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A Rotterdam Application to International Trade in Fresh Apples: A Differential Approach

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A Rotterdam import allocation model is used to fit import data for fresh apples in four importing markets important to U.S. apple exporters. Nested tests rejected homotheticity but could not reject homogeneity, symmetry, or separability among import suppliers. A Monte Carlo test rejected first-order autocorrelation in each market. Expenditure and price elasticities are calculated and reported.

Key words: apples, elasticities, import demand, multistage budgeting, Rotterdam model, separability, Working's model.

Although United States apples were the third most valuable fruit crop in 1989 and the third most valuable fresh fruits export, little research exists on the import demand for fresh apples. Although two studies (i.e., Roberts and Cuthbertson; Atkin and Blanford) have analyzed United Kingdom (U.K.) import demand for fresh apples, neither dealt with the U.S. as a supplier. Roberts and Cuthbertson analyzed the import demand for fresh apples in the U.K. during the period 1959–69. Their analysis suggested that Australia was declining in importance as an exporter of fresh apples to that market. Atkin and Blanford analyzed the import demand by source for fresh apples in the U.K. for the years 1973–79. Their analysis demonstrated the strong emergence of France as the number one supplier of fresh imported apples into the U.K. Both trends (France increasing and Australia decreasing in importance) continued throughout the 1970s and 1980s as shown in the analysis that follows.

In this article, a Rotterdam import allocation model is used to fit import data for fresh apples in four importing markets important to U.S. apple exporters. Specifically, the model is used to estimate a geographic import demand system for fresh imported apples in Canada, Hong Kong, Singapore, and the U.K. A multistage budgeting or a utility tree approach (Barten 1977) is chosen by which a country first allocates total income between domestic and foreign (imported) goods. Total expenditure on imports is then allocated among imported goods and, finally, conditional on the expenditure for an imported good, among the different suppliers of each good. Preferences for imported goods are represented by blockwise dependence (Theil) which allows one to estimate the geographic import demand subsystem for fresh apples independent of the import demand for all other imports. The conditional import demand system is derived from the differential approach and is parameterized according to the Rotterdam model specification. Tests for homogeneity, symmetry, autocorrelation, homotheticity, and separability among suppliers are performed, and results are reported for each market. From the estimated parameters of the model, conditional expenditure and price elasticities are calculated and reported. These elasticities measure the effect on import shares among import apple suppliers when expenditure for total apple imports changes and when prices of fresh imported apples from different geographic locations change, respectively. Income elasticities of demand for fresh imported apples as a group and by sources of imports are calculated using Working's model. Finally, conclusions from the study are summarized.

Methodology

The differential approach has been widely applied to estimate consumer demand (e.g., Barten 1977; Deaton; Theil; Theil and Clements 1987) but less frequently in estimating import demand. Three notable exceptions

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are Theil and Clements (1978), Clements and Theil, and more recently Lee, Seale, and Jierwiriyapant. Theil and Clements (1978) used the differential approach to production theory to estimate derived import demand for four aggregate import groupings, while Clements and Theil used this approach to estimate geographic import demand for 13 individual plus four groupings of countries for three broad categories of imports (food, raw materials, and manufactures) under the assumption of homothetic technology (Hickman and Lau). Lee, Seale, and Jierwiriyapant followed the approach by Barnett, using the differential approach to utility maximization to estimate Japanese import demand for five types of fresh fruits and also the geographic import demand for citrus juices. All three studies used the Rotterdam model for estimation purposes.

In this study we, too, estimate geographic import demand via the Rotterdam model, but, following Mountain, we treat each of four importing countries as an individual (representative) consumer. Mountain showed that in this case the Rotterdam model, like other popular flexible functional form models (e.g., translog, generalized Cobb–Douglas, and generalized Leontief), is at least a second-order approximation of the underlying demand system. Accordingly, the criticism that all expenditure and own-price elasticities must be unitary if the Rotterdam model's parameters are constant is incorrect.[1]

In our analysis, we utilize multistage budgeting as a means by which an importing country allocates expenditures first between domestic and imported goods, next among imported goods, and finally among geographic producers of each good. This method, also referred to as the utility tree approach (Barten 1977), is easily accommodated by the differential approach to utility maximization and is useful when one wants to estimate the demand for disaggregated (imported) goods. The Rotterdam parameterization under the differential approach is attractive because it allows for nested testing of restrictions for homogeneity, symmetry, homotheticity, and strong separability (additive preferences). Another popular model, the Deaton–Muellbauer model, allows nested testing of the first three restrictions but not for strong separability. This is because if one could impose strong separability on the Deaton–Muellbauer model, it would not be nested with the nonseparable model.[2]

Conditional Geographic Import Demand System

One implication of block independence between domestic and imported goods is that an importing country's utility function is additive, and therefore domestic and imported goods are separable. This means that the marginal utility of an imported good depends only on the consumption of other imports. Thus, demand for imported goods can be estimated conditional on total import expenditure and independently of demand for domestic goods.

Imports are made up of $g = 1, \ldots, n$ groups, each group consisting of one good bought from n_g countries. The import allocation problem is first to allocate total expenditure, E, between domestic and imported goods (first stage), next to allocate total import expenditure, E_m, among all imported goods (second stage), and finally to allocate expenditure on each good, E_g, among the n_g supplying countries (third stage). Thus, E_i is expenditure spent on import g from source country i $(= 1, \ldots, n_g)$. The preference structure between stages two and three can be represented by blockwise dependence (Theil). This enables one to estimate the import demand for good g from the n_g countries conditional on E_g, the expenditure spent on imported good g. Estimation of the conditional import demand for good g from source i is useful when the researcher is interested in the effects on the conditional trade shares when the consumption volume of the group, S_g, changes due to a change in total income or when the relative prices for good g among sources change.

