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Pass-through and Exposure

GORDON M. BODNAR, BERNARD DUMAS,
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ABSTRACT

Firms differ in the extent to which they “pass through” changes in exchange rates into foreign currency prices and in their “exposure” to exchange rates—the responsiveness of their profits to changes in exchange rates. Because pricing affects profitability, a firm’s pass-through and exposure should be related. This paper develops models of exporting firms under imperfect competition to study these related phenomena. From these models we derive the optimal pass-through decisions and the resulting exchange rate exposure. The models are estimated on eight Japanese export industries using both the price data pass-through and financial data for exposure.

EXCHANGE RATES CAN HAVE A MAJOR influence on the pricing behavior and profitability of exporting and importing firms. Firms differ in the extent to which they “pass through” the change in exchange rates into the prices they charge in foreign markets. They also differ in their “exposure” to exchange rates—the responsiveness of their profits to changes in exchange rates. Previous papers have studied either pass-through or exposure, but none has studied these two phenomena together. Yet, because pricing directly affects profitability, the exposure of a firm’s profits to exchange rates should be governed by many of the same firm and industry characteristics that determine pricing behavior. This paper develops models of firm and industry behavior that are used to study these closely related phenomena together. It also provides estimates of pass-through and exposure behavior using data from Japanese export industries.

To examine pass-through behavior and exchange rate exposure, we model a firm with sales to a foreign export market. This exporting firm competes with a foreign firm in that export market. The costs of the exporting firm are based primarily in the local (domestic) currency, while the foreign firm

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has only foreign currency costs. Thus, changes in exchange rates affect the relative competitiveness of the two firms' products.

Industries typically differ in a number of dimensions such as the substitutability between their products, their dependence on imported inputs, their relative marginal costs of production, and the form of competition between firms in the industry. We will specify demand behavior that allows for a wide degree of substitutability between products, as well as a variety of relative cost structures between a local exporting firm and competing firms in the foreign market. The form of competition between firms may significantly affect pricing and profitability. We study industry behavior under both quantity competition and price competition.

In the empirical section of the paper, we estimate equations for export prices and profits simultaneously. The equation specification is directly based on the theoretical model of the exporting firm, although we modify that model by adding a domestic market for the exporting firm. We estimate the model using Japanese price and share price data. Eight Japanese industries are studied, all of them major exporters. One goal of the investigation is to determine whether exposures estimated from stock market are in line with model predictions or are too small to be rationalized by the model.

Section I of the paper reviews the literature on pass-through and exposure. Section II of the paper describes the basic duopoly model that we use as a workhorse. Section III lays down a simple framework for the comparison of pass-through and exposure across industries. Section IV explains the data. Section V describes the empirical methodology and gives the empirical results. Section VI concludes.

I. Brief Literature Review

Most previous studies of pass-through have been empirically oriented. Pass-through behavior has been studied extensively using export and import price data from the United States, Japan, Germany, and other countries. Some studies such as Mann (1986), Feenstra (1987), and Ohno (1989) examine the adjustment of export or import prices to exchange rate changes after taking into account any changes in marginal costs. Other studies such as Krugman (1987), Marston (1990), and Knetter (1989, 1993) examine "pricing to market," the variation of export prices relative to the domestic prices of the same producers.¹ Most of these studies are based implicitly on a model of a monopoly firm with no strategic behavior relative to its competitors. Dornbusch (1987), Krugman (1987), Froot and Klemperer (1989), Feenstra, Gagnon, and Knetter (1996), and Yang (1997), however, analyze pricing behavior under various types of oligopoly. We would like to extend their analysis by considering the profits as well as the price behavior of firms producing similar, but not identical products.

Most previous studies of exchange rate exposure, such as Shapiro (1975), Adler and Dumas (1984), Hekman (1985), Flood and Lessard (1986), von

¹ For a recent survey of this literature, see Goldberg and Knetter (1997).

Ungern-Sternberg and von Weizsacker (1990), Levi (1994), and Marston (2001) have investigated exposure in theoretical models of firm behavior. None of these studies has attempted to provide empirical estimates of their models. Empirical papers on exchange rate exposures (Jorion (1990), Bodnar and Gentry (1993), He and Ng (1998), and Griffin and Stulz (2001)) report estimates of exposure elasticities using share price data in place of direct measures of profits, but these estimates do not constitute direct tests of specific models of exposure. Campa and Goldberg (1999) and Allayannis and Ihrig (2001) examine the relation between exposure elasticities and industry structure. However, papers examining exchange rate exposure have rarely analyzed pricing behavior even though the extent of pass-through undoubtedly affects the profitability of a firm, and therefore affects the exchange rate exposure of that firm. This study specifies a theoretical model of exchange rate exposure that explicitly incorporates optimal export pricing behavior, and provides direct estimates of this structural model. Most empirical studies measuring exposures on stock market data tend to conclude that exposures seem excessively small, or in other words, that the stock market may not recognize the extent to which firms are involved in exchange-rate sensitive activities. Griffin and Stulz (2001) make this point, in particular. None of these studies is based on an explicit model of firm-level behavior, however, so it is difficult to assess whether estimated exposures are too small or too large. A by-product of our investigation will be to provide a benchmark for judging the size of the exposure coefficients.

Researchers in the area of industrial organization have estimated models that are in many ways similar to the ones we estimate in the present paper. A recent survey by Slade (1995) distinguishes static versus dynamic games. Our paper belongs obviously in the category of static games. That is, the players play only once and simultaneously; furthermore, the decisions of each player are one period in nature. A further classification concerns the type of goods considered—differentiated or homogenous. We assume that goods are differentiated although we allow the degree of substitutability to vary. In that subcategory, the survey paper lists three published papers.² All three papers discuss and estimate the degree of (tacit) collusion between firms, a task that we do not undertake here: We assume that exporting and foreign firms do not collude in the foreign market. One of these papers (Slade (1986)) empirically tests the first-order condition of the firm whereas the other two empirically fit the price and quantity behaviors that are implied by the theory. All three papers rely on more types of data than are available to us. In particular, in contrast to these studies, we use only price data and do not use quantity variables.³ Finally, we consider here only prices or quantities as the decision variables in the duopoly game, whereas Gasmi, Laffont, and Vuong (1992) also include the level of advertising expenditure.

² These are: Slade (1986), which studies the gasoline distribution market in one area of Vancouver; Bresnahan (1987), which considers the U.S. automobile market in 1954, 1955, and 1965; and Gasmi, Laffont, and Vuong (1992), which analyzes the soft-drink market.

³ Slade (1986) also uses data on marginal cost.

While the research in the area of industrial organization makes use of cost data to explain pricing strategy, we instead make use of profit data (represented by stock prices) and attempt to establish a relationship with prices of goods.

II. Basic Model Setup

A. Demand Behavior

Since the currency pass-through and the exchange rate exposure are both dependent on the degree of substitutability between the export goods and those produced locally in the foreign market, we would like to start with a framework that allows the degree of substitutability between these goods to vary. One utility function that permits variation in the degree of substitutability between these products is the CES function. Designating the exporting firm as firm one and the foreign import competing firm as firm two, the CES function has the form

$$U(X_1, X_2) = [\alpha X_1^\rho + (1 - \alpha) X_2^\rho]^{1/\rho} \quad (1)$$

where

$U(\cdot)$ = the utility function of the consumers in the foreign market,

X_1 = the quantity of the exporting firm's product sold in the foreign market,

X_2 = the quantity of the foreign import-competing firm's product sold in the foreign market,

α = a preference weighting parameter, and

ρ = a parameter measuring the substitutability between these products.

This utility function is similar to that used by Dixit and Stiglitz (1977) in their study of imperfect competition.⁴

As in the case of the CES production function, ρ is related to the elasticity of substitution, σ , by the relationship $\sigma = 1/(\rho - 1)$. As ρ approaches 1, substitutability becomes perfect (i.e., $\sigma \rightarrow -\infty$). At the other extreme, the two goods remain substitutes (so that demands are positively related to the price of the other good) as long as $\rho > 0$. So we will assume that $0 < \rho < 1$ and, therefore, that $-\infty < \sigma < -1$. We will use this utility function as the basis for our models of an exporting firm's behavior under both quantity and price competition assumptions.

The demand functions for the two products relate prices in the currency of the export market, P_1 and P_2 , to outputs as follows:⁵

⁴ Previous papers in the pass-through literature that use a similar specification include Feenstra et al. (1996) and Yang (1997).

⁵ The quantity competition model is more conveniently solved using inverse rather than direct demand functions (the latter of which relate output to prices in the two markets).

$$P_1 = D_1(X_1, X_2) = \frac{\alpha X_1^{(\rho-1)} Y}{[\alpha X_1^\rho + (1 - \alpha) X_2^\rho]} \quad (2a)$$

$$P_2 = D_2(X_1, X_2) = \frac{(1 - \alpha) X_2^{(\rho-1)} Y}{[\alpha X_1^\rho + (1 - \alpha) X_2^\rho]}, \quad (2b)$$

where Y equals total expenditure on this industry's products.⁶ The own and cross-price derivatives of these demand functions are negative (i.e., $D_{ii} < 0$ and $D_{ij} < 0$), which means that increases in outputs of either good lead to declines in price.

The market shares of the exporting firm and foreign import-competing firm play a central role in the analysis. Define λ as the market share of the exporting firm in the foreign market. Using (2a), this market share can be written as

$$\lambda = \frac{P_1 X_1}{Y} = \frac{\alpha X_1^\rho}{\alpha X_1^\rho + (1 - \alpha) X_2^\rho}. \quad (3)$$

The share of the foreign good in its own market is then given by $(1 - \lambda)$. Unless otherwise stated, we assume that both firms sell in the foreign market, so $0 < \lambda < 1$.

