Pass-through and Exposure

Gordon M. Bodnar
Wharton School, University of Pennsylvania
2300 SH-DH
Philadelphia, PA 19104-6367
215-898-4260
bodnarg@wharton.upenn.edu

Bernard Dumas
HEC Graduate School of Management
78351 Jouy-en-Josas Cedex - France
331-3967-7282
dumas@gwsmtp.hec.fr

Richard C. Marston
Wharton School, University of Pennsylvania
2300 SH-DH
Philadelphia, PA 19104-6367
215-898-7626
weisscen@wharton.upenn.edu

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PASS-THROUGH AND EXPOSURE

Abstract

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" changes 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 pricing behavior should be governed by many of the same firm and industry characteristics which determine the exposure of a firm's profits to exchange rates. This paper will develop models of firm behavior, which will be used to study these closely related phenomena together.

We consider an imperfectly competitive environment where a local exporting firm competes against a foreign import-competing firm in the export market. Equilibrium behavior is solved for the case of quantity competition (the solution under price competition is displayed in the appendix). From the equilibrium specifications, we derive the optimal pass-through decisions and determine the exchange rate exposure that would result.

The quantity competition model is estimated on Japanese export-industry data that combines both the price data used in pass-through studies and the financial data used in exposure studies. In contrast to reduced form pass-through and exposure regressions previously estimated in the literature, we estimate non-linear regressions directly related to the structural model developed in this paper. The pass-through and exposure estimates are then compared across industries. The model is capable of simultaneously explaining the behavior of price and profit data across the industries with theoretically plausible parameter values estimates; although in some industries the degree of substitution and implied market share seem to be too large.

JEL Classifications: F3, L1

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I. INTRODUCTION

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" changes 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 pricing behavior should be governed by many of the same firm and industry characteristics which determine the exposure of a firm's profits to exchange rates. This paper will develop models of firm and industry behavior that will be used to study these closely related phenomena together. It will also provide estimates of pass-through and exposure behavior using data from Japanese export industries.

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 (1989), and Ohno (1989) examine the adjustment of export or import prices to exchange rate changes after taking into account any changes in marginal costs. Others 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.

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[1] For a recent survey of this literature, see Goldberg and Knetter (1996).

Most previous studies of *exchange rate exposure* such as Adler and Dumas (1984), Hekman (1985), Shapiro (1975), Flood and Lessard (1986), von Ungern-Sternberg and von Weizsacker (1990), Levi (1994), and Marston (1996) have investigated exposure in theoretical models of firm behavior. None of these studies have attempted to provide empirical estimates of their models. Jorion (1990) and Bodnar and Gentry (1993) have reported empirical 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 (1995) and Allayannis and Ihrig (1997) 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 will specify a theoretical model of exchange rate exposure that explicitly incorporates optimal export pricing behavior, and will provide direct estimates of this structural model.

To examine pass-through behavior and exchange rate exposure, we will model a firm with sales to a foreign export market. This exporting firm will compete with a foreign import-competing firm in that export market. The costs of the exporting firm are based primarily in the local (domestic) currency, while the foreign firm has only foreign currency costs. Thus changes in exchange rates will 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. In the body of the paper we will study industry behavior under quantity competition. Behavior under price competition is derived and discussed in the appendix.

In the empirical section of the paper, we will estimate the quantity competition equations for export prices and profits simultaneously. The equation specification will be directly based on the theoretical model of the exporting firm, although we will modify that model by adding a domestic market for the exporting firm. We will estimate the model using Japanese price and share price data. Eight Japanese industries will be studied, all of them major exporters.

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 vs. dynamic games. Our paper belongs obviously in the category of static games. 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 which 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 *et al.* (1992) also include the level of advertising expenditure. 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.

[2] These are: Slade (1986) which studies the gasoline distribution market in one area of Vancouver, Bresnahan (1987) which considers the US automobile market in 1954, 1955 and 1965, and Gasmi *et al.* (1992) which analyzes the soft-drink market. A fourth study by Brander and Zhang concerning the airline industry is apparently misclassified by Slade as it truly concerns a homogenous product.

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

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.

II. BASIC MODEL SETUP

A. Demand behavior

In the following sub sections we shall develop a duopoly model of an exporting firm and a foreign import-competing firm under quantity competition.[4] We are interested in deriving specifications for the optimal pass-through and exposure of the exporting firm. Since the currency pass-through and 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 to vary. One utility function, which permits variation in the degree of substitutability between these products, is the CES function, which has the form:

(1) $$U(X_1, X_2) = \left[aX_1^r + (1-a)X_2^r\right]^{1/r}$$

where: $U(.)$ is the utility function of the consumers in the foreign market

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

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

a is a preference weighting parameter

r is a parameter measuring the substitutability between these products.

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[4] A solution to the model under price competition can be found in the appendix.

This utility function is similar to that used by Dixit and Stiglitz (1977) in their study of imperfect competition.[5]

As in the case of the CES production function, ρ is related to the elasticity of substitution, σ, by the relationship $s = 1 / (r - 1)$. As ρ approaches 1, substitutability becomes perfect (i.e., $s \rightarrow -\infty$). 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 $r > 0$. So we will assume that $0 < r < 1$ and, therefore, that $-\infty < s < -1$. 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:[6]

(2a) $$P_1 = D_1\left(X_1, X_2\right) = \frac{aX_1^{(r-1)}Y}{\left[aX_1^{\ r} + (1-a)X_2^{\ r}\right]}$$

(2b) $$P_2 = D_2\left(X_1, X_2\right) = \frac{(1-a)X_2^{(r-1)}Y}{\left[aX_1^{\ r} + (1-a)X_2^{\ r}\right]}$$

where Y equals total expenditure on this industry's products.[7] 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 will play a central role in the analysis. Define l as the market share of the exporting firm in the foreign market. Using (2a), this market share can be written as:

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[5] Previous papers in the pass-through literature that use a similar specification include Feenstra, Gagnon, and Knetter (1996) and Yang (1997).

[6] 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).

[7] Thus we assume that this industry's product is weakly separable from all other goods in the consumer's utility function. See Varian (1984 pp. 148-149).

$$(3) \qquad l = \frac{P_1 X_1}{Y} = \frac{a X_1^{r}}{a X_1^{r} + (1-a) X_2^{r}}$$

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

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

$$(4) \qquad \begin{bmatrix} \dfrac{\P P_1 / \P X_1}{P_1 / X_1} & \dfrac{\P P_1 / \P X_2}{P_1 / X_2} \\ \dfrac{\P P_2 / \P X_1}{P_2 / X_1} & \dfrac{\P P_2 / \P X_2}{P_2 / X_2} \end{bmatrix} = \begin{bmatrix} r(1-l)-1 & -r(1-l) \\ -rl & rl-1 \end{bmatrix},$$

or, by matrix inversion:

$$(5) \qquad \begin{bmatrix} \dfrac{\P X_1 / \P P_1}{X_1 / P_1} & \dfrac{\P X_1 / \P P_2}{X_1 / P_2} \\ \dfrac{\P X_2 / \P P_1}{X_2 / P_1} & \dfrac{\P X_2 / \P P_2}{X_2 / P_2} \end{bmatrix} = \frac{1}{1-r} \begin{bmatrix} rl-1 & r(1-l) \\ rl & r(1-l)-1 \end{bmatrix}.$$

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 r) raises all price elasticities.

Recall that firm 1 is the exporting firm whose production is based in its home country, while firm 2 is the foreign 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 $(C_1^* + S C_1) \cdot X_1$ 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.[8] The profit of the exporting firm in its home currency is given as:

(6) $$\pi_1^* = SP_1 X_1 - (C_1^* + SC_1) X_1 .$$

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

(7) $$\pi_2 = P_2 X_2 - C_2 X_2 .$$

The import-competing firm (firm 2) sells only in the foreign market and has costs based only in the foreign currency.

B. Solution of the Model

1. Prices and quantities

We solve the model under the assumption of quantity competition where each firm in this market makes output decisions taking as given the output of the other firm.[9] Profit maximizing first-order conditions for the two firms are given by:

(8) $$\begin{cases} \dfrac{\partial \pi_1^*}{\partial X_1} = S \dfrac{\partial P_1}{\partial X_1} X_1 + SP_1 - (C_1^* + SC_1) = 0 \\ \dfrac{\partial \pi_2}{\partial X_2} = \dfrac{\partial P_2}{\partial X_2} X_2 + P_2 - C_2 = 0 \end{cases}$$

Rewriting these in terms of elasticities, we get:

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

[9] The solution to the model under price competition can be found in the appendix. For alternatives to this assumption of quantity competition, see Marston (1996).