Let $q_1, \ldots, q_{n_g}$ and $p_1, \ldots, p_{n_g}$ represent quantities and prices of good g from the n_g source countries, and $W_g = E_g/E_m$ and $w_i = E_i/E_m$ represent the import shares of group S_g (i.e., good g) and of good g from source i, respectively. Define θ_{ij} such that $\theta_{ij} = (\mu/\phi E)p_i u^{ij} p_j$, where μ represents the marginal utility of income, u^{ij} is the i, jth element of U^{-1}, the inverse of the Hessian matrix for the utility function (Theil), and ϕ is the income flexibility or the reciprocal of the income elasticity of the marginal utility of income $(1/\phi = (d\mu/dE)E/\mu)$. Additionally, let $\theta_i = (\partial p_i q_i/\partial E)$ represent the marginal share of good g from i, $\Theta_{gh} = \Sigma_{i\in S_g} \Sigma_{j\in S_h} \theta_{ij}$, and $\Theta_g = \Sigma_h \Theta_{gh}$ $(g, h = 1, \ldots, G)$ represent the marginal import share of group S_g. From $E_g = \Sigma_{i\in S_g} E_i$, it follows that $W_g = \Sigma_{i\in S_g} w_i$. Following Theil, Chung, and Seale (sec. 6.6), it can be shown that the conditional differential import demand for good g from source $i \in S_g$ is

$$w_i^* d\log(q_i) = \theta_i^* d\log(Q_g) + \sum_{j\in S_g} \pi_{ij}^* d\log(p_j), \tag{1}$$

where $\theta_i^* = \theta_i/\Theta_{gg}$ is the conditional marginal import share for good $i \in S_g$, and p_i is the price of good g from country i such that, letting x_i represent either p_i or q_i, $d\log(x_i) = dx_i/x_i$. The π_{ij}^*s are conditional Slutsky price parameters, $d\log(Q_g) = \Sigma_{i\in S_g} w_i^* d\log(q_i)$ is the Divisia quantity index for S_g, and $w_i^* = w_i/W_g$. The adding-up condition requires $\Sigma_i \theta_i^* = 1$ $(i \in S_g)$ while homogeneity and symmetry require that $\Sigma_{j\in S_g} \pi_{ij}^* = 0$ and $\pi_{ij}^* = \pi_{ji}^*$, $i, j \in S_g$, respectively. By assuming θ_i^* and π_{ij}^* are constants, we obtain the conditional absolute price version of the Rotterdam model (Rotterdam A.P.),

$$\bar{w}^*_{it}Dq_{it} = \theta^*_i DQ_{gt} + \sum_{j\in S_g} \pi^*_{ij}Dp_{jt} + \epsilon_{it}, \tag{2}$$

where $\bar{w}^*_{it} = (w^*_{it} + w^*_{i,t-1})/2$ and $Dx_{it} = \log(x_{it}) - \log(x_{i,t-1})$ where x represents q, p, or Q_g.[3] To estimate the system of equations represented by equation (2), omit one equation and estimate the system's $n_g - 1$ equations. Parameter estimates are invariant to the equation omitted (Barten 1969), and the parameters of the omitted equation can be recovered from $\theta^*_{n_g} = 1 - \Sigma_{i\neq n_g} \theta^*_i$ (the adding-up condition) and from $\pi^*_{in_g} = -\Sigma_{i\neq n_g} \pi^*_{ij}$ (the homogeneity condition). With symmetry imposed, the $n_g - 1$ equations can be estimated jointly using an iterative seemingly unrelated regressions (SUR) technique.

Separability or preference independence (Theil) among supply sources of good g also can be imposed on equation (2). Under blockwise dependence, the conditional Slutsky price parameters are

$$\pi^*_{ij} = (\phi_{gg})\,(\theta^*_{ij} - \theta^*_i\theta^*_j), \tag{3}$$

where $\theta^*_{ij} = \theta_{ij}/\Theta_{gg}$ and $\phi_{gg} = (\phi\Theta_{gg})/W_g$ is the Frisch own-price elasticity of the group S_g (Theil, Chung, and Seale). When we impose strong separability within group S_g (using $\Sigma_{i\in S_g} \theta^*_{ij} = \theta^*_i$), $\theta^*_{ij} = \theta^*_i$ for $i = j \in S_g$ and 0 for $i \neq j \in S_g$. Accordingly,

$$\pi^*_{ij} = \begin{cases} \phi_{gg}\theta^*_i(1 - \theta^*_i) & \text{for } i = j \in S_g \\ -\phi_{gg}\theta^*_i\theta^*_j & \text{for } i \neq j \in S_g. \end{cases} \tag{4}$$

By summing the constrained π^*_{ij}s times the Dp_{jt}s over $j \in S_g$, we have

$$\sum_{i\in S_g} \pi^*_{ij}Dp_{jt} = \phi_{gg}\theta^*_i Dp_{it} - \phi_{gg}\theta^*_i\theta^*_i Dp_{it} - \sum_{j\neq i\in S_g} \phi_{gg}\theta^*_i\theta^*_j Dp_{jt}. \tag{5}$$

