EXCHANGE RATE PASS-THROUGH IN U.S. MANUFACTURING INDUSTRIES

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Abstract—This paper studies exchange rate pass-through in U.S. manufacturing industries and its cross-sectional variation. Through an adapted Dixit–Stiglitz model of product differentiation, the paper predicts that pass-through is positively related to the degree of product differentiation and inversely related to the elasticity of marginal cost with respect to output. Empirical estimates of the pass-through elasticities show that pass-through is incomplete and varies across industries. The degree of pass-through is found to be positively correlated to different proxies for product differentiation, and negatively to a proxy for the elasticity of marginal cost.

I. Introduction

THE LARGE swings of exchange rates in the past decade have revived interest in the relationship between exchange rate movements and the price adjustments of traded goods. It has been observed that import prices in the United States do not fully reflect changes in exchange rates, a phenomenon that has often been termed ''incomplete'' or ''partial'' exchange rate pass-through in the literature. Exchange rate changes are usually perceived as cost shocks for a foreign firm producing in its home country and selling in its export market. When the exchange rate changes, the firm may choose to pass the cost shock fully into its selling prices (complete pass-through), to absorb the shock to keep its selling price unchanged (no pass-through), or some combination of these (partial pass-through).

Recent studies of the subject have drawn heavily on models of industrial organization and focused on the impact of market structure on the foreign firm's pricing behavior. In particular, the current literature emphasizes the convexity of demand schedules in explaining price adjustments following exchange rate changes. (See, for example, Dornbusch (1987), Feenstra (1989), and Marston (1990).) For instance, partial pass-through will occur if demand becomes more elastic as price increases. The literature also suggests that the degree of pass-through varies across industries, and that the variation relates to industry characteristics such as the degree of competition, product substitutability, and the relative domestic and foreign shares in the market. For example, Dornbusch (1987) predicts that in a Cournot model the pass-through is larger the more competitive the industry (the smaller the markup of price over marginal cost) and the larger the share of imports in total sales.

The purpose of this study is twofold. First, it shows that partial pass-through can result from increasing marginal cost as well as from variable demand elasticity.[1] It also shows that, in an adapted Dixit–Stiglitz model (Dixit and Stiglitz (1977)), where product substitutability determines demand elasticity, pass-through is larger the more differentiated (or the less substitutable) the products in an industry, and the smaller the elasticity of marginal cost with respect to output. Second, the paper offers a cross-sectional test of these hypotheses using import prices for three- and four-digit SIC industries in the U.S. manufacturing sector. There is an extensive empirical literature on the impact of exchange movements on import or export prices at various industry levels.[2] Yet formal empirical studies of cross-industry variations of exchange rate pass-through are apparently lacking in the current literature, except for Cumby and Huizinga (1990) and Lee (1991).[3] As Knetter (1993) points out, industry is the critical dimension in explaining firms' pricing behavior. This paper attempts to bridge a gap in this area.

The organization of the paper is as follows. Section II develops a modified version of the Dixit–Stiglitz model of product differentiation, in which the elasticity of pass-through is related to industry characteristics such as product substitutability, the elasticity of marginal cost, and the import share of the market. The empirical framework is specified in section III, which also describes the data. The ensuing section presents and discusses the estimation results. The final section summarizes and concludes.

II. A Model with Product Differentiation[4]

Assume that domestic and foreign firms compete in the domestic market with heterogeneous products, which belong to a well-defined industry category but are imperfect substitutes for each other in the eyes of consumers. Assume also that each individual firm is sufficiently large to affect industry price, which will be defined later. The theoretical framework follows the extended Dixit–Stiglitz model in Dornbusch (1987), but differs from it in two major aspects.

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[1] A number of studies have either explicitly or implicitly mentioned the role of variable marginal cost in the exchange rate and trade price relationship. (See Mann (1986), Krugman (1987), Giovannini (1988), and Knetter (1989), for example.) An analysis of the variability of marginal cost in export pricing can be found in Marston (1990).

[2] See empirical work by Krugman and Baldwin (1987) at a highly aggregated level; Mann (1986) at the four-digit SIC industry level; Giovannini (1988) and Marston (1990) at narrowly defined Japanese manufacturing industries; and Feenstra (1989), Gagnon and Knetter (1991), and Knetter (1989, 1993) at specific product levels.

[3] Cumby and Huizinga (1990) investigate the cross-sectional variations of the impact of exchange rate changes on relative import and export prices for the two-digit SIC industries in the U.S. manufacturing sector. Lee (1991) studies the relationship between exchange rate pass-through in Korean import prices and three-firm concentration ratios.

[4] For a more general model of exchange rate and tariff pass-through, see Feenstra (1989).

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First, marginal cost is assumed to be variable rather than constant so that the effects of both the variability of marginal cost and the variability of demand elasticity on exchange rate pass-through can be examined. Second, this paper provides a specific solution to the model, which offers implications for empirical testing.

A representative consumer's preference consists of a number of subutility functions that have the property of "homogeneous functional separability" so that a two-stage maximization procedure is consistent.[5] Each subutility function resembles the Dixit–Stiglitz model with differentiated products belonging to the same industry (or product category) as arguments. I focus hereafter on one such industry.

There are n_h domestic firms and n_f foreign firms, each supplying a different variety of the product in the domestic market. For ease of exposition, a number of simplifying assumptions are made. First, all foreign firms are from one single country (thus we are in a two-country world). Second, firms of the same country are identical. With these simplifications, the analysis is equivalent to a two-firm model. The subutility function X that resembles the Dixit–Stiglitz model can thus be modified as[6]

$$X = [n_h X_h^{(\epsilon-1)/\epsilon} + n_f X_f^{(\epsilon-1)/\epsilon}]^{\epsilon/(\epsilon-1)} \tag{1}$$

where X_h and X_f are the quantities consumed of variants produced by the representative home firm (h) and the representative foreign firm (f), respectively. ϵ ($\epsilon > 1$) is a measure of substitutability among the variants. A larger ϵ presents a higher degree of substitution, or a lower degree of product differentiation, as perceived by the consumers. The consumer's budget constraint for consuming products in this particular industry is

$$n_h P_h X_h + n_f P_f X_f = E_x \tag{2}$$

where E_x is the amount of income allocated for the consumption of products in the industry and is obtained through first-stage maximization of the total utility function. Maximizing X subject to the budget constraint yields the following demand functions for the domestic and foreign variants in the domestic market:

$$X_i = X\left(\frac{P_i}{P}\right)^{-\epsilon} = \frac{E_x}{P}\left(\frac{P_i}{P}\right)^{-\epsilon}, \qquad \text{for } i = h, f \tag{3}$$

where

$$P = (n_h P_h^{1-\epsilon} + n_f P_f^{1-\epsilon})^{1/(1-\epsilon)} \tag{4}$$

which is the industry price index such that $PX = E_x$ according to the property of homogeneous functional separability.