(9) $$\begin{cases} 1+\dfrac{X_1}{P_1}\dfrac{\P P_1}{\P X_1}=\dfrac{C_1^{\ *}+SC_1}{SP_1} \\ 1+\dfrac{X_2}{P_2}\dfrac{\P P_2}{\P X_2}=\dfrac{C_2}{P_2} \end{cases}.$$

Substituting (4), we get:

(10) $$\begin{cases} r(1-l)=\dfrac{C_1^{\ *}+SC_1}{SP_1}=\dfrac{C_1^{\ *}+SC_1}{S}\dfrac{X_1}{lY} \\ r\,l=\dfrac{C_2}{P_2}=C_2\dfrac{X_2}{(1-l)Y} \end{cases}.$$

The two first-order conditions can be solved to express output in terms of relative marginal costs, R, as follows:

(11) $$X_1/X_2=R$$

where:

(12) $$R=\frac{SC_2}{C_1^{\ *}+SC_1}\ .$$

Outputs of the two goods are inversely related to their marginal costs. This relationship is simple enough so that the model can be solved analytically to express market shares, outputs, prices, and profits in their reduced forms (as a function of marginal costs).

The equilibrium market share is:

(13) $$l=\frac{aR^r}{1+aR^r}$$

where: $a = \alpha/(1-\alpha)$. It is easy to establish that a rise in S (depreciation of the exporter's currency) raises the exporter's market share and therefore lowers that of the foreign firm.

Once market share has been determined, the exporter's price and quantity sold in the foreign market can be read from equation (10):

(14) $$P_1=\frac{C_1^{*}+SC_1}{Sr\,(1-l)}$$

(15) $$X_1 = l\,Y\,\frac{S\,r\,(1 - l)}{C_1^{*} + SC_1}$$

The exporter’s price is proportional to its marginal cost as well as its relative market share.

Similarly, the foreign import-competing firm has the following equilibrium prices and output in the foreign market:

(16) $$P_2 = \frac{C_2}{r\,l}$$

(17) $$X_2 = (1 - l)\,Y\,\frac{r\,l}{C_2}$$

The exchange rate enters these 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.

2. Profit function

A reduced form expression for the exporter’s profits is obtained by substituting expressions for prices and output in the profit expression (6):

(18) $$p_1{*} = SY\,l\left[1 - r\,(1 - l)\right]$$

The exporting firm’s profits are the product of the exporter’s share of the total expenditures in foreign market, SYl, and its percentage markup in that market, $[P_1 - (C_1^{*} + SC_1)]/P_1 = 1 - r\,(1-l)$. This completes the description of the basic quantity-competition model.

III. PASS-THROUGH AND EXPOSURE COMPARED ACROSS INDUSTRIES

A. Pass-through

In this model, 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 import-based costs, so changes in exchange rates will 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 (14) with respect to S. First define γ as the fraction of marginal costs due to imported inputs:

(19) $$g = \frac{SC_1}{C_1^* + SC_1}.$$

Then pass-through can be expressed in the form of an elasticity as follows: [10]

(20) $$h_1 = -\frac{d \ln P_1}{d \ln S} = (1-g)(1-r\,l).$$

Since r and l are assumed to be between 0 and 1, 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 the fall in price is ***less than proportionate***. That is, the pass-through is generally ***incomplete***. As long as $g < 1$, the pass-through elasticity must be greater than zero, so in that case, $0 < h_1 < 1$.

It is important to understand why pass-through is incomplete even if there are no imported inputs ($g = 0$). 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 foreign market over its costs in percentage terms (i.e., its profit margin) is given by

$$(21) \qquad M_1 = \frac{SP_1 - (C_1^* + SC_1)}{SP_1} = 1 - r(1 - l).$$

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

$$(22) \qquad \frac{d \ln M_1}{d \ln S} = \frac{(1-g)\, r^2\, l(1 - l)}{(1 - r(1 - l))} \; > \; 0,$$

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.

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

$$(23) \qquad h_2 = -\frac{d \ln P_2}{d \ln S} = r(1 - l)(1-g).$$

As long as $g < 1$, 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.

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 r) is to **moderate** the pass-through of exchange rate changes into foreign currency prices. To show this, we differentiate h_1 from (20) with respect to r, holding market shares constant:[11]

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

[11] Higher product substitutability also affects the market shares of the two firms:

(24) $$\frac{dh_1}{dr} = -l(1-g) < 0 \quad \text{if } g < 1$$

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.[12]

The degree of substitutability is not the only factor that influences pass-through. From the expression (20) for h_1, it is evident that a higher market share (13) ***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, a, and relative marginal costs, R, as well as r. An increased preference for the export (higher a) 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.[13]

$$dl/dr = l\,(1-l)\ln R = -\,d(1-l)/dr.$$

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 (20) is reached by viewing the pair (r, l) as a sufficient representation of the full set of parameters: (r, a, C_1, C^*_1, C_2). Holding l fixed when we change r implies that the other parameters adjust.

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

$$\frac{dh_2}{dr} = (1-l)(1-g) > 0 \quad \text{if } g < 1.$$

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.

[13] 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 will have a bigger increase his market share than with similar costs. Thus, with a cost advantage, the sensitivity of pass-through to substitutability should be even greater.

C. Exchange Rate Exposure

To develop a measure of exchange rate exposure, we must start with an operational definition of a firm's value. The value of a firm can be expressed in terms of a stream of present and future cash flows as:

$$V = \sum_{t=1}^{\infty} \frac{CF_t}{(1+r)^t} \tag{25}$$

where CF_t represents the cash flows of the firm which are equal to after-tax profits plus net investment and where r is the discount rate. The simplest measure of economic exposure is $d\ln V/d\ln S$.[14] In order to keep the model tractable, we assume that the net investment of the firm is equal to zero and that cash flows are constant from year to year. In that case, the present value can be written:

$$V = \frac{CF}{r} = \frac{(1-t)}{r} p \tag{26}$$

where t is the tax rate and p is profit before taxes. With taxes and the discount rate constant, economic exposure can be measured by the derivative:

$$\frac{d \ln V}{d \ln S} = \frac{d \ln p}{d \ln S}\,. \tag{27}$$

So 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, *dlnp/dlnS*, that we want to derive. This term, denoted ***d*** (delta), is obtained by differentiating (18) with respect to *S*.

$$d = \frac{d \ln p_1^*}{d \ln S} = \left[1 + (1-g)\, r\, (1-l)\right] + \frac{(1-g)\, l\, r^2 (1-l)}{(1 - r(1-l))} \tag{28}$$

The two terms capture the two different impacts of the exchange rate change on profits. The term in the square brackets captures the proportional impact of the exchange rate change on profits for the original

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[14] In standard terminology, exposure is defined as d*V*/d*S*, but we will be estimating exposure coefficients using rate of return data, so the percentage formulation, or ***d*** (delta) 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.

profit margin. This includes both the impact of the exchange rate change on the domestic currency value of total expenditures and the impact of the exchange rate change on the share of total expenditures accruing to the exporter. Recall that the exchange rate changes the relative prices, R, and therefore the exporter's market share. The second 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 (21)). Together these two effects constitute the full impact of the exchange rate change on profits. Since the term in square brackets is greater than one and the second term is positive (unless $g = 1$), 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 delta 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 delta can best be understood by recalling that delta 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 delta will increase as ρ increases and market share is held fixed. This intuition is verified by taking the derivative of (27) with respect to r, holding l fixed:

$$(29) \qquad \frac{dd}{dr} = (1-g)(1-l)\frac{(1-r)^2 + 2l^2r^2 + lr(4-3r)}{[1 - r(1-l)]^2} > 0.$$

This expression is always positive since $0 < r,\ l < 1$.

This prediction of the structural model is consistent with the results of Campa and Goldberg (1995) and Allayannis and Ihrig (1997) 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 (29) it is apparent that higher r results in higher ***d***.

Market share also has an impact on delta. Differentiating (28) with respect to l, holding r fixed, we can see the effect of market share on delta:

$$(30) \qquad \frac{dd}{dl} = -r(1-g) + \frac{(1-g)\left[r^2(1-2l) - r^3(1-l)^2\right]}{(1-r(1-l))^2} \quad .$$

This derivative is negative, except for a small region where l is low and r is high.[15] The negative value implies that delta 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 r, 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 (21)). 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.

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[15] These combinations correspond to low levels of λ (< 0.15) and high values for $\rho \in (.5, 1)$. 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 delta 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.

E. Relation between Delta and Pass-through

A firm's pass-through behavior and exchange rate delta 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*** delta. So there is an inverse relationship between pass-through and delta as depicted in Figure 1a. Each curve in this figure corresponds to a different level of market share. Along each curve, substitutability increases from zero to one moving right to left.