Factoring out $\phi_{gg}\theta^*_i$ and combining the second and third terms on the right yields

$$\sum_{i\in S_g} \pi^*_{ij}Dp_{jt} = \phi_{gg}\,\theta^*_i\left(Dp_{it} - \sum_{j\in S_g} \theta^*_j Dp_{jt}\right) = \phi_{gg}\theta^*_i D\left(\frac{p_{it}}{P^*_{gt}}\right), \tag{6}$$

where $P^*_{gt} = \Sigma_{j\in S_g} \theta^*_j Dp_{jt}$ is the Frisch price index of group S_g at time t.[4] The resulting conditional demand equation for good g from source i under blockwise dependence among groups but preference independence within group S_g is

$$\bar{w}^*_{it}Dq_{it} = \theta^*_i DQ_{gt} + \phi_{gg}\theta^*_i D\left(\frac{p_{it}}{P^*_{gt}}\right) + \zeta_{it}. \tag{7}$$

Because equation (7) is nested within equation (2), we can test for strong separability among sources of good g by estimating both of these equations and performing a likelihood ratio test.[5] We refer to equation (7) as the conditional Rotterdam P.I. (preference independence) model.

Data, Procedures, and Results

The four U.S. export markets for fresh apples chosen for study were Canada, Hong Kong, Singapore, and the U.K. These markets imported 56% of all U.S. fresh apple exports in 1987. Canada is by far the largest market, purchasing 37% of all U.S. fresh apple exports; Hong Kong, Singapore, and the U.K. imported 11%, 5%, and 3%, respectively, of U.S. apple exports in 1987.

The period of analysis was 1962 through 1987.[6] During this period, U.S. apple exports to Canada, Hong Kong, and Singapore increased significantly; those to the U.K. increased more modestly. Expenditure and quantity import data in each market by source for fresh apples, SITC 051.4, were obtained from the United Nations Trade Data Tape, 1962–87. Because of our interest in import demand for U.S. fresh apples, the U.S. was included for analysis in each market. The export suppliers chosen for analysis in the four markets were as follows: South Africa, U.S., and Rest of the World (ROW) for Canada; Australia, China, U.S., and ROW for both Hong Kong and Singapore; and Australia, France, New Zealand, U.S., and ROW for the U.K.[7] Because these markets, although important to the U.S., account for only one-quarter of world imports of fresh apples, import prices of apples by source were treated as exogenously determined. Accordingly, a Newton–Ralphson maximum likelihood algorithm was used to estimate the import demand for fresh apples by source via the Rotterdam A.P. model [equation (2)] and the Rotterdam P.I. model [equation (7)]. This procedure is esentially an iterative seemingly unrelated regressions (SUR) technique. The NLS (nonlinear least squares) with Newton–Ralphson option and ANALYZ procedures

Table 1. Log of Likelihood Functions for Rotterdam Model under Different Restrictions

Restrictions (1)	Import Markets: Canada (2)	Hong Kong (3)	Singapore (4)	United Kingdom (5)
Free Rotterdam	72.04 (8)[a]	129.96 (15)	121.93 (15)	243.40 (24)
Homogeneity	71.30 (6)	127.83 (12)	121.08 (12)	242.95 (20)
Symmetry	70.99 (5)	126.61 (9)	119.91 (9)	240.00 (14)
Unitary Expenditure Elasticities	56.64 (3)	109.62 (6)	100.41 (6)	227.87 (10)
Separability	70.82 (4)	122.37 (4)	117.63 (4)	232.40 (5)
Unitary Expenditure Elasticities	45.75 (1)	100.07 (1)	94.32 (1)	214.98 (1)

[a] The number of free parameters for each model are in parentheses.

of Gaussx (Breslow), a shell program for Gauss (Aptech Systems, Inc.), were used to estimate model parameters, expenditure elasticities, price elasticities, and their associated asymptotic standard errors.

Testing Restrictions and Goodness-of-Fit

The Rotterdam A.P. model [equation (2)] was estimated with no restrictions, with homogeneity imposed, and with homogeneity and symmetry imposed. The logs of the concentrated likelihood functions for each of the four importing markets under these three conditions are reported in rows (1)–(3), columns (2)–(5) of table 1. Figures in parentheses in the table are the number of free parameters for each of these specified conditions. Because the free and homogeneous Rotterdam models are nested, minus twice the log ratio of the respective concentrated likelihood functions is asymptotically distributed as χ^2 with q degrees of freedom, q representing the number of restrictions (difference between numbers in parentheses). Symmetry (with homogeneity imposed) is tested with respect to the homogeneous model. For all markets, homogeneity and symmetry cannot be rejected. Accordingly, we impose both homogeneity and symmetry and test for first-order autocorrelation using a Monte Carlo test for a system of equations developed by Theil and Shonkwiler. First-order autocorrelation is rejected for all markets. Since the Rotterdam model fits data in first differences, this is not surprising.

Armington developed the framework for a world trade model in which he suggested imposing homotheticity (unitary import expenditure elasticities) for sources of an imported good. This restriction can be imposed on the symmetric Rotterdam A.P. model as well as the separable Rotterdam P.I. model. In both cases, this was accomplished by replacing the marginal import share of i (θ^*_{it}) in equations (2) and (7) with the average import share of i ($\bar{w}^*_{it}$) in each time period. Nested χ^2 tests—based on minus twice the log ratio of the concentrated likelihood functions (i.e., divide that of the symmetric Rotterdam A.P. model with homotheticity imposed by that of the symmetric Rotterdam A.P. model) and the number of restrictions—rejected unitary expenditure elasticities (homotheticity) for each market.