Using these expressions for market shares, we can express the partial elasticities of demand as functions of ρ and λ as follows:

$$\begin{bmatrix} \frac{\partial P_1 / \partial X_1}{P_1 / X_1} & \frac{\partial P_1 / \partial X_2}{P_1 / X_2} \\ \frac{\partial P_2 / \partial X_1}{P_2 / X_1} & \frac{\partial P_2 / \partial X_2}{P_2 / X_2} \end{bmatrix} = \begin{bmatrix} \rho(1 - \lambda) - 1 & -\rho(1 - \lambda) \\ -\rho\lambda & \rho\lambda - 1 \end{bmatrix}, \quad (4)$$

or, by matrix inversion:

$$\begin{bmatrix} \frac{\partial X_1 / \partial P_1}{X_1 / P_1} & \frac{\partial X_1 / \partial P_2}{X_1 / P_2} \\ \frac{\partial X_2 / \partial P_1}{X_2 / P_1} & \frac{\partial X_2 / \partial P_2}{X_2 / P_2} \end{bmatrix} = \frac{1}{1 - \rho} \begin{bmatrix} \rho\lambda - 1 & \rho(1 - \lambda) \\ \rho\lambda & \rho(1 - \lambda) - 1 \end{bmatrix}. \quad (5)$$

Since the market share of the exporter in the foreign market is assumed to lie between zero and one, a rise in product substitutability (higher ρ) raises (the absolute value of) these price elasticities.

⁶ Thus, we assume that this industry's product is weakly separable from all other goods in the consumer's utility function. See Varian (1984).

B. Firms' Profits

Recall that firm one is the exporting firm whose production is based in its home country, while firm two is the local import-competing firm with sales only in the foreign market. Exchange rate exposure is going to be measured with respect to a firm's own currency, so we define each firm's profits measured in its own currency. First, define the exchange rate, S , as the price of the foreign currency in units of the exporting firm's home currency. (So, if Japan is the exporter and the dollar is the currency of the foreign market, then the exchange rate is measured in yen/dollar.) The exporting firm is assumed to produce its product using inputs from its home market as well as imports from abroad. So its total costs can be written $(C_1^* + SC_1)X_1$ where C_1^* (C_1) is the marginal cost of the exporting firm in its home (foreign) currency. Note that the stars are used to denote home currency amounts.⁷ The profit of the exporting firm in its home currency is given as

$$\pi_1^* = SP_1X_1 - (C_1^* + SC_1)X_1. \quad (6)$$

The profit of the import-competing firm in the foreign market measured in the foreign currency is given as

$$\pi_2 = P_2X_2 - C_2X_2. \quad (7)$$

The import-competing firm (firm two) sells only in the foreign market and has costs based only in the foreign currency.

C. Solutions of the Models

Since the steps of the model derivations are well known, we merely provide the equilibrium solutions in Table I. The exchange rate enters the price expressions in two ways. Both prices are a function of the exchange rate through its impact on market shares. In addition, the exporter's price is proportional to its marginal cost converted into foreign currency using the exchange rate. Under quantity competition, the exporting firm's profits are the product of the exporter's share of the total expenditures in foreign market, $SY\lambda$, and its percentage markup in that market, $[SP_1 - (C_1^* + SC_1)]/SP_1 = 1 - \rho(1 - \lambda)$. Under price competition, the percentage markup is instead, $[SP_1 - (C_1^* + SC_1)]/SP_1 = (1 - \rho)/(1 - \rho\lambda)$.

III. Pass-through and Exposure Compared across Industries

In this section, we discuss the determinants of the two elasticities of interest in this paper, pass-through and exposure. We focus our discussion on the more transparent quantity competition version of the model. Some re-

⁷ Since the model focuses on competition in the foreign export market, we depart from the usual convention of denoting foreign variables with stars.

Table I
Analytic Solutions to the Models

The table shows the analytic solutions for various equilibrium firm level variables for both the exporting firm (firm 1) and the foreign import-competing firm (firm 2) under either the quantity competition model or the price competition model.

	Quantity Competition Model	Price Competition Model
Cost ratio, R	$R = \frac{SC_2}{C_1^* + SC_1}$	$R = \frac{SC_2}{C_1^* + SC_1}$
Equilibrium market share, λ	$\lambda = \frac{aR^\rho}{1 + aR^\rho}$ where $a = \alpha/(1 - \alpha)$	Obtained as solution of $\lambda = \frac{aR^\rho Z^\rho}{1 + aR^\rho Z^\rho}$ and $Z = \frac{[1 - \rho(1 - \lambda)]}{1 - \rho\lambda}$
Exporter's price in the foreign market, P_1	$P_1 = \frac{C_1^* + SC_1}{S\rho(1 - \lambda)}$	$P_1 = \frac{C_1^* + SC_1}{S} \frac{1 - \rho\lambda}{\rho(1 - \lambda)}$
Exporter's quantity sold in the foreign market, X_1	$X_1 = \lambda Y \frac{S\rho(1 - \lambda)}{C_1^* + SC_1}$	$X_1 = \frac{\rho(1 - \lambda)}{1 - \rho\lambda} \frac{S\lambda Y}{C_1^* + SC_1}$
Foreign import-competing firm price, P_2	$P_2 = \frac{C_2}{\rho\lambda}$	$P_2 = \frac{[1 - \rho(1 - \lambda)]C_2}{\rho\lambda}$
Import-competing firm quantity sold, X_2	$X_2 = (1 - \lambda)Y \frac{\rho\lambda}{C_2}$	$X_2 = \frac{\rho\lambda(1 - \lambda)Y}{[1 - \rho(1 - \lambda)]C_2}$
Exporter's profit in HC, π_1^*	$\pi_1^* = SY\lambda[1 - \rho(1 - \lambda)]$	$\pi_1^* = SY\lambda \frac{1 - \rho}{(1 - \rho\lambda)}$

marks in the last subsection will alert the reader to some differences in the specification of pass-through and exposure for the case of price competition.

A. Pass-through

In this paper, the term *pass-through* refers to the effect of the exchange rate on the exporter's price in foreign currency. Changes in exchange rates should lead to proportionate changes in the exporter's foreign currency price except for two factors. First, the exporting firm has foreign-currency based costs, so changes in exchange rates change marginal costs in its home currency. Second, changes in exchange rates should cause the exporting firm to change its markup. For both reasons, the pass-through is likely to be less than proportionate.

An expression for the exporter's pass-through can be obtained by differentiating (10a) with respect to S . First, define γ as the fraction of marginal costs due to foreign currency-based inputs:

$$\gamma = \frac{SC_1}{C_1^* + SC_1}. \quad (15)$$

Then pass-through can be expressed in the form of an elasticity as follows:⁸

$$\eta_1 = -\frac{d \ln P_1}{d \ln S} = (1 - \gamma)(1 - \rho\lambda). \quad (16)$$

Since ρ and λ are assumed to be between 0 and 1, the pass-through elasticity must be less than 1. A depreciation of the exporter's currency ($dS > 0$) leads to a fall in its price in foreign currency, but the fall in price is less than proportionate. That is, the pass-through is generally incomplete. Since $\gamma < 1$, the pass-through elasticity must be greater than 0, so in that case, $0 < \eta_1 < 1$.

It is important to understand why pass-through is incomplete even if there are no imported inputs ($\gamma = 0$). Partial pass-through occurs because the demand functions derived from the CES specification permit price elasticities, and therefore markups, to vary as prices change. If markups were constant, as in the case of a Cobb–Douglas demand function, a depreciation of the exporter's currency would lead to an equally proportionate fall in the exporter's price in the foreign market, resulting in pass-through of 1. But with the CES utility specification used here, a depreciation of the exporter's currency leads to an increased markup (in the exporter's currency) and partial pass-through. The markup of the exporter's home-currency price in the

⁸ Since $d \ln P_1/dS < 0$, this derivative is multiplied by -1 to ensure that the elasticity is positive.

foreign market over its costs in percentage terms (i.e., its profit margin) is given by

$$M_1 = \frac{SP_1 - (C_1^* + SC_1)}{SP_1} = 1 - \rho(1 - \lambda). \quad (17)$$

The pass-through is incomplete because the adjustment of this markup,

$$\frac{d \ln M_1}{d \ln S} = \frac{(1 - \gamma)\rho^2\lambda(1 - \lambda)}{(1 - \rho(1 - \lambda))} > 0, \quad (18)$$

reduces the pass-through. When the exporter's currency depreciates ($dS > 0$), the exporter's costs relative to the foreign competitor improve, causing it to increase its market share. This increase in market share reduces the exporter's elasticity of demand, giving him more market power. Increased market power, in turn, causes the exporter to increase its home currency markup by passing through less than the full exchange rate change. Thus pass-through will be less than proportional.⁹

B. Pass-through: Comparative Statics

First, let us consider the impact of differences in the degree of substitutability for the quantity competition model. As one would expect, the impact of higher product substitutability (higher ρ) is to moderate the pass-through of exchange rate changes into foreign currency prices. To show this, we differentiate η_1 from (16) with respect to ρ , holding market shares constant:¹⁰

$$\frac{d\eta_1}{d\rho} = -\lambda(1 - \gamma) < 0 \quad \text{if } \gamma < 1. \quad (19)$$

⁹ The price behavior of the foreign import competing firm is also of interest. Expressing the change in P_2 as an elasticity, we obtain

$$\eta_2 = -\frac{d \ln P_2}{d \ln S} = \rho(1 - \lambda)(1 - \gamma).$$

As long as $\gamma < 1$, meaning that the exporter has costs based in its own currency, a depreciation of the exporter's currency ($dS > 0$) forces the foreign firm to lower its price.

