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6 Export Prices and Exchange Rates: An Industry Approach

Lawrence Schembri

The ability of domestic firms to compete with foreign firms in domestic and foreign markets is greatly influenced by the relative price of domestic- and foreign-produced goods. This relative price is, in part, determined by the level of the exchange rate. Under purchasing power parity (PPP), relative prices should change in proportion to any exchange rate movement. However, since 1980, the U.S. dollar has appreciated and then depreciated by roughly 50 percent vis-à-vis the Japanese yen and the West German mark, while the prices of many traded goods exported to the United States have moved much less. As a result, U.S. import prices expressed in foreign currency have moved sharply relative to foreign exporters' domestic prices. This failure of foreign-produced traded goods prices to respond to exchange rate changes has had a significant effect on the international competitiveness of U.S. firms.

Recently, several studies (most notably Krugman 1987; Dornbusch 1987; and Giovannini 1988) have tried to explain this "pricing to market" phenomenon by appealing to various theories of imperfect competition.[1] Both Krugman (1987) and Giovannini (1988) note that a complete explanation must include two elements. First, the exporting firm must be able to price discriminate across markets (i.e., it must face different elasticities of demand across markets, and arbitrage across markets must be less than perfect). Second, the firm must incur dynamic costs of adjustment on the supply side

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(and also perhaps on the demand side [see Krugman 1987; and Froot and Klemperer 1988]) that affect the exporting firm's reaction to an exchange rate change. In general, the firm's reaction to an exchange rate change that alters foreign demand conditions will depend on the expected magnitude and permanence of the change. That is, a large exchange rate change that is perceived as being permanent may cause the exporting firm to adjust its export price expressed in foreign currency and expand or contract its productive capacity and its foreign sales and distribution networks. However, if the change is perceived as being temporary, the firm's reaction will be much more muted in that it will probably maintain export prices and quantities at relatively constant levels and absorb the exchange rate change in its profit margin.

Most of the empirical work that has been done on this issue consists of either simple comparisons of domestic and imported goods prices in the aggregate or by sectors (see, e.g., Mann 1986; Dornbusch 1987; and Krugman 1987) or the estimation of pass-through equations (see, e.g., Feinberg 1987; and Feenstra 1987). This evidence clearly demonstrates the existence of the pricing to market phenomenon, especially in differentiated goods markets. Hence, while this evidence has limited explanatory power, it does indicate that pricing to market seems to occur in markets where firms are likely to be able to set different prices.

Giovannini (1988) estimates a nonstructural time-series model to explain deviations from PPP for selected categories of Japanese export goods to the United States. While he finds that deviations from PPP are forecastable, he cannot consistently distinguish between the two possible explanations of this occurrence, ex ante price discrimination or exchange rate surprises in conjunction with long-term price setting. Furthermore, although his model has the appearance of being dynamic because firms maximize the expected present discounted value of profits, it is essentially static; dynamic costs of adjustment are not modeled.

Knetter (1989) estimates an export-pricing equation for selected U.S. and German export goods to determine whether firms in the domestic export industry price discriminate across markets in different countries. He uses a panel data set consisting of export prices over time and across markets that allows him to control for shifts in the marginal cost of production that are unobservable but common to all markets and to isolate discriminatory country-specific effects. These effects arise in part because of movements in bilateral exchange rates that affect the elasticity of demand in export markets. These country-specific exchange rate effects are found to be significantly different across markets, indicating that price discrimination is being practiced. The simplicity of the model precludes a structural interpretation of the effect of exchange rate changes on export prices.

The purpose of this paper is to build a structural model of an export industry that can be empirically implemented to estimate the effect of an exchange rate change on domestic prices, export prices, and industrial activity and to test directly for differences in the price elasticities of demand across markets. While the model employed in the paper is static, which implies that any exchange rate change is expected to be permanent, it is still possible to obtain meaningful estimates of the elasticities of demand and to determine how the exchange rate changes that did occur affected markups (the price–marginal cost differential) in the domestic and export markets. Furthermore, this structural model provides a framework that can be extended to include dynamic costs of adjustment.

The model described in this paper is an extension of the closed-economy industry model of Applebaum (1979). Since the theoretical model is of a single export industry, it is necessarily partial equilibrium in nature. However, its usefulness derives from the fact that both the demand and the supply side of the industry are explicitly modeled.

The empirical version of the model is estimated using a carefully collected data set on a major Canadian export industry.[2] This export industry produces almost exclusively for sales in the Canadian and U.S. markets. More than three-quarters of the output of the industry is exported, and its sales to the United States account for more than half of U.S. consumption. The output of this industry is a relatively homogeneous commodity so that high-quality price data are available on domestic and export sales. Therefore, this Canadian industry provides a good case study for the empirical implementation of the theoretical model and the test of different price elasticities of demand.

In figure 6.1, the percentage difference between the U.S. export price and the Canadian domestic price (both prices expressed in Canadian dollars) is

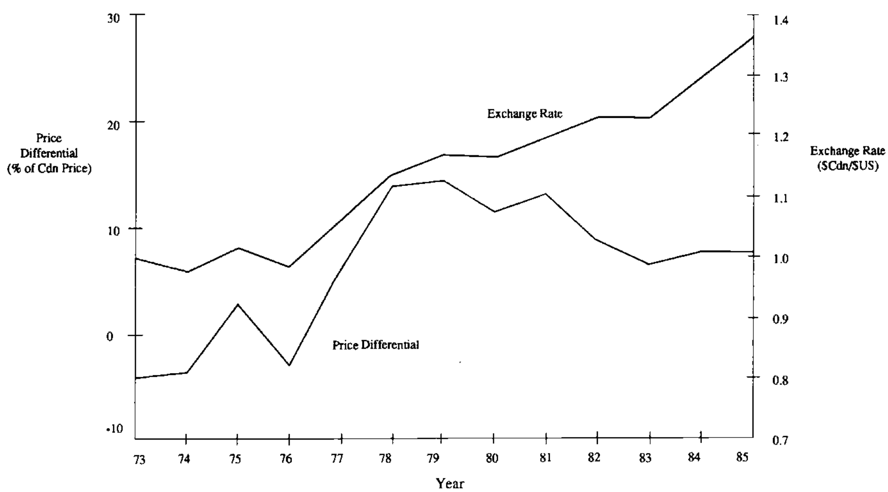

Fig. 6.1 The U.S. export/Canadian domestic price differential and the bilateral exchange rate

plotted along with the Canadian exchange rate (\$Canadian/U.S.\$) over the years 1973–85. It is important to note that, whenever the Canadian dollar depreciated (e.g., 1976–79 and 1983–85), the export/domestic price differential increased sharply. Indeed, the U.S. export price was significantly above the Canadian price for most of this period. Hence, it appears that Canadian exporters were pricing to market as they tried to maintain the local prices of their goods in the face of sizable exchange rate movements.

6.1 Theoretical Framework

The theoretical model is of an industry in the domestic country that produces an intermediate good that is primarily exported but is also sold domestically. To develop the structure of the model, consider the export industry as a single firm, a monopolist, that sells in two markets, domestic and foreign or export. The monopolist's technology is defined by the production function F, where $y_0 = F(z)$ is the output of the intermediate good produced by an n-dimensional vector of inputs z and F is a continuous-from-above, nondecreasing, and quasi-concave function.[3] In addition, assume that the intermediate good, y_0, is consumed as an input by two sets of firms that operate in a final goods industry in the domestic and foreign countries. Therefore, $y_0 = y_1 + y_2$, where y_1 and y_2 denote domestic and foreign consumption of the intermediate good, respectively.

Each firm in the domestic final goods industry has a production function defined by G_1, where $x_{10} = G_1(y_1, x_1)$ is the output produced and x_1 is an m-dimensional vector of inputs other than y_1 used in the production process. Similarly, each firm in the foreign final goods industry has a production function defined by G_2, where $x_{20} = G_2(y_2, x_2)$ is the output and x_2 is the m-vector of other inputs. If the firm production functions at home and abroad, G_1 and G_2, are subject to constant returns to scale (in addition to being quasi concave and nondecreasing) and all firms in the final goods industry in each country face the same prices and act competitively, then G_1 and G_2 can be interpreted as the industry production functions for the two sets of firms that employ y_0 as a productive input.

Let the prices of y_1, y_2, and z in domestic currency be p_1, p_2, and q, the prices of x_{10} and x_1 in domestic currency be w_{10} and w_1, and the prices of x_{20} and x_2 in foreign currence be w_{20}^* and w_2^* (asterisks denote value in foreign currency).[4]

If domestic and foreign firms in the final goods industry competitively maximize profits, then profit functions for the domestic and foreign industries, J_1 and J_2, can be defined as the solutions to the following problems—domestic:

(1) $$\max_{y_1, x_1} w_{10}G_1(y_1, x_1) - p_1 y_1 - w_1^T x_1 \equiv J_1(p_1, w_{10}, w_1),$$

and foreign:

$$\max_{y_2, x_2} w_{20}^* G_2(y_2, x_2) - ep_2 y_2 - w_2^{*T} x_2 \equiv J_2(ep_2, w_{20}^*, w_2^*), \tag{2}$$

where e is the exchange rate defined as the foreign currency price of domestic currency.