Although Armington did not explicitly suggest imposing separability among sources of an imported good, he implicitly did so by utilizing a constant elasticity of substitution specification for that stage. This restriction (separability) can be tested in the above manner because the Rotterdam A.P. and P.I. models (as shown above) are nested. The logs of the concentrated likelihood functions with separability imposed are reported in row (5) of table 1. Separability cannot be rejected for any market. Further, when homotheticity is imposed on the separable model (as described above), it is rejected in all four import markets. Empirical evidence on separability among suppliers of imports is mixed. Winters rejected separability between one source and all other sources of U.K. aggregated manufactures imports for seven of 10 cases while Alston et al. found mixed evidence for selected wheat and cotton import markets.

Single-equation measures of R^2 are not appropriate in measuring the goodness-of-fit of a system of equations. Several systemwide R^2s have been suggested in the literature (e.g., Buse; Glahn); here we use one suggested by McElroy. Essentially, this R^2, which we call R^2_W, can be related to a Wald test, corrected for degrees of freedom, with restrictions that all parameters are zero:

$$R^2_W = 1 - \frac{1}{1 + W^*/(T - k)(n - 1)}, \tag{8}$$

where W^* is the Wald test statistic, T is the number of observations, k is the number of regressors in each equation, and n is the number of equations in the full system (Bewley, p. 188). As we must omit one equation to estimate our demand system, it must be noted that R^2_W is not invariant with respect to

Table 2. Parameter Estimates of Canadian Import Allocation Model for Fresh Apples, 1964-86

	Rotterdam A.P.[a]				Rotterdam P.I.[b]	
	Conditional Slutsky Coefficients, π_{ij}^*			Conditional Marginal Shares, θ_i^*	Conditonal Marginal Shares, θ_i^*	Frisch Own-Price Elasticity, Imported Apples, ϕ_{gg}
Exporting Country (1)	U.S. (2)	South Africa (3)	ROW[c] (4)	(5)	(6)	(7)
U.S.	−.084	.042	.042	.790	.779	−.558
	(.053)[d]	(.022)	(.049)	(.079)	(.071)	(.228)
South Africa		−.058	.016	.108	.116	
		(.018)	(.016)	(.055)	(.048)	
ROW			−.058	.101	.104	
			(053)	(.061)	(.061)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

the equation omitted. Because we are least interested in results for ROW, the R_W^2s are calculated for both the Rotterdam A.P. and P.I. models for each market when the ROW equation is omitted. The R_W^2 values for the Rotterdam A.P. and P.I. models, respectively, are .93 and .97 for Canada, .83 and .77 for Hong Kong, .76 and .80 for Singapore, and .64 and .57 for the U.K. These results indicate a reasonably good fit for three (Canada, Hong Kong, and Singapore) of the four markets.[8]

Conditional Marginal Import Shares and Expenditure Elasticities

The conditional marginal import shares indicate the share of an additional dollar allocated among imported apple suppliers when that dollar is added to expenditures on all apple imports. Their estimates and associated asymptotic standard errors for both the Rotterdam A.P. and P.I. models are reported in the second and third columns from the far right of tables 2–5. The estimated marginal shares are all positive except for the case of the Rotterdam A.P. model in the U.K. market where that of Australia is negative,

Table 3. Parameter Estimates of Hong Kong Import Allocation Model for Fresh Apples, 1963-87

	Rotterdam A.P.[a]					Rotterdam P.I.[b]	
	Conditional Slutsky Coefficients, π_{ij}^*				Conditional Marginal Shares, θ_i^*	Conditional Marginal Shares, θ_i^*	Frisch Own-Price Elasticity, Imported Apples, ϕ_{gg}
Exporting Country (1)	U.S. (2)	China (3)	Australia (4)	ROW[c] (5)	(6)	(7)	(8)
U.S.	−.476	.327	.062	.087	.436	.568	−1.264
	(.156)[d]	(.095)	(.074)	(.112)	(.110)	(.082)	(.400)
China		−.139	−.073	−.115	.274	.192	
		(.102)	(.047)	(.081)	(.094)	(.096)	
Australia			−.086	.097	.109	.075	
			(.059)	(.063)	(.053)	(.042)	
ROW				−.069	.181	.165	
				(.129)	(.082)	(.085)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

Table 4. Parameter Estimates of Singapore Import Allocation Model for Fresh Apples, 1963–87

Exporting Country (1)	Rotterdam A.P.[a] Conditional Slutsky Coefficients, π^*_{ij} U.S. (2)	China (3)	Australia (4)	ROW[c] (5)	Conditional Marginal Shares, θ^*_i (6)	Rotterdam P.I.[b] Conditional Marginal Shares, θ^*_i (7)	Frisch Own-Price Elasticity, Imported Apples, ϕ_{gg} (8)
U.S.	−.215 (.071)[d]	.088 (.053)	.135 (.050)	−.088 (.048)	.189 (.087)	.246 (.089)	−.598 (.216)
China		−.093 (.067)	−.018 (.040)	.022 (.054)	.182 (.073)	.148 (.075)	
Australia			−.158 (.062)	.041 (.046)	.545 (.102)	.510 (.096)	
ROW				−.055 (.066)	.085 (.080)	.096 (.067)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

albeit insignificant (α = .05); with the Rotterdam P.I. model, the estimated marginal import share of Australian apples in this market is positive, insignificant (α = .05), and close to zero. In three of the markets, the individual supplying country nearest to the market has the largest estimated marginal share (i.e., U.S. for Canada, Australia for Singapore, and France for the U.K.). This indicates the importance of proximity of the supplier to these apple-importing markets. In the Hong Kong market, the U.S. has the largest marginal share although China is closer to Hong Kong than is the U.S. This can be explained partially due to China's erratic behavior in export markets.