The demand elasticity perceived by domestic or foreign firms in the domestic market is, therefore,

$$\xi_i = -\epsilon + (\epsilon - 1)\eta_i, \qquad \text{for } i = h, f \tag{5}$$

where

$$\eta_i = \frac{d \log P}{d \log P_i} \tag{6}$$

which is the elasticity of the industry price with respect to domestic or foreign firms' prices. In the original Dixit–Stiglitz model (Dixit and Stiglitz (1977)) and in the love-for-varieties models of the intraindustry trade literature that are based on the Dixit–Stiglitz model,[7] the assumption of a large number of firms is adopted. As a result, the impact of any individual firm's price changes on the industry price is treated as negligible, so that η_i is zero and demand elasticity facing each firm is constant. I drop the large-number-of-firms approach in the current model and assume that each individual firm is large enough to affect the industry price.[8] It can be shown that the elasticity of the industry price with respect to a representative firm i's price is just firm i's market share,

$$\eta_i = s_i, \qquad \text{for } i = h, f. \tag{7}$$

Thus the demand elasticity facing any individual firm i is

$$\xi_i = -\epsilon + (\epsilon - 1)s_i, \qquad \text{for } i = h, f. \tag{8}$$

It is clear that the perceived demand elasticities for domestic and foreign firms are functions of their respective market shares (s_i) and the degree of substitutability among variants (ϵ).

For the supply side of the model, the representative domestic and foreign firms' profit functions are specified as follows:

$$\pi_h = P_h X_h - C(X_h) \tag{9}$$

$$\pi_f = P_f X_f - eC(X_f) \tag{10}$$

[5] The total utility function is often assumed to have a homogeneous commodity and a differentiated product as arguments, as in Dornbusch (1987) and most of the intraindustry trade models. Krugman (1981) employs a utility function that has two differentiated products as arguments. For properties of homogeneous functional separability, see Green (1964, chap. 4).

[6] The model also assumes there is an effective spatial separation between home and foreign markets so as to focus on the pricing in the home market, as in Dornbusch (1987).

[7] See Krugman (1980, 1981), for example, and Helpman (1984) for discussions.

[8] Conjectural variation among firms was also included in the model in an earlier version of this paper. Since conjectural variation is difficult to specify and test empirically, it has been eliminated.

where e is the nominal exchange rate defined as the number of units of domestic currency per unit of foreign currency.[9] As stated in the previous section, since the foreign firm's cost is measured in foreign currency terms, any change in the exchange rate represents a cost shock to the foreign firm. Marginal cost for both the domestic and the foreign firms is assumed to be increasing. Profit maximization yields the following first-order conditions:

$$P_h\left(1 + \frac{1}{\xi_h}\right) = C'(X_h) \tag{11}$$

$$P_f\left(1 + \frac{1}{\xi_f}\right) = eC'(X_f). \tag{12}$$

Since either a domestic or a foreign firm's market share is affected by both domestic and foreign prices, the demand elasticity of either firm will also depend on both prices. Totally differentiating the first-order conditions, and solving for the elasticities of the foreign firm's price with respect to the exchange rate, we have

$$\begin{aligned} \tau_f &= \frac{dP_f}{de}\frac{e}{P_f} \\ &= \left\{1 - \omega\xi_f - \frac{\delta s_f}{\xi_f}\left[1 + \frac{\delta s_h}{\xi_h(1 - \omega\xi_h) - \delta s_h}\right]\right\}^{-1} \end{aligned} \tag{13}$$

where $\delta = (\epsilon - 1) > 0$ and ω is the elasticity of marginal cost with output, which is assumed to be positive (indicating increasing marginal cost) and the same for both the domestic and the foreign firms.

Equation (13) yields a number of interesting implications regarding exchange rate pass-through. The expression in large brackets is positive and greater than 1, which implies that, in general, exchange rate pass-through is less than complete.[10] Recall that

$$\xi_i = -\epsilon + (\epsilon - 1)s_i, \qquad \text{for } i = h, f.$$

Thus, the magnitude of pass-through is a function of three parameters in the model: the degree of substitution among the variants (ϵ), the elasticity of marginal cost with respect to output (ω), and the foreign firms' market share (s_f), or equivalently the domestic firms' market share. Specifically,

$$\frac{d\tau_f}{d\epsilon} < 0, \qquad \frac{d\tau_f}{d\omega} < 0, \qquad \frac{d\tau_f}{ds_f} < 0. \tag{14}$$

The degree of exchange rate pass-through is negatively related to the degree of substitution among different variants in the industry (or positively related to the degree of product differentiation). When products in the industry are highly substitutable, a price increase is more likely to lead consumers to switch to other variants. Thus, foreign firms are more likely to keep their prices in line with the domestic price and absorb exchange rate shocks rather than passing them on to prices. On the other hand, when products are highly differentiated (so that they are less substitutable), firms are less worried about losing customers in case of a price increase and will be able to pass cost shocks to prices.

There is a negative relationship between exchange rate pass-through and the elasticity of marginal cost with respect to output. Everything else held constant, an appreciation of the foreign currency tends to increase the foreign firm's price in the domestic currency, which, in turn, will reduce demand for the foreign firm's products. If the elasticity of marginal cost with respect to output is positive, as assumed in the model, a reduction in output will lead to a decrease in marginal cost and tend to reduce the foreign firm's price in domestic currency. Thus, the higher the elasticity of marginal cost with respect to output, the more the change in marginal cost will offset the effect of exchange rate movements on the foreign firm's price in the domestic market. Exchange rate pass-through is, therefore, negatively related to the elasticity of marginal cost with respect to output.