At this point, two important issues should be noted. First, since the model is partial equilibrium and the exchange rate is a macroeconomic variable, then e can be treated in the model as an exogenous variable. Second, the exchange rate is assumed to affect only the foreign currency price of the export good. For simplicity, the possible effects of the exchange rate on other input prices are ignored.[5]

Assuming that the profit functions defined in (1) and (2) have the usual regularity properties (see Varian 1978) and are differentiable with respect to the input prices, the optimal demand functions for the intermediate good, y_1 and y_2, and for the other inputs, x_1 and x_2, are given by Hotelling's lemma as

$$-y_1 = \partial J_1(p_1, w_{10}, w_1)/\partial p_1 \equiv H_1(p_1, w_{10}, w_1), \tag{3}$$

$$-x_1 = \nabla_{w_1} J_1(p_1, w_{10}, w_1), \tag{4}$$

and

$$-y_2 = \partial J_2(ep_2, w_{20}^*, w_2^*)\partial ep_2 \equiv H_2(ep_2, w_{20}^*, w_2^*), \tag{5}$$

$$-x_2 = \nabla_{w_2^*} J_2(ep_2, w_{20}^*, w_2^*). \tag{6}$$

Equations (3) and (5) represent the domestic and foreign demand functions for the intermediate good that the monopolist faces, and they can be inserted into the monopolist's profit maximization problem, which is given by:

$$\begin{aligned} \max_{p_1, p_2, y_1, y_2} \; & [p_1 y_1 + p_2 y_2 - q^T z \colon y_1 + y_2 = F(z), \\ & -y_1 = H_1(p_1, w_{10}, w_1),\ -y_2 = H_2(ep_2, w_{20}^*, w_2^*)] \end{aligned} \tag{7}$$

or

$$\begin{aligned} \max_{p_1, p_2, y_0} \; & [-p_1 H_1(p_1, w_{10}, w_1) \\ & - p_2 H_2(ep_2, w_{20}^*, w_2^*) - C(q, y_0) \colon y_0 = y_1 + y_2] \end{aligned} \tag{8}$$

or

$$\begin{aligned} \max_{p_1, p_2} \; & \{-p_1 H_1(p_1, w_{10}, w_1) - p_2 H_2(ep_2, w_{20}^*, w_2^*) \\ & - C[q, -H_1(\cdot) - H_2(\cdot)] \colon p_1, p_2 \geqslant 0\}, \end{aligned} \tag{9}$$

where $C(q, y_0) \equiv \min_z[q^T z \colon F(z) = y_0]$ is the cost function that is the dual to the monopolist's production function F. Note that having the cost function depend on total output, y_0, rather than on y_1 and y_2 separately implies that the cost associated with producing and selling a unit of the monopolist's output to domestic and foreign buyers is the same.[6] It is assumed as well that the monopolist is a price taker in markets for the inputs denoted by z and that the cost function has the usual regularity properties (see Varian 1978). However, it need not be assumed that the cost (production) functions of the monopolist exhibit constant returns to scale.

The monopolist's demand for inputs conditional on output y_0 can be obtained by applying Shepherd's lemma and differentiating the cost function with respect to input prices:

$$z = \nabla_q C(q, y_0). \tag{10}$$

If the demand functions for the intermediate good given by H_1 and H_2 and the cost function are differentiable with respect to p_1 and p_2 and y_0, then the first-order conditions for the monopolist's profit maximization problem in (9) are

$$p_1 + H_1(p_1, w_{10}, w_1)/[\partial H_1(\cdot)/\partial p_1] - \partial C(q, y_0)/\partial y_0 = 0, \tag{11}$$

$$p_2 + H_2(ep_2, w_{20}^*, w_2^*)/[e\partial H_2(\cdot)/\partial ep_2] - \partial C(q, y_0)/\partial y_0 = 0. \tag{12}$$

Equations (11) and (12) can be interpreted simply as the condition that marginal revenue be equated across the two markets to the marginal cost of production.

Equations (11) and (12) can be rewritten as

$$p_1 = \gamma_1(p_1, w_{10}, w_1) + \partial C(q, y_0)/\partial y_0 \tag{13}$$

and

$$p_2 = \gamma_2(ep_2, w_{20}^*, w_2^*) + \partial C(q, y_0)/\partial y_0. \tag{14}$$

Hence, the monopolist's selling prices in the two markets equal the marginal cost of production plus market-specific markups, which are defined as follows:

$$\begin{aligned}\gamma_1(p_1, w_{10}, w_1) &= -H_1(p_1, w_{10}, w_1)/[\partial H_1\ (p_1, w_{10}, w_1)/\partial p_1] \\ &= -[\partial J_1(p_1, w_{10}, w_1)/\partial p_1]/[\partial^2 J_1(p_1, w_{10}, w_1)/\partial p_1^2],\end{aligned} \tag{15}$$

$$\begin{aligned}\gamma_2(ep_2, w_{20}^*, w_2^*) &= -H_2(ep_2, w_{20}^*, w_2^*)/[e\partial H_2(ep_2, w_{20}^*, w_2^*)/\partial ep_2] \\ &= -[\partial J_2(ep_2, w_{20}^* w_2^*)/\partial ep_2]/[e\partial^2 J_2(ep_2, w_{20}^*, w_2^*)/\partial(ep_2)^2].\end{aligned} \tag{16}$$

The model derived so far represents a complete partial equilibrium model of the demand and supply of the intermediate good y_0. If functional forms are specified for the profit functions, J_1 and J_2, and the cost function, C, and data collected on the variables p_1, p_2, e, w_{10}, w_1, w_{20}^*, and w_2^*, then several interesting empirical results can be obtained.

First, estimates of the values of γ_1 and γ_2 can be determined. In addition, an estimate of the inverse elasticity of demand for y_0 in each market can be obtained from the expressions $\epsilon_1 = \gamma_1/p_1$ and $\epsilon_2 = \gamma_2/p_2$. If $\gamma_1 = \gamma_2 = 0$, that is, the markups are zero, then the monopolist is a price taker in his two output markets since the elasticities of demand are infinite. If γ_1 and γ_2 are estimated to be greater than zero and different, then the monopolist faces different elasticities of demand in the two markets since different markups are being applied to the same marginal cost of production.

Second, the effect of an exchange rate change on the domestic and foreign (export) prices, p_1 and p_2, the level of output, y_0, and the monopolist's demand for inputs can be estimated.[7] Theoretically the effect of the exchange rate change can be determined by totally differentiating (13) and (14) with respect to the exchange rate to obtain (for a complete derivation, see the Appendix):

$$(17) \qquad \frac{dp_1}{de} = \frac{B_{23}}{|D|}[\partial^2 C(q, y_0)/\partial^2 y_0][e\partial^2 J(ep_2, w_{20}^*, w_2^*)/\partial(ep_2)^2]$$

and

$$(18) \quad \frac{dp_2}{de} = \frac{B_{23}}{|D|}\{1 + B_{11} + [\partial^2 C(q, y_0)/\partial^2 y_0][\partial^2 J_1(p_1, w_{10}, w_1)/\partial p_1^2]\}.$$

The second derivative of the cost function with respect to output can be negative, positive, or zero, depending on whether the monopolist's technology exhibits increasing, decreasing, or constant returns to scale. The second derivative of the profit functions J_1 and J_2 and $|D|$ are unambiguously positive in sign while B_{11} is likely to be positive and B_{23} negative (for more details, see the Appendix). Therefore, the derivatives in (17) and (18) will probably be negative if marginal costs are increasing so that a depreciation of the exporter's currency, a fall in e, will raise the domestic and export prices (expressed in domestic currency) of the intermediate good.

The effect of an exchange rate change on the export price expressed in foreign currency is given by:

$$(19) \qquad \frac{dep_2}{de} = p_2 + e\frac{dp_2}{de}.$$

The sign of this expression is less obvious than the sign of (18). It is more likely to be positive.[8]

Furthermore, the effect of an exchange rate change on the monopolist's level of output is equal to

$$(20) \quad \frac{dy_0}{de} = -\frac{\partial H_1(p_1, w_{10}, w_1)}{\partial p_1}\frac{dp_1}{de} - \frac{\partial H_2(ep_2, w^*_{20}, w^*_2)}{\partial ep_2}\left(p_2 + e\frac{dep_2}{de}\right)$$

$$= -\frac{\partial^2 J_1(p_1, w_{10}, w_1)}{\partial p_1^2}\frac{dp_1}{de} - \frac{\partial^2 J_2(ep_2, w^*_{20}, w^*_2)}{\partial (ep_2)^2}\left(p_2 + e\frac{dp_2}{de}\right),$$

and the effects on the monopolist's input demands are given by:

$$(21) \quad \frac{dz_j}{de} = \frac{\partial[\partial C(q, y_0)/\partial q_j]}{\partial y_0}\frac{dy_0}{de}, \quad j = 1, \ldots, n.$$

Since theory in the form of regularity conditions and second-order conditions for profit maximization cannot unambiguously determine the signs of the expressions in (17) and (18), the door is left open for empirical estimation to help resolve the issue. Moreover, while the best that theory can do is to determine the signs of the effects of an exchange rate change on the endogenous variables, empirical work can provide an estimate of the magnitude of the effect. Therefore, it is now time to implement the model empirically in order to provide further answers.