¹⁰ Higher product substitutability also affects the market shares of the two firms:

$$d\lambda/d\rho = \lambda(1 - \lambda)\ln R = -d(1 - \lambda)/d\rho.$$

As long as the marginal costs of the two firms are close together, however, $R \cong 1$ and $\ln R \cong 0$, so this indirect effect of substitutability on pricing can be ignored. An alternative interpretation of the comparative static equation (19) is reached by viewing the pair (ρ, λ) as a sufficient representation of the full set of parameters: $(\rho, \alpha, C_1, C_1^*, C_2)$. Holding λ fixed when we change ρ implies that the other parameters adjust.

The reason for this is that the increase in substitutability raises the elasticity of demand faced by the exporter, and as a result, smaller price changes are necessary to achieve the new profit-maximizing level of sales in the foreign market.¹¹

The degree of substitutability is not the only factor that influences pass-through. From expression (16) for η_1 , it is evident that a higher market share, (9a), lowers pass-through. The reason is that higher market share increases the sensitivity of the markup to the exchange rate. Market share, in turn, is a function of the preference parameter, α , and relative marginal costs, R , as well as ρ . An increased preference for the export (higher α) raises the market share of the exporter, so it lowers pass-through. Similarly, a decrease in the exporter's relative marginal cost (higher R) also raises the market share of the exporter, so it lowers pass-through.¹²

C. Exchange Rate Exposure

The value of a firm, V , can be expressed as the present value of present and future cash flows. The simplest measure of economic exposure is $d \ln V / d \ln S$.¹³ The value of the firm, V , is equal to the discounted value of after-tax profits. With taxes, discount, and growth rates assumed to be constant, economic exposure can be measured by the derivative:

$$\frac{d \ln V}{d \ln S} = \frac{d \ln \pi}{d \ln S}. \quad (20)$$

Thus, economic exposure is equal to the percentage change in profits induced by a one percent change in the exchange rate. It is this latter derivative, $d \ln \pi / d \ln S$, that we want to derive. This term, denoted δ (delta), is obtained by differentiating (14a) with respect to S :

$$\delta = \frac{d \ln \pi_1^*}{d \ln S} = 1 + (1 - \gamma)\rho(1 - \lambda) + \frac{(1 - \gamma)\lambda\rho^2(1 - \lambda)}{[1 - \rho(1 - \lambda)]}. \quad (21)$$

¹¹ On the other hand, the foreign import competing firm's price adjustment is positively related to product substitutability:

$$\frac{d\eta_2}{d\rho} = (1 - \lambda)(1 - \gamma) > 0 \quad \text{if } \gamma < 1.$$

The more substitutable are the two firm's products, the more the price of the local firm adjusts to match the adjustment of the exporter's price in response to an exchange rate change.

¹² While changes in relative marginal costs have this direct effect on pass-through, values of R different from one also allow substitutability to influence the market share. When the exporter has a cost advantage (lower marginal costs), an increase in substitutability leads to a bigger increase in his market share than with similar costs. Thus, with a cost advantage, the sensitivity of pass-through to substitutability should be even greater.

¹³ In standard terminology, exposure is defined as dV/dS , but we estimate exposure coefficients using rate of return data, so the percentage formulation, or δ , of the firm is more appropriate to derive analytically. Whereas normal exposure measures are measured as an amount of foreign currency, our measurement of the exchange rate delta of the firm measures the exposure as a percentage of current firm value.

This elasticity captures three different impacts of the exchange rate change on profits. The first term captures the proportional impact of the exchange rate change on profits (the simple “translation” or “conversion” effect). The second term captures the impact of the exchange rate change on the share of total expenditures accruing to the exporter (the market share effect). Recall that the exchange rate changes the relative prices, R , and therefore the exporter’s market share. The third term captures the impact of the change in the exchange rate on the domestic-currency profit margin of the exporter. As we saw above, the change in market share induced by the exchange rate change causes the exporter’s pass-through to be less than proportional, resulting in a change in the profit margin in domestic currency (see (17)). Together these three effects constitute the full impact of the exchange rate change on profits. Since the first two terms together are greater than one and the third term is positive (unless $\gamma = 1$), the exposure elasticity of the exporter is always greater than one. Thus, the profits of a pure exporting firm are more exposed than a foreign currency cash position. This exposure would be reduced, however, if the exporter also sold goods in its own market.

D. Exchange Rate Exposure: Comparative Statics

The size of the exporter’s exposure changes with both the degree of substitutability between the two products in the export market and the relative market shares of the firms. The impact of a change in substitutability on exposure can best be understood by recalling that δ is determined by the ratio of the change in profits from an exchange rate change to the level of profits. Substitutability has its greatest impact on the level of profits, rather than on the sensitivity of profits to the exchange rate. The sensitivity of profits to the exchange rate is determined primarily from the size of the net foreign currency cash flows, which is affected most directly by market share. For a given level of market share, increasing substitutability implies more elastic demand, lower markups, and smaller profits. Thus δ increases as substitutability increases and market share is held fixed. This intuition is verified by taking the derivative of (21) with respect to ρ , holding λ fixed:

$$\frac{d\delta}{d\rho} = (1 - \gamma)(1 - \lambda) \frac{(1 - \rho)^2 + 2\lambda^2\rho^2 + \lambda\rho(4 - 3\rho)}{[1 - \rho(1 - \lambda)]^2} > 0. \quad (22)$$

This expression is always positive since $0 < \rho, \lambda < 1$.

This prediction of the structural model is consistent with the results of Campa and Goldberg (1999) and Allayannis and Ihrig (2001), who find that exposures are generally higher the more competitive the industry. Competitive industries, defined in their work as industries with low markups, correspond in our model to industries with high substitutability. From (22), it is apparent that higher ρ results in higher δ .

Market share also has an impact on exposure. Differentiating (21) with respect to λ , holding ρ fixed, we can see the effect of market share on δ :

$$\frac{d\delta}{d\lambda} = -\rho(1 - \gamma) + \frac{(1 - \gamma)[\rho^2(1 - 2\lambda) - \rho^3(1 - \lambda)^2]}{[1 - \rho(1 - \lambda)]^2}. \quad (23)$$

This derivative is negative, except for a small region where λ is low and ρ is high.¹⁴ The negative value implies that δ decreases as market share increases. This occurs because higher market share has a stronger effect on the level of profits than on the amount by which profits change when the exchange rate changes. For a fixed ρ , an increase in market share increases the level of profits not only by increasing total sales but also increasing the profit margin, which increases monotonically with market share (see (17)). Since lower relative marginal costs for the exporter (higher R) and increased preference for exports (higher a) raise market share, they both generally lead to lower exchange rate exposure for the exporter.

E. Relation Between Exposure and Pass-through

A firm's pass-through behavior and exchange rate δ are closely related because they are both functions of product substitutability. As discussed above, for any given market share, higher product substitutability lowers pass-through and raises δ . Thus, there is an inverse relationship between pass-through and δ as depicted in Figure 1a. The points that make up each path in this figure correspond to a different level of market share. Along each path, substitutability increases from zero to one, moving right to left.

F. Comparing the Quantity Competition and Price Competition Models

An expression for the exporter's pass-through under price competition can be obtained by differentiating (10b) with respect to S . Recall that γ is the fraction of marginal costs due to imported inputs. Pass-through can be expressed in the form of an elasticity as follows:¹⁵

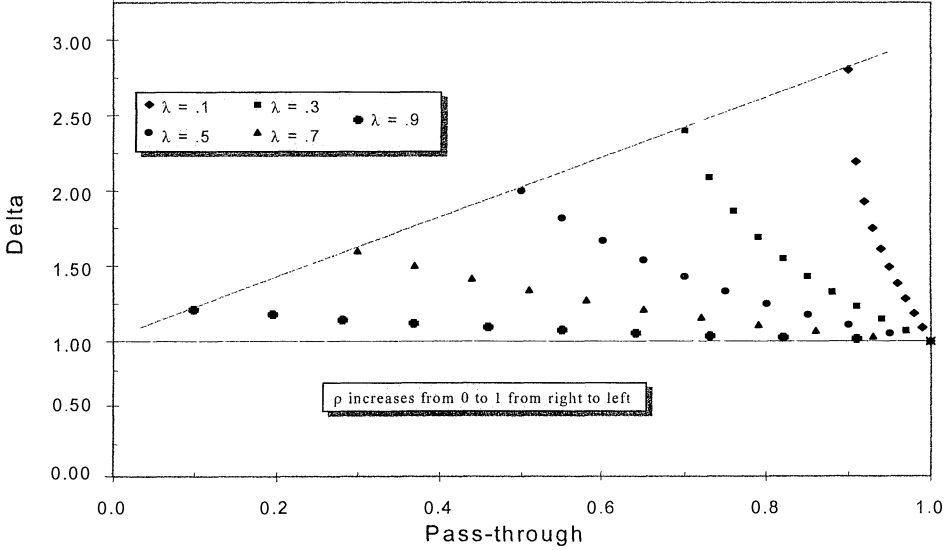
$$\eta_1 = -\frac{d \ln P_1}{d \ln S} = (1 - \gamma) \left\{ \frac{(1 - \lambda\rho)}{1 - \rho^2\lambda(1 - \lambda)} \right\}. \quad (24)$$

With $\gamma > 0$, and with ρ and λ assumed to be between zero and one, the pass-through elasticity must be less than one. A depreciation of the exporter's currency ($dS > 0$) leads to a fall in its price in foreign currency, but once again the fall in price is less than proportionate.

¹⁴ These combinations correspond to low levels of λ (< 0.15) and high values for $\rho \in (0.5, 1)$. These are situations where the exporter has very low market power. For these values, the proportional impact of higher market share on profits, holding profit margins fixed, is smaller in absolute value than the proportional impact of higher market shares on the profits through the exchange-rate-induced profit margin adjustment. The result is a positive change in exposure for increased market share in these cases. However, once market power is sufficiently large, either through market share or low substitutability, this derivative turns everywhere negative.

¹⁵ Since $d \ln P_1 / dS < 0$, this derivative is multiplied by -1 to ensure that the elasticity is positive.