Equation (13) also indicates an inverse relationship between the market share of foreign firms and exchange rate pass-through. When a firm has a larger market share, its price tends to be more stabilizing following cost shocks. As the model implies, a firm with a larger market share has a higher markup due to the relatively lower demand elasticity facing the firm. It is, therefore, more able to absorb cost shocks by varying its profit margins. This may be termed the "large-firm pricing stabilization effect."[11]

III. Empirical Framework and Data

The degrees of exchange rate pass-through in import prices are not directly observable and therefore need to be estimated before the hypotheses formulated from the theoretical model can be tested. Following Cumby and Huizinga (1990) and Lee (1991), I adopt a two-stage estimation procedure. In the first stage, the pass-through elasticities are estimated. In the second stage, these estimates are used as the dependent variable and regressed against variables that are supposed to affect the pass-through elasticities according to the model developed in the previous section.

[9] To be consistent with the domestic firm's profit function, the foreign firm is also assumed to maximize profits in the destination market's currency. More realistically, the foreign firm can be set to maximize profits in its own currency. The results of the model will remain the same.

[10] If marginal cost is constant (so that $\omega = 0$) and substitutability is very low among variants (so that δ approaches zero), then pass-through approaches 1—a complete pass-through.

[11] A sufficient condition for the relationship between foreign firms' market share and exchange rate pass-through in equation (14) to hold is that the marginal cost elasticity (ω) is smaller than or equal to the degree of product substitution (ϵ). When marginal cost elasticity is sufficiently large, this relationship could be reversed. In a more general model, Feenstra et al. (1993) show that this relationship can be potentially nonlinear for low market shares.

The specification of the model suggests that the import price is affected by the domestic price, in addition to the influence of exchange rate movements. Moreover, as stated in Cumby and Huizinga (1990), although the model is static in nature, it is unlikely that there is only a once and for all effect of exchange rate changes on prices. A lagged dependent variable is therefore also included in the empirical framework. Thus, the first-stage regression for each industry involves three time series: the import price, the domestic price, and the exchange rate. It has become increasingly known that many time series are not stationary in their levels; that is, they contain unit roots.[12] Standard asymptotic distribution theory often does not apply to regressions involving such variables, and inference can go seriously astray if this is ignored. Using the Fuller and the Dickey–Fuller tests for unit roots, I found that, with very few exceptions, the import price index series, the U.S. producer price index series, and the exchange rate series involved do contain unit roots.[13] As a result, the first differences of the time series variables are used in the first-stage regressions. The regression model for each industry is thus specified as

$$\Delta \ln MP_{k,t} = a_{1,k}\Delta \ln EXR_t + a_{2,k}\Delta \ln PP_{k,t} + a_{3,k}\Delta \ln MP_{k,t-1} + \nu_{k,t} \tag{15}$$

where $MP_{k,t}$ is the import price index for industry k, EXR_t is the reciprocal of the nominal effective exchange rate index for the U.S. dollar, and $PP_{k,t}$ is the corresponding domestic price index for industry k. $a_{1,k}$ is the elasticity of exchange rate pass-through, which is expected to be positive and smaller than unity. The coefficients for the domestic price and the lagged dependent variable are also expected to be positive, showing interaction between domestic price and import price and persistence in the import price.

The U.S. Bureau of Labor Statistics (BLS) compiles quarterly price indexes for imports and reports for selected two-, three-, and four-digit SIC industries, which are mostly in the manufacturing sector. The longest series cover a period from December 1980 through December 1991. I chose the three- and four-digit SIC industry series in the manufacturing sector in the empirical test. There are 87 such series available (51 three-digit and 36 four-digit SIC industry series; see appendix A for a list of the industries), which represent 17 of the 20 two-digit SIC industry series in the manufacturing sector.[14] A nonoverlapping sample is formed from these 87 industries. The following criterion was used to eliminate the overlaps. If a three-digit SIC industry series overlaps with only one constituent four-digit SIC industry series, I chose the three-digit series. If a three-digit SIC industry series overlaps with more than one constituent four-digit SIC industry series, I selected the four-digit series. The resulting sample thus contains 64 nonoverlapping three- and four-digit SIC industry import price index series (again see appendix A for industries included in the sample). For purposes of comparison and sensitivity analysis, two alternative samples are selected from the 87 industries, with one containing all the three-digit SIC industry series and the other containing all the four-digit SIC industry series.

For the domestic prices, the U.S. producer price index series are used. Two problems arise in matching the import price index series and producer price index series. First, the import price index series are compiled using the 1977 SIC classifications, whereas the up-to-date producer price index series are only available under the 1987 SIC classifications. The two classification systems do not match exactly for a large number of industries on a one-to-one basis.[15] Second, for some industries where differences between the two classifications are small, the producer price index series are unavailable for the entire sample period. To deal with these problems, I chose the 1987 SIC producer price index series from *Producer Price Index* or the wholesale price index series from *Citibase,* which have similar industry specifications as the import price index series. For most industries, these are producer prices either at a more general level or for related industries (see appendix A).

The final category in the time series data is the exchange rate, for which I used Morgan Guaranty's nominal effective exchange rate of the U.S. dollar against 15 other industrial-country currencies.

The second-stage regression model is specified as

$$a_{1,k} = c_0 + c_1 PD_k + c_2 EMC_k + c_3 MR_k + \nu_k \tag{16}$$

where PD_k is a variable measuring the degree of product differentiation for industry k, EMC_k is a measure of the elasticity of marginal cost, and MR_k is the ratio of total imports to total supply in the industry. According to the model developed in the previous section, c_1 is expected to be positive[16]—the higher the degree of product differentiation, or the lower the degree of product substitution, the larger the exchange rate pass-through. c_2 is expected to be negative—the higher the elasticity of marginal cost, the smaller the pass-through. Similarly, the sign of c_3 is supposed to be negative—the higher the import share, the smaller the pass-through.

