using the Rotterdam model. Five cross-price elasticities actually change signs (United States/European Union, Oceania/ROW, European Union/Oceania, European Union/ROW, and European Union/United States). The largest difference occurred with E.U./Oceania elasticity, which was estimated to be -0.534 in the Rotterdam model and 1.114 in the derived-demand model. Using the Rotterdam elasticities, one would assess that E.U. whey and Oceania whey were complements, while the derived-demand model indicates a substitutional relationship.

Summary and Conclusions

The primary objective of this article was to compare and contrast the use of the differential production approach with the Rotterdam model. Given the intuitive and conceptual appeal of a production approach to import demand analysis instead of a consumer approach (the Rotterdam model), this article investigates the empirical differences due to approach selection. When one compares the conditional derived-demand to the conditional consumer demand system, there is no empirical difference. However, when comparing the unconditional derived-demand elasticities with the unconditional consumer demand elasticities, significant differences emerge. This is due to the differences in the first-stage estimation procedure between the two approaches. In fact, first-stage estimation using the Rotterdam model is often not accomplished due to difficulty in defining product groups that make up the first stage. However, in this study, it was shown that first-stage estimation is possible with the production approach and leads to unconditional elasticity estimates. One empirical difference is that, with the production approach, the derived-demand elasticities with

respect to output price, wages, and other input prices are derived. This is not the case with the Rotterdam model. In comparing the consumer demand own-price/cross-price elasticities with the derived-demand own-price/cross-price elasticities, it is clear that use of the Rotterdam model when a production approach should be used can lead to overestimation, underestimation, incorrect signs, and erroneous insignificance when deriving the unconditional price effects.

References

Armington, P.S. "A Theory of Demand for Products Distinguished by Place of Production." Staff Paper, International Monetary Fund, Washington, DC, 1969.

Barten, A.P. "Consumer Demand Functions Under Conditions of Almost Additive Preferences." *Econometrica* 32(1964):1–38.

Burgess, D.F. "A Cost Minimization Approach to Import Demand Equations." *The Review of Economics and Statistics* 56(1974a):225–34.

———."Production Theory and the Derived Demand for Imports." *Journal of International Economics* 4(1974b):103–17.

Davis, G.C., and K.L. Jensen. "Two-Stage Utility Maximization and Import Demand Systems Revisited: Limitations and an Alternative." *Journal of Agricultural and Resource Economics* 19(1994):409–24.

Diewert, W.E., and C.J. Morrison. "Export Supply and Import Demand Functions: A Production Theory Approach." *Empirical Methods for International Trade.* Robert C. Feenstra, ed. Cambridge, MA: MIT Press, 1989.

Economagic.com: Economic Time Series Page. *Japan's Input Price Index for the Manufacturing Sector.* Internet site: http://www.economagic. com/cm-cgi/data.exe/bjap/hprice06 (Accessed December 15, 2001).

Food and Agricultural Organization of the United Nations Statistics (FAO). Internet site: http://apps. fao.org/page/collections?subset = agriculture (Accessed December 15, 2001).

Government of Japan, Statistics Bureau Management and Coordination Agency. *Annual Report on the Family Income and Expenditure Survey.* Tokyo, 1999.

Kohli, U.R. "A Gross National Product Function and the Derived Demand for Imports and Sup-

ply of Exports." *Canadian Journal of Economics* 11(1978):167–82.

———. *Technology, Duality and Foreign Trade: The GNP Function Approach to Modeling Imports and Exports.* New York: Harvester, Wheatsheat, 1991.

Laitinen, K. *The Theory of the Multiproduct Firm.* New York: North-Holland Publishing Company, 1980.

Laitinen, K., and H. Theil. "Supply and Demand of the Multiproduct Firm." *European Economic Review* 11(1978):107–54.

Lee, J.Y., J.L. Seale, Jr., and P.A. Jierwiriyapant. "Do Trade Agreements Help U.S. Exports? A Study of the Japanese Citrus Industry." *Agribusiness: An International Journal* 6(1990): 505–14.

Mas-Colell, A., M.D. Whinston, and J.R. Green. *Microeconomic Theory.* New York: Oxford University Press, 1995.

Seale, J.L., Jr., A. Sparks, and B.M. Buxton. "A Rotterdam Application to International Trade in Fresh Apples: A Differential Approach." *Journal of Agricultural and Resource Economics* 17(1992):138–49.

Theil, H. "The Information Approach to Demand Analysis." *Econometrica* 33(1965):67–87.

———. *The System-Wide Approach to Microeconomics.* Chicago: The University of Chicago Press, 1980.

Theil, H., and K.W. Clements. *Applied Demand Analysis Results from System-Wide Approaches.* Cambridge, MA: Ballinger Publishing Company, 1987.

Truett, L.J., and D.B. Truett. "The Demand for Imports in Korea: A Production Analysis Approach." *Journal of Development Economics* 56(1998):97–114.

U.S. Department of Labor, Bureau of Labor Statistics. *International Comparisons of Hourly Compensation Costs for Production Workers in Manufacturing 1975–2000.* September (2001). Internet site: ftp://ftp.bls.gov/pub/special.requests/ ForeignLabor/suootab.txt (Accessed December 15, 2001).

Zhang, P., S.M. Fletcher, and D.H. Carley. "Japan's Peanut Import Demand: Implications for United States Exports." *Agricultural Economics* 11(1994):51–59.

Zhou, M., and A.M. Novakovic. "Exporting to China: Possibilities and Challenges for U.S. Dairy Industry." *Agribusiness: An International Journal* 12(1996):1–13.

Zhu, Y., T. Cox, and J.P. Chavas. "Spatial Equilibrium Analysis of Trade Liberalization and the U.S. Dairy Sector." NRI grant 94-37400-0966, 1998. Internet site: http://aae.wisc.edu/ GlobalIMT/nri-gatt/ (Accessed August 25, 1999).