IV. DATA FOR THE EMPIRICAL ANALYSIS

The empirical portion of this study builds on two separate empirical literatures in international finance, the literatures on exchange rate pass-through and exchange rate exposure. These literatures have remained distinct despite the fact that they both study a firm's or industry's adjustment to exchange rates changes, although from different perspectives. One reason that studies of pass-through and exposure have been done independently 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 rates changes. The export price series are either price indexes developed by national statistical authorities or unit values derived from customs data. Changes in firm value are derived from equity return data, which are used at either 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% of exports), electrical machinery (31.3% of exports), and transport equipment (24.2% of exports),[16] 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 wide variety of manufactured products at various levels of aggregation. Moreover, we need share price series that match the export categories as closely as possible. If a particular export product was produced by an identifiable set of firms, then we chose to include that product in the estimation. Share price data generally determined the level of aggregation of the industries. 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

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[16] These weights are from the 1995 export price series.

Company Handbook. All of the portfolios contain only firms listed on the first section of the Tokyo stock exchange. We also obtain the Nikkei 225 index as a measure of the overall market movement.

In addition to goods and share prices, we also require exchange rate series for estimating our models. 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 costs 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.[17] The 22 countries represent 85 % of Japan's exports. Table 1 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 income index, we formed a weighted sum of foreign GDP series for the 13 countries (of the 22 above) which 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 GDP's themselves. Since all of the other data are monthly, we converted each quarterly GDP series into a monthly series through interpolation.[18] 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, ten years gives us 120 observations. On the other hand, we believe that over ten years the

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

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

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 2 displays this data. The first quantity displayed is “gamma”, the share of imported inputs in total costs; we observe that, for most industries in our sample, that share is small. Second, “theta” is the share of profit that a Japanese firm derives from abroad. As a surrogate measure (since this information is not revealed by most Japanese firms), we use the value of the export ratio, which imposed the assumption that average operating profitability is equal at home and abroad.

V. ESTIMATES OF PASS-THROUGH AND EXPOSURE

Estimation in this paper departs from the previous empirical studies of pass-through and exposure in several ways. First, we estimate equations for pass-through and exposure jointly using a common theoretical framework. Second, we use non-linear estimation methods in order to estimate directly the parameters in these theoretical models. Most previous studies have either been loosely based on microeconomic models of behavior or have linearized a specific microeconomic model before estimation.

A. Equation Specification

The model of pass-through and exposure outlined in Section III has two major drawbacks as far as estimation is concerned. First, the model describes the behavior of an exporting firm, whereas the Japanese exporters that we will study also have significant domestic markets. Second, the model specifies export prices and profits as a function 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:

(31) $$P_1^* = m^* \, (C_1^* + S\,C_1).$$

The Japanese export price (equation 14) then can be rewritten as

(32) $$S\,P_1 = \frac{(C_1^* + S\,C_1)}{r}(1 + a\,R^r) = \frac{P_1^*}{m^*\,r}(1 + a\,R^r).$$

In turn, relative marginal costs between the Japanese exporter and the foreign import competitors, (R from equation (12)) can be written as:

(33) $$R = \frac{S\,C_2}{(C_1^* + S\,C_1)} = \frac{(S\,C_2)\,m^*}{P_1^*}.$$

Foreign marginal costs, SC_2, are represented in the estimation by the weighted average of foreign wholesale prices of Japan's twenty-two most important export markets expressed in yen (FWPI). In some export sectors, Japanese technological progress may introduce trends to relative marginal costs, so we modify the specification to allow for a time trend in relative marginal costs.

Equation (32) for export prices (of industry j) can then be rewritten in log form (for industry j) as:

(34) $$\ln(PX_j) = \ln(PD_j) - \ln(m_j^*\,r_j) + \ln\left[1 + a_j\left(R_j\right)^{r_j}\right]$$

where: $$a_j\left(R_j\right)^{r_j} = a_j\left[\frac{FWPI}{m_j PD_j + d_j T}\right]^{r_j}$$

and PX_j = export price in industry j (in yen),

PD_j = domestic price in industry j (in yen),

$FWPI$ = weighted average of foreign wholesale prices.

Since the coefficients a_j, m_j, and d_j are not separately identified, and since, in any case, the coefficient of PD_j, would not measure the markup accurately because PD_j and $FWPI$ are price indexes rather than actual prices, we set: $m_j = 1$ so that, in effect:

$$(35) \qquad a_j \left(R_j\right)^{r_j} = a_j \left[\frac{FWPI}{PD_j + d_j\, T} \right]^{r_j} .$$

Furthermore, to reduce problems of nonstationarity, we estimate the equation in change form as:

$$(36) \qquad \Delta \ln(PX_j) \quad = \quad \Delta \ln(PD_j) \quad + \quad \Delta \ln\left[1 + a_j\left(R_j\right)^{r_j}\right].$$

For the exposure estimates, we begin with the profit equation (18), which relates profits to relative marginal costs as well as income in the foreign market. We make several important modifications to this profit equation. 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. Recall equation (26) relating a firm's value to its profits. To account for valuation changes for the market as a whole (which are driven by the discount factor changes in equation (25) 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).

The second modification involves taking into account the impact of domestic sales on the exporting firm's profits. If some firms derive only 25% of their profits from exports while others derive 75% of their profits from exports, the exposure estimates will differ even if competitive behavior is identical across industries. We don't 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,. In order 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 activity abroad (see Table 2).

Thus we start with equation (18), which gives us the profits of a pure exporting firm. Denoting the profits from exporting in industry j as π_j^{Export} (and dropping the stars representing domestic currency) we have:

(37) $$p_{1j}^{Export} = SY\, l_j \left[1 - r_j (1 - l_j)\right]$$

By the assumption that exchange rates only affect export profits and our definition of θ,[19]

(38) $$\frac{dp_j^{Total}}{dS} = \frac{dp_j^{Export}}{dS} \qquad and \qquad q_j = \frac{p_j^{Export}}{p_j^{Total}},$$

then taking log differences of equation (37) gives

(39) $$\Delta \ln(p_j^{TOTAL}) = q_j \Delta \ln\{l_j [1 - r_j (1 - l_j)] SY\}.$$

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

(40) $$\Delta \ln p_j^{Total} = \Delta V_j - b_j \Delta \ln V_{NIKi},$$

where: V_j = the market value of industry j (in yen),

V_{NIK} = the market value of the Nikkei 225 index.

We can then rewrite equation (39) as:

(41) $$\Delta \ln(V_j) - b_j \Delta \ln(V_{NIK}) = q_j \Delta \ln\{l_j [1 - r_j (1 - l_j)] SY\},$$

where $l_j = \dfrac{a_j (R_j)^{r_j}}{1 + a_j (R_j)^{r_j}}$ and $a_j(R_j)^{r_j}$ is given by (35). Thus, the firm's profitability is a non-linear function of relative marginal costs and income even when the equation is expressed in logs.

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[19] Note that $\left(d \ln p_j^{Total} / dS\right) = \left(dp_j^{Total} / dS\right)\left(Sq / p_j^{Export}\right) = q\left(d \ln p_j^{Export} / dS\right).$

The two-equation model (equations (36) and (41)) to be estimated for each industry includes one key parameter, ρ, the parameter from the utility function measuring substitutability between the export good and the competing product in the foreign market. Higher values of ρ 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 close to zero represent low levels of substitutability and relatively large market power.

B. Traditional Linear Estimates

We start our empirical investigation with a linearized version of the two models, which abstracts also from the cross-equation restrictions on the parameters. This specification allows us to present empirical measurements of pass-through and exposure elasticities, corresponding to the basic statistical definitions of these two quantities, without making reference to any economic model. We report in Panel A of Table 3, ″Benchmark: linear regression″, the GLS (i.e. SUR) estimates of the two following regressions, estimated industry-by-industry:

(42) $$\Delta \ln(PX_j) = A_j + B_j \Delta \ln(PD_j) + C_j \Delta \ln(FWPI / PD_j) + n_j$$

(43) $$\Delta \ln(V_j) = D_j + b_j \Delta \ln(V_{NIK}) + E_j \Delta \ln(FWPI / PD_j) + e_j \, ,$$

These regressions are similar to those commonly estimated in the pass-through and exchange rate exposure literatures. In these equations, the value of $1 - C_j$ represents the pass-through estimate and the coefficient E_j is the exposure (delta) estimate. Notice that an industry-specific concept of the real exchange rate, namely $FWPI/PD_j$, is used on the right-hand side.