Because the right-hand-side variables in the second-stage regressions are not directly observable except for the shares of imports, proxy variables are employed. Four candidates for a measure of the degree of product differentiation are considered: the ratio of scientists and engineers to total employment (*SER*), the ratio of nonproduction workers to

[12] See Dickey et al. (1991) and Campbell and Perron (1991) for review and discussions.

[13] Results of the unit root tests are not reported in this paper to save space, but are available upon request.

[14] SIC 21 (tobacco products), SIC 27 (printing and publishing), and SIC 29 (petroleum and coal products) are not covered.

[15] Although the correspondence between the two classifications is published (see *Standard Industrial Classification Manual, 1987,* app. A), conversion of a time series between the two classifications is not possible due to the lack of exact conversion factors.

[16] Note that a large value of ϵ in the theoretical model indicates a high degree of product substitution, but a low degree of product differentiation.

total employment (*NPWR*), advertising intensity (*ADVR*), and the intraindustry trade index (*IIT*). *SER* is an indication of the research and development (R&D) intensity in an industry. Most R&D activities are related to product development and innovation. Therefore, *SER* may serve as a proxy of product differentiation. Alternatively, *NPWR* is a measure of activities that facilitate and service production but are not directly involved in the production process. It is reasonable to assume that many of these activities are related to the level of product sophistication and differentiation. The use of advertising intensity as a proxy for product differentiation is relatively widespread in industrial organization studies. It has been argued that where specifications of goods differ, there are clear incentives for firms to make the details of their specifications known through the medium of advertising. Thus, the greater the number of varieties encompassed in the product spectrum, the greater advertising intensity will be.[17] Finally, as the intraindustry trade literature suggests, intraindustry trade is associated with product differentiation. Following the empirical literature on intraindustry trade, a working measure of the extent of intraindustry trade (*IIT*) is constructed as an index of trade overlap:

$$IIT_k = 1 - \frac{|X_k - M_k|}{X_k + M_k}$$

where X_k and M_k are the values of exports and imports in industry k, respectively. A higher value of the index is posited to indicate a higher degree of product differentiation in an industry.

The proxy for the elasticity of marginal cost is more difficult to specify. Consider the two major production factors—capital and labor. It is common to assume that, in the short run, capital is fixed while labor is variable. Industries with higher capital-to-labor requirements have more difficulties in adjusting their production in the short run than those with lower capital-to-labor requirements. It is plausible to argue that the elasticity of marginal cost is higher in industries with higher capital-to-labor requirements. Thus I used the capital-to-labor ratio to proxy the elasticity of marginal cost with respect to output. (See data appendix for descriptions of this and other variables discussed above.)

IV. Estimation and Discussion

Results obtained from the first-stage regressions for individual industries are presented in appendix A. The estimated coefficients for the producer prices are mostly positive, consistent with the prediction specified in the previous section. For the purpose of this study, I will focus on the estimates of pass-through elasticities. For 77 of the 87 industries, the estimates of the short-run pass-through elasticities are positive and smaller than 1. This indicates that when the dollar appreciates, import prices in general become lower, but less than proportionally. This confirms the general claim of partial pass-through in the literature. The average pass-through elasticity for the nonoverlapping sample is 0.3185, indicating that, in general, foreign firms absorb a larger part of exchange rate changes by varying their export prices measured in their domestic currencies. This contrasts with the U.S. firms' export pricing behavior found in a number of studies, where more pass-through for U.S. firms is observed (See, for example, Knetter (1989), Marston (1990), and Gagnon and Knetter (1991).)[18]

For these 77 industries, the results also show large variations in the pass-through across industries, ranging from 0.025 for SIC 2435 (hardwood veneer and plywood) to 0.757 for SIC 3555 (printing trades machinery). Variation across major manufacturing industries (two-digit SIC) in the nonoverlapping sample is presented in table 1. Generally, industries belonging to SIC 35 (machinery, except electrical) and SIC 38 (instruments and related products) have relatively higher pass-through (about 0.55) than other industries. On the other hand, industries that are subcategories of SIC 24 (lumber and wood products) and SIC 23 (apparel and other textile products) show relatively lower pass-through (about 0.10). The substantial variation in the estimated values of pass-through coefficients by industry is also evidenced by Knetter (1993), where more disaggregated data are used.

TABLE 1.—CROSS-INDUSTRY VARIATIONS IN EXCHANGE RATE PASS-THROUGH

SIC	*N*	*a*	*b*
20	8	0.1875	0.2485
22	2	0.2091	0.3124
23	3	0.1099	0.1068
24	2	0.0897	0.0812
25	1	0.3067	0.3576
28	2	0.3754	0.5312
30	1	0.4285	0.5318
31	3	0.2845	0.3144
32	1	0.6213	0.8843
33	3	0.1625	0.2123
34	4	0.2221	0.3138
35	10	0.5635	0.7559
36	8	0.2930	0.3914
37	1	0.2144	0.3583
38	4	0.5470	0.7256
39	3	0.2305	0.2765

Average 0.3185 (short-run), 0.4205 (long-run)
Total $N = 56$

Definitions:
N = number of constituent three- and four-digit SIC industries included in the study. Industries with negative estimates are omitted. Estimates for the two industries belonging to SIC 26 in the nonoverlapping sample both show negative signs and are omitted from this table.
a = average of estimates of short-run pass-through elasticities.
b = average of estimates of long-run pass-through elasticities.

[17] For discussions of advertising intensity as a proxy of product differentiation, see Greenaway (1984).

[18] As one referee points out, if the firm sells both in the domestic and the foreign markets and cannot price discriminate, the pass-through elasticity would not only depend on the firm's market share in the foreign market, but also on the share of its domestic market relative to the foreign market. This distinction could explain the differences in behavior between U.S. exports and U.S. imports.

The calculated long-run exchange rate pass-through elasticities show a similar pattern, except that the values are somewhat higher, with an average of 0.42 for the nonoverlapping sample.[19] The elasticities for a number of industries belonging to SIC 35 are about 1.0, meaning the pass-through is essentially complete over time. The average short-run and long-run elasticities for the two alternative samples are very similar.

