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# IS PRICE ADJUSTMENT ASYMMETRIC?: EVALUATING THE MARKET SHARE AND MARKETING BOTTLENECKS HYPOTHESIS

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## ABSTRACT

The theoretical literature on pricing-to-market has identified two possible reasons why the elasticity of prices to exchange rate changes may be asymmetric across appreciations and depreciations. If firms are attempting to increase market shares in foreign markets subject to the possibility of trade restrictions, then more pricing-to-market may occur during appreciations of the exporter's currency. If firms face capacity constraints in their distribution networks, then pricing-to-market may be exaggerated during periods of depreciation of the exporter's currency. This paper uses panel data on German and Japanese 7-digit industry exports to compare these competing explanations for asymmetries in pricing-to-market behavior. While the data seldom reject the null hypothesis of a symmetric response of prices to exchange rates, some industries, notably automobiles, provide empirical support for the market share model. Only a pooled regression with Japanese data supports the marketing bottlenecks model.

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# Is Price Adjustment Asymmetric?: Evaluating the Market Share and Marketing Bottlenecks Hypotheses

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Recent empirical research in international economics has established that exchange rate fluctuations are associated with large and persistent common currency price differentials of similar products across countries.[1] Paul Krugman (1987) has labelled this phenomenon "pricing to market", reflecting the general view that these differentials arise as a result of firms consciously seeking to stabilize prices in units of the local (i.e., importer's) currency in their export markets. Existing evidence on the pattern of price adjustment suggests that Japanese and German exporters use profit margins to absorb part of the impact of exchange rate changes, whereas U.S. firms tend to keep margins relatively stable.[2] This paper will address a subsidiary issue concerning the relationship between export prices and exchange rates for German and Japanese exporters. Are the changes in destination-specific markups associated with exchange rate changes asymmetric? In particular, are appreciations more likely to be offset by destination-specific markup adjustment than depreciations, or vice-versa? Furthermore, does pricing to market frequently arise from capacity constraints in distribution networks?[3]

Asymmetries in the response of export prices to appreciations and depreciations of the exporter's currency can be motivated in several ways. Harry Foster and Baldwin (1986) introduce a fixed proportions marketing technology which is required to sell products in the foreign market. This "bottlenecks" model predicts that in the period of rising dollar in the early 1980's that some foreign firms with inadequate investment in marketing capacity may have been unable to increase sales by allowing their dollar prices to fall. If sales are already constrained by marketing capacity, then exporters should respond to a dollar appreciation by increasing their foreign currency export prices to keep dollar prices stable and clear the market. Since there is no similar constraint that could bind in an appreciation of the exporter's currency, one might expect more markup adjustment to stabilize local currency prices with depreciation than with appreciation of the exporter's currency. There have been indications in the popular press that bottlenecks encountered when the exporter's currency is relatively weak may persist due to uncertainty about future exchange rates.[4]

Another scenario which would give rise to asymmetric response of the same sort as the bottlenecks model is the presence of binding quantity constraints in export markets due to trade restrictions. For example, Japanese auto producers apparently faced binding quantity constraints in the U.S. market during much of the 1980s. Consequently, they should charge the market clearing dollar price for the permitted quantity in each period. This requires that profit margins adjust to fully offset any depreciations of the yen. The depreciation will not be passed through to lower dollar prices, since the quantity of cars sold in the U.S. was already at its upper bound. Appreciations of the yen may not elicit complete pricing to market, however, since the number of cars shipped can be below the quota level.

A different kind of asymmetric response arises if exporters are intent on building market share in their export markets subject to a constraint on their behavior due to the threat of anti-dumping or other restrictive trade laws. When their currency appreciates vis-a-vis an importing country's currency, exporters may offset the implied increase in local currency prices by reducing their markups. When their currency depreciates, they maintain (rather than increase) their markups and allow the local currency price of their products to fall. This enables them to gain market share in periods when their currency is weak without necessarily triggering dumping charges since the lower prices are justified by lower costs.[5]

The bottlenecks model suggests that we may observe more PTM during depreciations of the exporter's currency, whereas the "market share" model predicts the opposite. Marston has examined Japanese export price adjustment and found that there was significant evidence of more vigorous markup adjustment during the Yen appreciation against the dollar after 1985 than during the Yen depreciation from 1980 to 1985 for five of 17 industries studied. Specifically, Marston found statistically significant evidence that PTM was greater during appreciations for small cars, small trucks, motorcycles, microwave ovens, and cameras.[6] This provides some support for the market share story. Ohno's findings are more consistent with the bottlenecks model. For most Japanese machinery and equipment industries markups are more frequently used to offset the impact of depreciations than appreciations, although it is difficult to reject the null hypothesis that the coefficients are independent of the sign of the exchange rate change. Mann's study of profit margin adjustments to exchange rate changes appears to support a symmetric response for a number of four-digit industries, although there is no way to evaluate the statistical significance of those findings.

This paper will test the asymmetry hypotheses within the panel data framework for studying export price adjustment introduced in Knetter (1989). The unique features of this framework are that it enables an indirect way to control for changes in marginal cost of the exporter and it uses the most disaggregated industry-level data available.[7] Since a cross-section of export prices to various destination markets are observed over time, it is possible to control for unobserved factors influencing prices charged to all of the markets by introducing a full set of time dummies into the model. Consequently, changes in marginal cost (or other factors that would affect prices in all destinations) will be accounted for by the time effects in the model. The destination-specific demand variables, such as exchange rates, will explain destination-specific changes in the export prices that are due to destination-specific changes in markups. The basic framework is modified by allowing for an asymmetric response to appreciations and depreciations through interactive dummy variables. More detailed tests of the bottlenecks model use past quantity flows to isolate those periods in which capacity constraints are most likely to be binding.

