Source Diversification and Import Price Risk

Andrew Muhammad

In this article, I present a theoretical framework and derive an empirical model that relates import price risk to the allocation of an import across exporting sources (source diversification). A differential approach to expected utility theory and firm demand is used to derive a model comparable to more popular demand systems such as the Rotterdam and AIDS models. The model is used in estimating carnation demand in the United Kingdom. Results show that while total carnation imports, expected prices and seasonality are important determinants of import demand by source, there is significant information loss when price risk is not considered.

Key words: differential approach, import demand, price risk, Rotterdam model, source differentiation.

JEL Codes: D81, F14, Q11, Q17.

Since Armington's (1969) seminal paper highlighting the importance of country of origin and the imperfect substitutability of a product across supplying countries, demand analyses of products differentiated by source have become commonplace in the economics literature. The fundamental assumption of Armington is that factors unique to country of origin cause a product to be somewhat different across countries. This assumption has allowed for examining the competition among exporting countries, and more importantly, the estimation of source-specific price effects for a given product in destination markets. Clearly, an understanding of how a commodity's price in country *j* affects exports from *j* and other competing countries is fundamental to projecting the outcome of price-distorting trade policies.

Although the Armington framework is commonly applied to analyses of agricultural imports, the reasons for source differentiation are not always obvious. For products like wine, source differentiation is clearly plausible because country of origin is an important product attribute (Seale, Marchant, and Basso 2003; Carew, Florkowski, and He 2004; Muhammad 2011). However, source differentiation has also been assumed for commodities like wheat (Alston et al. 1990; Koo, Mao, and Sakurai 2001), meats (Yang and Koo 1994; Mutondo and Henneberry 2007), whey (Washington and Kilmer 2002), butter (Muhammad and Kilmer 2008), cotton (Arnade, Pick, and Vasavada 1994), and apples (Seale, Sparks, and Buxton 1992). It could be argued that source differentiation is misapplied in these studies, particularly given the use of consumer-based demand systems such as the Almost Ideal Demand System (AIDS) and Rotterdam model for empirical analysis. For many agricultural products, it is difficult to conceptualize how consumer preferences can differ by source when product attributes are not necessarily source specific. Nevertheless, trade statistics show that countries often import a product from multiple sources even when it is relatively homogeneous and the price in one country is consistently less than prices in other countries (Wolak and Kolstad 1991). As noted by MacLaren (1990), this is a phenomenon that cannot be explained by trade models of homogeneous goods.

The empirical specifications used to model import demand by source have been rather basic. Quantity demanded disaggregated by source is usually specified as a system where the aggregate expenditure across all sources and source-specific prices are typically the only explanatory variables. While these specifications have been empirically successful in that prices and aggregated expenditure often

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explain a significant portion of the variability in quantity demanded, other factors unique to source are seldom considered (Davis 1995). One factor that is overlooked is import price risk. Similar to prices, price risk could also be source specific, vary overtime, and affect how an import is allocated across supplying countries.

According to Wolak and Kolstad (1991), the allocation of an import across exporting sources could be a diversification strategy used by firms to reduce the risk associated with unexpected fluctuations in import prices. Put differently, in purchasing a commodity from multiple countries, firms are diversifying away the price risk associated with relying on a single exporter. In this article, a theoretical framework is presented and an empirical model is derived that relates price risk (the unexplained variance in import prices) to the allocation of an import across supplying countries. The primary goal is to show that the competitiveness of an exporting country depends on price risk as well as prices.

While the list of studies focusing on import demand by source is quite extensive, the role of risk in the allocation process has received little attention in the literature. Many studies have examined the effects of risk on import demand but have focused on aggregate trade flows (e.g., Anderson and Garcia 1989; Pick 1990; Appelbaum and Kohli 1997; Langley et al. 2000; Cho, Sheldon, and McCorriston 2002; Appelbaum and Woodland 2010). A search of the literature resulted in only two studies that examined the relationship between source diversification and import price risk: Wolak and Kolstad (1991) and Seo (2001). Neither study proposed an empirical model as easy to implement as the AIDS or Rotterdam models which have particularly long histories and are often used to model import demand. However, Wolak and Kolstad (1991) do provide a theoretical framework for an importing firm facing price risk, which is used in this article to derive an empirical specification comparable to more popular demand systems allowing for practicable estimation of import demand.

In the following section, I show that the optimal allocation of an import across exporting sources can be specified as the outcome of an expected utility problem that is the first stage of a two-stage profit maximization procedure. Assuming a general functional form for expected utility and import demand, a differential approach procedure similar to Theil (1977, 1980), Laitinen (1980), and Theil and Clements (1987) is used to derive an empirical specification that accounts for the effects of total imports, expected prices, and price risk on import demand by source. Theil (1977, 1980) applied the differential approach to firm and consumer theory which resulted in the Rotterdam demand system. To extend this literature, I apply the differential approach to the allocation problem of an importing firm and derive an empirical model that allows for straightforward estimation of demand coefficients and elasticities.

The carnation import market in the United Kingdom (UK) is considered for the empirical implementation of the model. When firms face import price risk, the quantity imported depends on the moments of the import price distributions. To obtain information on these moments, a multivariate autoregressive conditional heteroskedasticity model is used to estimate the conditional mean, variance, and covariance of import prices. These estimates are then used as explanatory variables in estimating import demand. Results show that while total carnation imports, expected prices and seasonality are important determinants of import demand by source, there is significant information loss when import price risk is not considered.

Differential Approach to Import Allocation

The import allocation model derived in this section is based on the theory of the firm and expected utility maximization. In this procedure, imports are treated as intermediate goods that are used with domestic resources to produce one or several outputs and risk is due to unexpected import price fluctuations. Given a firm that imports a commodity from n exporting countries, the objective is to optimally allocate imports across exporting sources given total imports, expected import prices, and price risk. A key feature of this methodology is that price risk plays an important role in the allocation process.