PANEL A



PANEL B

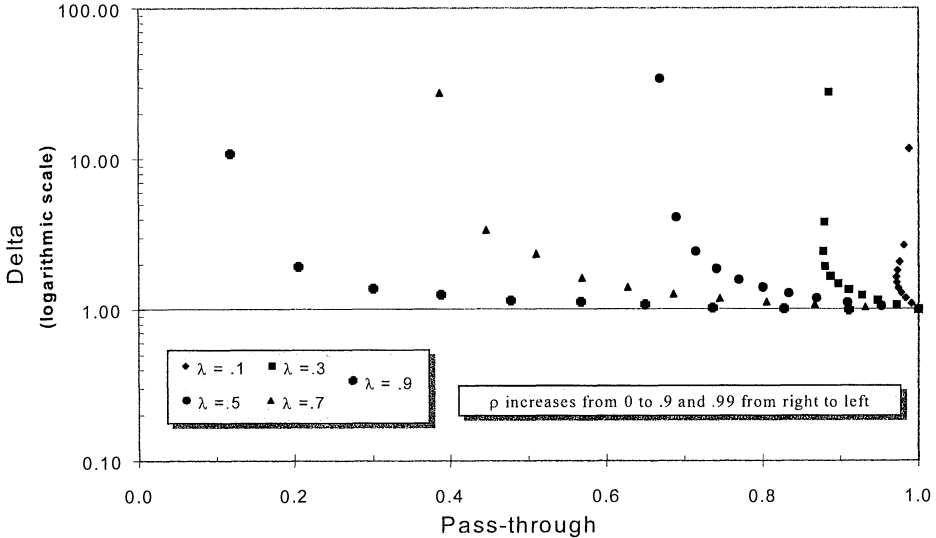


Figure 1. Relation between pass-through and delta for pure exporter as ρ changes, for different levels of market share: quantity competition model (Panel A) and price competition model (Panel B). Panel A shows the relation between exposure (delta) and pass-through as a function of market share, λ , and substitutability, ρ , for the quantity competition model. The figure is shown for a percentage of foreign currency costs, gamma, of zero. Positive values of gamma would result in the loci of points moving to the southwest. Panel B shows the relation between exposure (delta) and pass-through as a function of market share, λ , and substitutability, ρ , for the quantity competition model. The figure is shown for a percentage of foreign currency costs, gamma, of zero. Positive values of gamma would result in the loci of points moving to the southwest.

As above, the exchange rate exposure of the exporter, $d \ln \pi_1^*/d \ln S$, can be derived from differentiating the profit function (14b) with respect to S :

$$\delta = \frac{d \ln \pi_1^*}{d \ln S} = 1 + \frac{(1 - \lambda)(1 - \gamma)\rho[1 - \rho(1 - \lambda)]}{(1 - \rho)[1 - \rho^2\lambda(1 - \lambda)]}. \quad (25)$$

Since the numerator and denominator of the second term are greater than zero, the exposure expression is always greater than one. Thus, as in the case of quantity competition, a depreciation of the exporter's currency leads to a more than proportional increase in exporting profits.

The variation of pass-through and exposure across industries under price competition is fundamentally similar to the relation under quantity competition. Figure 1b displays the relation between pass-through and exposure for different levels of fixed market share as ρ increases from right to left (high levels of substitutability (>0.99) are not shown in the figure). As in the quantity competition case, the curves have a negative slope.¹⁶ However, in contrast to the quantity competition case, the slope of the relationship increases drastically as substitutability increases, because δ goes to infinity as $\rho \rightarrow 1$, while pass-through reaches a finite limit with a fixed market share.¹⁷

IV. Data for the Empirical Analysis

One reason why empirical studies of pass-through and exposure have been done independently in the past is that they use very different data sets. Pass-through regressions typically relate export or import price series changes to exchange rate changes, while exchange rate exposure regressions relate firm value changes to exchange rate changes. The export price series are either price indexes developed by national statistical authorities or unit val-

¹⁶ For low enough market shares, however, the curve bends backward as $\rho \rightarrow 1$.

¹⁷ In addition, when market share is allowed to be endogenous, a strange feature of the price competition model with respect to pass-through becomes apparent. From formula (24), it can be shown that pass-through under price competition is equal to 100 percent of foreign cost $(1 - \gamma)$ as $\rho \rightarrow 0$, regardless of the market share. This result is directly intuitive: When the two goods are poor substitutes, the duopolist is in effect a monopolist facing a constant-price-elasticity demand curve; his price is proportional to marginal cost. What is less clear is the result as $\rho \rightarrow 1$ and market share is endogenous. One might think that perfect substitution would cause the exporting firm to pass through very little of its costs variations. However, when substitutability becomes perfect in this model, we reach a situation of pure Bertrand competition (see Tirole (1988, p. 209)). In this case, it is known that the two firms behave separately like pure competitors. They price at marginal cost, and based upon cost and demand preferences, one firm grabs the entire market, or if relative prices and demand preferences are perfectly balanced, the two firms perfectly split the market. In the case where conditions imply that the exporter will take the full market as $\rho \rightarrow 1$, he behaves increasingly like a perfect competitor and $\eta_1 \rightarrow 0$ as $\rho \rightarrow 1$. In contrast, in the case where conditions imply that the exporter will lose the market as $\rho \rightarrow 1$, he increasingly behaves as a monopolist as his market share shrinks to zero, and $\eta_1 \rightarrow (1 - \gamma)$ as $\rho \rightarrow 1$. Finally, when conditions are such that both the exporter and the foreign competitor maintain a positive market share when $\rho \rightarrow 1$, then pass-through has a limit between 0 and $(1 - \gamma)$ while δ goes to infinity.

ues derived from customs data. Changes in firm value are derived from equity return data, which are either used at a firm-level basis or aggregated to form industry-level indexes of returns.

In this paper, we use goods price and share price data from Japanese industries to examine whether the relation between pass-through behavior and exchange rate exposure suggested by the model outlined above is consistent with real-world behavior. We choose Japanese data for several reasons. First, we want to study oligopolistic industries that are heavily export oriented because the model developed above yields clear-cut results for such cases. In Japan, exports are concentrated in three industries: General Machinery (18.1 percent of exports), Electrical Machinery (31.3 percent), and Transport Equipment (24.2 percent),¹⁸ thus providing a concentrated set of export-oriented firms. Although Japanese firms have recently become more like American multinationals in their reliance on overseas production, they remain much more export oriented than firms in the United States. Evidence from international exchange rate exposure comparisons (see, e.g., Bodnar and Gentry (1993)), moreover, suggests that exchange rate exposures are economically and statistically more significant in Japan than in other industrialized countries.

In addition, we want export price series that are genuine price indexes rather than unit value series, as the latter suffer from well-known drawbacks. Japan has high quality export and domestic wholesale price indexes for a variety of manufactured products at various levels of aggregation. This disaggregation is important, as we need to match the export categories as closely as possible with share price series. Share price data generally determines the level of aggregation of the industries. If a particular export product is produced by an identifiable set of firms, then we choose to include that product in the estimation. In the case of the motor vehicle industry, for example, while there are several disaggregated output price series for automobiles and other motor vehicles, most of this equipment is made by a common set of firms. So the level of aggregation for this industry was dictated by the stock market data, not the price data.

We choose eight Japanese industries with heavy export ratios and major foreign competitors. These industries are: Construction Machinery, Copiers, Electronic Parts, Motor Vehicles, Cameras, Measuring Equipment, Film, and Magnetic Recording Products. Export and domestic price series for the goods produced by each industry we examine are taken from the Bank of Japan's *Price Index Annual*. The Japanese stock price data are taken from DataStream® and are self-constructed value-weighted total-return indexes for each industry based upon constituent lists of firms provided by DataStream or the *Japan Company Handbook*.¹⁹ All of the portfolios contain only firms listed on the first section of the Tokyo Stock Exchange. We use the Nikkei 225 index as a measure of the overall market movement.

¹⁸ These weights are from the 1995 export price series.

¹⁹ We take only the large firms in the constituency lists from DataStream, as our portfolios are value weighted. As a result, across the eight industries we have 38 of the largest companies.

In traditional studies of exchange rate exposure, end-of-month stock returns are related to end-of-month exchange rates. In this study, we are relating stock returns to real exchange rates as well as expenditure. Real exchange rates are calculated using monthly average prices, while expenditure is also measured as a monthly average. So the stock returns that we use in the exposure equations are monthly averages based on the daily stock prices during that month. Similarly, the nominal exchange rates used to calculate the real exchange rate are monthly averages. The use of monthly average exchange rates implies that our measurement of exposure elasticity is somewhat different from previous studies of Japanese exposure.

Exchange rates enter the structural model in two ways. In both the price and profit equation, market share is a function of relative marginal costs, proxied by foreign wholesale prices, which are converted into yen using yen/fc exchange rates. In the profit equation, total foreign expenditures, proxied by foreign GDP, are converted into yen, again using yen/fc exchange rates. To create the foreign marginal cost index, we form a weighted average of foreign wholesale price indexes using the export weights of 22 of Japan's 23 most important export markets.²⁰ The 22 countries represent 85 percent of Japan's exports. Table II lists the countries together with their respective shares in the foreign price index. Yen/fc exchange rates are used to convert the 22 national price indexes into yen. Note that some countries do not have wholesale price indexes for the entire period, in which case we substituted consumer price indexes. To create the foreign expenditure index, we form a weighted sum of foreign GDP series for the 13 countries (of the 22 above) that report quarterly GDP. The GDP series are in national currency units, so we convert them into yen using the yen/fc exchange rates. The weights for the resulting aggregate GDP exchange rate series are the relative GDPs themselves. Since all of the other data are monthly, we convert each quarterly GDP series into a monthly series through interpolation.²¹ All the wholesale, GDP, and exchange rate data are taken from the International Financial Statistics database.