Ten of the 87 industries show negative estimates for the short-run pass-through elasticities, with four belonging to the food and kindred products industries (SIC 201, 2033, 207, and 2076), two to the textile and apparel industries (SIC 221 and 233), two to the paper and allied products industries (SIC 261 and 262), and the remaining two to the rubber and miscellaneous plastics products (SIC 301) and primary metal industries (SIC 3313). None of the negative estimates is, however, statistically significant at even the 10% level.

In the second-stage regression, since there are four proxies for the degree of product substitution, four separate models are employed in the cross-sectional regressions, each using a different proxy for the degree of product differentiation. These models are estimated by the weighted least-squares (WLS) method (using the inverse of the standard error of pass-through elasticity estimates as weights) to allow for heteroskedasticity of the first-stage estimates.[20] The results using the nonoverlapping sample are presented in tables 2 and 3 for the short-run and the long-run pass-through elasticities, respectively.

TABLE 2.—SECOND-STAGE ESTIMATES (SHORT-RUN PASS-THROUGH)

Model	Variable	Estimates	*t*-Statistic	*F*	Adj. r^2
1	Constant	0.1385	1.725	34.95	0.68
	NPWR	0.8284[a]	3.812		
	KLR	−0.0023[a]	−4.463		
	MR	−0.2390	−1.292		
2	Constant	0.3179	5.250	28.28	0.63
	SER	0.0173[b]	2.139		
	KLR	−0.0020[a]	−3.647		
	MR	−0.3316[c]	−1.685		
3	Constant	0.1718	1.942	30.81	0.65
	IIT	0.0670[a]	2.890		
	KLR	−0.0016[a]	−2.796		
	MR	−0.0082	−0.037		
4	Constant	0.3943	6.545	25.48	0.60
	ADVR	−0.0101	−0.634		
	KLR	−0.0020[a]	−3.445		
	MR	−0.3226	−1.579		

[a] Significant at the 1% level.
[b] Significant at the 5% level.
[c] Significant at the 10% level.

TABLE 3.—SECOND-STAGE ESTIMATES (LONG-RUN PASS-THROUGH)

Model	Variable	Estimates	*t*-Statistic	*F*	Adj. r^2
1	Constant	0.1157	1.299	27.28	0.62
	NPWR	1.0824[a]	4.145		
	KLR	−0.0023[a]	−4.144		
	MR	−0.2788	−1.275		
2	Constant	0.3075	4.350	22.12	0.57
	SER	0.0287[a]	2.786		
	KLR	−0.0020[a]	−3.361		
	MR	−0.3159	−1.355		
3	Constant	0.1770	1.858	22.69	0.58
	IIT	0.3170[a]	2.968		
	KLR	−0.0016[a]	−2.621		
	MR	−0.0242	−0.096		
4	Constant	0.3859	4.989	17.87	0.51
	ADVR	−0.0003	−0.015		
	KLR	−0.0020[a]	−3.151		
	MR	−0.3176	−1.281		

[a] Significant at the 1% level.

The variables *NPWR, SER, ITT,* and *ADVR* are supposed to proxy product differentiation. For each of these variables a higher value indicates a higher degree of product differentiation, or a lower degree of product substitution. According to the theoretical model developed in this paper, they should be positively correlated with the exchange rate pass-through elasticities. This is confirmed in the three regressions involving *NPWR, SER,* and *IIT.* The coefficients for these variables are all positive and significant at the 5% level or better for both the short-run and the long-run pass-through elasticities. The estimate for *ADVR* is, however, negative and insignificant. It may be noted that doubts have been raised regarding advertising intensity as a measure of product differentiation. As pointed out by Greenaway (1984), empirical analyses of advertising intensity and market structure are inconclusive, and there are questions about the presence of a systematic relationship between product differentiation and advertising intensity.

The capital-to-labor ratio (*KLR*) variable is used as a proxy for the elasticity of marginal cost with respect to output. As stated earlier, a higher capital-to-labor ratio is supposed to indicate a higher elasticity of marginal cost and is expected to demonstrate a negative relationship with the exchange rate pass-through elasticity. The parameter estimates for this variable are negative and significant at the 1% level in all regressions. The magnitude of estimates is fairly consistent across models. The parameter estimates for the import share are uniformly negative across regressions, but the general insignificance of the results show only weak support of the theoretical prediction.

To see if the estimates are robust across samples, the two alternative samples (the three-digit and the four-digit SIC industries samples) are also utilized for cross-sectional analysis, and the results from both ordinary and weighted least-squares procedures are reported in appendixes B and C, which also contain estimates for nonoverlapping samples. These results confirm those shown in tables 2 and 3. Parameter estimates for *NPWR, SER,* and *KLR* are significant and consistent across models, whereas those for *ADVR* are all negative but insignificant, and those for *MR* show mixed results.

[19] See notes at the end of appendix A for calculating long-run pass-through elasticities.

[20] The statistically nonsignificant pass-through elasticities estimated in the first-stage regressions are included in the second-stage analysis, for they represent industries with low or no pass-through. With the WLS method, these estimates receive smaller weights in the computations of the sums and, therefore, have less influence in the second-stage estimates.

V. Summary and Concluding Remarks

Modeling of exchange rate pass-through has often focused on the variability of the demand elasticity to explain partial adjustments of import prices following exchange rate changes. This paper presents a modified Dixit–Stiglitz model showing that pass-through can result from increasing marginal cost as well as from variable demand elasticity. The paper formulates that the exchange rate pass-through is higher in industries with a higher degree of product differentiation and a lower elasticity of marginal cost. The model also shows a negative relationship between import share and exchange rate pass-through.

Using import price data for three- and four-digit SIC industries in the U.S. manufacturing sector, this paper finds that partial pass-through is common but varies across industries. In the cross-sectional study, three of the four product differentiation proxy variables show a strong positive relationship to the exchange rate pass-through, as hypothesized by the theory. As a proxy of the elasticity of marginal cost, the capital-to-labor ratio relates negatively and significantly to the exchange rate pass-through, supporting the proposition that the pass-through is lower the higher the elasticity of marginal cost with respect to output. The import market share has generally been found insignificant in affecting the exchange rate pass-through across industries.