6.2 Empirical Implementation

The first step in implementing the theoretical model for the purpose of empirical estimation is to specify functional forms for the monopolist's cost function and for the profit functions of the consuming industries at home and abroad. These functional forms should be flexible in that they should provide second-order Taylor approximations to any arbitrary functions that satisfy the regularity properties. In addition, the functional forms for the profit functions should yield simple expressions for the markup terms γ_1 and γ_2.

Another consideration in specifying the functional forms is the time horizon of the analysis. So far it has been assumed that an exchange rate change does not affect input prices. This assumption is reasonable only if the time horizon of the analysis is relatively short. Therefore, the theoretical model developed earlier that treats all inputs to the production process as variable (which is true only in the long run) needs to be modified to reflect the shorter time horizon of the empirical analysis. This could be accomplished by treating the capital stock (the nth input) as a quasi-fixed factor so that the monopolist's cost function would become a variable cost function and the profit functions of the consuming industries would be restricted or short-run profit functions. While making the resulting empirical model more realistic, this modification does not significantly affect the results derived from the theoretical model.

Given these considerations, the normalized quadratic was chosen from the set of popular flexible functional forms, which also includes the generalized

Leontief and the translog.[9] Therefore, the monopolist's variable cost function is given by

$$(22)\quad C^r(q^r, y_0, K_0) = a_0 + \sum_{i=2}^{n-1} a_i q_i^r + \frac{1}{2}\sum_{i=2}^{n-1}\sum_{j=2}^{n-1} a_{ij} q_i^r q_j^r + a_y y_0 + a_K K_0 + \frac{1}{2} a_{yy} y_0^2 + \frac{1}{2} a_{KK} K_0^2 + a_{yK} y_0 K_0 + \sum_{i=2}^{n-1} a_{yi} y_0 q_i^r + \sum_{i=2}^{n-1} a_{Ki} K_0 q_i^r ,$$

where $a_{ij} = a_{ji}$ and the superscript r denotes normalized. That is, $C^r = C/q_1$, and $q_i^r = q_i/q_1$, where C is total variable cost and q_1 is the factor price used to normalize the function. Note that constant returns to scale is not imposed on the function, but linear homogeneity of the function in prices is obtained by the normalization. Moreover, this restriction is not nested and thus is not testable.[10]

Similarly, the restricted normalized profit functions for the consuming industries are defined as

$$(23)\quad J_1^r(p_1^r, w_{10}^r, w_1^r; K_1) = K_1\Bigg[d_0 + \sum_{i=2}^{m-1} d_i w_{1i}^r + \frac{1}{2}\sum_{i=2}^{m-1}\sum_{j=2}^{m-1} d_{ij} w_{1i}^r w_{1j}^r + d_p p_1^r + d_w w_{10}^r + \frac{1}{2} d_{pp}(p_1^r)^2 + \frac{1}{2} d_{ww}(w_{10}^r)^2 + d_{pw} p_1^r w_{10}^r + \sum_{i=2}^{m-1} d_{pi} p_1^r w_{1i}^r + \sum_{i=2}^{m-1} d_{wi} w_{10}^r w_{1i}^r\Bigg] ,$$

and

$$(24)\quad J_2^r(ep_2^r, w_{20}^{*r}, w_2^{*r}; K_2) = K_2\Bigg[f_0 + \sum_{i=2}^{m-1} f_i w_{2i}^{*r} + \frac{1}{2}\sum_{i=2}^{m-1}\sum_{j=2}^{m-1} f_{ij} w_{2i}^{*r} w_{2j}^{*r} + f_p ep_2^r + f_w w_{20}^{*r} + \frac{1}{2} f_{pp}(ep_2^r)^2 + \frac{1}{2} f_{ww}(w_{20}^{*r})^2 + f_{pw}(ep_2^r)(w_{20}^{*r}) + \sum_{i=2}^{m-1} f_{pi}(ep_2^r)(w_{2i}^{*r}) + \sum_{i=2}^{m-1} f_{wi}(w_{20}^{*r})(w_{2i}^{*r})\Bigg] ,$$

where $d_{ij} = d_{ji}$, $f_{ij} = f_{ji}$, $J_1^r = J_1/w_{11}$, and $J_2^r = J_2/w_{21}^*$. Treating the quasi-fixed capital stock as a multiplicative factor imposes constant returns to scale on these functions.

To actually estimate the model, firm-level data on this Canadian export industry are employed along with industry-level data on the Canadian and U.S. final goods industries.[11] It is assumed that three variable inputs—labor, materials, and energy—are used in the production of the intermediate good, and this good, labor, and energy are employed as variable inputs into the final goods industries.

To implement the theoretical model for the Canadian export industry empirically, data on a set of firms rather than on a single monopolist firm are used. Although the Canadian export industry is fairly concentrated with a four-firm concentration ratio of approximately 50 percent, it is not reasonable to assume that the firms in the industry collude to mimic the behavior of a monopolist. Therefore, it would be incorrect simply to sum the data for each firm and treat the aggregate as a single monopolistic firm. Instead, each firm is assumed to face similar output market conditions and employ the same production technology. While the firms are assumed to act competitively in factor markets, the amount of each variable input used in production depends on firm-specific input prices.

Furthermore, the objective of the empirical model is to test not whether the demand curves facing the entire industry are horizontal but whether individual firms set prices above the shadow price of production, which is the marginal variable cost of the last unit of output produced. If each firm is identical and acts as a perfect competitor, then prices should be equal to the shadow price of production regardless of the slope of the industry demand curves. Therefore, since the model focuses on the pricing decision at the firm level, it does provide a valid test of price-taking behavior across markets.[12]

Using the functional forms specified for the variable cost function of the Canadian export industry and for the variable profit functions of the Canadian and U.S. final goods industries—equations (22)–(24)—the empirical model corresponding to equations (10), (13), and (14) can be derived. For each function, the wage rate in the corresponding industry is chosen as the normalizing price. By applying Shepherd's lemma to the cost function, the input demand equations for energy and materials are

$$\text{(25)} \quad \frac{\partial(C/q_L)}{\partial(q_M/q_L)} = z_M = a_M + a_{ME}(q_E/q_L) + a_{MM}(q_M/q_L) + a_{KM}K_0 + a_{yM}y_0,$$

$$\text{(26)} \quad \frac{\partial(C/q_L)}{\partial(q_E/q_L)} = z_E = a_E + a_{EE}(q_E/q_L) + a_{ME}(q_M/q_L) + a_{KE}K_0 + a_{yE}y_0 .$$

Note that the estimated demand function for labor can be derived as a residual from the other two functions. That is,

$$z_L = (C/q_L) - [(q_E/q_L)z_E + (q_M/q_L)z_M].$$

Using (15), (16), (23), and (24), the expressions for the markup terms are given by

$$(27)\quad \gamma_1 = -\frac{K_1[d_p + d_{pp}(p_1/w_{1L}) + d_{pw}(w_{10}/w_{1L}) + d_{pE}(w_{1E}/w_{1L})]}{K_1[d_{pp}]}$$

$$= -(1/d_{pp})[d_p + d_{pp}(p_1/w_{1L}) + d_{pw}(w_{10}/w_{1L}) + d_{pE}(w_{1E}/w_{1L})]$$

and

$$(28)\quad \gamma_2 = -\frac{K_2[f_p + f_{pp}(ep_2/w^*_{2L}) + f_{pw}(w^*_{20}/w^*_{2L}) + f_{pE}(w^*_{2E}/w^*_{2L})]}{K_2[ef_{pp}]}$$

$$= -(1/f_{pp})[f_p(1/e) + f_{pp}(p_2/w^*_{2L}) + f_{pw}(w^*_{20}/ew^*_{2L}) + f_{pE}(w^*_{2E}/ew^*_{2L})].$$

The expression for marginal variable cost is

$$(29)\quad \frac{\partial C}{\partial y_0} = q_L\frac{\partial(C/q_L)}{\partial y_0}$$

$$= q_L[a_y + a_{yM}(q_M/q_L) + q_{yE}(q_E/q_L) + a_{yy}y_0 + a_{yK}K_0].$$

Therefore, the two equations that relate price in each market to marginal cost are

$$(30)\quad p_1 + (p_1/w_{1L}) = -\left(\frac{d_p}{d_{pp}}\right) - \left(\frac{d_{pw}}{d_{pp}}\right)(w_{10}/w_{1L}) - \left(\frac{d_{pE}}{d_{pp}}\right)(w_{1E}/w_{1L})$$

$$+ a_yq_L + a_{yM}q_M + a_{yE}q_E + a_{yy}y_0q_L + a_{yK}K_0q_L$$

and

$$(31)\quad p_2 + (p_2/w^*_{2L}) = -\left(\frac{f_p}{f_{pp}}\right)(1/e) - \left(\frac{f_{pw}}{f_{pp}}\right)(w^*_{20}/ew^*{}_{2L}) - \left(\frac{f_{pE}}{f_{pp}}\right)(w^*_{2E}/ew^*_{2L})$$

$$+ a_yq_L + a_{yM}q_M + a_{yE}q_E + a_{yy}y_0q_L + a_{yK}K_0q_L\ .$$

Note that the relative price terms with a coefficient of one are moved to the left-hand side of each equation.