In the Canadian market, the estimated Rotterdam A.P. and P.I. marginal import shares are similar, with those of the U.S. approximately .8. This means that if Canada spent one additional dollar on fresh apple imports, 80¢ would go towards purchasing U.S. fresh apples. In Hong Kong, the U.S. again has the largest estimated marginal import shares for both the A.P. (.4) and P.I. (.6) models; the supplier with the

Table 5. Parameter Estimates of United Kingdom Import Allocation Model for Fresh Apples, 1963–87

Exporting Country (1)	Rotterdam A.P.[a] Conditional Slutsky Coefficients, π^*_{ij} U.S. (2)	New Zealand (3)	Australia (4)	France (5)	ROW[c] (5)	Conditional Marginal Shares, θ^*_i (7)	Rotterdam P.I.[b] Conditional Marginal Shares, θ^*_i (8)	Frisch Own-Price Elasticity, Imported Apples, ϕ_{gg} (9)
U.S.	−.052 (.026)[d]	.012 (.012)	.036 (.028)	.012 (.019)	−.008 (.029)	.146 (.051)	.122 (.044)	−.167 (.133)
New Zealand		−.015 (.013)	−.036 (.018)	−.008 (.018)	.048 (.024)	.123 (.051)	.146 (.056)	
Australia			−.120 (.055)	−.004 (.025)	.125 (.048)	−.134 (.069)	.008 (.061)	
France				−.066 (.052)	.067 (.045)	.403 (.135)	.434 (.120)	
ROW					−.231 (.077)	.461 (.121)	.289 (.111)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

Table 6. Canadian Expenditure and Price Elasticities of Import Demand for Fresh Apples by Source Estimated at Sample Means, 1964-86

Exporting Country	Expenditure Elasticities		Cournot Own-Price Elasticities		Cournot Cross-Price Elasticities		
	A.P.[a]	P.I.[b]	A.P.	P.I.	U.S.	South Africa	ROW[c]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
U.S.	1.04	1.02	−.90	−.91	—	−.03	−.11
	(.10)[d]	(.09)	(.07)	(.07)		(.03)	(.07)
South Africa	1.38	1.48	−.85	−.85	−.52	—	−.02
	(.70)	(.61)	(.25)	(.24)	(.55)		(.26)
ROW	.63	.65	−.46	−.43	−.22	.05	—
	(.38)	(.38)	(.37)	(.29)	(.25)	(.10)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

second largest marginal import shares is China at .3 and .2 for the A.P. and P.I. models, respectively. Australia is the dominant source of imported fresh apples in the Singapore market with marginal import shares of .5; the U.S. marginal import shares are both approximately .2, while those of China are .2 for the A.P. model and .1 for the P.I. model. The results for the U.K. market support earlier findings by Roberts and Cuthbertson and by Atkin and Blanford: Australia is no longer an important supplier of fresh imported apples into the U.K., and France is the dominant supplier (with marginal import shares of .4). The U.S. and New Zealand have marginal import shares of similar size at approximately .1.

Conditional expenditure elasticities are calculated at the sample means by dividing the conditional marginal import shares by the mean of the average import shares [i.e., $\theta_i^*/\bar{w}_i^*$, where $\bar{w}_i^* = (1/T)\Sigma_t \bar{w}_{it}^*$] and are reported in columns (2) and (3) of tables 6–9. These elasticities are conditional on expenditures for imported apples and indicate the percentage response in quantities demanded from each of the suppliers which would result from a 1% increase in total fresh apple import expenditure. Because separability was not rejected, the estimates from the P.I. model are probably more precise.

The point estimates of the expenditure elasticities in the Canadian market suggest U.S. fresh apple imports are unitary elastic, South Africa's are elastic (1.4 and 1.5 for A.P. and P.I. models, respectively), while ROW's are inelastic (.6 for A.P. and .7 for P.I.). These results indicate that the U.S. import shares would remain relatively constant in an expanding Canadian import market for fresh apples; South Africa's would increase while that of ROW would decline.[9]

Table 7. Hong Kong Expenditure and Price Elasticities of Import Demand for Fresh Apples by Source Estimated at Sample Means, 1963-87

Exporting Country	Expenditure Elasticities		Cournot Own-Price Elasticities		Cournot Cross-Price Elasticities			
	A.P.[a]	P.I.[b]	A.P.	P.I.	U.S.	Australia	China	ROW[c]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
U.S.	1.09	1.42	−1.62	−.134	—	.04	.54	−.04
	(.27)[d]	(.20)	(.33)	(.25)		(.20)	(.27)	(.31)
Australia	1.01	.69	−.90	−.88	.17	—	−.93	.66
	(.49)	(.39)	(.56)	(.46)	(.58)		(.49)	(.61)
China	1.07	.75	−.82	−.95	.84	−.40	—	−.70
	(.36)	(.37)	(.44)	(.45)	(.32)	(.20)		(.33)
ROW	.77	.71	−.48	−.91	.06	.33	−.69	—
	(.35)	(.37)	(.58)	(.50)	(.41)	(.28)	(.37)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