These estimates are uniformly significant for both pass-through and exposure. Pass-through varies from 0.808 in Construction Machinery to 0.158 in Film. However, while there is some dispersion in pass-through, most of the linear pass-through estimates are low, less than 0.5, with four industries having pass-through between 0.2 and 0.3. The linear exposure elasticities range from 0.268 for Construction Machinery to 0.804 for Copiers. Since the exposure estimates will depend on the degree of foreign activities, which varies across these industries, we also report the linear exposure elasticity adjusted upwards by our estimate of the ratio of foreign to total profits. We divide the linear estimates by the theta variables from Table 2. These estimates (labeled: pure exporter") provide an approximation to the exposure of the industries if all profits accrued from exporting. For two industries, Construction Machinery and Cameras, this adjusted elasticity is less than one, whereas the exposure elasticities in the structural model must exceed one (see equation (28)).

In the estimation of the structural model that follows, we retain throughout the value of b_j obtained from the linear regression. This is because we believe that the estimation of a firm's sensitivity to the general financial market index should be kept separate from our attempt to explain its sensitivity to exchange rates.

C. Estimates of the Structural Model

The two equation model of pass-through and exposure is estimated using a non-linear generalized least square (GLS) estimation procedure. The starting values are obtained by setting R at its mean value, normalized to one, and solving an approximation to the system of equations explaining exposure and passthrough (13, 20, 28) under quantity competition for the linear estimates of pass-through and exposure estimated above.[20] Table 4, Panel A reports the estimates of r and the other parameters together with their t-statistics. The parameter r is constrained to be no larger than one; when this constraint is binding, no t-statistics can be calculated for the estimate.

The estimates of r range from 0.545 in Construction Machinery to unity or close to unity for many other sectors. Finding relatively low substitutability in the Construction Machinery seems consistent with the specialized nature of these products. High substitutability in some of the other industries is also not

[20] For this exercise, we set γ at zero. Table 2 shows that "gamma" is never very large.

surprising, namely, Film, Electronic Parts, and Magnetic Recording Products. But there are also industries where the degree of substitutability appears high, most notably in Motor Vehicles where ρ is implausibly high.

Estimates of a, which is a function of the preference parameter in the utility function, are generally greater than one, except for Construction Machinery and Measuring Equipment. Estimates of a greater than one indicate a preference by foreign consumers for the Japanese good over foreign-produced substitutes and suggest substantial Japanese market share.

Panel B of Table 4 reports average market share, average pass-through, and exposure elasticities based upon the estimates in Panel A. Measures of market-share, pass-through and exposure are constructed by substituting the estimates of r and a into the expressions for market share, l, in equation (13), pass-through, h_1, in equation (20), and the exposure elasticity, d, in equation (28). l, h_1, and d are time varying since they are functions of prices and other variables. The values in the panel represent the sample averages of these for each industry. Exposure is provided on the basis of the structural model for the pure exporter ("pure exporter") and also after it has been reduced to account for the share of domestic profits of the firms in the industry ("local and export markets").

The sample average of the reconstructed market shares, l, are given in the top row of Table 4, Panel B. In any industry with differentiated products, market share is difficult to define, since products in the same "industry" may have little substitutability with one another. An example would be professional and disposable cameras. Having said that, some of the market shares in Table 4 appear to be excessively large, including Motor Vehicles (0.742) and Film (0.800). In our model, high market shares allow lower pass-through (note from equation (20) that for g = 0, the minimal possible pass-through is (1-l). So in order to fit the low pass-through behavior of certain Japanese industries, the model requires relatively high market shares.

The reconstructed pass-through elasticities in Panel B of Table 4 range from 0.202 in Film and 0.267 in Motor Vehicles, to 0.802 in Construction Machinery and 0.755 in Measuring Equipment. Most of these estimates are consistent with what we know about the industries. In the case of Film, for example, Fuji and Konica are presumably limited in their ability to raise prices in markets where they compete with Kodak. Firms producing differentiated products like measuring equipment, on the other hand, presumably have more market power to set prices. Moreover, the reconstructed estimates of the pass-through are very close to the estimates that we obtained from the unrestricted linear regression of the export price on the domestic price and the real exchange rate, all in first-difference form. However, this is not surprising because the GLS procedure weights more heavily the price equation than the profit equation due to its lower overall variance.

The exposure elasticities implied by our model (labeled "pure exporter") are obtained by substituting the estimated parameters into equation (28). While all greater than unity by definition, these elasticities also vary widely, from 1.287 in Cameras to 2.166 in Measuring Equipment. These elasticities measure how profits vary with the exchange rate, so a larger elasticity implies that profits vary proportionally more for a given exchange rate change. Equation (28) used to calculate the exposure is based upon the assumption that the firm obtains all of it profits from exporting. So, in Panel B of Table 4, we also report the exposure elasticity estimates (labeled "local and export markets") that are adjusted for the ratio of export profits to total profits (using the quantity "theta" from Table 2).[21] These latter estimates also vary widely, from 0.479 for Film to 0.908 for Cameras. Unlike the structural pass-through estimates, not all these adjusted exposure elasticities match the linear estimates well. In three industries, Construction Machinery, Motor Vehicles and Cameras, the structural exposure estimates vary widely from the linear estimates. In all three cases the structural exposures are larger than the linear exposures. The linear

[21] The adjustment is $d_{Local\ and\ Export\ Market} = d_{Pure\ Exporter} \cdot q$

estimates for two of these industries are below the theoretical lower limit of one, whereas all three structural estimates exceed one. For the other five industries, the structural exposure estimates are reasonably close to the linear exposures.

The parameter estimates from the quantity model are strongly influenced by the price equation—because the weighting scheme of GLS puts relatively low weight on the high-variance stock return series relative to the export price series. Estimates of the price equation for most industries imply high degrees of substitutability between products. Given these high degrees of substitutability, it is not surprising that we obtain relatively high exposure in these industries. (recall the positive relation between delta and ρ in the theoretical model).

D. The "Fit" of the Model

From Figure 2, we can visually inspect the ability of the model to simultaneously explain the observed patterns between exchange rates, on one hand, and export price and adjusted stock prices, on the other. The figure plots the predictions of the structural model for both export prices and profits against the actual data for all eight industries.[22] In order to make the presentation easier to see, the export price data for each industry is presented relative to the domestic price of the good to remove implications of changes in marginal costs from the level of the export price. This relative price or proxy for the markup on exports is plotted against the relative price ratio (FWPI/PD). These are the top plots on each page, labeled "Pass-through". Exchange rates impact the profit equation through both relative prices and foreign income. However, since profits are affected most directly by foreign income and only indirectly (through changes in lambda) by changes in relative prices, we plot the actual and predicted exporting profits against the foreign income-weighted exchange rate (FGDP). These are the bottom plots on each page, labeled "Delta".

Inspection of the plots in Figure 2 reveal several points alluded to above. Due to the fact that r is very close to one for most industries and R is centered close to one and does not vary significantly, the predicted ratio of the export price to the import price is virtually linear in relative prices. For most industries the model captures most of the exchange rate-related variation in export prices. Only for Electronic Parts, Film, and especially Magnetic Recording Products, is the model unable to match the actual data. The model appears less successful in explaining profits due to the greater dispersion in the profit data, but it does a reasonable job for several industries, especially, Film and Magnetic Recording Products.

In order to test the model, we would like to examine the cross-equation restrictions on the parameters. Specifically, we would like to test whether the r and a are the same in the export price and profit equations. Circumstances encountered here make such a test close to impossible because it is so difficult to estimate the pass-through and exposure equations separately. The cost ratio, R (proxied by FWPI/PD in Figure 2), varies only moderately over the sample. In addition, as Figure 2 makes clear, the ratio of the export prices relative to the domestic prices varies linearly with R over the sample. So it is impossible to identify the two parameters. r and a, in the pass-through equation and therefore, to test the cross-equation parameter restrictions.

Though it was not possible to carry out standard statistical tests of the model, we can examine one measure of how well the model is able to explain the data. We examine whether there is any systematic component to prediction errors (the difference between the actual data values and the values for those series predicted by the structural model). Although not a formal econometric test of the model, it does provide a method of determining if the errors in the model are significant in a statistical sense. To do this we calculate the difference between the actual export price series and the predicted export price series and the difference

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[22] Note that although the model was estimated in first differences, the plots display the adjusted levels of the price and profit (i.e. share price) data.

between the actual adjusted stock price (export profit proxy) and the predicted export profit series. We then regress the first differences of these prediction errors on the changes in *R*, the relative price variable (FWPI/PD). The results of this procedure are reported in Table 5. In most cases, the prediction errors of the quantity competition model are unrelated to the real exchange rate variable. The three exceptions occur for the export price prediction errors of Copiers, Electronic Parts and Magnetic Recording Products. In the other cases, the structural model's prediction for export price behavior and profit behavior do a sufficiently good job explaining the data that the prediction errors contain no statistically significant exchange rate related variation.