In addition, the two demand equations given by H_1 and H_2 in the theoretical model can be derived from the profit functions by applying Hotelling's lemma to obtain

$$(32)\quad y_1/K_1 = -d_p - d_{pp}(p_1/w_{1L}) - d_{pw}(w_{10}/w_{1L}) - d_{pE}(w_{1E}/w_{1L})$$

and

(33) $y_2/K_2 = -f_p - f_{pp}(ep_2/w^*_{2L}) - f_{pw}(w^*_{2O}/w^*_{2L}) - f_{pE}(w^*_{2E}/w^*_{2L})$,

where the expression on the left-hand side of each equation is demand per unit of capital. The inclusion of these two equations in the empirical model permits the identification of the key parameters d_{pp} and f_{pp}. The identity $y_0 \equiv y_1 + y_2$ is also included in the empirical model.

The final step in implementing the model for estimation is to embed the empirical model in a stochastic framework by adding mean-zero error terms to equations (25), (26), (30), (31), (32), and (33) to capture optimization errors.

6.3 Data

All the data employed in estimating the model are annual and taken from the period 1973–85 (thirteen years). Data prior to 1973 were not readily available on a consistent basis.

The data on the Canadian export industry were taken from the Census of Manufacturers data base. A consistent series of establishments that primarily produce the intermediate good was collected. The establishment-level data were aggregated to the firm level so that data on outputs and inputs are for sixteen firms that account for 90–95 percent of the industry's shipments of the intermediate good. Labor data are the number of hours worked and wages paid for production and related workers. Data on materials consist of quantity and price Divisia indexes for several components. Energy data consist of quantity and price Divisia indexes for coal, natural gas, gasoline, fuel oil, liquid petroleum gases, and electricity used.

Capital stock series at the firm level were constructed using the data collected from the annual capital expenditures survey conducted by Statistics Canada.[13] The capital stock data are midyear net stocks in constant dollars.

Output is the sum of shipments in tons of the intermediate good and other related products. Establishments in the sample were selected on the basis that intermediate good of interest accounted for at least three-quarters of their total shipments.

Separate series are collected by Statistics Canada on prices of the intermediate good for domestic and export sales.[14] The prices of the intermediate good are f.o.b. (freight on board) plant and, therefore, net of any transport costs. U.S. data on quantity and value of imports of the intermediate good from Canada provide an alternate source of export price data. These prices are also net of transport costs.[15]

Consistent data series for the Canadian final goods industry were obtained for wages, industry selling prices, energy input prices, and capital stock. In particular, data used to construct a wage rate for production and related workers and an energy input price index (a Divisia index formed from natural gas, gasoline, fuel oil, and electricity) were taken from the Census of Manufacturers. Capital stock data are midyear net stocks in constant 1971 dollars obtained in unpublished form from the Science, Technology and Capital Stock Division, Statistics Canada. The industry selling price index is the ratio of value added in current dollars to value added in constant dollars.

For the U.S. final goods industry, a wage rate series and energy price index series were taken from the Annual Survey of Manufacturing. The industry selling price series was taken from the U.S. Commerce Department publication *U.S. Industrial Outlook*. Capital stock data are midyear net stocks in constant 1972 dollars obtained in unpublished form from the U.S. Commerce Department.

The exchange rate is the average noon spot rate in U.S. dollars per Canadian dollar.

All the data used in estimation were scaled to take the value of one at the sample mean.

6.4 Estimation and Results

The empirical model represented by equations (25), (26), and (30)–(33) is a simultaneous system with six endogenous variables—input demands, z_M and z_E, intermediate good prices, p_1 and p_2, and intermediate good sales, y_1 and y_2. To estimate this system efficiently so as to impose the across-equation restrictions and allow for contemporaneous correlation of the disturbances across equations, a full-information, maximum likelihood estimation technique was tried. Unfortunately, the nonlinear optimization routine failed to converge despite repeated attempts. Given the size of the system with twenty-one unknown parameters and the limited number of time-series observations on the Canadian and U.S. consuming industries (thirteen years), this failure is not surprising.

In an effort to limit the number of parameters to be estimated at one time and to keep the system as linear as possible, it was decided to estimate the empirical model in two steps. First, equations (25), (26), (30), and (31) were estimated simultaneously using iterated three-stage least squares.[16] Second, equations (32) and (33) were jointly estimated using Zellner's (1962) seemingly unrelated regression technique.

Initially, all the across-equation restrictions were imposed when the first four equations were estimated. These restrictions were strongly rejected by the data using a modified F-test statistic. In particular, the restrictions between the first and the second pairs of equations appeared to be the ones most inconsistent with the data. Therefore, these restrictions were dropped, and only the symmetry restriction between the first two input demand equations and the restrictions on the equivalence of marginal cost across the last two markup equations were maintained.

The results from this estimation are given in table 6.1. In the input demand equations, the coefficients on the own price terms are significantly negative. From these estimates, the cost function is found to be concave in prices at all points in the sample. The coefficient on output is significantly positive in both equations, and the symmetry restriction on the cross-price variable is not rejected by the data at the 1 percent level. In addition, the relatively large values for the Durbin-Watson statistic provide no evidence of model misspecification.

The results for the markup equations are less satisfactory. While many of the estimated coefficients are statistically significant, the low-value Durbin-Watson statistics for both equations indicate serial correlation of the disturbances and possible model misspecification. The restrictions that the marginal cost parameters be the same across the two equations is not rejected at the 1 percent level. However, they are rejected at the 5 percent level, again perhaps indicating some misspecification of the model. The estimated coefficient a_{yy} is positive, which implies that the estimated marginal variable cost function is upward sloping.

It should be noted that, because the complete empirical model is not being estimated, the parameters d_{pp} and f_{pp} cannot be identified in the first step of the estimation procedure. Nevertheless, it is still possible to obtain estimates of the markup terms γ_1 and γ_2. These are given in table 6.2, along with the estimated inverse elasticities of demand.

Table 6.1 **Estimation Results 1: Equations (1)–(4)**

Coefficient	Estimate	Standard Error
Equation (1):[a]		
a_M	.400***	.151
a_{ME}	.044	.034
a_{MM}	−.188***	.052
a_{KM}	.002	.034
a_{yM}	.741***	.131
R^2	.971	
D-W	1.964	
ρ	.012	
Equation (2):[b]		
a_E	.172	.149
a_{ME}	.044	.034
a_{EE}	−.275***	.049
a_{KE}	−.014	.044
a_{yE}	1.074***	.158
R^2	.971	
D-W	1.792	
ρ	.100	

Table 6.1 (continued)

Coefficient	Estimate	Standard Error
Equation (3):[c]		
d_p/d_{pp}	.257***	.078
d_{pw}/d_{pp}	.463***	.081
d_{pE}/d_{pp}	.453***	.071
a_y	−1.018***	.291
a_{yM}	.442***	.086
a_{yE}	−.011	.081
a_{yy}	1.219***	.256
a_{yK}	−.025	.082
R^2	.971	
$D\text{-}W$	1.062	
ρ	.460	
Equation (4):[d]		
f_p/f_{pp}	1.017***	.093
f_{pw}/f_{pp}	−.501***	.091
f_{pE}/f_{pp}	.884***	.062
a_y	−1.018***	.291
a_{yM}	.442***	.086
a_{yE}	−.011	.081
a_{yy}	1.219***	.025
a_{yK}	−.025	.082
R^2	.971	
$D\text{-}W$	.988	
ρ	.498	

Note: Estimation technique is iterated three-stage least squares. Estimation period is 1973–85. Number of observations is 208. R^2's are for the whole four-equation system. Statistical significance is based on asymptotic t-ratios: *** at the 1 percent level; ** at the 5 percent level; and * at the 10 percent level. While the stacked data set consists of 206 observations (thirteen years times sixteen firms), the number of distinct observations on the final goods industries in Canada and the United States is thirteen.

[a]Dependent variable is z_M.

[b]Dependent variable is z_E.

[c]Dependent variable is $p_1(1 + 1/w_{1L})$.

[d]Dependent variable is $p_2(1 + 1/w_{2L}^*)$.

The estimated markups are found to be significantly greater than zero at the 1 percent level in both markets in each year of the sample. More interestingly, the markup on U.S. sales tended to increase over the sample period. This reflects the fact that export prices rose at a faster rate (10.7 percent per annum on the average) than wage rates (10.1 percent) and unit materials costs (9.1 percent). These two components represent 80–85 percent of variable costs in any given year. Only unit energy costs increased at a faster rate (13.2 percent). Markups in both markets fell in the oil price shock years of 1974 and 1979, when unit energy costs jumped by 29 percent and 18 percent, respectively.