Following the theory of Wolak and Kolstad (1991), the optimal allocation of an import at time t is determined in the first stage of a two-stage profit maximization procedure. In the second stage, firms determine the optimal level of output(s), domestic inputs (labor, capital, etc.), and total imports, given output and domestic input prices, which are assumed to be known with certainty. Let R denote the net revenue from outputs and domestic resources, and p_i and q_i denote the price and quantity of an imported commodity from the ith country $(i = 1, 2 \cdots n)$. The optimal allocation of $\mathbf{q}$ is the solution to the following utility maximization problem:

$$\begin{aligned} &\underset{\mathbf{q}}{\text{Max}} \quad U[R_t - E(\mathbf{p}_t'\mathbf{q}_t), V(\mathbf{p}'_t\mathbf{q}_t)] \\ &\text{s.t.} \quad Q_t = \iota'\mathbf{q}_t, \mathbf{q}_t \geq \mathbf{0} \end{aligned}$$

Note that E and V are the expectation and variance operator, respectively; $\mathbf{q}$ and $\mathbf{p}$ are n-vectors containing quantities and prices; Q is total imports and ι is an n-unit vector.[1]

Let the conditional expectation and variance of $\mathbf{p}$ be denoted as $\tilde{\mathbf{p}}$ and $\mathbf{\Omega}$, respectively, where $\tilde{\mathbf{p}} = E(\mathbf{p})$ and $\mathbf{\Omega} = E\{(\mathbf{p} - \tilde{\mathbf{p}})(\mathbf{p} - \tilde{\mathbf{p}})'\}$. The Lagrangian for the utility maximization problem is

$$(1) \qquad \Lambda = U(R - \tilde{\mathbf{p}}'\mathbf{q}, \mathbf{q}'\mathbf{\Omega}\mathbf{q}) + \lambda(Q - \iota'\mathbf{q})$$

and the first-order condition with respect to the ith import is

$$(2) \qquad \Lambda_i = \frac{\partial \Lambda}{\partial q_i} = -U_1\tilde{p}_i + 2U_2\left(q_i\sigma_i^2 + \sum_{j\neq i} q_j\sigma_{ij}\right) - \lambda = 0$$

U_1 and U_2 are the derivatives of U with respect to the first and second arguments, respectively; σ_i^2 is the variance of p_i; and σ_{ij} is the ijth price covariate.

The import allocation model is derived using a methodology and procedure similar to Theil (1977, 1980), Laitinen (1980), and Theil and Clements (1987), termed the differential approach. The benefits of the differential approach are that no specific functional forms are needed for utility and demand, the resulting empirical model is linear in coefficients and is therefore easy to estimate, theoretical restrictions are easily imposed on model estimates, and the conversion of differential terms to finite changes for empirical analysis is often accomplished by first differencing variables, which can alleviate problems of nonstationarity (Matsuda 2005).

From the optimization problem, we get an import demand function expressed in general form as follows:

$$(3) \qquad q_i^* = q_i(Q, \tilde{p}_1, \tilde{p}_2, \ldots, \tilde{p}_n, \sigma_1^2, \sigma_2^2, \ldots, \sigma_n^2, \sigma_{12}, \ldots, \sigma_{1,n}, \sigma_{23}, \ldots, \sigma_{2,n}, \ldots, \sigma_{n-1,n}).$$

Equation (3) states that the optimal quantity imported from the ith exporting source is a function of the total imported from all sources, expected prices, and the variance and covariance of prices.

Derivation of the model starts with the total differential of equation (3),

$$(4) \qquad dq_i = \frac{\partial q_i}{\partial Q}dQ + \sum_{j=1}^{n}\frac{\partial q_i}{\partial \tilde{p}_j}d\tilde{p}_j + \sum_{j=1}^{n}\frac{\partial q_i}{\partial \sigma_j^2}d\sigma_j^2 + \sum_{g\neq h}\sum_{\substack{h\neq g \\ h>g}}\frac{\partial q_i}{\partial \sigma_{gh}}d\sigma_{gh}$$

and with some manipulation, equation (4) is restated in log-differential form,

$$(5) \qquad s_i d\log q_i = \frac{\partial q_i}{\partial Q}d\log Q + s_i\sum_{j=1}^{n}\frac{\partial \log q_i}{\partial \log \tilde{p}_j}d\log\tilde{p}_j + s_i\sum_{j=1}^{n}\frac{\partial \log q_i}{\partial \log \sigma_j^2}d\log\sigma_j^2 + s_i\sum_{g\neq h}\sum_{\substack{h\neq g \\ h>g}}\frac{\partial \log q_i}{\partial \log \sigma_{gh}}d\log\sigma_{gh}$$

where $s_i = q_i/Q$ is the share of total imports from country i.

Equation (5) shows that the relationships between an import from the ith source and total imports, expected price, and the variance and covariance of price is respectively due to the following effects: $\partial q_i/\partial Q, s_i\partial \log q_i/\partial \log \tilde{p}_j, s_i\partial \log q_i/\partial \log \sigma_j^2$ and $s_i\partial \log q_i/\partial \log \sigma_{gh} \cdot \partial q_i/\partial Q$, is the marginal import share which measures how a unit increase in total imports affects imports from source i. We expect $\partial q_i/\partial Q$ to be positive for all i; however, there is the possibility of q_i being inferior where an increase in total imports could actually have a negative effect on q_i. $s_i\partial \log q_i/\partial \tilde{p}_j$ is the price effect which measures how the price in source j affects imports from source i. When $i = j$, this term

[1] Henceforth, the time subscripts (t) are omitted until the presentation of the empirical model.

should be negative, in part due to a higher price lowering expected returns and hence utility. When $i \neq j$, positive (negative) values indicate that i and j are substitutes (complements). $s_i \partial \log q_i / \partial \log \sigma_j^2$ and $s_i \partial \log q_i / \partial \log \sigma_{gh}$ are the variance and covariance effects, respectively. Both can be negative or positive depending on the risk preference of importers and the competitive relationship between any two exporting countries.