Our estimation period is from January 1986 to December 1995. This 10-year period represents a compromise between the competing objectives of longer sample size and stable parameter estimation. With monthly data, 10 years gives us 120 observations. On the other hand, we believe that over 10 years, the form of competition in Japanese industry is stable enough to yield meaningful estimates of pricing and profit behavior.

In the estimation below, we also require estimates of the degree of involvement of Japanese firms in foreign markets. Table III displays this data. The first quantity displayed is "gamma," the share of imported inputs in total costs. This data is taken from Japanese input-output tables. We observe that, for most industries in our sample, the share is small. Second, "theta" is the share of profits that each Japanese industry derives from abroad. As a

²⁰ China was omitted because it does not have a price index available for the entire period.

²¹ Since it is permanent income that belongs in the demand equation, the resulting smoothed series should be an acceptable proxy.

Table II
Japanese Exchange Rate Index

The table displays the countries, the percentage weights, and the price index used to create the 22-country trade-weighted exchange-rate index for the real value of the Japanese yen and the 13-country GDP-weighted nominal exchange rate for the nominal value of the Japanese yen. Trade weights are based upon total bilateral trade flows for the year 1994. Wholesale price indices (WPI) are used when available and consumer price indices (CPI) are used otherwise. China is not included in the list, despite being a major trading partner with Japan, due to a lack of price data over part of the sample period. GDP weights are based upon January 1990 relative GDP weights in yen.

Panel A: Composition of Japanese 22 Country Real Exchange Rate Index		
Country	Trade Weight	Price Index
United States	35.41%	WPI
Hong Kong	7.68%	CPI
Korea	7.27%	WPI
Taiwan	7.10%	WPI
Singapore	5.85%	CPI
Germany	5.31%	WPI
Thailand	4.39%	CPI
Malaysia	3.69%	CPI
Australia	2.60%	WPI
Indonesia	2.29%	WPI
United Kingdom	3.80%	WPI
Netherlands	2.54%	WPI
Canada	1.76%	WPI
Panama	1.76%	CPI
Philippines	1.76%	WPI
France	1.57%	CPI
Mexico	1.25%	WPI
Belgium	1.13%	CPI
Italy	1.00%	CPI
South Africa	0.55%	WPI
Switzerland	0.66%	CPI
Spain	0.63%	WPI
	100.0%	

Panel B: Composition of Japanese 13-Country GDP-Weighted Exchange-Rate Series	
Country	GDP Weight
United States	46.94%
Germany	12.01%
France	9.66%
Italy	8.72%
United Kingdom	7.86%
Canada	4.87%
Australia	2.48%
Netherlands	2.29%
Mexico	1.92%
Switzerland	1.76%
South Africa	0.88%
Korea	0.49%
Philippines	0.10%
	100.0%

Table III
Japanese Industry Data

The table reports industry data on the following. Gamma: the percentage of imported inputs in the Japanese firms' input costs; imported input ratio as a percentage of costs with data from Japanese I-O tables. Measured as the ratio of imported inputs to the sum of gross output less operating surplus and depreciation of fixed capital. Data taken from *1990 Input Output Tables for Japan, Summary in English, March 1995* (1995). Theta: the percentage of foreign sales to total sales; export ratio measured as the simple average of the export ratio (foreign sales plus exports to total sales) reported in the *Japanese Company Handbook* over the years 1985, 1990, and 1994, converted into portfolios based upon the 1990 total sales figures. Data collected at firm level and formed into portfolio data. Leverage: total debt over total market value of firm; total book value of debt divided by the sum of total book value of debt plus market value of equity. Figures are the average of monthly data over 1986–1995. Data obtained from DataStream. Total debt data is annual and interpolated to obtain monthly estimates. Data is collected at firm level and aggregated into portfolios value weights.

Industry	Gamma % imported inputs	Theta % foreign sales	Leverage debt/(debt + equity)
Camera	4.38%	70%	32%
Construction Machinery	1.32%	38%	36%
Copiers	3.32%	48%	39%
Electronic Parts	4.23%	33%	18%
Film	6.01%	34%	16%
Magnetic Recording Products	2.05%	41%	12%
Measuring Equipment	4.80%	32%	22%
Motor Vehicles	1.39%	46%	34%

surrogate measure (since this information is not revealed by most Japanese firms), we use the sales-weighted ratio of export and foreign sales to total sales for the firms in each industry portfolio. The use of this sales ratio imposes the assumption that average operating profitability is equal at home and abroad. These data are from various editions of the Japan Company Handbook.

V. Estimates of Pass-through and Exposure

The estimation in this paper is a noteworthy departure from the previous empirical studies of pass-through and exposure. Unlike previous studies that estimate reduced form equations of either pass-through or exposure, we estimate equations for pass-through and exposure jointly using a common theoretical framework.

A. Equation Specification

The models of pass-through and exposure outlined in Section II have two major drawbacks as far as estimation is concerned. First, the models describe the behavior of a pure exporting firm, whereas the Japanese exporters that we will study also have significant domestic markets. Second, the models specify export prices and profits as functions of marginal costs, but

marginal costs are notoriously difficult to estimate. We attempt to solve both problems by introducing a simple markup model of pricing in the domestic Japanese market, rather than trying to model competition among the Japanese exporting firms in that market. Japanese domestic prices in many of our industries are quite sticky, so the assumption of a fixed domestic markup may not be a bad approximation.

If P_1^* is the price of the Japanese good in its own market (in yen), then the markup equation is given by

$$P_1^* = m^*(C_1^* + SC_1), \quad (26)$$

and the domestic price can be used to control for costs. Substituting (26) into (10a) for the quantity competition model or (10b) for the price competition model, and linearizing around a value of λ equal to the unconditional expected value of market share, we obtain for industry j

$$d \ln (S \cdot P_{1,j}) - d \ln P_{1,j}^* = (1 - \eta_{0,j})[d \ln S + d \ln C_2 - d \ln P_{1,j}^*], \quad (27)$$

with $\eta_0 = \eta/(1 - \gamma)$, where η is the original pass-through coefficient from the theoretical model, which is given by (16) for the quantity competition model and by (24) for the price competition model.²²

Linearizing similarly the profit equations (equations (14a) and (14b)) after substituting (26), we obtain

$$d \ln \pi_1^* = d \ln (SY) + (\delta_0 - 1)d \ln \left[\frac{SC_2}{P_1^*} \right], \quad (28)$$

with $(\delta_0 - 1) = (\delta - 1)/(1 - \gamma)$, where δ is the exposure elasticity from the theoretical model given by (21) for the quantity competition model and by (25) for the price competition model.

The original models outlined in the previous section were nonlinear, which implies that the coefficients of the linearized equations are not constant over time. The assumption we are making implicitly when we assume that the coefficients are constant is that market share λ does not move much over time. This is an assumption we shall have to return to.

We make several important modifications to our empirical profit equation (28) to facilitate estimation. Because accounting data for profits are considered so unreliable and available only infrequently, we transform the profit equation into an equation explaining the firm's value so that we can use share price data. To account for valuation changes for the market as a whole (which are driven by the discount factor changes in the Japanese stock mar-

²² The reason why η_0 replaces η is that the expression for P_1^* eliminates the direct influence of γ from the model and makes the estimates of pass-through and exposure for the industries interpretable in terms of Figure 1a and b.

ket as well as other common macro-factors), we include the stock market index (V_{NIK}) in the equation and estimate a coefficient (beta) for the market's influence on the industry's stock price (V_j). Hence, $d \ln(\pi_1^*)$ in (28) is interpreted for industry j as being $d \ln(V_j)$ purged of the Japanese market-wide movement adjusted by the industry's beta:

$$d \ln \pi_j = d \ln V_j - \beta_j d \ln V_{NIK}, \quad (29)$$

where

V_j = the market value of industry j (in yen),
 V_{NIK} = the market value of the Nikkei 225 index, and
 β_j = the beta of industry j with the Nikkei 225 index.

The second modification involves taking into account the impact of domestic sales on the exporting firm's profits. If some firms derive only 25 percent of their profits from exports while others derive 75 percent of their profits from exports, the exposure estimates will differ even if competitive behavior is identical across industries. We do not attempt to model demand behavior in the domestic market. Were we to estimate the share of profit coming from abroad, any degree of foreign exchange exposure would be tautologically explainable because the share of profit would be a free parameter in the profit equation. To solve this problem, we assume that the share of total profit coming from abroad, expected at the beginning of each period, is a constant equal to θ_j , the share of sales from abroad (see Table III).

Starting with equations (14a) and (14b), which give us the profits of a pure exporting firm and denoting the profits from exporting in industry j as π_j^{EXPORT} , we have

$$\frac{\pi_j^{EXPORT}}{\pi_j^{TOTAL}} = \theta_j. \quad (30)$$

If exchange rates affect only export profits, taking log differences of equation (30) and substituting equation (28) gives

$$d \ln \pi_j^{TOTAL} = \theta_j \left\{ d \ln(SY) + (\delta_{0,j} - 1) d \ln \left[\frac{SC_2}{P_{1,j}^*} \right] \right\}. \quad (31)$$

From our use of market adjusted stock returns as a proxy for profit changes we define

$$d \ln \pi_i^{TOTAL} = d \ln V_i - \beta_i d \ln V_{NIK}, \quad (32)$$

and we can then rewrite equation (31) as^{23,24}

$$d \ln V_j - \theta_j d \ln SY = \beta_j d \ln V_{NIK} + \theta_j (\delta_{0,j} - 1) [d \ln S + d \ln C_2 - d \ln P_{1,j}^*]. \quad (33)$$

The third modification makes an adjustment for the effects of leverage on the return data. Our theoretical model provides the exposure elasticity for an unleveraged firm, so to correctly estimate the model we need to adjust the equity return data by an appropriate leverage factor, $D/V(\text{Debt}/(\text{Debt} + \text{Equity}))$. We obtain data on total debt (book value) and the market value of equity from DataStream. Since the debt data is only available annually, we interpolate between annual observations to create a monthly series for leverage. The average leverage factors for each industry are shown in Table III and range between 0.12 and 0.39. The return on the Nikkei is similarly adjusted by a leverage factor for the market as a whole. The delevered equity returns are used in all estimations of exchange rate exposure.²⁵

Given these three modifications, the two-equation empirical model (equations (27) and (33)) to be estimated for each industry involves two fundamental parameters from the utility function. The key parameter is ρ_j , the degree of substitutability between the export good and the competing product in the foreign market. Higher values of ρ_j indicate higher levels of substitutability, with a value of unity representing perfect substitutability between export and foreign product. At the other extreme, values of ρ_j close to zero represent low levels of substitutability and relatively large market power. The other fundamental parameter is a product of the utility preference parameter, α , and the price-cost markup in the domestic market, m^* . Since these parameters appear together, they cannot be separately identified, so we simply denote their combination as a^* .