VI. CONCLUSION

We have developed a duopoly model of an exporting firm and solved it under the assumption of quantity 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 crucial role played in this matter by the elasticity of substitution between the home-produced and the foreign-produced goods: Keeping market share fixed, as substitutability increases, pass through declines and exposure increases. Market share also impacts these values. Holding substitutability fixed, increases in market share reduce both pass-through and exposure elasticities.

In empirical tests of the model conducted on Japanese data, we have found that this model is capable of explaining the main features of the data. More specifically, this model explains the pass-through behavior of Japanese firms with values of the parameters that in most cases are theoretically plausible. These same parameter values generate estimates of exchange rate exposure that also fit the data reasonably well. While the parameter estimates that were obtained from the joint estimation were generally economically meaningful, in some industries estimates of the degree of substitution and market share seemed to be too large. These large market shares and high substitutability estimates are necessary for the structural model to generate the observed combination of ***low pass-through*** and ***low exposure*** for many of these Japanese industries. Thus it appears that for some industries pass-through is too low when compared to exposure, or exposure is too low 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.

APPENDIX: PRICE COMPETITION MODEL

This appendix derives the price competition solution to the model and examines the resulting relation between pass-through and exposure. For the price competition model we assume that both firms in the market make pricing decisions assuming the pricing decision of the other firm. Under this assumption the profit maximizing first-order conditions for the two firms (taken from (6) and (7) are given by:

(A1)
$$\begin{cases} \dfrac{\partial \pi_1^*}{\partial P_1} = SX_1 + SP_1 \dfrac{\partial X_1}{\partial P_1} - (C_1^* + SC_1)\dfrac{\partial X_1}{\partial P_1} = 0 \\ \dfrac{\partial \pi_2}{\partial P_2} = X_2 + P_2 \dfrac{\partial X_2}{\partial P_2} - C_2 \dfrac{\partial X_2}{\partial P_2} = 0 \end{cases}$$

We can rewrite these conditions as:

(A2)
$$\begin{cases} 1 + \dfrac{P_1}{X_1}\dfrac{\partial X_1}{\partial P_1} = \dfrac{C_1^* + SC_1}{SP_1}\left[\dfrac{P_1}{X_1}\dfrac{\partial X_1}{\partial P_1}\right] \\ 1 + \dfrac{P_2}{X_2}\dfrac{\partial X_2}{\partial P_2} = \dfrac{C_2}{P_2}\left[\dfrac{P_2}{X_2}\dfrac{\partial X_2}{\partial P_2}\right] \end{cases}.$$

Substituting the elasticities from (5), we get:

(A3)
$$\begin{cases} -\dfrac{\rho(1-\lambda)}{(\rho\lambda - 1)} = \dfrac{C_1^* + SC_1}{SP_1} = \dfrac{C_1^* + SC_1}{S}\dfrac{X_1}{\lambda Y} \\ \dfrac{-\rho\lambda}{[\rho(1-\lambda)-1]} = \dfrac{C_2}{P_2} = C_2 \dfrac{X_2}{(1-\lambda)Y} \end{cases}.$$

Once again the two first-order conditions can be solved to express output in terms of relative marginal costs, but in this case there is an additional term:

(A4)
$$\frac{X_1}{X_2} = RZ$$

where:
$$Z = \frac{[1-\rho(1-\lambda)]}{1-\rho\lambda}.$$

Now, equilibrium market share becomes:

(A6)
$$\lambda = \frac{aR^\rho Z^\rho}{1 + aR^\rho Z^\rho}$$

where: $a = \alpha/(1-\alpha)$. This is an implicit function since the value of lambda depends on variables that are themselves functions of lambda. So, the solution of the model is more complex than in the case of quantity-competition.

Once market share has been determined, the exporter's price and quantity sold in the local market can be read from equation (A3):

(A7)
$$X_1 = \frac{\rho(1-\lambda)}{1-\rho\lambda}\frac{S\lambda Y}{C_1^* + SC_1}$$

(A8)
$$P_1 = \frac{C_1^* + SC_1}{S}\frac{1-\rho\lambda}{\rho(1-\lambda)}$$

Similarly, the import competing firm in the foreign market has the following equilibrium prices and output:

(A9) $$X_2 = \frac{r\,l\,(1-l\,)Y}{\left[1-r(1-l\,)\right]C_2}$$

(A10) $$P_2 = \frac{\left[1-r(1-l\,)\right]C_2}{r\,l}$$

A reduced form expression for the exporter's profits in its home currency is obtained by substituting expressions for prices and output in the profit expression (6):

(A11) $$p_1{*} = S\;Y\;l\;\frac{1-r}{(1-r\,l\,)}$$

The exporting firm earns profits only in the foreign export market. These profits are the product of the exporter's share of the total expenditures in the foreign market, SYl, and its percentage markup, $[P_1 - (C_1^* + SC_1)]/P_1 = (1-r)/(1-r\,l)$.

An expression for the exporter's pass-through under price competition can be obtained by differentiating (A8) with respect to S. Recall that g is the fraction of marginal costs due to imported inputs. Pass-through can be expressed in the form of an elasticity as follows : [1]

(A12) $$h_1 = -\frac{d\ln P_1}{d\ln S} = (1-g\,)\left\{\frac{(1-l\,r\,)}{1-r^2\,l\,(1-l\,)}\right\}.$$

With $g > 0$, and with r and l assumed to be between 0 and 1, 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.

As above, the exchange rate exposure of the exporter, $d\ln p_1^*/d\ln S$, can be derived from differentiating the profit function (A11) with respect to S:

(A13) $$d = \frac{d\ln p_1^*}{d\ln S} = 1 + \frac{(1-l\,)(1-g\,)\,r\,[1-r(1-l\,)]}{(1-r\,)[1-r^2\,l\,(1-l\,)]}.$$

Since the numerator and denominator of the second term are greater than zero, the exposure expression is always greater than one. So 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 delta across industries under price competition is fundamentally very similar to the relation under quantity competition. Figure 1b displays the relation between pass-through and delta for three different levels of fixed market share, λ, as r increases from right to left (high levels of substitutability are not shown in the figure). As in the quantity competition case, the curves are downward sloping.[2] However, in contrast to the quantity competition case, the slope of the relationship increases more drastically as substitutability increases because delta goes to infinity as $r \to 1$ while pass-through reaches a finite limit with a fixed market share.

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 (A12) it can be shown that pass-through under price competition is equal to 100% of foreign cost $(1-\gamma)$ as $r \to 0$, 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 $r \to 1$ and market share is endogenous. One might think that

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

[2] For low market shares, however, the curve bends backward as $\rho \to 1$.

perfect substitution would cause the exporting firm to pass-through very little of its cost variations. However, when substitutability becomes perfect in this model, we reach a situation of pure Bertrand competition. 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.[3] In the case where conditions imply that the exporter will take the full market as $r \rightarrow 1$, he behaves increasing like a perfect competitor and $h_1 \rightarrow 0$ as $r \rightarrow 1$. 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 $h_1 \rightarrow (1\text{-}g)$ as $r \rightarrow 1$. Finally, when conditions are perfect such that both the exporter and foreign competitor maintain a positive market share, when $r \rightarrow 1$, then pass-through has a limit between 0 and (1-g) while delta goes to infinity.

This razor-edge feature of the price competition model for high substitutability, draws into question attempts to empirically estimate the model. The price competition model moreover, is not capable of producing pass-through at the lower end of the range, where many of the linear estimates are situated (0.2 – 0.3) without driving market share to one (perfect substitutability), which in turn causes delta to go to infinity. Thus, for all intents and purposes, this model is rejected. As a result, we decide not to investigate empirically this model.

[3] See Tirole (1989) page 209. Tirole calls this the ″The Bertrand Paradox″. The Bertrand paradox is that, as the products of two price-competing oligopolists become perfectly substitutable (ρ goes to one), the firms behave as pure price-takers and price at marginal cost with the low-cost producer taking all of the market.