The parameterization of equation (5) requires that the marginal import share, price, variance, and covariance effects be treated as fixed parameters. However, further derivations are required to better understand the factors that determine the sign and magnitude of these effects. Thus, the next step in this procedure is to define these effects at optimal utility. In particular, each effect is defined according to the derivatives of the first-order condition with respect to the exogenous variables (Laitinen 1980; Theil and Clements 1987). Based on mathematical derivations in a supplementary appendix online, the price, variance, and covariance effects are respectively defined as follows:

$$(6) \quad s_i \frac{\partial \log q_i}{\partial \log p_j} = s_i u^{ij} \gamma_j - s_i E_j \sum_{j=1}^{n} u^{ij} \psi_{1,j} + \frac{\partial q_i}{\partial Q} \frac{\partial \log Q}{\partial \log \lambda} \frac{\partial \log \lambda}{\partial \log p_j}$$

$$(7) \quad s_i \frac{\partial \log q_i}{\partial \log \sigma_j^2} = -s_i u^{ij} \phi_j - s_i V_j \sum_{j=1}^{n} u^{ij} \psi_{2,j} + \frac{\partial q_i}{\partial Q} \frac{\partial \log Q}{\partial \log \lambda} \frac{\partial \log \lambda}{\partial \log \sigma_j^2}$$

$$(8) \quad s_i \frac{\partial \log q_i}{\partial \log \sigma_{gh}} = - s_i u^{ig} \phi_{gh} - s_i CV_{gh} \sum_{j=1}^{n} u^{ij} \psi_{2,j} + \frac{\partial q_i}{\partial Q} \frac{\partial \log Q}{\partial \log \lambda} \frac{\partial \log \lambda}{\partial \log \sigma_{gh}}.$$

u^{ij} denotes the ijth element of $\mathbf{U}^{*-1}$. $\mathbf{U}^* = [u_{ij}]$ is an $n \times n$ matrix where the ijth element is $u_{ij} = \delta_{ij}\phi_i + (1 - \delta_{ij})\phi_{ij} + \gamma_i \psi_{1,i} E_j + \psi_{2,i} V_j' q_j$. δ_{ij} is the Kronecker delta where $\delta_{ij} = 1$ when $i = j$ and 0 otherwise. $\phi_i = q_i \sigma_i^2 / (q_i \sigma_i^2 + \sum_{j \neq i} q_j \sigma_{ij})$ and $\phi_{ij} = q_j \sigma_{ij} / (q_i \sigma_i^2 + \sum_{j \neq i} q_j \sigma_{ij})$ are component shares of the variance marginal utility (or variance derivative) with respect to changes in q_i. $\gamma_i = U_1 \tilde{p}_i / 2U_2(q_i \sigma_i^2 + \sum_{j \neq i} q_j \sigma_{ij})$ is the marginal rate of substitution between the expected returns and variance due to changes in q_i. $\psi_{1,i} = (\gamma_i U_{11}/U_1 - U_{21}/U_2)$ and $\psi_{2,i} = (U_{22}/U_2 - \gamma_i U_{12}/U_1)$ are measures of utility function curvature where U_{11}, U_{12}, U_{21}, and U_{22} are the second derivatives of U. E_j is the jth expected value $(p_j q_j)$, V_j is the jth variance $(q_j^2 \sigma_j^2)$, and CV_{gh} is the ghth covariance $(2q_g q_h \sigma_{gh})$. V_j' is the variance derivative with respect to q_j, $\partial V / \partial q_j = 2q_j \sigma_j^2 + 2\sum_{i \neq j} q_i \sigma_{ij}$.

Equations (6)–(8) show that the responsiveness of q_i to changes in the price, variance, or covariance is the result of three terms. The first terms involve the utility-inverse term u^{ij}. For the price effect, u^{ij} interacts with the marginal rate of substitution (γ_j), which is negative if firms are risk averse. Holding other factors constant, as the marginal rate of substitution increases in absolute value, the responsiveness of import demand to price should also increase in magnitude. For the variance and covariance effects, u^{ij} interacts with the component shares of the variance marginal utility (ϕ_i and ϕ_{ij}). While ϕ_i should be positive, the sign of ϕ_{ij} depends on the sign of σ_{ij}. Given that the component shares add to one, if the variance share (ϕ_i) increases, the greater (lesser) the effect of the variance (covariance) on import demand, ceteris paribus.

The second terms show that the responsiveness of imports to the jth price and variance also depends on the jth expected value E_j and variance V_j, as well as the summation terms and $\sum_j u_{1,j}^{ij}$ and $\sum_j u_{2,j}^{ij}$. While little can be said about the sign and magnitude of the summation terms, we see that the effects of p_j and σ_j^2 on q_i increases in absolute value with E_j and V_j (ceteris paribus). Similarly, the covariate effect also increases in magnitude with the covariance CV_{gh}.

The third terms are the total import effects and indicate that import responsiveness is also due to how the price, variance, or covariance indirectly affects total imports through the marginal utility of total imports (λ).[2] These terms depend on the size of the marginal import share $(\partial q_i / \partial Q)$ and the responsiveness of the marginal utility of total imports to changes in total imports $(\partial \log \lambda / \partial \log Q)$, which is negative if the λ diminishes in Q.

[2] Note that $\lambda = \partial \Lambda / \partial Q$, which is the marginal utility of total imports.

Empirical Model

To derive the empirical model, we start with the parameterization of equation (5). First, continuous log changes are replaced with finite log changes. Following Theil (1980), first differences are used where for any variable x, $d\log x_t \approx \Delta x_t = \ln(x_t) - \ln(x_{t-1})$. Given equations (5) – (8), the empirical specification, termed the differential import allocation (DIA) model or system, is as follows:

$$(9) \quad \bar{s}_{i,t}\Delta q_{i,t} = \theta_i \Delta Q_t^* + \sum_{j=1}^{n} \pi_{ij}\Delta\tilde{p}_{j,t} + \sum_{j=1}^{n} \nu_{ij}\Delta\sigma_{j,t}^2 + \sum_{g\neq h}\sum_{\substack{h\neq g\\ h>g}} \omega_{igh}\Delta\sigma_{gh,t} + \varepsilon_{i,t}.$$