B. Estimates of the Structural Models

B.1. Quantity Competition

For our own model of exposure to be properly interpreted in terms of behavior, we need to estimate pass-through equations along with exposure equa-

²³ In equations (33) and (34), we adopt the convention of placing on the right-hand side the terms that involve a parameter to be estimated, and which, for that reason, will generate an orthogonality condition.

²⁴ Because share prices will be influenced by factors not included in our model, the actual exposure regressions will contain an error term even though no error term appears explicitly in equation (33).

²⁵ The equity return data is delevered by scaling the excess return by $(1 - D/V)$ and then adding back in the risk-free rate. This approach implicitly assumes that the beta of the firm's debt is zero and that there are no tax effects. The use of the delevered data results in proportionally smaller estimates of delta than would be obtained from the normal leveraged returns. Given that the leverage factors and the corresponding probabilities of default are on average small (less than 0.4), any optionlike impact of the leverage on the exposure estimates is not material. We are grateful to René Stulz for pointing out this leverage adjustment.

tions. The reason pass-through equations are needed is that the exposure regression alone cannot identify the key structural parameter ρ_j along with the market share λ_j , which is a function of ρ_j , and a_j^* . If the pass-through and exposure equations are estimated jointly, then ρ_j and λ_j are just identified as equations (27) and (33) make clear.

The two-equation model of pass-through and exposure is estimated using a generalized least square (GLS) estimation procedure.²⁶ We then use the estimates of $(1 - \eta_{0,j})$ and $(\delta_{0,j} - 1)$ to solve for the structural parameters of our models, ρ_j , and a_j^* , choosing their values in such a way that the model reconstructs the average values of pass-through and exposure over time.

Table IV reports the estimates of $\eta_{0,j}$ and $\delta_{0,j}$ together with the implied estimates of the structural parameters for the quantity competition model.²⁷ The table also shows in parentheses, below each estimate, the standard error of that estimate.²⁸ In addition, because our estimation technique requires market share, pass-through, and exposure to be constant (even though the structural model allows them to be time varying), we report one more standard deviation, shown in a second row of parentheses, which measures the variation of these variables over time. This last standard deviation will be used to validate the linearization that has been performed prior to estimating the model.

Table IV shows that in three of the eight industries, namely, Copiers, Measuring Equipment, and Magnetic Recording Products, the parameter estimates for pass-through and exposure are within the theoretical limits of our model. Figure 2a shows combinations of $\eta_{0,j}$ and $\delta_{0,j}$, plotted in the theoretical space defined by various market shares and substitutability. The above named industries all lie within the limits of this figure.

²⁶ Intercept terms are included in the two equations.

²⁷ Note that the exposure estimates from the structural model, $\delta_{0,j}$, are for the industry as if it were a pure exporter. This allows direct comparison of the relation between pass-through and exposure across a set of industries with disparate export ratios.

²⁸ Consider several variables such as time-averaged pass-through, η , exposure, δ , or market share, λ , explained by our theory in relation to two parameters, ρ and a^* :

$$\eta = \eta(\rho, a^*); \delta = \delta(\rho, a^*); \lambda = \lambda(\rho, a^*).$$

Suppose we know the variance-covariance matrix, Ω , of the estimates of η and δ . Then, the variance-covariance matrix, Σ , of the estimates of ρ and a^* is given by

$$\Sigma = \begin{bmatrix} \partial\eta/\partial\rho & \partial\eta/\partial a^* \\ \partial\delta/\partial\rho & \partial\delta/\partial a^* \end{bmatrix}^{-1} \Omega \begin{bmatrix} \partial\eta/\partial\rho & \partial\delta/\partial\rho \\ \partial\eta/\partial a^* & \partial\delta/\partial a^* \end{bmatrix}^{-1}.$$

And the variance of the estimate of λ is provided by

$$[\partial\lambda/\partial\rho \quad \partial\lambda/\partial a^*] \Sigma \begin{bmatrix} \partial\lambda/\partial\rho \\ \partial\lambda/\partial a^* \end{bmatrix}.$$

Table IV
Estimation of Pass-through and Exposure Equations for the Quantity Competition Model

The table reports estimates of pass-through, $\eta_{0,j}$, and “pure exporter” exposure, $\delta_{0,j}$, from the two-equation quantity competition model for eight Japanese export industries over the period from 1986 to 1995. Estimation is done using a generalized least square (GLS) estimation procedure (intercept terms are included in the two equations). The estimates of $\eta_{0,j}$ and $\delta_{0,j}$ are used to solve for the structural parameters of the model, ρ_j , and a_j^* , choosing their values in such a way that the model will reconstruct the average values of pass-through and exposure over time. When the point estimate of either pass-through or exposure lies outside the theoretically allowable range, we are unable to solve for the structural parameters. When available, these structural parameters are used to construct the resulting implied market share, λ . Below each parameter estimates the table also shows, in parentheses, the standard error of that estimate. Because our solution technique requires the market share, pass-through, and exposure to be constant (even though the structural model allows them to be time varying), we also report a second standard deviation for $\eta_{0,j}$, $\delta_{0,j}$, and λ_j , shown in a second row of parentheses, which measures the variation of these variables *over time*. This last standard deviation is used to validate the linearization that has been performed prior to performing the estimation of the model.

Industry j	Estimates of Pass-through, $\eta_{0,j}$, and Exposure, $\delta_{0,j}$ (Pure Exporter) (Eqs. 27 & 33)		Implied Estimates of Structural Parameters under Quantity Competition Model		Resulting Time-average of Market Share
	$\eta_{0,j}$	$\delta_{0,j}$	ρ_j	$a_j^* = a_j \times (m_j^*) - \rho_j$	
Cameras	0.471 (0.062)	0.687 (0.143)			>1 Exposure is too low
Construction Machinery	0.805 (0.025)	0.384 (0.269)			>1 Exposure is too low
Copters	0.284 (0.036)	1.087 (0.231)	0.765 (0.133)	14.427 (37.333)	0.935 (0.158) (0.004)
Electronic Parts	0.003 (0.244)	(0.006) 1.658	(0.006) >1		
Film	0.043 (0.146)	(0.482) 1.494	Pass-through is too low >1		
Magnetic Recording Products	0.043 (0.057)	(0.446) 1.433	Pass-through is too low 0.999	3.487 (2.782)	0.783 (0.133) (0.058)
Measuring Equipment	0.058 (0.074)	(0.116) (0.627)	(0.175) (0.174)		0.263 (0.086) (0.019)
Motor Vehicles	0.750 (0.018)	2.282 (0.026)	0.950 (0.174)	0.359 (0.161)	>1 Exposure is too low
	0.262 (0.029)	0.711 (0.317)			