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Table 1: Japanese Exchange Rate Index

Panel A: Composition of Japanese 22 Country Real Exchange Rate Index

Country	Trade Weight	Price Index
U.S.	35.41%	WPI
Korea	7.27%	WPI
Taiwan	7.10%	WPI
Germany	5.31%	WPI
Australia	2.60%	WPI
Indonesia	2.29%	WPI
U.K.	3.80%	WPI
Canada	1.76%	WPI
Netherlands	2.54%	WPI
Philippines	1.76%	WPI
Mexico	1.25%	WPI
S. Africa	0.55%	WPI
Spain	0.63%	WPI
Hong Kong	7.68%	CPI
Singapore	5.85%	CPI
Thailand	4.39%	CPI
Malaysia	3.69%	CPI
France	1.57%	CPI
Italy	1.00%	CPI
Panama	1.76%	CPI
Belgium	1.13%	CPI
Switzerland	0.67%	CPI
	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%

The tables display the countries, the percentage weights and the price index used to create the 22 country trade-weighted average index for the real value of the Japanese yen and the 13 country GDP weighted average index for 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 of Japan, due to a lack of price data over part of the sample period. GDP weights are based upon Jan 1990 relative GDP weights in yen.

Table 2. Some data on Japanese industries' involvement in foreign markets

Industry	Gamma %imported inputs	Theta %sales abroad
Camera	4.38%	70%
Construction Machinery	1.32%	38%
Electonic Equipment/Parts	4.23%	33%
Film	6.01%	34%
Magnetic Tapes	2.05%	41%
Motor Vehicles	1.39%	46%
Measuring Equipment	4.80%	32%
Copiers	3.32%	48%

Sources:

Gamma

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," Management and Coordination Agency, 1995.

Theta:

Export ratio measured as the simple average export ratio reported in the Japanese Company Handbook over the years 1985, 1990, and 1994, converted weighted into portfolios based upon the 1990 total sales figures.

Data taken from various issues of the Japan Company Handbook. Data collected at firm level and formed into portfolio data.

Table 3: Pass-through and Exposure Elasticities Measured Directly

	Construction Machinery	Copiers	Electronic Parts	Motor Vehicles	Camera	Measuring Equipment	Film	Magnetic Recording Products
Panel A:								
Theta (from Table 2)	0.38	0.48	0.33	0.46	0.70	0.32	0.34	0.41
Linear estimates								
Pass-through	0.808	0.296	0.237	0.258	0.506	0.750	0.158	0.297
tstat	8.070	19.070	17.530	25.710	7.480	3.400	19.060	9.770
beta	0.929	0.591	0.744	0.682	0.897	0.648	0.613	0.584
t stat	11.858	6.240	6.850	9.060	9.760	2.070	6.225	4.710
Exchange Rate Exposure (Delta) *(local and export markets)*	0.268	0.804	0.663	0.474	0.555	0.648	0.415	0.694
tstat	1.374	3.490	2.510	2.550	2.640	2.066	1.744	2.850
Implied Exchange Rate Exposure *("pure" exporter)* (linear delta adjusted upwards by theta)	0.710	1.676	1.990	1.028	0.787	1.972	1.218	1.693

Table 4: Pass-through and Exposure Elasticities Reconstructed from Duopoly Model

	Construction Machinery	Copiers	Electronic Parts	Motor Vehicles	Camera	Measuring Equipment	Film	Magnetic Recording
Panel A: Parameter Estimates								
ρ	0.545	1.000	1.000	0.991	0.705	0.915	1.000	0.900
t-stat	1.738			6.380	4.566	3.220		5.399
a	0.572	1.817	1.561	2.473	3.036	0.367	3.983	2.090
t stat	1.098	2.145	1.526	1.624	4.566	1.838	0.785	1.590
Time trend				-0.002				
t-stat				-3.650				
Panel B: Constructed Measures from Structural Model.								
Market share	0.363	0.644	0.610	0.742	0.752	0.267	0.800	0.686
Pass-through	0.802	0.356	0.390	0.265	0.469	0.755	0.202	0.383
Exchange Rate Exposure (Delta) *("pure" exporter)*	1.452	1.713	1.779	1.509	1.287	2.166	1.404	1.524
Exchange Rate Exposure (Delta) *(local and export markets)* (structural delta adjusted downward by theta)	0.548	0.8215	0.593	0.696	0.908	0.712	0.479	0.625

Table 5: Regressions of Prediction Errors from Quantity Competition Model on Exchange Rate Variable

	Construction Machinery		Copiers		Electronic Parts		Motor Vehicles	
PASSTHROUGH PREDICTION ERROR	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg
Coefficient	0.0001	-0.0031	0.0005	0.0741	-0.0031	0.1502	0.0017	0.0385
t Stat	(0.2123)	-(0.1254)	(0.5000)	(2.0500)	-(2.6491)	(3.5433)	(2.1409)	(1.2953)
Adjusted R Square	-0.0084		0.0264		0.0892		0.0057	
EXPORTING PROFIT PREDICTION ERRORS	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg
Coefficient	0.0027	-0.1744	0.0038	0.1264	0.0016	0.1633	0.0047	-0.0692
t Stat	(0.5382)	-(0.9107)	(0.6425)	(0.5810)	(0.2282)	(0.6429)	(0.9553)	-(0.3789)
Adjusted R Square	-0.0014		-0.0056		-0.0050		-0.0073	

	Cameras		Measuring Equipment		Film		Mag Rec Products	
PASSTHROUGH PREDICTION ERROR	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg
Coefficient	0.0018	0.0036	0.0003	0.0116	-0.0038	0.0558	-0.0059	0.1659
t Stat	(1.0029)	(0.0597)	(0.1638)	(0.1535)	-(3.2950)	(1.3136)	-(4.4854)	(4.0326)
Adjusted R Square	-0.0085		-0.0083		0.0061		0.1145	
EXPORTING PROFIT PREDICTION ERRORS	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg	Intercept	RXR chg
Coefficient	-0.0007	-0.0749	0.0006	-0.0596	0.0050	0.0378	-0.0031	0.2870
t Stat	-(0.1151)	-(0.3850)	(0.0680)	-(0.1884)	(0.7900)	(0.1639)	-(0.3827)	(1.2567)
Adjusted R Square	-0.0073		-0.0082		-0.0083		0.0049	

Table notes: These results are from industry by-industry regressions of the prediction errors of the structural model (using parameter estimates from Table 4) for the changes in export prices and exporting profits against the change in the trade-weighted real exchange rate index for each industry. The prediction errors are defined as the actual changes in the export price/export profit (adjusted stock returns) less the changes predicted by the structural model. Regressions are run using OLS.

Figure 1a: Relation between Pass-through and Delta for Pure Exporter as ρ Changes