Note that s_i is replaced with a two period average $\bar{s}_{i,t} = 0.5(s_{i,t} + s_{i,t-1})$ (Theil 1980). $\theta_i = \partial q_i/\partial Q$ is the marginal share. $\pi_{ij} = s_i u^{ij}\gamma_j - s_i E_j \Theta_{1,j} + \theta_i \varphi^{-1}\varphi_j^p$ is the expected price effect. $\nu_{ij} = -s_i u^{ij}\phi_j - s_i V_j \Theta_{2,j} + \theta_i\varphi^{-1}\varphi_j^\sigma$ is the variance effect, and $\omega_{igh} = -s_i u^{ig}\phi_{gh} - s_i CV_{gh}\Theta_{2,j} + \theta_i\varphi^{-1}\varphi_{gh}^\sigma$ is the covariance effect. $\Theta_{1,j} = \sum_j u^{ij}\psi_{1,j}$, $\Theta_{2,j} = \sum_j u^{ij}\psi_{2,j}$, $\varphi = \partial\log\lambda/\partial\log Q$, $\varphi_j^p = \partial\log\lambda/\partial\log\tilde{p}_j$, $\varphi_j^\sigma = \partial\log\lambda/\partial\log\sigma_j^2$, and $\varphi_{gh}^\sigma = \partial\log\lambda/\partial\log\sigma_{gh}$. $\theta_i, \pi_{ij}, \nu_{ij}$, and ω_{igh} are treated as fixed parameters for estimation and $\varepsilon_{i,t}$ is an error term accounting for errors in optimization and random disturbances.

Note that the constraint implies that $\sum_{i=1}^{n} s_i d\log q_i = d\log Q$. To ensure that this condition (adding-up) is satisfied empirically, $\Delta Q_t = \ln(Q_t) - \ln(Q_{t-1})$ is replaced with ΔQ_t^* where $\Delta Q_t^* = \sum_{i=1}^{n}\bar{s}_{i,t}\Delta q_{i,t}$. Consequently, the following conditions will hold true by construction: $\sum_{i=1}^{n}\theta_i = 1$; $\sum_{i=1}^{n}\pi_{ij} = 0$; $\sum_{i=1}^{n}\nu_{ij} = 0$; and $\sum_{i=1}^{n}\omega_{igh} = 0$.

According to Stewart (1978), given decreasing absolute risk aversion, an increase in input-price uncertainty reduces the use of a risky input if firms are risk adverse. Alghalith (2005) also shows that given non-increasing absolute risk aversion, risk and input use are inversely related. Thus, risk aversion could be implied by the own-variance effect being negative ($\nu_{ii} < 0\forall i$). Holding price risk and total imports constant, it is conceivable that a proportional change in all prices would not affect the allocation share (homogeneity) which implies that $\sum_{j=1}^{n}\pi_{ij} = 0$. Although the theoretical reasoning is not as straightforward as in the consumer demand case, the possibility that the price effects are symmetric ($\pi_{ij} = \pi_{ij}$) could also be considered. Lastly, risk neutrality implies that price risk has no effect on import demand. This can be verified by testing the restriction $\nu_{ij} = \omega_{igh} = 0\forall g, h, i$, and j.

Total import, price, risk (variance), and covariance elasticities are easily derived from equation (9). $\eta_i = \theta_i/\bar{s}_i$ is the percentage responsiveness of imports from country i to a percentage change in total imports; $\eta_{ij} = \pi_{ij}/\bar{s}_i$ is the own- and cross-price elasticity of demand; $\eta_{ij}^\sigma = \frac{\nu_{ij}}{\bar{s}_i}$ measures the percentage responsiveness of imports from country i to percentage changes in the variance for country j (risk elasticity), and $\eta_{igh}^\sigma = \omega_{igh}/\bar{s}_i$ measures the percentage responsiveness of imports from country i to percentage changes in the covariance between countries g and h.

Equation (9) is similar to the Rotterdam model with exception of the following: the average and marginal share (s_i and θ_i) are defined in terms of quantity and not expenditures; import allocations are based on the aggregate quantity imported and not the aggregate import expenditure; import demand is determined by expected prices and not actual prices; and finally but most important, changes in import demand are in part explained by the variance and covariance of prices. It must be noted that the quantity/expenditure distinction may be of little significance empirically since expenditures are typically defined in real terms in the Rotterdam model. Additionally, the responsiveness of import demand to expected prices may not differ significantly from the responsive to actual prices. However, using expected prices could mitigate problems arising from import price endogeneity. The main distinction between equation (9) and more popular specifications is that this specification accounts for the effects of price risk on import demand, and given the theory from which the model is derived, the DIA system is particularly suited for modeling the source allocation of agricultural commodities.

Empirical Application

The DIA model is used in estimating carnation demand in the UK. This application raises the question, is this theoretical framework and model appropriate for a differentiated product like carnations? Although a homogeneous product would be more ideal, many agricultural products do not satisfy this condition. The reason being, even if differences in product attributes are minimal, there are still perceived differences such as a country's reputation for a quality product, trade history, reliability and consistency, and political issues tied to trade (Blonigen and Wilson 1999; MacLaren 1990). Given these factors, source heterogeneity could be argued for any agricultural product.

Regarding the appropriate use of the DIA model, the following should be considered. First and foremost, it must be conceivable that price risk contributes to import allocations. If so, the DIA model is applicable even in the presence of source heterogeneity. Source heterogeneity is usually accounted for by disaggregating an import by country of origin and specifying demand equations accordingly. Differentiation is reflected by the parameter estimates being different across countries. For instance, in testing if Japanese meat demand was source differentiated, Yang and Koo (1994) estimated a source-differentiated demand system using the AIDS model and tested the validity of restricting the expenditure and price coefficients equal across exporting sources. While the underlying theory attributes import allocations to price risk, the DIA model does not negate the possibility of source heterogeneity. Like other demand systems, source differentiation is accounted for by allowing for differences in the total import, price, and risk coefficients across countries.

Another consideration is that the theoretical framework technically allows for one country as the sole supplier.[3] With increasing source heterogeneity, this outcome becomes less plausible because source diversification is more the result of differentiation than price risk. The rationale for trade in differentiated products is that consumers benefit from greater variety and choice, and to restrict imports to any one source would lead to a significant loss in consumer welfare (Krugman 1980; Feenstra 2010). This raises the question for any product being considered, would there be a significant loss in welfare if only one country supplied it? For highly differentiated products like automobiles and wine, the welfare loss due to decreased variety and choice is apparent, but would this also be the case for an agricultural product like soybeans? If not, this implies that while a product may be somewhat different across countries, these differences are not important enough to affect consumer preferences, and although unlikely, one country could be the sole supplier without a significant loss in welfare.