The findings in this paper have a number of theoretical and practical implications. First, the results provide further evidence that market structure matters in international price transmissions. The results confirm findings by Knetter (1993) that industry differences are important in understanding differences in pass-through behavior. Second, although this paper specifically models the effect of exchange rate movement on import prices, the theoretical predictions also apply to the effects of many other shocks, such as inflation, trade restrictions, and changes in industrial policies. Third, the findings of this paper imply that exchange rate policy may well be ineffective in affecting import flows. Import prices are little affected by exchange rate changes in industries with low product differentiation. In industries with high product differentiation, where import prices do respond to a greater extent to exchange rate changes, demand adjustment may be sluggish since the products are less substitutable. Consequently, the overall effect of exchange rate policy on the import flow may be rather small.

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APPENDIX

DATA APPENDIX

Import Price Indexes

The data are from computer printouts from the Bureau of Labor Statistics.

Producer Price Indexes

In appendix A, for series with SIC codes (variables names begin with PP) the data are from the *Producer Price Indexes,* Bureau of Labor

Statistics, various issues; for series whose titles begin with PW the data are obtained from *Citibase: Citibank Economic Database (machine-readable magnetic data file).* The following is a list of the series obtained from Citibase and used in this paper:

PW101	Iron and steel
PW102	Nonferrous metals
PW112	Construction machinery & equipment
PW113	Metalworking machinery & equipment
PW114	General-purpose machinery & equipment
PW117	Electrical machinery & equipment
PW125	Home electronic equipment
PW21	Cereal and bakery products
PW25	Sugar and confectionery products
PW26	Beverages & beverage materials
PW381	Apparel
PW44	Other leather products
PW67	Other chemicals
PW711	Crude rubber
PW91	Pulp, paper, & products excluding building paper
PWAUTO	Motor vehicles & equipment
PWFE	Processed foods and feeds
PWFH	Furniture and household durables
PWLU	Lumber and wood products
PWM	Total manufactures
PWMET	Metals and metal products
PWMIS	Miscellaneous products
PWSK	Hides, skins, leather, & related products
PWTEX	Textile products and apparel

Exchange Rate

Nominal effective exchange rate of the U.S. dollar against 15 other industrial-country currencies from *World Financial Markets,* Morgan Guaranty Trust Company, various issues.

Cross-Sectional Data

NPWR Nonproduction workers to total employees ratio: *1982 Census of Manufacturers,* vol. 1, table 3. The ratio is calculated as

$$\frac{\text{production workers}}{\text{all employees}}.$$

SER Scientists and engineers to total employees ratio: *1980 Census of Population,* vol. 2, table 4. The ratio is calculated as

$$\frac{\text{natural scientists} + \text{engineers}}{\text{employed persons 16 years and over}}.$$

The industries listed mainly correspond to three-digit SIC industries. The same data are matched to the corresponding four-digit SIC industries in this study.

IIT Intraindustry trade index. Import and export values are from computer printouts from the U.S. Department of Commerce. The indexes are calculated as

$$\frac{\text{export value} - \text{import value}}{\text{export value} + \text{import value}}.$$

The variable used in the study is a simple average of the calculated indexes for 1980, 1982, 1984, and 1986.

ADVR Advertising intensity. Advertising expenditure to total output ratio from *1982 Input–Output Study—542-Industry Level,* Bureau of Economic Analysis, U.S. Department of Commerce. Industries listed mainly correspond to four-digit SIC industries. Data for each three-digit SIC industry are calculated by summing up advertising expenditures and output for relevant four-digit industries, then dividing the total expenditures by the total output for the three-digit SIC industry.

KLR Capital-to-labor ratio. Calculated as total assets divided by total employees. Data for assets are 1982 values from 1983 *Annual Survey of Manufactures.* Data for total employees are same as used in calculating *NPWR.*

MR Import share. The same source as *IIT.* The variable used in the study is a simple average of the import shares of 1980, 1982, 1984, and 1986.

Appendix A.—First-Stage Estimation Results

$$\Delta \ln MP_{k,t} = a_{1,k}\Delta \ln EXR_t + a_{2,k}\Delta \ln PP_{k,t} + a_{3,k}\Delta \ln MP_{k,t-1} + v_{k,t}$$

SIC	*PP*[b]	a_1	$t(a_1)$[c]	a_2	$t(a_2)$[c]	a_3	$t(a_3)$[c]	b[d]
201[a]	PP2015	−0.002	−0.008	−0.028	−0.208	−0.084	−0.469	−0.002
2011	PP2011	0.046	0.259	0.405	2.935	0.060	0.415	0.049
202[a]	PW21	0.299	2.609	0.518	1.476	0.526	4.036	0.631
203[a]	PP2033	0.234	0.881	0.969	1.458	−0.222	−1.496	0.191
2033	PP2033	−0.042	−0.147	0.855	1.201	−0.075	−0.483	−0.039
206	PW25	0.425	1.392	0.455	1.032	−0.149	−0.950	0.370
2062[a]	PP2062	0.114	0.907	0.925	2.695	−0.379	−2.418	0.082
2066[a]	PP2066	0.190	1.075	0.668	1.845	−0.171	−0.939	0.163
207[a]	PP2077	−0.823	−1.671	1.054	3.605	0.085	0.623	−0.900
2076	PP2075	−0.685	−1.094	0.340	1.213	0.181	1.140	−0.836
208	PW26	0.073	1.833	0.566	4.922	0.517	5.281	0.150
2082[a]	PW26	0.047	1.040	0.422	3.383	0.238	1.795	0.062
2084[a]	PW26	0.158	3.079	0.728	5.170	0.470	4.802	0.298
2085[a]	PP2085	0.046	0.994	0.799	6.380	0.305	2.994	0.066
209[a]	PWFE	0.412	4.444	0.097	0.333	0.168	1.160	0.495
221[a]	PP221	−0.061	−0.546	1.156	2.519	0.138	0.780	−0.070
222[a]	PP222	0.144	0.741	0.114	0.151	0.116	0.699	0.163
229[a]	PW381	0.274	3.434	0.231	0.604	0.406	3.313	0.462
231[a]	PP231	0.214	3.209	1.227	4.596	−0.243	−1.656	0.172
232[a]	PW381	0.051	0.853	0.667	2.140	0.331	2.296	0.076
2321	PW381	0.070	1.083	0.586	1.789	0.332	2.288	0.105
233[a]	PWTEX	−0.042	−0.328	1.986	2.612	−0.128	−0.594	−0.037
238[a]	PW381	0.065	0.821	0.636	1.452	0.099	0.576	0.072
242[a]	PP242	0.145	1.571	1.022	9.775	−0.201	−2.180	0.121
2421	PW2421	0.188	1.691	1.170	10.894	−0.076	−0.938	0.175
243[a]	PWLU	0.034	0.339	0.350	2.022	0.176	1.193	0.042
2435	PWLU	0.025	0.238	0.328	1.861	0.302	2.102	0.036