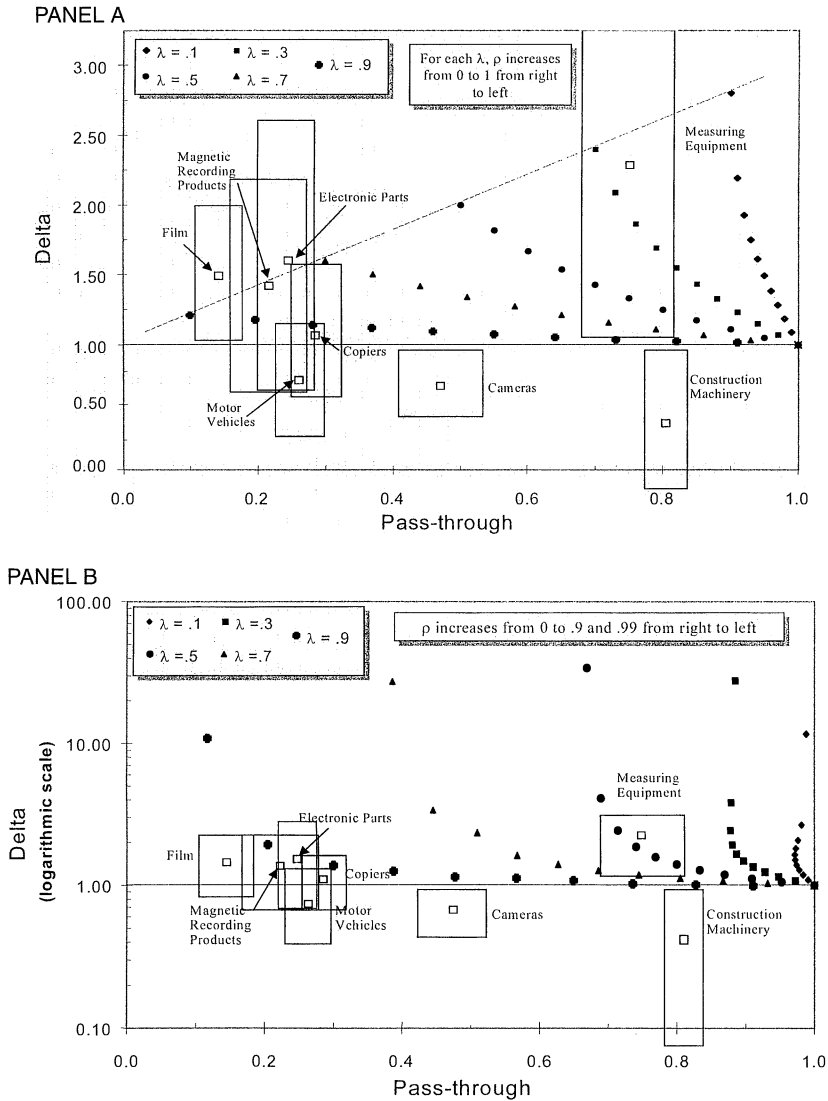


Figure 2. Estimates for exposure (delta) and pass-through for eight Japanese industries: quantity competition model (Panel A) and price competition model (Panel B). Panel A shows empirical estimates of exposure (delta) and pass-through consistent with the structural model for quantity competition for the eight Japanese industries examined. The estimates are adjusted to a pure exporter with no foreign currency costs to allow the estimates to be overlaid on the state space defined by the structural model for various market shares and elasticities of substitutions (ρ). The estimates are plotted along with two standard deviation bands around the point estimates. Panel B shows empirical estimates of exposure (delta) and pass-through consistent with the structural model for price competition for the eight Japanese industries examined. The estimates are adjusted to a pure exporter with no foreign currency costs to allow the estimates to be overlaid on the state space defined by the structural model for various market shares and elasticities of substitutions (ρ). The estimates are plotted along with two standard deviation bands around the point estimates.

In three other industries, namely, Construction Machinery, Motor Vehicles, and Cameras, the estimate of exposure is “too low” to be consistent with the quantity competition model (for any level of pass-through). That is, the estimates are below the lower limit of exposure of 1.0 permitted by the model. The figure also shows two standard deviation bands around the point estimates. For two of these three industries, Construction Machinery and Cameras, the estimates of delta are significantly below 1.0, while for Motor Vehicles we cannot reject the possibility that the true exposure is within the theoretical range (though it would require a high market share and degree of substitutability). For these three industries, the exposure elasticity is too low to be consistent with a simple quantity-based profit maximizing model.

For the other two industries, Film and Electronic Parts, the estimated pass-through and exposure coefficients lie northwest of all the curves in Figure 2a (though not statistically so). We can interpret these estimates in two alternative ways:

1. In these two sectors, pass-through is too low to be consistent with the quantity competition model. That is, estimated values of pass-through are so low that they imply ρ_j s that are greater than one. Previous studies of Japanese pricing had found pass-through coefficients that seemed too low, but we are able to be more precise about the meaning of *too low* because our joint model of pass-through and exposure allows us to extract structural parameters from the estimates.
2. It is equally valid to say that in these two industries, exposure is too high to be consistent with the quantity competition model. In the case of Film, for example, a lower estimate of $\delta_{0,j}$ together with the estimated value of pass-through would give values of ρ_j and λ_j consistent with the model (see Figure 1a). So in the case of two industries, rather than finding estimates of exposure that are too low, we have found exposure estimates that are too high. In only three industries do we find corroboration for the view in the exposure literature that estimates are too low.

We should not overemphasize this finding, however, since in the case of the two industries with exposure that is too high, the estimates are within two standard errors of parameter values acceptable to the model. (That is, the standard error bands around the estimates lie within the range permitted by the model.) The most we can say is that we find only weak evidence that exposure is too low.

B.2. Price Competition

The estimates of $\eta_{0,j}$ and $\delta_{0,j}$ can also be interpreted in terms of the price competition model. That is, estimates of $\eta_{0,j}$ and $\delta_{0,j}$ can be solved for the underlying parameters using the price competition model rather than the quantity competition model. The results are reported in Table V according to the same format as in Table IV. For the same three industries, namely, Con-

Table V

Estimation of Pass-through and Exposure Equations for the Price Competition Model

The table reports estimates of pass-through, $\eta_{0,j}$, and “pure exporter” exposure, $\delta_{0,j}$, from the two-equation price competition model for eight Japanese export industries over the period from 1986 to 1995. Estimation is done using a generalized least square (GLS) estimation procedure (intercept terms are included in the two equations). The estimates of $\eta_{0,j}$ and $\delta_{0,j}$ are used to solve for the structural parameters of the model, ρ_j , and α_j^* , choosing their values in such a way that the model reconstructs the average values of pass-through and exposure over time. When the point estimate of either pass-through or exposure lies outside the theoretically allowable range we are unable to solve for the structural parameters. When available, these structural parameters are used to construct the resulting implied market share, λ . Below each parameter estimates the table also shows, in parentheses, the standard error of that estimate. Because our solution technique requires the market share, pass-through, and exposure to be constant (even though the structural model allows them to be time varying), we also report a second standard deviation for $\eta_{0,j}$, $\delta_{0,j}$, and λ_j , shown in a second row of parentheses, which measures the variation of these variables over time. This last standard deviation is used to validate the linearization that has been performed prior to performing the estimation of the model.

Industry j	Estimates of Pass-through, $\eta_{0,j}$, and Exposure, $\delta_{0,j}$ (Pure Exporter)		Implied Estimates of Structural Parameters under Price Competition Model		Resulting Time-average of Market Share
	$\eta_{0,j}$	$\delta_{0,j}$	ρ_j	$\alpha_j \times (m_j^* - \rho_j)$	
Cameras	0.471 (0.062)	0.687 (0.143)			Average(λ_j) >1 Exposure is too low
Construction Machinery	0.805 (0.025)	0.384 (0.269)			>1 Exposure is too low
Copters	0.284 (0.036)	1.087 (0.231)	0.743 (0.075)	12.640 (31.085)	0.970 (0.071)
Electronic Parts	0.244 (0.043)	1.658 (0.482)	0.865 (0.050)	2.574 (1.167)	(0.002) 0.895 (0.044)
Film	0.146 (0.043)	1.494 (0.446)	0.907 (0.041)	3.294 (2.071)	(0.019) (0.032)
Magnetic Recording Products	0.218 (0.057)	1.433 (0.383)	0.866 (0.051)	3.081 (1.477)	(0.007) 0.918 (0.042)
Measuring Equipment	0.750 (0.074)	2.282 (0.627)	0.778 (0.091)	0.937 (0.167)	(0.038) 0.466 (0.086)
Motor Vehicles	0.262 (0.029)	0.711 (0.317)			(0.040) >1 Exposure is too low

struction Machinery, Motor Vehicles, and Cameras, the exposure elasticity estimates lie below the lower limit of 1.0 (although just as in the case of quantity competition, for one of these industries, the estimates are within two standard errors of 1.0). Figure 2b plots all eight industries for the price competition case. In the case of the other five industries, the price competition model can simultaneously rationalize the observed exposure and pass-through behavior. These include two industries, namely, Electronic Parts and Film, which could not satisfactorily be “explained” by the quantity competition model. This is primarily because the price competition model is able to cover a larger area of the pass-through-exposure space. In many of those sectors, however, the implied estimates for market share are implausibly large. Examples would be Copiers, Motor Vehicles, and Film. In the case of film, Fuji and Konica share the world market with Kodak, and the Japanese market share is far smaller than the 0.949 estimate.

Some industries in Table V show time variations of the three variables, market share, pass-through, and exposure. Where this happens, this calls into question the legitimacy of our linearization. In the case of Electronic Parts, the standard error of the pass-through estimate assumed to be constant is 0.043 while the time variation of the variable in the model is equal to 0.021. The latter is not negligible next to the former. A similar picture emerges as far as market share is concerned. For Magnetic Recording Products, all three variables appear to have significant variation over time, so the linearization is also suspect in this case. It may be true that for those industries, nonlinearities are important enough to require estimation of the actual (nonlinear) structural equations.

C. Comparison with Previous Estimates of Exposure

In previous empirical studies (see references in Section I), the most common approach used for estimating exchange rate exposure was to regress the stock return of firm/industry j on a market return and the change in a nominal exchange rate variable. In our notation, this common specification can be written as²⁹

$$d \ln V_j - \beta_j d \ln V_{NIK} = h_j d \ln S, \quad (34)$$

where $d \ln S$ is the percentage change in the nominal effective exchange rate. The coefficient h_j , which is rightfully used as a variance-minimizing hedge ratio between the stock price and the exchange rate, is generally reported as the exchange rate exposure of the firm. This is then often analyzed as representing the behavior of the firm’s profits in response to the exchange rate.

²⁹ For simplicity, we do not write constant terms in both equations (33) and (34) but they are present. For purposes of comparison, we have moved the term $\beta_j d \ln V_{NIK}$ to the left-hand side in (34), retaining here the value of β_j estimated under (33).

It is interesting to consider the difference between this standard estimate of exposure and our estimate given by (33). In contrast to h_j above, the coefficient $\delta_{0,j}$ from (33) is the exposure measure that can be interpreted in economic terms, using a model of the firm like the ones presented in this paper. In general, the two coefficients will be different, and it is only the latter coefficient, $\delta_{0,j}$ that can be interpreted as “too small” or “too large” in relation to the activities of the firm. While being the correct measure of a hedge ratio, equation (34) is misspecified as a representation of the economic behavior of the firm in response to a pure exchange rate change, because of missing variables.

Table VI displays the hedge ratios estimated with specifications like those found in the rest of the literature (as in equation (34)), and compares them with the structural delta coefficients estimated from our (quantity competition) model. Table VI reports both the “pure exporter” delta for the industry, $\delta_{0,j}$, in column 1 and the adjusted delta coefficient $\theta_j \times \delta_{0,j}$ of column 2, which incorporates the ratio of export profits to total profits θ_j .³⁰ The relevant comparison to be made is between the hedge ratio of column 4 and the adjusted delta estimate of column 2.