Since the model is based on quantity allocations, the import in question must be aggregatable across countries. As a product becomes more source-differentiated, expenditure aggregations are still reasonable while quantity aggregations become more nonsensical. For instance, if a country imported cotton fabric, yarn, and raw cotton from different sources, an expenditure allocation model may still be applicable; however, a quantity allocation model becomes less feasible since aggregations across different measuring units and products requires the use of equivalency measures (i.e., the raw cotton equivalent of a square meter of fabric). This only suggests that the import in question be precisely defined such that quantity aggregations are plausible.

A final point is that the underlying theory treats imports as intermediate goods, but carnations are for the most part imported in final form. Given the role of intermediaries in international trade, final goods can still be treated as inputs or intermediate goods. Sanyal and Jones (1982) note that even when an import is not physically altered, activities such as handling, insurance, transportation, storing, repackaging, and retailing still occur, resulting in a significant amount of domestic value added before final delivery.

Carnation Demand in the United Kingdom

The UK is one of the largest importers of carnations in the world, which are sourced from within (Netherlands and Spain) and outside (Colombia and Kenya) the European Union (EU). Additionally, UK firms are faced with the decision to import directly from developing countries or indirectly through Dutch intermediaries (CBI 2007b). According to the United Nations, world carnation trade was valued at $498 million in 2007 and UK imports were valued at $126 million, accounting for 25% of total world trade that year. In 2007, Colombia, Kenya, the Netherlands, and Spain accounted for 87% of UK carnation imports and each represented 31.3%, 22.2%, 20.8%, and 12.4%, respectively.

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3 This is assuming no supply constraints in the exporting county and minimal price risk.

According to the International Labour Organization, world flower prices are for the most part set by auctions in the Netherlands due to their large share of international trade. However, supply and demand dynamics and climatic conditions can have a strong impact on prices, and short-term and seasonal price volatility. Prices can also differ due to quality where imports from outside the EU are often sold at lower prices when compared to the Netherlands, which supplies a wider range of products and more expensive specialized varieties. The quality issue is to a large extent due to the vase life of flowers, which is affected by the time required for shipment and delivery. Supermarkets in the United Kingdom have circumvented this issue by buying directly from producers in developing countries through long-term contracts bypassing the Dutch auction system. Hale and Opondo (2005) note that UK supermarkets have developed integrated relationships with Kenyan growers to shorten the time of distribution, eliminate the cost of intermediaries, ensure adequate supplies of desired varieties, and maintain compliance with safety and traceability regulations. These contractual arrangements are primarily dictated by the need for quality and traceability (Barrett et al. 1999), but could also assist in mitigating price risk.

Import prices in the UK are plotted in figure 1. What stands out is that prices are relatively more volatile in Spain and the Netherlands. During 2000 and 2001, imports from Spain were consistently cheaper than all other sources and prices were relatively stable. In more recent years however, the price of carnations from Spain fell to as low as €200 per 100 kg in 2006 and then increased to about €500 in 2007. In early 2008, prices peaked at around €900, and then immediately fell to around €200. Prices in the Netherlands have been even more volatile. From 2002 to 2007, prices significantly decreased from about €700 to €100 in 2003, then steadily increased to over €900 in 2006, and then immediately fell to about €500 in late 2006. In contrast, Kenyan and Colombian prices have been relatively stable ranging between €400 and €600 in most years.

Estimation and Empirical Results

Monthly data (January 2000-December 2009) are used for estimation which are provided by the Statistical Office of the European Communities (Eurostat) and defined according to the HS classification 06031200: *fresh cut carnations and buds of a kind suitable for bouquets or for ornamental purposes*. Import quantities are measured in units of 100 kg and values are in euros which include cost, insurance, and freight. Prices are calculated by dividing the value of the commodity by the quantity resulting in a euro per 100 kg unit value. The following exporting countries are considered for the analysis: Spain, the Netherlands, Kenya, Colombia, and *the rest of the world* (ROW). ROW is an aggregation of all countries not specified.

A two-step procedure is used to estimate the model similar to Appelbaum and Woodland (2010). The first step is to estimate the moments of the distribution of $\mathbf{p}$, and in the second step, the moments are used in estimating import demand. The following multivariate autoregressive conditional heteroskedasticity (M-ARCH) model is estimated to obtain the conditional expectation, variance, and covariance of import prices:

$$\Delta \mathbf{p}_t = \boldsymbol{\alpha}_0 + \mathbf{A}_1 \Delta \mathbf{p}_{t-1} + \mathbf{A}_2 \Delta \mathbf{z}_t + \varepsilon_t \qquad (10)$$

$$\hat{\boldsymbol{\Omega}}_t = \mathbf{B}_0 + \mathbf{B}_1 \boldsymbol{\varepsilon}_{t-1} \boldsymbol{\varepsilon}'_{t-1} \mathbf{B}_1$$

Δ is the log-change operator as previously defined. $\boldsymbol{\alpha}_0$ is a vector of constants, $\mathbf{A}_1$ is a diagonal matrix of partial adjustment coefficients, and $\mathbf{A}_2$ is a coefficient matrix. $\mathbf{B}_0$ and $\mathbf{B}_1$ are $n \times n$ square matrices. Based on Augmented Dickey Fuller (ADF) tests, we can reject the hypothesis of a unit root for each price series in first differences, but not in levels (table 1). Consequently, first differences are used in estimating the M-ARCH model.

From equation (10), we see that price expectations are in part naive since they are affected by prices in the previous period. Price expectations are also a function of $\mathbf{z}$, a vector containing the following variables: the UK plant and flower consumer price index (CPI), pound-to-euro exchange rate, and monthly dummy variables.[4] The plant and flower CPI represents carnation prices at the retail level and accounts for the resale value of imports, as well as the relationship between domestic demand and import prices. For a large importing country, retail prices could have a significant effect on import prices. Exchange rates play an important role in price formation and can affect

[4] The plant and flower CPI is provided by the UK Statistics Authority, Office for National Statistics, and the exchange rate is provided by the OANDA Corporation.