Table 8. Singapore Expenditure and Price Elasticities of Import Demand for Fresh Apples by Source Estimated at Sample Means, 1963-87

Exporting Country (1)	Expenditure Elasticities A.P.[a] (2)	Expenditure Elasticities P.I.[b] (3)	Cournot Own-Price Elasticities A.P. (4)	Cournot Own-Price Elasticities P.I. (5)	Cournot Cross-Price Elasticities U.S. (6)	Cournot Cross-Price Elasticities Australia (7)	Cournot Cross-Price Elasticities China (8)	Cournot Cross-Price Elasticities ROW[c] (9)
U.S.	.93	1.21	−1.25	−.79	—	.32	.26	−.26
	(.43)[d]	(.43)	(.37)	(.32)		(.25)	(.27)	(.26)
Australia	1.48	1.38	−.97	−.91	.07	—	−.33	−.24
	(.28)	(.26)	(.17)	(.16)	(.16)		(.12)	(.15)
China	.94	.77	−.66	−.54	.27	−.44	—	−.11
	(.38)	(.39)	(.36)	(.23)	(.30)	(.22)		(.30)
ROW	.36	.41	−.32	−.32	−.11	.04	.03	—
	(.34)	(.29)	(.30)	(.23)	(.23)	(.20)	(.24)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

In Hong Kong, the point estimates of the P.I. model suggest expenditure elastic demand (1.4) for U.S. fresh apples but inelastic demand for all other sources (.7 for Australia and ROW, and .8 for China). The P.I. expenditure elasticity estimate of U.S. apples in Singapore is also elastic (1.2), but the A.P. elasticity estimate is inelastic (.9). Australia's apples are elastic (1.4 for P.I.), while those of China (.8 for P.I. and .9 for A.P.) and ROW (.4) are inelastic.

Three source countries (U.S., France, and New Zealand) face expenditure elastic import demand in the U.K. for their apples, while two (Australia and ROW) face expenditure inelastic import demand. The U.S. point estimates (2.8 for the P.I. and 3.4 for the A.P. models) are more elastic than those of any other country, followed by those of New Zealand and France. Australia's expenditure elasticity estimates are essentially zero for the P.I. model and negative (−1.0) for the A.P. model.

Price Parameters and Elasticity Estimates

The conditional Slutsky parameter estimates of the symmetric Rotterdam A.P. model for each of the four import markets are presented in tables 2–5 starting at column (2). Due to symmetry, the bottom half (not shown) is a mirror image of the top half. All own-price parameters (along the diagonal) in all four import markets are negative as expected. As the price of fresh apple imports from a supplying country increases, the amount of fresh apple imports demanded from that country declines. The signs of the off-diagonal Slutsky coefficients indicate substitution ($\pi^*_{ij} > 0$) or complementarity ($\pi^*_{ij} < 0$) between apples of different sources *à la* Hicks. Results from the A.P. model would indicate pairwise Hicksian substitution between apples from the exporting countries to Canada. For Hong Kong, apples from China are Hicksian complements with apples from Australia and ROW; however, these Slutsky parameters are insignificant at $\alpha = .05$. All other apples into Hong Kong are Hicksian substitutes. In Singapore, apples from China and Australia again are indicated to be Hicksian complements as well as apples from the U.S. and ROW; however, asymptotic standard errors for the estimates are large. All other cross-price Slutsky estimates indicate Hicksian substitution for Singapore. In the U.K., U.S. apples are indicated to be Hicksian substitutes with other apple imports except ROW apples. The signs of the Slutsky parameters indicate apple imports from Australia and New Zealand are Hicksian complements for French apples but these estimates have large standard errors.

The results indicating Hicksian complementarity should be interpreted with caution since only Australian and New Zealand imported apples into the U.K. were significantly shown to be Hicksian complements. All other estimates indicated Hicksian substitution or insignificant results. Additionally, it should be remembered that separability could not be rejected, casting further doubt on the estimates for the cross-price terms.

The Frisch-deflated own-price elasticity (ϕ_{gg}) for the group, imported apples, was estimated for each market using the P.I. model; results are reported in the last column of tables 2–5. The point estimates were similar (−.6) and significant ($\alpha = .05$) for Canada and Singapore; that of Hong Kong was greater than one absolutely (−1.3), while that of the U.K. was −.2 but insignificant. These point estimates indicate

Table 9. United Kingdom Expenditure and Price Elasticities of Import Demand for Fresh Apples by Source Estimated at Sample Means, 1963–87