Table 6.2 Estimated Markups and Inverse Elasticities of Demand

	Markups				Inverse Elasticities of Demand	
	Canada		United States			
Year	γ_1	SE	γ_2	SE	Canada	United States
1973	.348	.043	.363	.083	.890	.877
1974	.260	.047	.317	.082	.536	.612
1975	.234	.049	.262	.084	.409	.402
1976	.161	.047	.280	.081	.257	.417
1977	.159	.051	.294	.089	.235	.370
1978	.193	.054	.372	.094	.272	.416
1979	.179	.053	.326	.096	.223	.321
1980	.149	.053	.370	.098	.161	.325
1981	.209	.060	.399	.102	.201	.308
1982	.260	.062	.504	.105	.230	.372
1983	.383	.062	.638	.104	.353	.499
1984	.342	.061	.557	.107	.343	.392
1985	.267	.058	.529	.111	.267	.340
At sample mean	.242	.054	.401	.095	.256	.401

Note: The markup represents the difference between price and estimated marginal variable cost. It can be interpreted as a percentage only at the sample mean.

The markup on U.S. export sales is greater than the markup on Canadian sales in every year, although this difference is significant only at the 5 percent level in the years 1976, 1978, 1980, and 1983–85. In particular, the difference in markups is relatively large in the years after 1976, when the Canadian dollar depreciated almost continuously against the U.S. dollar. It is clear that during these years firms did not pass the lower value of the Canadian dollar into lower U.S. dollar export prices. They absorbed the exchange rate movement into their profit margins by pricing to market.

Evaluated at the sample mean, both markups are significantly greater than zero, and the U.S. markup is significantly greater than the Canadian markup at the 10 percent level. This supports the hypothesis that Canadian firms had the ability to price discriminate across the two markets.

Also, the fact that the inverse elasticities of demand lie between zero and one in both markets at all points in the sample is consistent with profit-maximizing behavior. Firms with market power are always on the elastic part of the demand curve.

In order to estimate the effect of an exchange rate change on the prices of the intermediate good for domestic and export sales and on output and input demands in the Canadian export industry, it is necessary to obtain estimates of the parameters d_{pp} and f_{pp}. They represent the second-order derivatives of the profit functions, J_1 and J_2, with respect to the price of the intermediate good. As these parameters are not identified in the first step of the estimation procedure, which involved the first four equations in the empirical model, the demand equations for the intermediate good, (32) and (33), need to be estimated.

The results obtained by applying seemingly unrelated regression to these two equations are given in table 6.3. Owing to the small number of degrees of freedom (nine), accurate estimates of the coefficients in the demand equations could not be obtained; most of the coefficients are not statistically significant. In particular, the estimates of the coefficients d_{pp} and f_{pp}, while having the theoretically correct positive sign, are not significantly different from zero. The Durbin-Watson statistics for both equations are in the inconclusive range.

Employing these estimates for d_{pp} and f_{pp} along with earlier estimates, equations (17) and (18) can be evaluated at the sample mean to determine the elasticities of the domestic and export intermediate good prices with respect to an exchange rate change. The estimated elasticity of the domestic price, p_1, with respect to the exchange rate is -0.22 percent, while estimated elasticity for the export price, p_2, is -0.85 percent. Hence, a 1 percent depreciation (appreciation) of the Canadian dollar against the U.S. dollar will cause the domestic price of the intermediate good to rise (fall) by 0.22 percent, while the export price will rise (fall) by 0.85 percent. Under the same circum-

Table 6.3 **Estimation Results 2: Equations (5) and (6)**

Coefficient	Estimate	Standard Error
Equation (5):[a]		
d_p	$-.975$*	.561
d_{pp}	.084	.373
d_{pw}	.015	.277
d_{pE}	$-.124$	.114
R^2	.347	
D-W	1.493	
ρ	.252	
Equation (6):[b]		
f_p	-1.192***	.354
f_{pp}	.465	.401
f_{pw}	$-.196$	.485
f_{pE}	.123	.313
R^2	.347	
D-W	1.602	
ρ	.189	

Note: Estimation technique is seemingly unrelated regression. Estimation period is 1973–85. Number of observations is thirteen. The R^2's are for the whole two-equation system. Statistical significance based on asymptotic t-ratios: *** at the 1 percent level; ** at the 5 percent level; and * at the 10 percent level.

[a]Dependent variable is y_1/K_1.

[b]Dependent variable is y_2/K_2.

stances, the U.S. dollar export price will fall (rise) by 0.15 percent. Thus, the U.S. dollar price is not very responsive to an exchange rate change.

Using equation (20), the elasticity of the level of output with respect to the exchange rate change is computed to be -0.051 percent at the sample mean. Hence, a 1 percent depreciation (appreciation) of the Canadian dollar will cause output of the intermediate good to rise (fall) by 0.051 percent. Therefore, the changes in sales in the domestic and U.S. markets partially offset each other, resulting in a relatively small effect on output.

The effect of an exchange rate change on demand for inputs by the Canadian export industry can also be determined by using equation (21) and the regressions results in table 6.1. The elasticity of the demand for materials and energy with respect to the exchange rate computed at the sample mean are -0.038 and -0.055, respectively.[17]

Standard errors for the point estimates of the effects of an exchange rate change are difficult to determine. However, given that the estimates of d_{pp} and f_{pp} are known to be inaccurate, it is likely that the standard errors would be relatively large. Hence, while these point estimates do provide some insight as to the effect of an exchange rate change, they are not likely to be very robust.

6.5 Concluding Remarks

In this paper, a partial equilibrium model of the supply and demand of an exportable intermediate good is theoretically constructed and empirically estimated. The objective of this exercise is to develop a framework in which the effect of an exchange rate change on the industry could be determined so that the recently observed pricing to market behavior of foreign exporters to the United States could be studied. While the model developed in this paper is static, it was still possible to determine whether the export industry being analyzed price discriminates between its domestic and its export markets.

In the case of the major Canadian export industry considered in this paper, price markups over estimated marginal variable cost are found to be statistically greater than zero on sales in both the U.S. export market and the Canadian domestic market. In addition, the markups on U.S. sales were significantly greater than those on Canadian sales for several years in the sample and at the sample mean. This difference in markups tended to increase as the Canadian exchange rate depreciated. Hence, firms in this industry were able to price discriminate between the two markets, and exchange rate changes to a large extent were not passed through into U.S. dollar export prices but were absorbed into the firms' profit margins.

Since firms in the industry possess some degree of market power in each market and marginal costs are not constant, exchange rate changes would not result in one-for-one changes in prices. A 1 percent exchange rate depreciation is estimated to cause a 0.22 percent increase in the domestic ($Canadian) price and a 0.15 percent fall in the export ($U.S.) price.

Although the empirical results provide some support for the model and indicate the existence of pricing to market behavior in this industry, it was difficult to obtain accurate estimates of the effect of the exchange rate on the industry. Finally, it is hoped that the theoretical framework developed in this paper will provide a good basis on which to extend the model to consider dynamic costs of adjustment of quasi-fixed factors. Such an extension will permit a more complete analysis of the pricing to market phenomenon.

Appendix

To determine the effect of an exchange rate change on the model, it is necessary to begin by totally differentiating equations (13) and (14) with respect to the exchange rate:

$$\text{(A1)} \quad \frac{dp_1}{de} = \frac{\partial\gamma_1}{\partial e} + \frac{\partial^2 C(q, y_0)}{\partial y_0^2}\left[-\frac{\partial H_1(\cdot)}{\partial p_1}\frac{dp_1}{de} - \frac{\partial H_2(\cdot)}{\partial ep_2}\frac{\partial ep_2}{\partial p_2}\frac{dp_2}{de}\right],$$

$$\text{(A2)} \quad \frac{dp_2}{de} = \frac{\partial\gamma_2}{\partial e} + \frac{\partial^2 C(q, y_0)}{\partial y_0^2}\left[-\frac{\partial H_1(\cdot)}{\partial p_1}\frac{dp_1}{de} - \frac{\partial H_2(\cdot)}{\partial ep_2}\frac{\partial ep_2}{\partial p_2}\frac{dp_2}{de}\right].$$