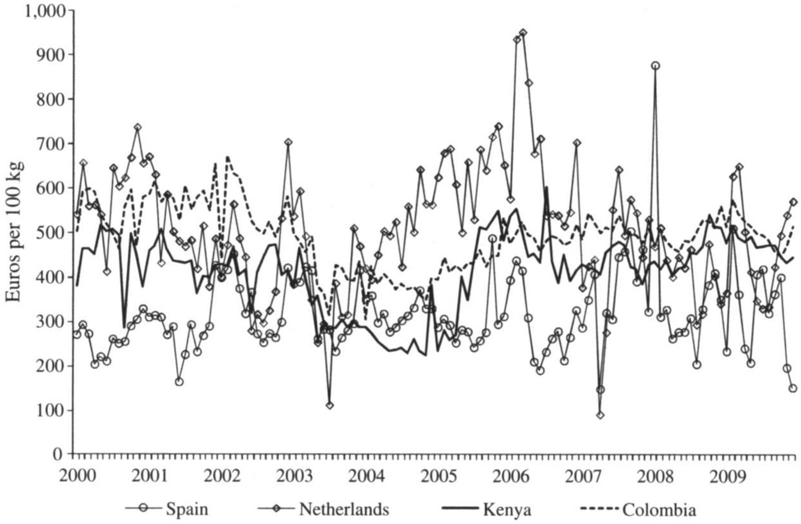

Figure 1. Carnation prices in the United Kingdom: January 2000-December 2009

Table 1. Augmented Dickey Fuller (ADF) Tests Statistics and M-ARCH Estimates

	ADF test statistics		M-ARCH Estimates	
Country/Price	levels	first differences	B_0	B_1
Spain	−4.692 [0.001]*	−4.854 [0.000]*	0.0356 (0.010)*	0.8070 (0.315)*
Netherlands	−3.806 [0.016]*	−4.749 [0.001]*	0.0400 (0.013)*	0.8551 (0.269)*
Kenya	−2.012 [0.595]	−4.136 [0.006]*	0.0119 (0.003)*	−0.5232 (0.326)
Colombia	−1.914 [0.648]	−8.439 [0.000]*	0.0016 (0.001)*	1.1546 (0.412)*
ROW	−2.445 [0.356]	−8.242 [0.000]*	0.0258 (0.008)*	0.6468 (0.271)*

Note: The P-values for the ADF tests are in brackets, and the M-ARCH estimate standard errors are in parentheses. *denotes significance level ≤ 0.05. ROW is the rest of the world.

the stability of import prices. Perée and Steinherr (1989) note that short-term exchange rate risk can be hedged in financial markets through forward exchange markets. This activity would mainly involve hedging against a major currency such as the euro, which is often used to invoice international transactions.[5] Monthly dummy variables are also included in **z** because the volatility in prices is partly due to seasonality.

Equation (10) is estimated using the Baba-Engle-Kraft-Kroner (BEKK) M-ARCH model (Engle and Kroner 1995). For this procedure, the off-diagonal elements in $\mathbf{B}_0$ and $\mathbf{B}_1$ are set to zero. M-ARCH estimates as well as the ADF test results are reported in table 1, and the conditional variance estimates from equation (10) are plotted in figure 2. With the exception of a few months, figure 2 shows that the conditional variances tended to be close to zero. However, post 2006 was an exceptionally erratic period for Spain. By and large, the conditional variance overtime was relatively small for Kenya and Colombia when compared to the EU countries. This is to be expected since prices in Spain and the Netherlands were relatively more volatile. Prices in the Netherlands exhibited the largest volatility with the variance peaking near 0.8 in 2003 and 1.3 in 2007. Comparably smaller, the highest peak for Spain was 0.5, and 0.08 and 0.1 for Kenya and Colombia, respectively.

Using the predicted prices and the conditional variances and covariances from equation (10), the DIA system is estimated in TSP using the multivariate Gauss-Newton method which is a maximum likelihood procedure (Hall and Cummins 2005). To account for the seasonality in import demand, monthly dummy variables are added to equation (9). Due to the adding-up property, the DIA system

[5] The Colombian peso and Kenyan shilling exchange rates were also considered, but were highly insignificant and did not contribute to the overall fit of the M-ARCH model.

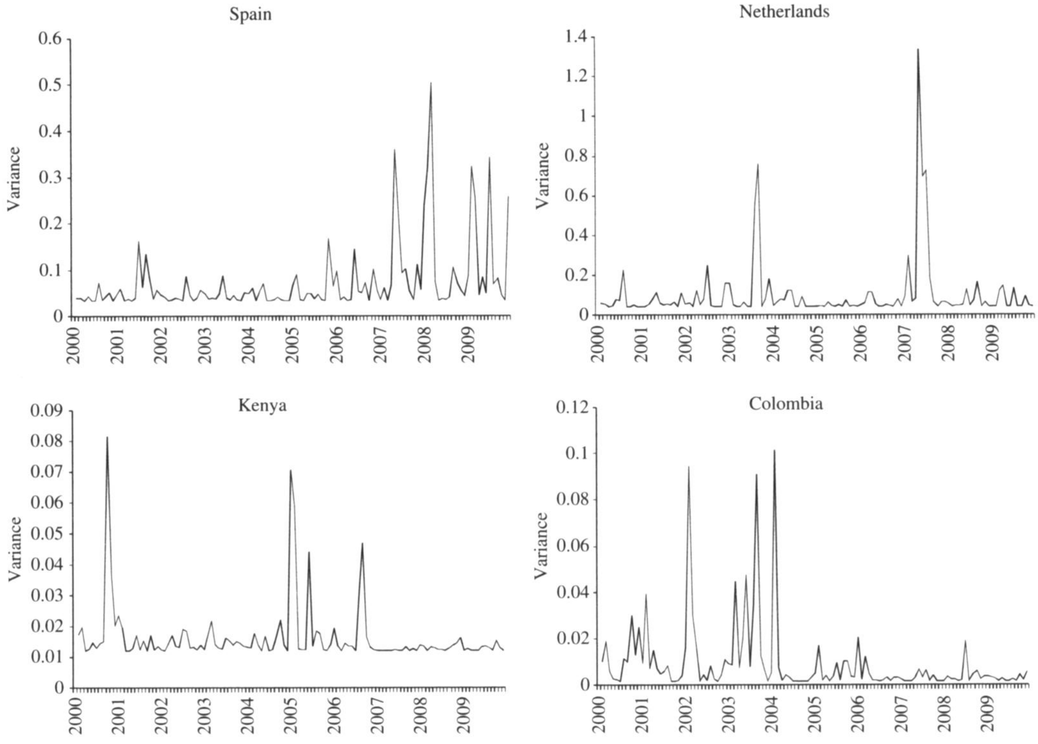

Figure 2. M-ARCH variance estimates: March 2000-December 2009

is singular which requires that an equation be deleted for estimation; however, maximum likelihood estimates are invariant to the chosen deleted equation (Barten 1969).[6] Descriptive statistics for model variables are reported in table 2.