	Expenditure Elasticities		Cournot Own-Price Elasticities		Cournot Cross-Price Elasticities				
Exporting Country (1)	A.P.[a] (2)	P.I.[b] (3)	A.P. (4)	P.I. (5)	U.S. (6)	Australia (7)	France (8)	New Zealand (9)	ROW[c] (10)
U.S.	3.39	2.82	−1.35	−.54	—	.37	−.91	.03	−1.52
	(1.19)[d]	(1.02)	(.61)	(.28)		(.63)	(.51)	(.27)	(.98)
Australia	−.98	.06	−.75	−.02	.30	—	.31	−.19	1.30
	(.50)	(.45)	(.38)	(.13)	(.21)		(.21)	(.13)	(.50)
France	1.16	1.25	−.59	−.55	−.02	−.17	—	−.11	−.27
	(.39)	(.35)	(.17)	(.15)	(.06)	(.09)		(.06)	(.23)
New Zealand	1.64	1.95	−.33	−.42	.09	−.71	−.68	—	−.01
	(.69)	(.61)	(.16)	(.15)	(.17)	(.25)	(.29)		(.51)
ROW	1.16	.73	−.79	−.38	−.07	.16	−.24	.03	—
	(.31)	(.28)	(.27)	(.15)	(.07)	(.11)	(.12)	(.06)	

[a] A.P. = absolute price version with homogeneity and symmetry imposed.
[b] P.I. = preference independence version.
[c] ROW = rest of the world.
[d] Asymptotic standard errors are in parentheses.

inelastic Frisch own-price import demand for fresh apples as a group in Canada, Singapore, and the U.K. but elastic demand in Hong Kong.

Conditional Slutsky (compensated) price elasticities can be calculated at the sample mean by dividing the Slutsky parameters by the mean of the average import shares (i.e., $\pi^*_{ij}/\bar{w}^*_i$). These elasticities indicate the percentage response in quantities demanded resulting from a 1% change in price, holding real expenditures on imported apples constant. Conditional Cournot (uncompensated) price elasticities are calculated from $C_{ij} = \pi^*_{ij}/\bar{w}^*_i - \theta^*_i\bar{w}^*_j/\bar{w}^*_i$, holding nominal income constant, and reflect both substitution and income effects from price changes. Frisch price elasticities (holding the marginal utility of income constant) can be obtained from $F_{ij} = v^*_{ij}/\bar{w}^*_i$, where $v^*_{ij} = \pi^*_{ij} + \phi_{gg}\theta^*_i\theta^*_j$, and ϕ_{gg} is the Frisch own-price elasticity of the group (i.e., imported apples). To estimate this, one could use the estimate ϕ_{gg} from the P.I. model. Slutsky price elasticities relate to the Hicksian demand curve, while Cournot price elasticities relate to the Marshallian demand curve. Here we report only the Cournot estimates, but for both the A.P. and P.I. models. Own-price elasticities are reported in columns (4) and (5) of tables 6–9, while cross-price elasticities from the A.P. model are reported starting in column (6) through the last column in these tables.

All Cournot own-price elasticities are negative in all four markets. In almost every case, the corresponding asymptotic standard errors of the P.I. model are smaller than those of the A.P. model. For Canada, the A.P. and P.I. own-price elasticities are essentially the same; those of the U.S. and South Africa are both significant ($\alpha = .05$) and approximately −.9. The estimates for ROW are −.5 (A.P.) and −.4 (P.I.). None of the Cournot cross-price elasticities of Canadian import demand are significantly different from zero.

In the Hong Kong market, only apple imports from the U.S. have Cournot own-price elasticities greater than unitary (−1.6 for A.P. and −1.3 for P.I.); all others are near to or less than unity. The own-price estimates for Australian apples are −.9, those for Chinese apples are −.9 for the A.P. and −1.0 for the P.I. models, and those for ROW apples are −.5 (A.P.) and −.9 (P.I.). Four Cournot cross-price elasticities (all involving Chinese apples) are significantly different from zero ($\alpha = .05$): U.S. apples with respect to Chinese apples (.5), Chinese apples with respect to U.S. apples (.8), Chinese apples with respect to Australian apples (−.4), and Chinese apples with respect to ROW apples (−.7).

In Singapore, the P.I. own-price elasticities are significantly different from zero except in the case of ROW; all point estimates are inelastic: −.9 for Australia, −.8 for the U.S., −.5 for China, and −.3 for ROW. The A.P. estimates are all higher than or the same as (in absolute terms) those of the P.I. model. Only cross-price elasticities of Chinese apples with respect to Australian apples (−.4) and Australian apples with respect to Chinese apples (−.3) are significantly different from zero ($\alpha = .05$). No cross-price estimates are greater than $|.5|$.

Cournot own-price elasticities of import demand in the U.K. from the P.I. model are all inelastic: −.5 for the U.S., −.6 for France, −.4 for New Zealand and ROW, and approximately zero for Australia. The A.P. own-price estimates are all higher than those of the P.I. model except for New Zealand's, which is only slightly lower (−.3); the A.P. own-price estimate for U.S. apples is elastic (−1.4). Four Cournot cross-price elasticities are significantly different from zero (α = .05): Australian apples with respect to ROW apples (1.3), New Zealand's apples with respect to Australian apples (−.7), New Zealand's apples with respect to French apples (−.7), and ROW apples with respect to French apples (−.2).