Using the expressions for γ_1 and γ_2 given by equations (15) and (16), the following results can be obtained:

$$\text{(A3)} \quad \frac{\partial\gamma_1}{\partial e} = -\left[\frac{1}{\partial^2 J_1(\cdot)/\partial p_1^2}\right]^2\left\{\left[\frac{\partial^2 J_1(\cdot)}{\partial p_1^2}\right]^2\left(\frac{dp_1}{de}\right) - \left[\frac{\partial J_1(\cdot)}{\partial p_1}\right]\left[\frac{\partial^3 J_1(\cdot)}{\partial p_1^3}\right]\left(\frac{dp_1}{de}\right)\right\},$$

$$\begin{aligned}\text{(A4)} \quad \frac{\partial\gamma_2}{\partial e} = {}& -\left[\frac{1}{e\partial^2 J_2(\cdot)/\partial(ep_2)^2}\right]^2\left\{\left[e\frac{\partial^2 J_2(\cdot)}{\partial(ep_2)^2}\right]\left[e\frac{\partial^2 J_2(\cdot)}{\partial(ep_2)^2}\left(\frac{p_2}{e} + \frac{dp_2}{de}\right)\right]\right.\\ & \left. - \left[\frac{\partial J_2(\cdot)}{\partial(ep_2)}\right]\left[\frac{\partial^2 J_2(\cdot)}{\partial(ep_2)^2} + e^2\frac{\partial^3 J_2(\cdot)}{\partial(ep_2)^3}\left(\frac{p_2}{e} + \frac{dp_2}{de}\right)\right]\right\},\end{aligned}$$

which can be simplified and rewritten as

$$\text{(A5)} \quad \frac{\partial\gamma_1}{\partial e} = -\left\{\frac{[J_1''(\cdot)]^2 - J_1'(\cdot)J_1'''(\cdot)}{[J_1''(\cdot)]^2}\right\}\frac{dp_1}{de_1} = -B_{11}\frac{dp_1}{de},$$

$$\begin{aligned}\frac{\partial\gamma_2}{\partial e} &= -\frac{p_2}{e} - \frac{dp_2}{de} + \frac{J_2'(\cdot)}{[eJ_2''(\cdot)]^2}\left[J_2''(\cdot) + e^2 J_2'''(\cdot)\left(\frac{p_2}{e} + \frac{dp_2}{de}\right)\right]\\ &= \frac{J_2'(\cdot)}{e^2 J_2''(\cdot)} - \left\{\frac{[J_2''(\cdot)]^2 - J_2'(\cdot)J_2'''(\cdot)}{[J_2''(\cdot)]^2}\right\}\left(\frac{p_2}{e} + \frac{dp_2}{de}\right),\end{aligned}$$

$$\text{(A6)} \quad \frac{\partial\gamma_2}{\partial e} = B_{21} - B_{22}\frac{p_2}{e} - B_{22}\frac{dp_2}{de}.$$

From the regularity properties of the profit function, $J_i''(\cdot) \leqslant 0$ and $J_i'(\cdot) \geqslant 0$ for $i = 1, 2$. The third derivative of the profit function with respect to an input price can be either negative or positive. If the derived input demand function is linear in its own price, then the derivative would be zero. The usual shape of the demand function is convex to the origin; thus, the third derivative would be a small negative number. Hence, B_{21} is negative, while B_{11} and B_{22} are most likely positive in sign.

Equations (3) and (5) can be used to obtain

$$\text{(A7)} \qquad \frac{\partial H_1(\cdot)}{\partial p_1} = \frac{\partial^2 J_1(\cdot)}{\partial p_1^2} = J_1''(\cdot),$$

$$\text{(A8)} \qquad \frac{\partial H_2(\cdot)}{\partial e p_2} = \frac{\partial^2 J_2(\cdot)}{\partial (e p_2)^2} = J_2''(\cdot).$$

Substituting (A5)–(A8) in equations (A1) and (A2) and writing them in matrix form gives

$$\text{(A9)} \quad \begin{bmatrix} 1 + B_{11} + C''(\cdot)J_1''(\cdot) & C''(\cdot)eJ_2''(\cdot) \\ C''(\cdot)J_1''(\cdot) & 1 + B_{22} + C''(\cdot)eJ_2''(\cdot) \end{bmatrix} \begin{bmatrix} \frac{dp_1}{de} \\ \frac{dp_2}{de} \end{bmatrix} = \begin{bmatrix} 0 \\ B_{23} \end{bmatrix},$$

where $C''(\cdot)$ is the second derivative of the cost function with respect to output and $B_{23} = B_{21} - B_{22}(p_2/e)$. Using Cramer's rule, it is straightforward to show that

$$\text{(A10)} \qquad \frac{dp_1}{de} = \frac{B_{23}C''(\cdot)eJ_2''(\cdot)}{|D|},$$

$$\text{(A11)} \qquad \frac{dp_2}{de} = \frac{B_{23}[1 + B_{11} + C''(\cdot)J_1''(\cdot)]}{|D|},$$

where $|D|$ is the determinant of the square matrix in (A9), and it must be positive for the second-order conditions of the monopolist's profit maximization problem to hold.

Notes

1. Dunn (1970) and Isard (1977) represent earlier references in this area. More recent references include Baldwin (1988), Feenstra (1987), Feinberg (1987), Fisher (1987), Froot and Klemperer (1988), Kiyono (1988), and Knetter (1989).

2. Owing to the data confidentiality requirements of Statistics Canada, the industry being considered cannot be identified.

3. To keep the notation relatively simple, quasi-fixed factors of production, such as the capital stock that is employed in estimating the model, are not explicitly included in the theoretical specification of the production, profit, and cost functions.

4. It is assumed without explicit justification that price arbitrage between the two markets is less than perfect. Typically, transport costs and other transactions costs are large enough for most intermediate goods to prevent effective arbitrage.

5. While this assumption may be justifiable in the context of a static short-run model such as the one estimated in this paper, it is clearly less reasonable the longer the time horizon of the analysis.

6. The cost function represents the cost of manufacturing only. While transport costs are likely to be different in the two markets, the selling prices of the intermediate good that are employed in estimation are f.o.b. (freight on board) plant.

7. Since the model is static rather than dynamic, expectations are also static. Therefore, any exchange rate change is by definition unanticipated and also permanent.

8. Giovannini (1988) finds with his model that dep_2/de is always positive if the exchange rate change is expected to persist.

9. Diewert (1985) points out that the quadratic function has the disadvantage that it is not symmetric in prices. Therefore, the empirical results will be affected by the choice of the normalizing price.

10. A time trend to capture technological change was initially included as an explanatory variable in the cost function and profit functions. However, it added little explanatory power in estimation and was omitted.

11. This intermediate good is used almost exclusively in the final goods industries. It is assumed that the U.S. industry producing the intermediate good behaves like a competitive fringe to the Canadian export industry.

12. Applebaum (1979) also makes this argument when he uses industry-level data for the industry producing the intermediate good. He argues that industry-level data are aggregated over all firms. Therefore, if individual firms are setting prices above marginal cost, then this will also be true in the aggregate.

13. For more details on the construction of firm-level capital stock series, see Schembri and Beaulieu (1988).

14. The domestic and export prices are collected from a survey of major manufacturers' selling prices of a clearly defined commodity sold under the same specified conditions. Therefore, the price data are actual spot prices, not unit values.

15. There are no tariffs on intermediate good imports to the United States.

16. In the iterated three-stage least squares procedure, all the exogenous variables in the model were used as instruments.

17. Since the restrictions across the input demand and markup equations were not imposed in the first step of the estimation procedure, it is not possible to obtain a consistent estimate of the effect on labor demand.

References

Applebaum, E. 1979. Testing price taking behaviour. *Journal of Econometrics* 9(3):283–94.

Applebaum, E., and U. Kohli. 1979. Canada–United States trade: Tests for the small-open-economy hypothesis. *Canadian Journal of Economics* 12(1):1–14.

Baldwin, R. E. 1988. Some empirical evidence on hysteresis in aggregate U.S. import prices. NBER Working Paper no. 2483. Cambridge, Mass.: National Bureau of Economic Research, January.

Diewert, W. E. 1985. The measurement of the economic benefits of infrastructure services. Working Paper no. 85-11. Department of Economics, University of British Columbia.

Dornbusch, R. 1987. Exchange rates and prices. *American Economic Review* 77(1):93–106.

Dunn, R. M. 1970. Flexible exchange rates and oligopoly pricing: A study of Canadian markets. *Journal of Political Economy* 78(1):140–51.

Feenstra, R. 1987. Symmetric pass-through of tariffs and exchange rates under imperfect competition. NBER Working Paper no. 2453. Cambridge, Mass.: National Bureau of Economic Research, December.

Feinberg, R. M. 1987. Recent foreign exchange movements, prices and U.S. trade flows. U.S. International Trade Commission. Typescript.

Fisher, E. 1987. A model of exchange-rate pass through. Board of Governors of the Federal Reserve, International Finance Discussion Paper no. 302.

Froot, K., and P. Klemperer. 1988. Exchange rate pass-through when market share matters. NBER Working Paper no. 2542. Cambridge, Mass.: National Bureau of Economic Research, March.

Giovannini, A. 1988. Exchange rates and traded goods prices. *Journal of International Economics* 24(1/2):45–68.

Isard, P. 1977. How far can we push the law of one price. *American Economic Review* 67(5):942–48.

Kiyono, K. 1988. Yen appreciation and Japan's pass-through structure. Faculty of Economics, Gakushuin University, Japan. Typescript.

Knetter, M. 1989. Price discrimination by U.S. and German exporters. *American Economic Review* 79(1):198–210.

Krugman, P. 1987. Pricing to market when the exchange rate changes. In *Real-financial linkages among open economies*, ed. J. D. Richardson and S. Arndt. Cambridge, Mass.: MIT Press.

Mann, C. 1986. Prices, profit margins and exchange rates. *Federal Reserve Bulletin* 72(6):366–79.

Morrison, C., and E. Berndt. 1981. Short-run labor productivity in a dynamic model. *Journal of Econometrics* 16(3):339–65.

Schembri, L., and E. Beaulieu. 1988. The construction of firm-level capital stocks. Department of Economics, Carleton University. Typescript.

Varian, H. 1978. *Microeconomic analysis*. New York: Norton.