Likelihood ratio (LR) tests are used to determine the importance of price risk to import demand. Results are in table 3 and indicate that there is significant information loss when the variances are not included in the model, but the same is not true for the covariances. The following restrictions are considered to assess the importance of price risk: the unrelated covariate effects are zero ($\omega_{igh} = 0 \forall g \neq i, h \neq i$) (model 2); all covariate effects are zero ($\omega_{igh} = 0 \forall g$ and h) (model 3); the cross variance effects are zero ($\nu_{ij} = 0 \forall i \neq j$) (model 4); and risk neutrality ($\nu_{ij} = \omega_{igh} = 0 \forall g$, h, i, and j) (model 5). Results indicate that the unrestricted model (model 1) and model 2 should be rejected in favor of model 3, which indicates that the covariates are not important determinants of import demand. However, model 3 should not be rejected in favor of model 4 or model 5. This suggests that exporters are affected by own-price instability as well as the price instability in competing countries, and overall, indicates that importers are not risk neutral.

The following discussion is limited to model 3 since it is the preferred model. The marginal share, price, and risk coefficients are reported in table 4 and the seasonality estimates are in a supplementary appendix online. Results show that a substantial degree of the variability in import demand is explained by the variables in the model. The marginal share estimates (θ_i) are all significant and indicate that a unit increase in total imports has a positive effect on all sources. Imports from the Netherlands are the most responsive to total imports (0.329), while imports from Kenya are the least responsive (0.087), and the responsiveness of imports from Spain (0.230) and Colombia (0.219) to total imports are about equal.

Consistent with theory, the own-price estimates (π_{ii}) are all negative and significant. Kenya is the only exception although not highly insignificant (p-value = 0.205). While there are significant differences in the marginal share estimates, the own-price estimates for Spain (−0.116), the Netherlands (−0.167), and

[6] Preliminary tests indicated that homogeneity and symmetry could not be rejected at any reasonable significance level. All results that follow have these properties imposed.

Table 2. Summary Statistics for Model Variables: January 2000-December 2009

Monthly quantity (100 kg)	Mean	SD	Min	Max
Total	18,714.47	4,848.65	10,367.00	32,858.00
Spain	4,348.08	2,779.99	498.00	12,435.00
Netherlands	2,819.03	1,398.33	1,072.00	12,260.00
Kenya	2,830.43	1,648.18	339.00	6,548.00
Colombia	6,158.13	1,680.47	3,110.00	10,130.00
ROW	2,558.79	2,001.38	20.00	9,256.00
Quantity share				
Spain	0.218	0.103	0.044	0.424
Netherlands	0.153	0.058	0.048	0.380
Kenya	0.163	0.102	0.012	0.387
Colombia	0.339	0.089	0.152	0.567
ROW	0.127	0.076	0.001	0.340
Price (Euros per 100 kg)				
Spain	318.59	91.34	149.77	879.56
Netherlands	508.74	143.44	92.21	952.88
Kenya	414.04	86.25	223.89	603.20
Colombia	492.30	71.38	304.49	674.62
ROW	283.59	85.36	116.33	553.15
Variance of price				
Spain	0.0737	0.0770	0.0337	0.5022
Netherlands	0.1012	0.1655	0.0400	1.3308
Kenya	0.0162	0.0103	0.0119	0.0814
Colombia	0.0093	0.0164	0.0016	0.1015
ROW	0.0413	0.0289	0.0258	0.2032
Covariance of price				
Spain-Netherlands	0.0152	0.0766	−0.1685	0.6489
Spain-Kenya	−0.0007	0.0104	−0.0510	0.0443
Spain-Colombia	0.0018	0.0130	−0.0345	0.0520
Spain-ROW	0.0023	0.0222	−0.0826	0.0920
Netherlands-Kenya	−0.0008	0.0097	−0.0416	0.0363
Netherlands-Colombia	0.0066	0.0289	−0.0431	0.2528
Netherlands-ROW	0.0089	0.0365	−0.0855	0.2831
Kenya-Colombia	0.0002	0.0069	−0.0170	0.0444
Kenya-ROW	0.0000	0.0069	−0.0299	0.0226
Colombia-ROW	0.0016	0.0125	−0.0281	0.1001

Note: SD is the standard deviation. ROW is the rest of the world.

Table 3. Likelihood Ratio Tests for Variance and Covariance Restrictions

Model	Variance	Covariance	Log-likelihood Value	LR Statistic	Restricted parameters	P-value
1	unrestricted	unrestricted	895.182			
2	unrestricted	restricted	877.851	34.663	24	0.074
3	unrestricted	= 0	865.234	25.233	16	0.066
4	restricted	= 0	845.435	39.599	16	0.001
5	= 0	= 0	841.390	8.089	4	0.088

Colombia (−0.180) are statistically equal. The cross-price estimates (π_{ij}) indicate that the price competition across countries is limited to the following: the Netherlands and Spain (0.069), the Netherlands and Colombia (0.099), and Colombia and ROW (0.082). There is only one significant complementary relationship, the Netherlands and ROW (−0.038).