Income Elasticities of Demand for U.S. Fresh Apples

Although the focus of this article is to estimate an import demand system conditional on total expenditure for imported fresh apples, in this section we report efforts (albeit crude) to obtain unconditional income elasticities of demand for imported apples as a group and also income elasticities of demand for U.S. imported apples. Because the budget share of imported apples is so small relative to that of all other goods and because of the difficulty involved with obtaining a Divisia volume index and a meaningful price index for all other goods, the Working model was chosen for analysis. This model postulates that the budget share of good g is a linear function of the log of total real expenditure:

(9) $$W_g = \alpha_g + \beta_g \log(M) + \epsilon_g,$$

where $W_g = E_g/E$ is the budget share of good g (= 1, . . . , n), M is total real expenditure (income), and $\epsilon_g \sim N(0, \sigma^2)$. The data for total real expenditure are those reported for real personal consumption in the *World Tables* (World Bank). The marginal share of good g in Working's model is equal to $W_g + \beta_g$; accordingly, the income elasticity of demand for good g is $(W_g + \beta_g)/W_g = 1 + (\beta_g/W_g)$. Note that a good is a necessity if $\beta_g < 0$, a luxury if $\beta_g > 0$, and unitary elastic if $\beta_g = 0$. For the four markets studied, the income elasticities of demand for the group, imported apples, calculated at the sample means are (with asymptotic standard errors in parentheses) 2.6 (.3) in Canada, .3 (.1) in Hong Kong, .8 (.1) in Singapore, and 1.4 (.3) in the U.K. This evidence indicates that imported apples are income elastic in Canada and the U.K., but income inelastic in Hong Kong and Singapore. Because Working's model implicitly assumes constant prices over the period of study, these elasticities should be considered rough estimates only. However, a literature search did not result in finding previously reported estimates for imported apples as a group.

The conditional expenditure elasticities of import demand for fresh apples from the different suppliers can be converted into unconditional income elasticities of demand by multiplying the income elasticity of demand for the group (imported fresh apples) times the conditional expenditure elasticity of demand for imported fresh apples from the different suppliers. Here we only report the unconditional income elasticities for the U.S. in each of the four markets based on the P.I. estimates: 2.7 for Canada, .5 for Hong Kong, 1.0 for Singapore, and 3.8 for the U.K. Again, these are "rough" estimates and should not be considered definitive.

Conclusions and Implications

A geographic Rotterdam import allocation model was used to fit data for fresh apple imports in four importing markets. Nested tests rejected homotheticity but could not reject homogeneity, symmetry, or separability among imported apple suppliers. A Monte Carlo test rejected first-order autocorrelation. Criteria such as goodness-of-fit measures, significance levels of estimated marginal import shares and expenditure elasticities, signs of own-price Slutsky parameters and Cournot own-price elasticities indicated that the model fit the data reasonably well. Excluding results for the group, ROW, 44 of 48 estimated marginal import shares and conditional expenditure elasticities were significantly different from zero (α = .05). All Slutsky own-price parameters and Cournot own-price elasticities were negative; 20 of 24 Cournot own-price elasticities were significantly different from zero. For the preference independence version of the Rotterdam model, only the U.K. estimate of the Frisch-deflated own-price elasticity for the group (ϕ_{gg}) was insignificant.

Results indicate that all included apple suppliers to Canada, Hong Kong, Singapore, and the U.K. (except Australia in the U.K. market) should increase apple exports if expenditure for imported fresh apples in these markets increases. Based on the P.I. point estimates for expenditure elasticities, a 1% increase in imported fresh apple imports would increase demand for U.S. fresh apple imports by more than 1% in the Hong Kong, Singapore, and U.K. markets, and by about 1% in the Canadian market. From this 1% increase, fresh apples from South Africa to Canada (if the ban on South African imports is lifted), from Australia to Singapore, and from France and New Zealand to the U.K. also would be expected to increase by more than 1%. Only apples from South Africa to Canada and from Australia to Singapore were more expenditure elastic than apples from the U.S. in these four markets. U.S. apples also tended to be more price elastic than the other apples. The exception was Australian apples in the

Singapore market; the P.I. own-price elasticities for France and the U.S. were essentially the same in the U.K. market.

As with most research, this article raises important questions left unanswered. One is the effect Chile's relatively recent entry into world apple markets has had or may have in the future on import consumption patterns in these four markets. To date, however, Chile remains a small exporter in share terms to these markets. Another possibly fertile area for future study would be to explore whether use of semiannual data (if available) may better explain demand relationships between apple exporters in the Northern versus Southern Hemispheres. Finally, estimation of demand for imported apples as a group certainly could be extended and improved.

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Notes

[1] This argument, which is correct only under stringent and unrealistic conditions, began with McFadden and was furthered by both Yoshihara and Phlips. Barnett showed this argument to be false for an aggregate Rotterdam model based on a per capita, random coefficients model; Mountain showed it to be false for an individual consumer.

[2] Winters developed an unnested test for separability using the Deaton–Muellbauer model. More recently, Alston et al. used this same procedure to test for separability.

[3] Note that the right-hand side of equation (2) is identical to the first-difference version of the Deaton–Muellbauer model.

[4] The Frisch own-price elasticity of demand for the group measures the percentage change in demand for all apple imports when the group price changes by 1%, holding the marginal utility of income constant.

[5] Using this method, Deaton tested for separability among four broad groups of consumer goods with U.K. data.

[6] The exception is for Canada where we utilize data from 1963 through 1986. This is because South Africa, the second largest source of imported apples to Canada, did not export apples to Canada in 1962 or in 1987.

[7] Chile, although now emerging as an important exporter of fresh apples, did not start exporting to these four markets until the middle to late 1970s and is still a relatively small exporter to all four markets. For these reasons, Chile is included in ROW.

[8] In the case of the U.K. market, the R^2_W measures are approximately .9 when the U.S., Australia, or New Zealand equations are omitted for estimation purposes.

[9] In 1987, Canada banned imports from South Africa for political reasons. Until Canada lifts the ban, South Africa's market share obviously will be zero.

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