Zellner, A. 1962. An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American Statistical Association* 57:348–68

Comment Alberto Giovannini

This thorough and interesting paper uses a new data set to estimate pricing behavior of internationally trading firms. The main interest of this work is in the unique character of the data, which includes firm-level information on

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prices and quantities of inputs and outputs. The sixteen firms in this unnamed Canadian industry produce an intermediate industrial good and account for 90–95 percent of the industry's total shipments. We also learn that the industry exports more than three-quarters of its output and that its exports account for more than 50 percent of U.S. consumption.

Interest in international pricing behavior stems from the work of Isard (1977), who demonstrated that, even at a very disaggregated level, relative prices of domestic and export goods in an industry vary dramatically and are sometimes correlated with exchange rates. These results, as Dornbusch (1987) documented, are even stronger when we look at more recent data, including the large swings of the dollar exchange rate since the beginning of 1980. One particularly striking aspect of the recent experience has been the insensitivity of import prices in the United States to fluctuations of the dollar exchange rate. This phenomenon is sometimes referred to as lack of "pass through": a change in the exchange rate, from the firm's viewpoint and other things being equal, represents a shift in demand from the domestic to the foreign market. If the foreign currency price of the export adjusts one for one with the exchange-rate change, then the shift in demand is not associated with any change in relative prices of the two goods, implying a relatively elastic supply curve by trading firms. If, on the other hand, exchange rate changes do not affect the foreign currency prices of exports significantly, then pass through is low, indicating that quantities are unlikely to change in response to changes in relative prices.[1]

The analysis of the relative movements of domestic and export prices is thus especially valuable to determine the elasticity of export supplies to changes in relative prices and provide invaluable information on the nature of the adjustment of trade imbalances to changes in relative prices.[2] Data on domestic and export prices of internationally trading firms are also of great interest to determine the presence of sluggish nominal price adjustment. In the presence of slow nominal price adjustments, which would occur, for example, when pricing decisions are less frequent than exchange rate changes, the correlations between the deviations from the law of one price and the nominal exchange rate depend in a very clear-cut way on the currency of denomination of exports: as is shown in Giovannini (1988a), if exports are denominated in foreign currency terms, in the presence of price stickiness deviations from the law of one price are highly correlated with the nominal exchange rate because the foreign currency price and the domestic currency price do not instantaneously respond to exchange rate innovations. On the other hand, when export prices are denominated in the same currency as domestic prices, then deviations from the law of one price should be uncorrelated with exchange rate innovations.

Although international price discrimination cannot really be studied independently of the issue of the frequency of price adjustments, Schembri concentrates exclusively on the measurement of the degree to which changes in relative demands give rise to changes in relative prices and changes in quantities. He assumes that producers can perfectly discriminate between the domestic and the foreign market and proceeds estimating the relevant parameters of demand and cost functions. Demand functions are obtained assuming that the "downstream" industries at home and abroad are profit maximizers and applying Hotelling's lemma to the postulated profit functions.

The whole analysis is carried out assuming that perfect price discrimination is possible, that is, that the domestic and foreign markets are perfectly isolated from each other. This assumption is questionable. It is likely that, when the U.S. and the Canadian markets are considered, transactions costs, even if high relative to the unit value of the good in question, should provide a natural limitation to the degree of price discrimination allowed to international traders. International price discrimination in the presence of a potential arbitrage industry clearly requires a modification of the model, including a specification of the technology of the incumbent arbitrage industry, which I do not want to pursue. Instead, I want to suggest alternative specifications of the markup equations. As the author shows, the current specification of these equations appears to perform poorly and might be at the root of the rejection of the cross-equation restrictions.

Schembri applies the same set of first-order conditions to each firm in the data set, implying that a "representative firm" exists and that the representative firm's efficiency conditions apply to each firm in the set. Since there are only sixteen firms in this industry, I prefer to take into account the firms' interactions explicitly by considering the markup equations in the case of a Cournot-Nash game. For each firm, let $\tilde{Y}$ represent the quantities produced by the rest of the firms in the market. The demand equations, following Schembri's notation, become

$$-(Y_1 + \tilde{Y}_1) = H_1(P_1, w_{10}, w_1), \tag{1}$$

$$-(Y_2 + \tilde{Y}_2) = H_2(eP_2, w_{20}^*, w_2^*). \tag{2}$$

Define the inverse demand equations Φ and Ψ as follows:

$$\Phi(Y_1 + \tilde{Y}_1, w_{10}, w_1) = P_1 , \tag{3}$$

$$\Psi(Y_2 + \tilde{Y}_2, w_{20}^*, w_2^*) = eP_2 , \tag{4}$$

where $1/\Phi_y = \partial H_1/\partial P_1$ and $1/\Psi_y = \partial H_2/\partial(eP_2)$. Profit maximization implies the two sets of first-order conditions

$$P_1 - Y_1\Phi_y - C_y = 0, \tag{5}$$

$$P_2 - Y_2\Psi_y/e - C_y = 0, \tag{6}$$

where subscripts indicate partial derivatives with respect to output and C stands for the cost function. Expressions (5) and (6) can be directly compared with Schembri's markup equations:

(7) $$P_1 + H_1(P_1, w_{10}, w_1)/(\partial H_1/\partial P_1) + \tilde{Y}_1/(\partial H_1/\partial P_1) = C_y ,$$

(8) $$P_2 + H_2(eP_2, w^*_{20}, w^*_2)/[e\partial H_2/\partial(eP_2)] + \tilde{Y}_2/[e\partial H_2/\partial(eP_2)] = C_y .$$

These equations are formally identical to Schembri's markup equations, except for the two terms representing, for each firm, the level of output supplied by the rest of the market. If firms in this industry are Cournot-Nash oligopolists, the equations estimated by Schembri suffer from an omitted variable problem, which, however, could be easily remedied. Equations (7) and (8) have the added advantage of permitting the estimation of the parameters of demand equations directly, through the coefficient of residual output terms rather than through the estimation of demand equations, for which little data are available.

One important feature of the alternative specification (7) and (8) is that the market price is the same for all firms, an assumption that Schembri is already exploiting since output prices data are not available for all firms. This assumption is acceptable if intrafirm price differences are just the result of sampling error and contain no information about firms' policies.

If intrafirm price differences were systematically related to demand and supply determinants, then an alternative model of product differentiation would be more plausible. In that case, information about other firms' quantities would not enter markup equations. Instead, other firms' prices would enter the equations as additional explanatory variables in the demand functions that each firm faces. These prices would be included in the cost functions of firms in the downstream industry, with coefficients representing the degree of substitutability of the differentiated products in the downstream industry's production function.

Notes

1. The interpretation of the results from these partial equilibrium pass-through equations has often been fallacious. Partial pass through at the firm level does not imply that, in the aggregate, changes in the nominal exchange rate that originate from purely nominal disturbances should not be reflected one to one in changes in nominal prices. For a discussion, see Giovannini (1988b).

2. For cross-industry evidence on exchange rate pass through, see Feinberg (1986) and Feenstra (1987).

References

Dornbusch, R. 1987. Exchange rates and prices. *American Economic Review* 77(1):93–106.

Feenstra, R. C. 1987. Symmetric pass-through of exchange rates under imperfect competition: An empirical test. University of California, Davis. Typescript.

Feinberg, R. M. 1986. The interaction of foreign exchange and market power effects on German domestic prices. *Journal of Industrial Economics* 35(1):61–70.
Giovannini, A. 1988a. Exchange rates and traded goods prices. *Journal of International Economics* 24, no. 1 (March):45–68.
———. 1988b. The macroeconomics of exchange-rate and price-level interactions: Empirical evidence on West Germany. NBER Working Paper no. 2544. Cambridge, Mass.: National Bureau of Economic Research, March.
Isard, P. 1977. How far can we push the "law of one price"? *American Economic Review* 67(4):942–48.

Comment Catherine J. Morrison

My comments will be divided into four sections. First, I will emphasize the important contributions that are made in the paper. Then, I will focus, second, on some of the problems I see with the model and its implementation and, third, on the interpretation difficulties that result. Finally, I will highlight the important implications of Lawrence Schembri's analysis.

Important Contributions

The questions that Schembri is considering are very interesting, and the general approach that he uses to address these issues is up to the task. The model is related to research that I am currently working on, so I both agree with his focus and commiserate with him about the difficulties in interpretation and implementation of such a model.

In particular, I believe that the structural approach to modeling the industry using production theory provides important and theoretically consistent implications about the full range of firm behavior and what it responds to. Depending on which characteristics of an industry are important, various types of firm decision variables can be incorporated and their effects on firm behavior explored through construction of performance indicators and elasticities. These types of models have had wide use in the production theory literature by researchers such as Elie Appelbaum, Mel Fuss, Ernst Berndt, Erwin Diewert, Robert Pindyck, Julio Rotemberg, myself, and a host of others. Related work along these lines in the macro area follows the lead of Robert Hall and, with a more industrial organization focus, includes Domowitz, Hubbard and Peterson, and Timothy Bresnahan.