The Netherlands and Kenya are the only countries with significant own-risk coefficients (−0.067 and −0.880) indicating that imports from these countries are negatively affected by

Table 4. Demand Estimates for UK Carnation Imports

Country	Marginal share θ_i	Price effects π_{ij}					Risk effects ν_{ij}				
		Spain	Netherlands	Kenya	Colombia	ROW	Spain	Netherlands	Kenya	Colombia	ROW
Spain	0.230	−0.116	0.069	0.038	−0.024	0.033	0.032	0.020	0.287	−0.196	−0.472
	$(0.037)^{a}$	$(0.051)^{b}$	$(0.040)^{c}$	(0.031)	(0.043)	(0.022)	(0.060)	(0.032)	(0.403)	(0.257)	$(0.162)^{a}$
Netherlands	0.329		−0.167	0.037	0.099	−0.038	0.204	−0.067	0.306	−0.126	0.186
	$(0.037)^{a}$		$(0.058)^{a}$	(0.036)	$(0.048)^{b}$	$(0.022)^{c}$	$(0.059)^{a}$	$(0.032)^{b}$	(0.398)	(0.263)	(0.161)
Kenya	0.087			−0.072	0.023	−0.025	−0.027	0.007	−0.880	0.401	−0.155
	$(0.026)^{a}$			(0.057)	(0.063)	(0.016)	(0.040)	(0.022)	$(0.273)^{a}$	$(0.180)^{b}$	(0.111)
Colombia	0.219				−0.180	0.082	−0.162	−0.007	0.431	−0.089	0.236
	$(0.035)^{a}$				$(0.092)^{c}$	$(0.022)^{a}$	$(0.055)^{a}$	(0.030)	(0.368)	(0.249)	(0.148)
ROW	0.135					−0.051	−0.048	0.047	−0.145	0.010	0.206
	$(0.032)^{a}$					$(0.022)^{b}$	(0.053)	$(0.028)^{c}$	(0.354)	(0.224)	(0.143)
	R^2	0.668	0.616	0.393	0.733	0.821					

Note: System $R^2 = 0.97$. Asymptotic standard errors are in parentheses. ROW is the rest of the world. a, b, and c denote the 0.01, 0.05 and 0.10 significance level, respectively.

own-price instability. Although Kenyan prices are the least volatile, price risk is the most important determinant of imports from Kenya, which could explain why UK retailers contract with Kenyan producers. In contrast, UK firms rely on flower auctions when importing from the Netherlands where prices tend to be more volatile.[7] Carnations account for a small percent of flower production in the Netherlands. In 2006 for instance, carnations accounted for only 1% of the total area in cut flower cultivation (3,100 hectares) (CBI 2007a).[8] This suggests that imports from the Netherlands are mostly transshipments from countries like Kenya. During periods of relative price instability, it appears that UK firms rely less on Dutch intermediaries to satisfy domestic demand. This is further evidenced by price risk in the Netherlands having a positive effect on imports from ROW (0.047), and price risk in Spain having a positive effect on the Netherlands (0.204). Although the price competition between Colombia and Kenya is insignificant, Kenya appears to benefit from price risk in Colombia (0.401); however, the reverse is not true. While imports are mostly substitutes across sources, there are two complementary risk relationships: ROW and Spain (−0.472), and Spain and Colombia (−0.162).

Total import, own-price, and own-risk elasticities are reported in table 5. The results show that imports from the Netherlands are the most responsive to a percentage change in total imports (2.16%). The responsiveness for Spain and ROW to total imports is somewhat smaller at 1.06%. Imports from the outside the EU are the least responsive to total imports at 0.53% for Kenya and 0.65% for Colombia. With the exception of the Netherlands (−1.10), carnation demand in the United Kingdom is mostly inelastic, and the own-price elasticities are relatively equal across countries ranging from −0.405 for ROW to −0.531 for Spain. In comparing the own-risk elasticities, what is particularly striking is that imports from Kenya are highly responsive to price risk. Recall that the own- and cross-price estimates for Kenya were insignificant and the total import elasticity relatively small. Thus, price risk is the most important determinant of imports from Kenya. Compared to the Netherlands, price volatility in Kenya has been relatively minimal; however, the own-risk elasticity for Kenya (−5.380) is over 10 times the estimate for the Netherlands (−0.442). Imports from the Netherlands are particularly sensitive to total imports and prices, more so than any other country, and to a lesser degree price risk. Risk aside, it appears that UK firms are more responsive to import-determining factors when using Dutch intermediaries, unlike when importing directly from carnation-producing countries.

Table 5. Demand Elasticities for UK Carnation Imports

Country	Total Import η_i	Own-price η_{ii}	Own-risk η^{σ}_{ii}
Spain	1.056	−0.531	0.148
	(0.171)[a]	(0.260)[b]	(0.274)
Netherlands	2.162	−1.096	−0.442
	(0.242)[a]	(0.378)[a]	(0.212)[b]
Kenya	0.532	−0.442	−5.380
	(0.157)[a]	(0.349)	(1.670)[a]
Colombia	0.645	−0.530	−0.263
	(0.102)[a]	(0.272)[c]	(0.734)
ROW	1.062	−0.405	1.620
	(0.254)[a]	(0.172)[b]	(1.124)

Note: Asymptotic standard errors are in parentheses. a, b, and c denote the 0.01, 0.05 and 0.10 significance level, respectively. ROW is the rest of the world.

Conclusion

The primary objective of this study was to derive a model that accounts for the effects of price risk on source-disaggregated demand. It is quite common for a good to be imported from multiple countries, and in past studies, this is solely attributed to product characteristics differing across countries. However, in addition to differentiating factors or even in the absence of source heterogeneity, price risk could play an important role in determining import demand by source.

It was shown that the optimal allocation of an import across exporting countries could be specified as the outcome of an expected utility problem. Given the theoretical framework, an empirical specification was derived that accounted for the effects of price risk as well as prices. To implement the model empirically, UK demand for imported carnations was considered. Results indicated that price risk was an important determinant of carnation demand in the UK, and likelihood ratio tests indicated that that there was significant information loss

[7] Approximately 82% of all trade in the Netherlands passes through flowers auctions.
[8] This is the total area under glass and excludes open area production which is about 2,500 hectares.

when price risk was not considered. Overall, carnation demand by source was determined by total carnation imports, expected prices and seasonality. This was the case for all countries except Kenya where the total import estimate was relatively small and the own- and cross-price estimates were all insignificant. However, imports from Kenya were particularly sensitive to own-price risk, more so than any other country. Kenya and the Netherlands were the only countries affected by own-price risk. Prices in the Netherlands were more volatile than any other country, while prices in Kenya were relatively more stable. The relative stability of Kenyan prices is in part due to the contractual arrangements between UK firms and Kenyan produces.

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