APPENDIX A.—(CONTINUED)

$\Delta \ln MP_{k,t} = a_{1,k}\Delta \ln EXR_t + a_{2,k}\Delta \ln PP_{k,t} + a_{3,k}\Delta \ln MP_{k,t-1} + v_{k,t}$

SIC	PP[b]	a_1	$t(a_1)$[c]	a_2	$t(a_2)$[c]	a_3	$t(a_3)$[c]	b[d]
259[a]	PWFH	0.307	5.101	0.838	2.460	0.143	1.199	0.358
261[a]	PW91	−0.015	−0.078	2.140	3.576	0.289	1.992	−0.021
262[a]	PP262	−0.076	−1.151	0.997	5.423	−0.008	−0.062	−0.075
281[a]	PW67	0.501	1.832	0.163	0.129	0.226	0.990	0.647
289[a]	PP289	0.250	3.350	0.303	1.259	0.399	2.718	0.416
301[a]	PW711	−0.055	−1.368	0.026	0.458	0.358	2.482	−0.086
307[a]	PP307	0.429	5.461	0.216	0.557	0.194	1.437	0.532
314	PWSK	0.220	3.031	0.210	1.179	0.009	0.060	0.222
3143[a]	PP3143	0.330	4.736	0.430	1.859	0.330	2.673	0.492
3144[a]	PW44	0.408	3.720	1.597	4.094	−0.378	−2.876	0.296
317[a]	PP317	0.116	1.470	0.996	2.513	0.255	1.432	0.155
326[a]	PWM	0.621	5.723	0.335	0.768	0.297	2.726	0.884
331	PW101	0.039	0.618	0.538	2.990	0.503	4.359	0.078
3312[a]	PP3312	0.055	0.887	0.540	3.046	0.458	3.929	0.101
3313[a]	PW101	−0.031	−0.128	1.046	1.608	0.520	4.001	−0.064
333[a]	PW102	0.197	0.995	0.948	4.470	0.029	0.231	0.203
3331	PW102	0.402	1.475	2.221	7.495	−0.155	−1.630	0.348
335[a]	PW102	0.236	2.850	0.378	4.007	0.292	2.683	0.334
345[a]	PWMET	0.169	2.197	0.513	2.155	0.440	3.292	0.302
349	PP349	0.209	2.827	1.213	3.243	0.097	0.612	0.231
3494[a]	PP3494	0.377	3.552	0.600	1.434	0.295	1.998	0.534
3496[a]	PWMET	0.066	1.053	0.251	1.332	0.337	2.274	0.100
3499[a]	PWMET	0.277	3.042	0.188	0.674	0.133	0.942	0.319
353	PW112	0.476	6.532	0.927	3.109	0.346	3.479	0.727
3531[a]	PP3531	0.402	4.616	0.607	1.729	0.297	2.491	0.572
3537[a]	PP3537	0.593	3.461	0.707	1.184	0.344	1.618	0.903
354[a]	PW113	0.574	8.099	0.912	2.969	0.193	2.031	0.711
3541	PP3541	0.556	7.052	0.327	1.016	0.346	3.287	0.850
355	PP355	0.730	6.551	0.898	1.475	0.255	2.095	0.981
3552[a]	PP3552	0.662	6.789	0.420	1.152	0.192	1.682	0.819
3555[a]	PP3555	0.757	5.623	0.728	1.017	0.307	2.627	1.093
3559[a]	PP3559	0.597	3.953	1.217	1.539	0.117	0.724	0.676
356	PW114	0.618	7.711	0.741	2.113	0.243	2.468	0.816
3562[a]	PP3562	0.535	6.539	0.532	2.469	0.315	2.696	0.782
3569[a]	PW114	0.756	6.575	0.890	1.779	0.207	1.909	0.953
357	PP3574	0.178	2.010	−0.227	−0.694	0.209	0.958	0.225
3574[a]	PP3574	0.046	0.313	0.009	0.018	−0.219	−0.811	0.038
3579[a]	PW125	0.714	7.575	0.405	1.345	0.296	3.016	1.014
362[a]	PP362	0.437	4.680	0.988	2.060	0.048	0.304	0.459
363[a]	PP363	0.256	4.332	1.467	2.879	0.360	2.720	0.400
3639	PP3639	0.281	3.546	0.286	1.048	0.141	0.840	0.327
364[a]	PP3643	0.521	5.770	0.562	1.644	0.284	2.546	0.728
3643	PP3643	0.658	5.199	0.765	1.599	0.281	2.439	0.914
365[a]	PW125	0.085	1.669	0.238	1.711	0.518	4.080	0.175
3651	PP3651	0.081	1.561	0.156	0.768	0.521	4.007	0.169
366	PW125	0.203	3.283	0.331	1.660	0.062	0.390	0.216
3661[a]	PW125	0.180	1.659	0.472	1.576	−0.058	−0.387	0.170
3662[a]	PW125	0.230	3.840	0.172	0.876	0.277	1.826	0.318
367[a]	PW125	0.217	2.093	0.491	1.435	0.178	1.079	0.264
3679	PW125	0.206	3.610	0.316	1.726	0.344	2.324	0.313
369[a]	PW117	0.418	5.692	0.353	0.937	0.322	2.891	0.617
371[a]	PWAUTO	0.214	3.932	0.394	5.361	0.402	4.119	0.358
382[a]	PWM	0.651	6.663	−0.094	−0.239	0.257	2.436	0.876
383[a]	PWM	0.653	6.243	−0.231	−0.551	0.294	2.713	0.925
386[a]	PWM	0.316	4.632	−0.038	−0.138	0.322	2.628	0.466
387[a]	PWM	0.568	5.945	−0.063	−0.165	0.106	0.930	0.635
391[a]	PWMIS	0.231	1.677	0.640	1.181	0.153	0.890	0.272
394[a]	PWMIS	0.134	2.205	0.274	1.278	0.156	0.832	0.159
3949	PP3949	0.061	0.962	0.756	2.560	0.302	1.686	0.088
396[a]	PWMIS	0.327	3.381	0.314	0.846	0.180	1.068	0.39

[a] SIC industries included in the nonoverlapping sample.
[b] PP refers to the corresponding U.S. producer prices. (See data appendix.)
[c] $t(a_i)$, $i = 1, 2, 3$, is the t-statistic that applies to the corresponding estimate.
[d] Long-run pass-through elasticity, calculated as $b = a_1/(1 - a_3)$.