The major indicator of interest in the current study is the index of price over marginal cost, or the markup indicator. The elasticities that are important are primarily exchange rate elasticities, although others clearly could be computed. Given the full structural model, a large number of interrelated firm responses, both for the export industry and the consuming industries, can be

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modeled. This is critical for consideration of important questions such as the effect of fluctuating exchange rates; what mechanisms cause us not to observe a direct proportional adjustment such as one would expect from a rescaling of prices? The ability to "explain" occurrences using this model is the advantage of Schembri's approach over the nonparametric or nonstructural time-series types of models. I should also note that there could also be other characteristics of a particular industry such as inventory holding, advertising, and monopsonistic effects that could potentially be incorporated into this type of framework and could be illuminating.

Schembri incorporates exchange rate responses into the basic structural production theory model and appends demand equations for the output of the "monopolistic" firm explicitly structured as input demand equations for domestic and "foreign" (U.S.) firms. This is a more complete consideration of differing market power across markets than I have seen in such a structural model; it provides much potential for interpretation. Note, however, that just including the *existence* of markups adds an extra dimension to the adjustments that a firm can make to cushion the effects of exogenous changes. This would allow some assessment of how changes in the exchange rate may fail to act like a pure price scale effect for the importing industry even in the absence of explicit modeling of exchange rate behavior.

On the empirical side, the data set appears to be excellent for looking at the questions posed. The data are at an establishment level aggregated to the firm, in an industry that is relatively homogeneous with a small number of firms, that produces "almost exclusively" for Canadian and U.S. consumption, and that exports much of its output. The advantages of this data set will help interpretation significantly once justifiable results are developed.

The frustration that arises from the data is that it is hard to analyze the results when one does not know which industry we are talking about. This may not be a solvable problem, although, elaborating as far as Statistics Canada will possibly allow, to mention, for example, whether this is a durable good industry or, perhaps, a natural resource industry would help.

What Are Some of the Problems?

Although I like the focus of the paper, serious difficulties—most of which I sympathize with—arise in implementation of the model. One of the most important theoretically may be the problem of interpreting results from a "monopoly" framework when the industry of interest is an oligopoly and it is therefore unlikely that marginal revenue (MR) and marginal costs (MC) are equated in the aggregate. The problem is whether anything effective can be done about this. Aggregation conditions are difficult to deal with explicitly, although they could possibly be used to rationalize a "representative firm" type of approach. Another way to go would be to assume some kind of tacit collusion, depending on whether the particular industry justified this. Alternatively, perhaps some limited type of conjectural variation framework could be developed to provide structure.

Overall, however, the use of the theory of the firm to obtain implications about the industry is problematic. This is recognized early in the paper when it is clarified that, as Elie Appelbaum has stated, if the results suggest that price (P) is not equal to marginal cost in the aggregate, we can conclude only that each individual firm does not set P = MC and that therefore some market power exists. In the results section of this paper, however, this care is discarded and interpretation is conducted as if the industry were monopolistic. Similarly, it is difficult rigorously to justify nonconstant returns to scale in the (export) industry because aggregation conditions will not be met in general. These types of aggregation problems are difficult to deal with, but at least interpretation of the results should be carried out with care.

It might also be useful to consider the implications of the functional forms used for the analysis. It has often been noted that the normalized quadratic form causes asymmetry of the demand equations for inputs that is not invariant to which input is used for normalization. This could be a serious problem, particularly when labor, which is likely relatively fixed in the short run, is used as the normalizing input. The main advantage of the quadratic form is the fact that second derivatives are simply parameters. However, since this property does not seem to be that important for the current model, other functional forms may be more appropriate. It should also be noted that the labor demand expression is not estimated in this study, which leaves the demand system incomplete. This cannot be accomplished in the current framework, however, because consistent estimates of all cost function parameters are not generated. In addition, the demand functions for the "monopolistically" produced good are also part of a system; ignoring the rest of the consuming firm's input demand structure leaves the demand functions facing the export industry somewhat incomplete. I do not think that this is worthwhile incorporating since this may be pursuing "completeness" of the model a bit too far. However, it may be worth taking into account. Finally, technological change is not included as an argument of the function.

Other difficulties arise when the analysis is suddenly expressed in terms of short-run functions at the point where functional forms are specified. It is stated that this shift does not significantly affect the results derived from the theoretical model very much, which is true. However, specification originally in terms of the short-run analysis would be desirable to make the empirical analysis more directly applicable to the model development. Also, constructing a short-run instead of long-run model as a basis for analysis implies additional questions about interpretation. For example, are we interested in short-run or long-run markups? Also, is it possible to develop a representation of the long run in this framework since capital in all industries considered must adjust to a steady state and the interactions to this "general equilibrium" may be difficult to tie down? It is important to address these issues.

Another problem is one of omission rather than commission. Schembri emphasizes in the introduction the role of dynamic adjustment and expectations that has been outlined by Krugman and Giovannini, and yet these characteristics are not included in either the theoretical or the empirical model. The current study is a good first cut to look at the questions identified, but, if these behavioral characteristics are so important, they should be included for the results to make sense. Exchange rate "surprises" in terms of exogenous shocks and responses are capable of being modeled in the current framework, but, since only static optimization is incorporated, the pattern of responses over time is ignored. At the very least, the focus on dynamic adjustment and expectations should be reduced in the introduction, and the emphasis should be on what contributions *are* made with the static model in the paper. A related but less critical problem is that the second half of the "complete explanation" of "pricing to market" phenomenon discussed in the introduction, the ability to set different prices across markets, does not receive much consideration or support in the interpretation of the empirical results.

Difficulties in Interpretation

This brings me to another dilemma; because of problems with the model and its implementation, interpretation of the results and providing justifiable conclusions become tricky at best.

The first dilemma is that the results are based on a very short data series, only thirteen years. However, the (perhaps related) problems with convergence that stimulated Schembri to estimate the model both in two parts and with not all symmetry conditions imposed raise even more questions. The problem is that the results for the second part differ substantially from those of the first part; the first coefficient I checked, for example, d_{pw}/d_{pp}, is estimated as .473 in the first part and .278 in the second. Although this is less of a difference than in previous versions of the paper, if these results are merged to make any implications, which they are for construction of the exchange rate elasticities, the results are seriously suspect. The rejection of symmetry conditions is also a problem because, when they are not imposed, the interpretation of the results is ambiguous; the integrated model breaks down, and aggregation conditions, for example, no longer stand.

At the very least, the effect of these inconsistencies should be clarified. It may be possible to determine, for example, how different the results would be if all the parameter estimates from the second stage were used rather than just appending the additional parameter estimates to the original set of estimates or if the "symmetry-imposed" estimates of parameters such as a_{yE} (or those from the other equation) were used. These tests would be crude, but they would provide some indication of sensitivity. Alternatively, and more ideally of course, some method of joint optimization should be pursued.

An additional interpretational difficulty arises with the exchange rate elasticities because there is so much endogeneity in the model that the elasticity computations may be suspect. I assume the reason p_1 is affected by the exchange rate even though it does not directly depend on e is that e

changes cause production to change, which, in turn, affects marginal cost. This mechanism is outlined to some extent in the Appendix, which is the computation that appears to motivate the elasticity calculation and is also discussed a bit earlier in the paper. It would, however, be useful to have the intuition of the elasticity construction spelled out more because it is not completely clear what is being held fixed as all the adjustments are made.

This uncertainty about the measurement of the elasticities is a serious problem for interpretation of the results. The implied output change, for example, is so small compared to the price change, especially in the light of the large effect that seems to come from the markup—it appears to attenuate 85 percent of the expected response of the U.S. price to an exchange rate change. I cannot see why this large effect should be directly counteracted by an opposite change in the Canadian market. It also seems that input demand increases with an exchange rate change even though output decreases. If I am interpreting this correctly, I think that there are some problems here with consistency.

An additional relatively minor interpretation problem arises from recent treatments of the purchasing power parity literature by Mel Fuss and his colleagues at the University of Toronto, who have worked extensively on how to adjust prices when comparing industries in different countries. They find, I believe, that we should not expect purchasing power parity to hold, which could be important for interpretation of the current results.

Theoretical and Policy Implications and Conclusions

The model and results from Schembri's study are potentially very useful. In terms of the production theory framework, the model of an industry with market power producing for another industry, and the potential discriminating monopolist stories that can be assessed in this framework are intriguing. In terms of the international ramifications, I do not know of any other treatment of exchange rate fluctuations that allows alternative decisions of firms to be explicitly characterized in a structural model. The potential insights about the deviations of exchange rate effects from those that would be expected from a strict purchasing power parity focus are fascinating and wide ranging. Since dramatic changes in exchange rates between such countries as Japan and the United States have resulted in significantly smaller changes in U.S. prices, and since this in turn has muted the effects of exchange rate changes on the balance of trade that would be expected, this type of explanation is provocative.

The model also provides a first cut at even more elaborate models, including dynamic effects and other characteristics of firms in a particular industry that may provide buffers to macro adjustments. I think that this is an important line of research. An extension to dynamic analysis will be particularly important for interpretation of the results. I am doing a study along these lines that suggests that incorporating slow adjustment for capital is particularly important and that including fixity of labor also has a significant effect, particularly if nonconstant returns to scale is incorporated. Ultimately, constructing a justifiable model of the expectations process will also provide important insights. Including these extensions allows one more carefully to interpret the indexes and elasticities and to facilitate more complete model specification.