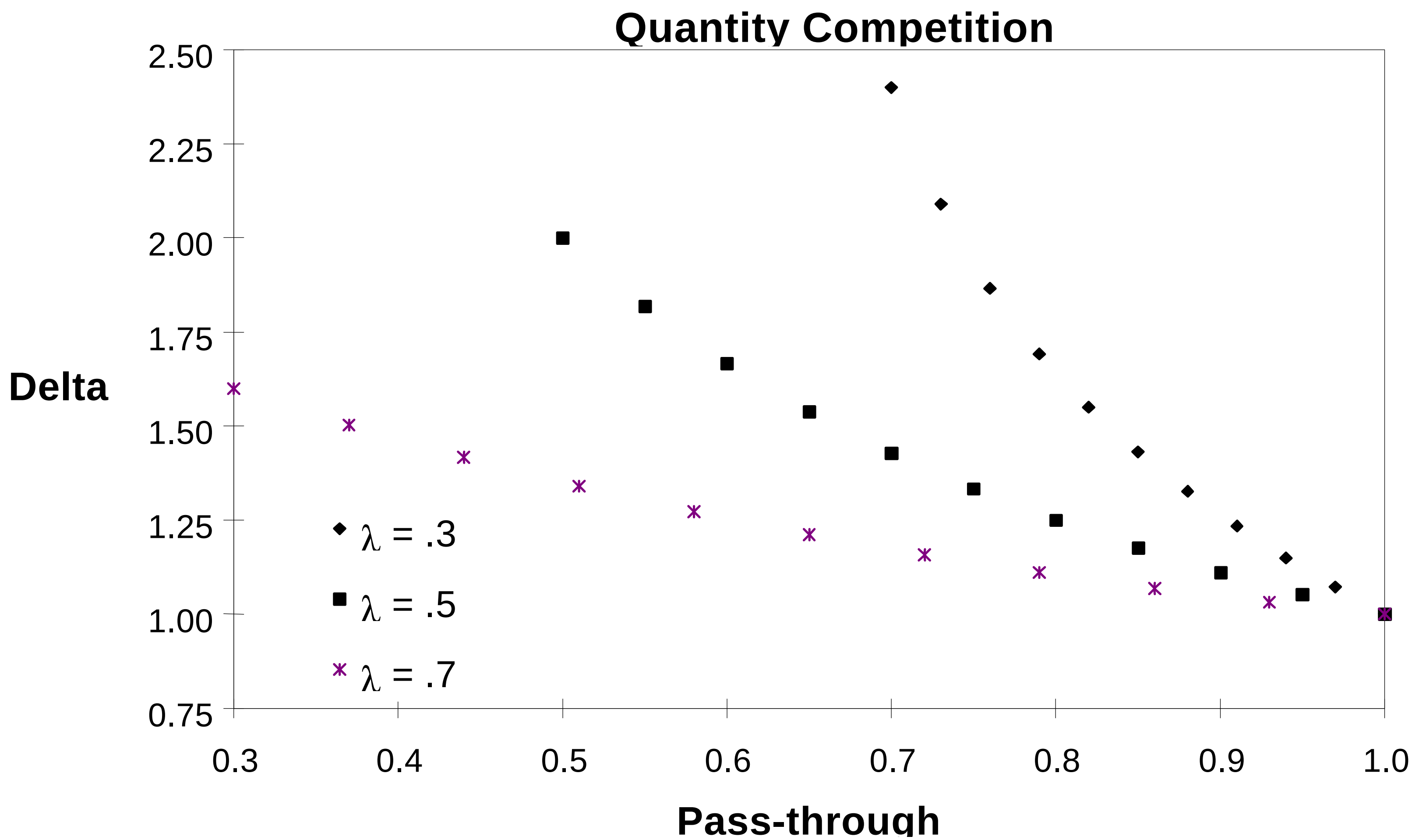

Figure 1b: Relation between Pass-through and Delta for Pure Exporter as ρ Changes

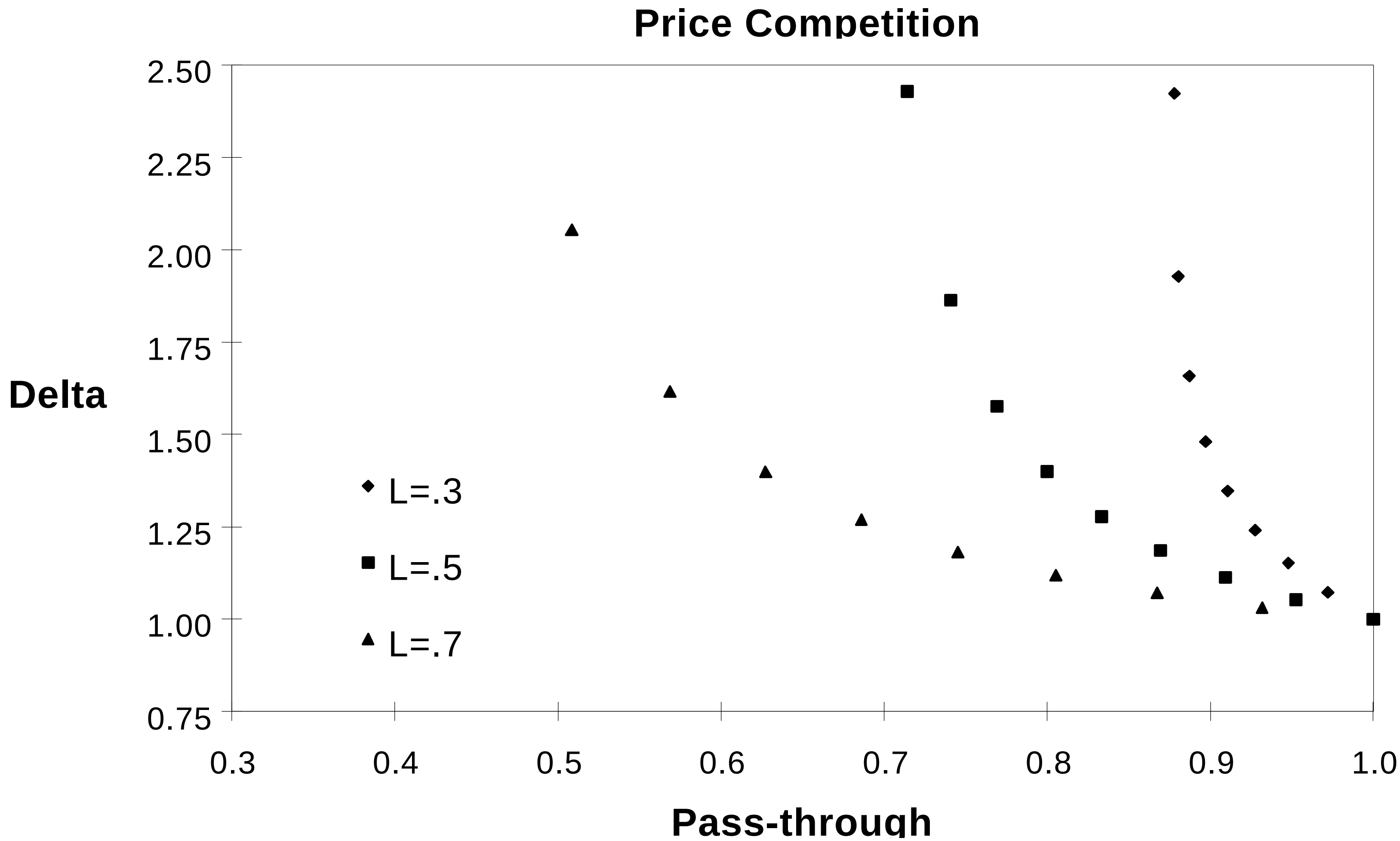

Figure 2: Visual Fit of the Quantity Competition Model

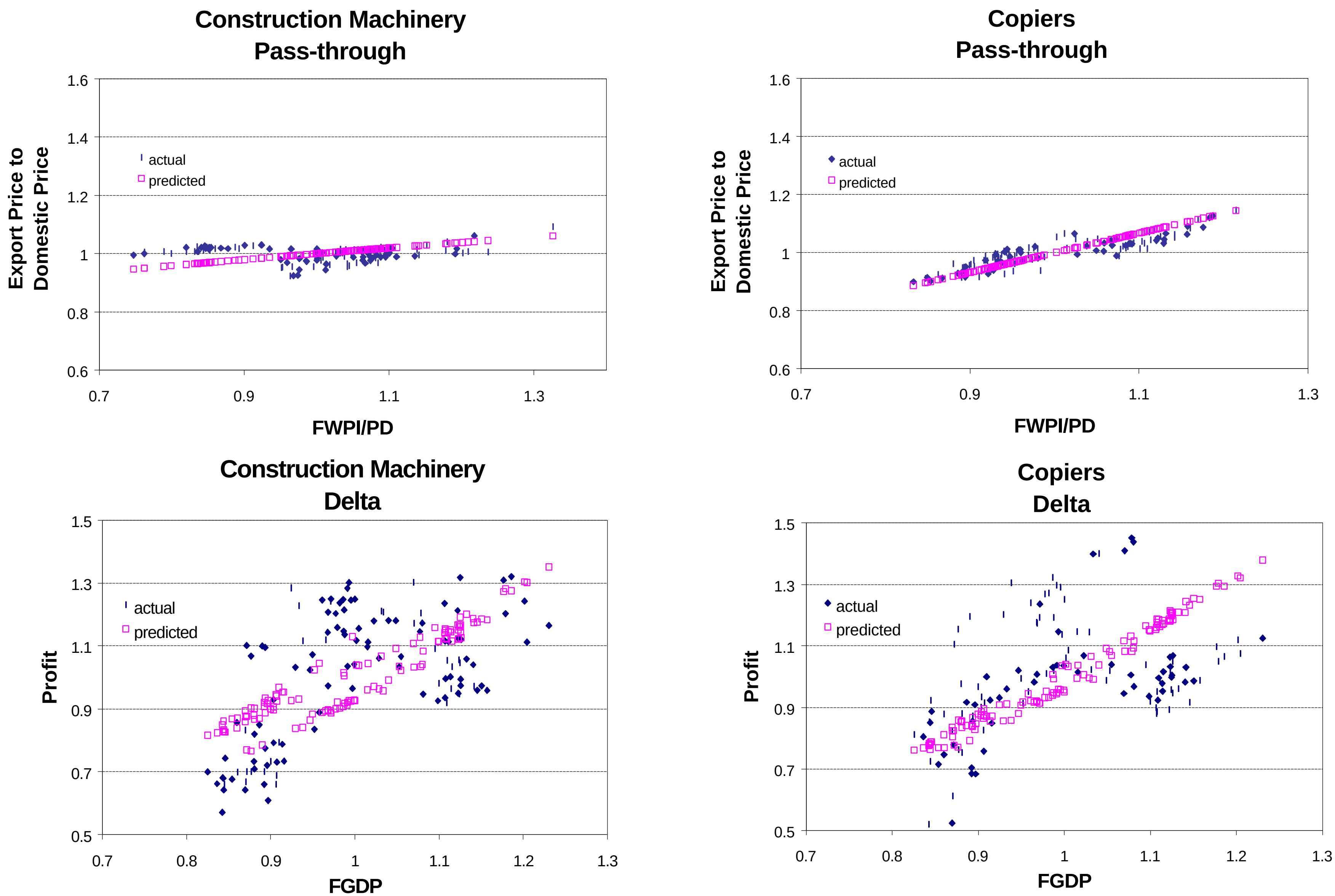

Figure 2: Visual Fit of the Quantity Competition Model con't (2 of 4)