APPENDIX B.—SENSITIVITY ANALYSIS OF SECOND-STAGE ESTIMATES
(SHORT-RUN PASS-THROUGH ELASTICITIES AS DEPENDENT VARIABLES)

$$a_k = c_0 + c_1 PD_k + c_2 KLR_k + c_3 MR_k + v_k$$

Panel	Model[a]	c_1	$t(c_1)$	c_2	$t(c_2)$	c_3	$t(c_3)$
NPWR	1	0.987	3.735	−0.002	−3.088	−0.003	−0.013
	2	0.828	3.812	−0.002	−4.463	−0.239	−1.292
	3	0.865	2.876	−0.002	−2.417	0.218	0.797
	4	0.468	2.044	−0.003	−3.555	−0.193	−0.875
	5	0.932	2.891	−0.002	−2.185	−0.018	−0.063
	6	0.842	3.315	−0.002	−3.523	−0.147	−0.657
SER	1	0.029	2.725	−0.002	−2.822	−0.035	−0.152
	2	0.017	2.139	−0.002	−3.647	−0.332	−1.685
	3	0.031	2.582	−0.002	−2.364	0.109	0.401
	4	0.016	1.919	−0.002	−3.380	−0.360	−1.740
	5	0.026	1.729	−0.002	−2.007	−0.043	−0.139
	6	0.012	1.167	−0.002	−2.799	−0.233	−0.940
IIT	1	0.084	2.922	−0.002	−2.869	0.266	1.040
	2	0.067	2.890	−0.002	−2.796	−0.008	−0.037
	3	0.128	3.750	−0.002	−2.912	0.653	2.160
	4	0.091	3.631	−0.002	−3.140	0.085	0.378
	5	0.058	1.543	−0.002	−1.998	0.171	0.522
	6	0.057	1.828	−0.002	−2.029	0.042	0.150
ADVR	1	−0.016	−0.745	−0.002	−2.729	−0.065	−0.264
	2	−0.010	−0.634	−0.002	−3.445	−0.323	−1.579
	3	−0.008	−0.328	−0.002	−2.091	0.027	0.094
	4	−0.015	−0.849	−0.002	−3.276	−0.365	−1.705
	5	−0.040	−1.144	−0.002	−2.201	0.009	0.029
	6	−0.020	−0.879	−0.002	−2.368	−0.181	−0.722

Note: *PD* is the degree of product differentiation variable, referring to *NPWR*, *SER*, *IIT*, and *ADVR* in different panels.
[a] Models 1 & 2—OLS and WLS estimates for the nonoverlapping sample; models 3 & 4—OLS and WLS estimates for the three-digit sample; models 5 & 6—OLS and WLS estimates for the four-digit sample.

APPENDIX C.—SENSITIVITY ANALYSIS OF SECOND-STAGE ESTIMATES
(LONG-RUN PASS-THROUGH ELASTICITIES AS DEPENDENT VARIABLES)

$$b_k = c_0 + c_1 PD_k + c_2 KLR_k + c_3 MR_k + v_k$$

Panel	Model[a]	c_1	$t(c_1)$	c_2	$t(c_2)$	c_3	$t(c_3)$
NPWR	1	1.487	4.426	−0.002	−3.037	−0.142	−0.501
	2	1.082	4.145	−0.002	−4.144	−0.279	−1.275
	3	1.299	3.460	−0.002	−2.429	0.204	0.598
	4	0.899	3.261	−0.002	−2.928	−0.012	−0.046
	5	1.477	3.575	−0.002	−2.313	−0.135	−0.364
	6	0.926	3.094	−0.002	−3.357	−0.149	−0.556
SER	1	0.042	3.007	−0.002	−2.682	−0.192	−0.635
	2	0.029	2.786	−0.002	−3.361	−0.316	−1.355
	3	0.043	2.839	−0.002	−2.314	0.032	0.093
	4	0.028	2.583	−0.002	−2.807	−0.194	−0.751
	5	0.041	2.113	−0.002	−2.058	−0.174	−0.432
	6	0.020	1.569	−0.002	−2.706	−0.185	−0.641
IIT	1	0.451	2.979	−0.002	−2.704	0.210	0.623
	2	0.317	2.968	−0.002	−2.621	−0.024	−0.096
	3	0.671	3.838	−0.002	−2.839	0.739	1.907
	4	0.435	3.416	−0.002	−2.578	0.294	0.978
	5	0.361	1.806	−0.002	−2.046	0.159	0.367
	6	0.233	1.715	−0.002	−2.146	0.031	0.102
ADVR	1	−0.022	−0.774	−0.002	−2.570	−0.234	−0.724
	2	−0.000	−0.015	−0.002	−3.151	−0.318	−1.281
	3	−0.007	−0.232	−0.002	−1.984	−0.081	−0.219
	4	0.002	0.085	−0.002	−2.432	−0.308	−1.131
	5	−0.056	−1.203	−0.002	−2.265	−0.094	−0.225
	6	−0.009	−0.354	−0.002	−2.592	−0.145	−0.488

Note: *PD* is the degree of product differentiation variable, referring to *NPWR*, *SER*, *IIT*, and *ADVR* in different panels.
[a] Models 1 & 2—OLS and WLS estimates for the nonoverlapping sample; models 3 & 4—OLS and WLS estimates for the three-digit sample; models 5 & 6—OLS and WLS estimates for the four-digit sample.