Differences between our structural equation (33) and the statistical equation (34) can be classified into two categories: The differences in the terms of the equation and the differences in the nature of the exogenous variable.³¹ In the first category, we note the fact that equation (33) contains the terms $-\theta_j d \ln SY + \theta_j [d \ln S + d \ln C_2 - d \ln P_{1,j}^*]$ whereas equation (34) does not. We also note the difference in the explanatory variable across the two equations. For equation (33), it is $[d \ln S + d \ln C_2 - d \ln P_{1,j}^*]$, the increment in the real exchange rate, while for equation (34), it is $d \ln S$, the increment in the nominal rate. The second category arises from the difference in orthogonality conditions. For some industries, the fact that the real exchange rate is the exogenous variable in (33) whereas the nominal exchange rate is the exogenous variable in (34) creates a large difference in the estimates.

To illustrate the relative importance of the two categories of differences, we insert column 3 in Table VI. Column 3 is calculated by estimating equation (33), artificially replacing the requirement that the residual should be

³⁰ The reason for this adjustment is that the model is based upon the assumption that the firm is a pure exporter. This facilitates cross-industry comparison of pass-through behavior (which is not dependent on the extent of exporting) to exposure (which is dependent upon the extent of exporting). The structural model derives a delta as if the industry was a pure exporter (100 percent exports). Such an assumption overstates the true exposure of the industry if exports are less than 100 percent. Adjusting the pure export delta by the export ratio scales the delta down for the actual level of exporting of the industry. Studies such as Jorion (1990) relate the coefficient h_j to the ratio of foreign to total sales, the same data that we use as a proxy for θ_j , the ratio of foreign-based profits to total profits.

³¹ There is one more difference between our estimates and traditional hedge ratio estimations. We have been forced to work with average monthly data (because export prices were available in this form) whereas traditional hedge ratio estimations are correctly performed on the basis of end-of-month to end-of-month rates of return. We do not discuss this difference because there is no reason for it systematically to be of one sign or the other.

Table VI
Comparison of Quantity Competition Model Delta with Standard Estimates of Hedge Ratio

The table compares the estimates of delta from the structural model with the simple hedge ratios commonly estimated elsewhere in the exposure literature. Column 1 displays the “pure exporter” delta estimate from Table IV. Column 2 shows this structural delta scaled down for nonexport activity by the factor θ , the proxy for the foreign income ratio for each industry. In these first two columns, the orthogonality condition for delta is with respect to the dependent variable and the real exchange rate for each industry. Column 3 displays estimates of a scaled delta where the orthogonality condition for delta is with respect to the dependent variable and the nominal exchange rate (the orthogonality condition for standard exposure estimates). Column 4 displays the standard exposure estimates as a simple hedge ratio, h_j (from equation (34)), where the orthogonality condition is with respect to the dependent variable and the nominal exchange rate. The difference between columns 3 and 4 is a result of the correlation between the nominal rate and the other variables in the structural model not controlled for when estimating the simple hedge ratio (i.e., Y , C_2 , and P_1^*). All estimates in this table are obtained by joint estimation with equation (27).

$$\text{Equation (33): } d \ln V_j - \beta_j d \ln V_{NIK} - \theta_j d \ln SY = \theta_j \times (\delta_{0,j} - 1)[d \ln S + d \ln C_2 - d \ln P_{1,j}^*]$$

$$\text{Equation (34): } d \ln V_j - \beta_j d \ln V_{NIK} = h_j d \ln S$$

Industry j	1	2	3	4
	$\delta_{0,j}$ Delta from Structural Model (Pure Exporter); Equation (33)	$\delta_{0,j} \times \theta_j$ Delta Scaled by Foreign Income Ratio; Equation (33)	$\delta_{0,j} \times \theta_j$ Orthogonality Condition with Respect to $d \ln S$; Equation (33)	Hedge ratio, h_j ; Equation (34)
Cameras	0.687 (0.143)	0.484 (0.101)	0.585 (0.109)	0.584 (0.108)
Construction Machinery	0.384 (0.269)	0.145 (0.101)	0.141 (0.103)	0.152 (0.101)
Copiers	1.087 (0.231)	0.522 (0.111)	0.513 (0.115)	0.516 (0.111)
Electronic Parts	1.651 (0.482)	0.552 (0.161)	0.596 (0.164)	0.587 (0.160)
Film	1.494 (0.446)	0.509 (0.152)	0.457 (0.156)	0.462 (0.155)
Magnetic Recording Products	1.433 (0.383)	0.588 (0.157)	0.920 (0.220)	0.875 (0.192)
Measuring Equipment	2.282 (0.629)	0.750 (0.207)	0.824 (0.210)	0.811 (0.200)
Motor Vehicles	0.711 (0.227)	0.328 (0.105)	0.334 (0.106)	0.338 (0.105)

uncorrelated with the real exchange rate by the requirement that it should be uncorrelated with the nominal exchange rate.³² For several industries, there are significant differences in exposure elasticities. The differences between columns 3 and 4 are entirely the result of the differences in the terms

³² We do this by means of an instrumental variable routine.

of the equation. This effect is generally quite small in comparison to the difference in the statistical exogeneity specification.

Algebraically, the difference between columns 2 and 3 of Table VI amounts to the following. Define z_j as the dependent variable:

$$z_j = d \ln V_j - \beta_j d \ln V_{NIK} - \theta_j d \ln(SY) + \theta_j [d \ln S + d \ln C_2 - d \ln P_{1,j}^*]. \quad (35)$$

Then the slope coefficient in column 2, which we estimated earlier, satisfies the requirement that

$$\text{cov}\{z_j - \theta_j \delta_{0,j} [d \ln S + d \ln C_2 - d \ln P_{1,j}^*], d \ln S + d \ln C_2 - d \ln P_{1,j}^*\}, \quad (36)$$

and is, therefore, equal to

$$\theta_j \delta_{0,j} = \frac{\text{cov}[z_j, d \ln S] + \text{cov}[z_j, d \ln C_2 - d \ln P_{1,j}^*]}{\text{var}[d \ln S] + \text{var}[d \ln C_2 - d \ln P_{1,j}^*] + 2 \text{cov}[d \ln S, d \ln C_2 - d \ln P_{1,j}^*]}, \quad (37)$$

whereas the slope coefficient in column 3 satisfies the requirement that

$$\text{cov}\{z_j - \theta_j \delta_{0,j} [d \ln S + d \ln C_2 - d \ln P_{1,j}^*], d \ln S\} = 0, \quad (38)$$

and is, therefore, equal to

$$\theta_j \delta_{0,j} = \frac{\text{cov}[z_j, d \ln S]}{\text{var}[d \ln S] + \text{cov}[d \ln S, d \ln C_2 - d \ln P_{1,j}^*]}. \quad (39)$$

For the purpose of comparing equations (37) and (39), we note that $\text{cov}[d \ln z_j, d \ln C_2 - d \ln P_{1,j}^*]$ may be of either sign, that $\text{var}[d \ln C_2 - d \ln P_{1,j}^*]$ is, of course positive, while it would make sense for $\text{cov}[d \ln S, d \ln C_2 - d \ln P_{1,j}^*]$ to be negative normally. As a result of these three influences, there can be a large difference between the two estimations.

While the estimate of exposure given by (39) is very close to the financial hedge ratio, the estimate of exposure given by (37) is the one that can be interpreted in terms of the economics of the firm. We can see that there can be differences between the two. It may frequently be difficult to judge a financial hedge ratio, as in (34), as being too high or too low relative to our concept of the firm's international activity.

While naïve estimates of exposure as per equation (34) are misspecified under our null hypothesis, it is quite possible that our model itself is also misspecified. As compared to the naïve model, we have reduced the likelihood of that occurring by providing sound economic foundations. However, some of our empirical results raise doubts about the validity of the model. Among these are the unreasonably high market share estimates of the price

competition model. Since these high estimates are the direct consequences of low observed pass-throughs, one might wish to consider alternative micro-foundations based on dynamic models of price competition, capable of generating price sluggishness.

VI. Conclusion

We have developed a duopoly model of an exporting firm and solved it under the alternative assumptions of quantity and price competition to explain simultaneously the behavior of the prices of goods and the profits for a firm that competes with a local firm in a foreign market. We have illustrated the role of two important variables in this matter: the elasticity of substitution between the home-produced and the foreign-produced goods and market share. In both models, as substitutability increases, keeping market share fixed, pass-through declines and exposure increases. Moreover, holding substitutability fixed, increases in market share reduce both pass-through and exposure elasticities.

These models define a structural relation between a firm's pass-through decision and its resulting exchange rate exposure and provide a framework for determining if estimates of exposure are sensible. We empirically test these models on data for a set of export intensive Japanese industries. We find that these models are capable of explaining some, but certainly not all, of the features of the data. For three of the eight industries, the data produce estimates of exposure that are too small to be consistent with either model, and in two of these cases, the estimates are significantly too low. For the quantity competition model, three of the remaining industries produce pass-through–exposure combinations that are within the acceptable range for the model, while the remaining two lie just outside the theoretical range though neither is a statistically significant violation. Estimates for five industries are within the theoretical limits of the price competition model (which generally allows for greater range of pass-through–exposure pairs than does the quantity model). Overall, the empirical estimation of our models provides no consistent evidence that exposures measured by stock market returns underestimate the true foreign currency sensitivity of firms with substantial export activities.

While the parameter estimates obtained from the joint estimation are generally economically meaningful, for several industries the estimates of the degree of substitution and of market share seem to be too large relative to casual observation. These large market shares and high substitutability estimates are necessary for the structural model to generate the observed combination of low pass-through and high exposure evident for many of these Japanese industries. Thus it appears that for these industries, pass-through is too low when compared to exposure, or exposure is too high relative to pass-through. Further research along the same lines as this study—examining pass-through and exposure simultaneously—may be able to explain these industries better by using more complex models of competition.

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