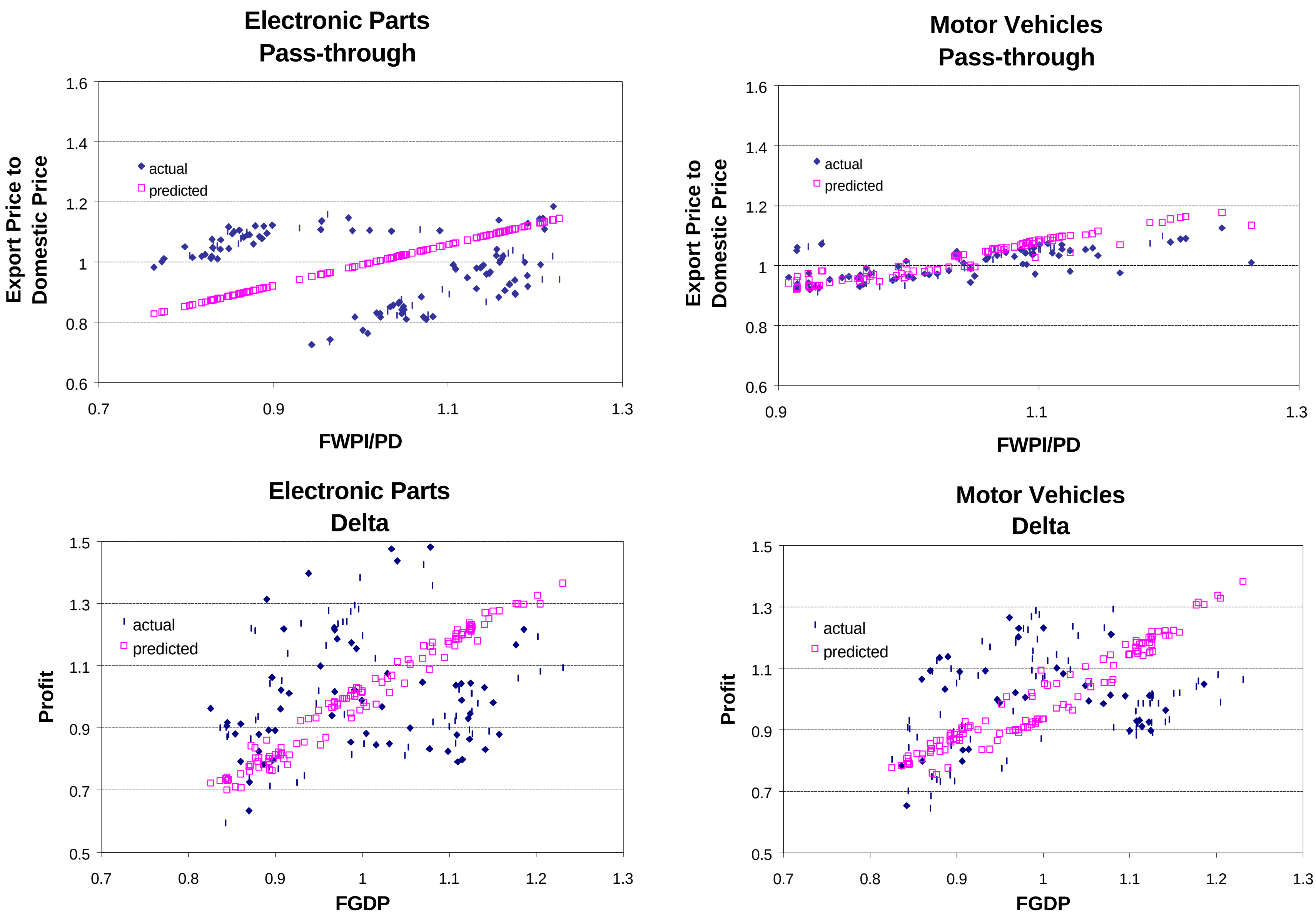

Figure 2: Visual Fit of the Quantity Competition Model con't (3 of 4)

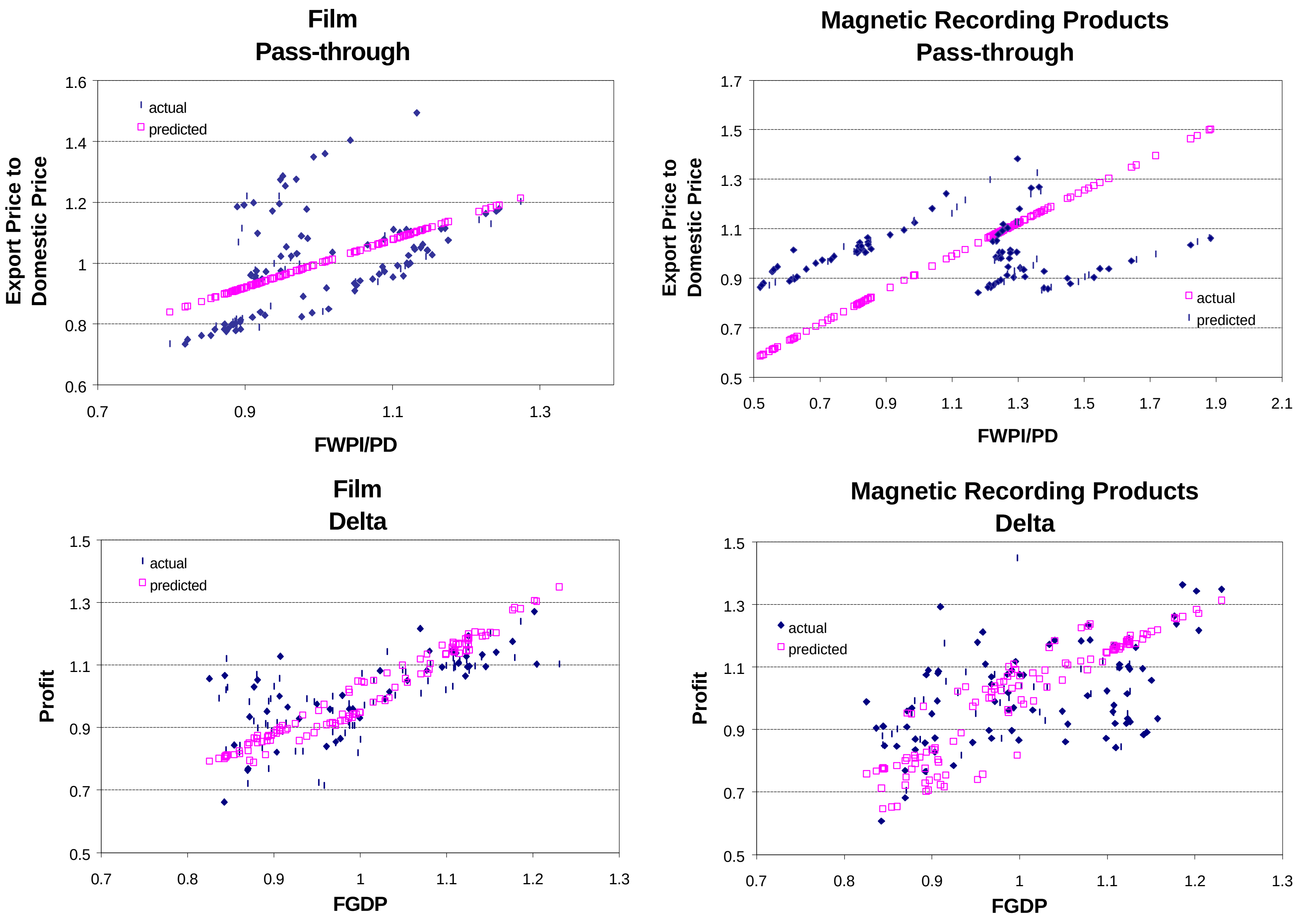

Figure 2: Visual Fit of the Quantity Competition Model con't (4 of 4)