The main finding of the paper is that although the data are seldom strong enough to reject symmetric response to appreciations and depreciations, more individual industries appear to favor the market share model. The specific predictions of the bottlenecks model are seldom evident in the data. The automobile industry provides the strongest evidence on this point. All seven categories of automobiles in the data sample (three Japanese and four German) exhibit more PTM when the exporter's currency is appreciating. This is most surprising since the bottlenecks model seems particularly applicable to this industry--due to the possibility of genuine bottlenecks in distribution and the existence of quantity restrictions on Japanese auto exports to a number of destination markets during the sample period.

Although most significant results at the industry level favor the market share model, there is one piece of evidence that favors the bottlenecks model. In a regression that pools the data for all Japanese industries, there is statistically significant evidence that more PTM occurs during Yen depreciations that during appreciations. While restriction on the data implied by the pooling is valid at conventional levels of significance, it is clearly masking some very different behavior at the industry level.

Section 1 of the paper lays out the empirical model. Section 2 discusses the German and Japanese export data. Section 3 presents and discusses the results of estimation. Section 4 concludes the paper.

## 1. The Empirical Model

The empirical framework adopted here follows Knetter (1989,1992). The motivation for the framework comes from a simple model of price discrimination by a monopolist selling to several export destinations. One can view the first-order conditions of the firm as a set of pricing equations, where price charged to each destination market is the product of marginal cost and a markup term. Marginal cost is common to all destinations, whereas the markup may be common or destination-specific. In imperfectly competitive markets, it is natural to think of markups as being destination-specific and therefore influenced by destination-specific variables, such as exchange rates, income, and other prices.

The general model of export price adjustment I propose to estimate for a 7-digit industry in a given source country can be written as follows:

$$(1)\quad \Delta p_{it} = \theta_t + \beta_i \Delta x_{it} + \varepsilon_{it}$$

where $i = 1,\ldots,N$ and $t = 1,\ldots,T$ index destination of exports and time respectively, $\Delta p$ is the change in the log of destination-specific export price (measured in units of the exporter's currency at the port of export), $\Delta x$ is the change in the log of the destination-specific exchange rate (expressed as units of the buyer's currency per unit of the seller's divided by the destination market price level), and $\theta_t$ and $\beta_i$ are (T+N) parameters to be estimated.[8] The $\theta_t$ are coefficients on the time effects which capture common movement in prices over time across all destinations. The $\beta_i$ measure the destination-specific response of export price to destination-specific changes in exchange rates. The error term $\varepsilon_{it}$ is assumed to be independent and identically distributed.

The model given by (1) is an analysis of covariance model in which the intercept term is allowed to vary due to unobservable factors that are constant across individuals but vary over time (captured by the $\theta$'s). The primary factor underlying the time effects is the change in marginal cost of the exporters. It is also possible that some common movement in prices is due to changes in the markup over marginal cost that are common to all destination markets. As written in equation (1), the model allows for the slope coefficients to vary across destinations. Knetter (1992) shows that it is seldom possible to reject the hypothesis that these coefficients are identical across destinations for a given industry. In accordance with that finding, the destination-specific response of prices to exchange rates will be assumed to be the same across destinations.

No attempt is made to distinguish temporary from permanent exchange rate changes for estimation purposes. There is no widely accepted method by which to make such distinctions. Furthermore, the empirical literature on exchange rate determination has yet to offer models that outperform a simple random walk in forecasting future realizations.[9] That finding supports the interpretation of exchange rate changes as permanent. I also treat the exchange rate changes as exogenous to the export industries, which seems natural in light of the fact that the data are at the 7-digit industry level.

In order to test specifically for asymmetries in the response of prices to exchange rates, the exchange rate changes are divided into two groups: depreciations of the exporter's currency ($\Delta x < 0$), denoted by $\Delta x_1$, and appreciations of the exporter's currency ($\Delta x > 0$), denoted by $\Delta x_2$. The equation estimated is then:

$$(2)\quad \Delta p_{it} = \theta_t + \beta_1 \Delta x_{1it} + \beta_2 \Delta x_{2it} + \varepsilon_{it}$$

where the response of prices to exchange rate changes is assumed to be identical across destinations, but depends on the direction of the exchange rate change. An F-test will be used to determine whether or not the data accept the restriction that the two slopes are equal.

The statistical interpretation of the $\beta$'s is straightforward. A value of zero implies that the markup to a particular destination is unresponsive to fluctuations in the value of the exporter's currency against the buyer's. Thus, changes in currency values are fully passed through to the buyer apart from any possible impact they may have on all prices via the common marginal cost. Negative values of $\beta$ imply that markup adjustment is associated with stabilization of local currency prices. For example, a value of -.5 means that in response to a 10% appreciation (depreciation) of his currency against the currency of destination $i$, the exporter would reduce (increase) his markup to destination $i$ by 5% relative to the markups to other destinations. Assuming constant costs, the price paid in units of the buyer's currency would rise (fall) by only 5%. Positive values of $\beta$ correspond to the case in which destination-specific changes in markups amplify the effect of destination-specific exchange rate changes on the price in units of the buyer's currency.[10]

The market share model predicts that more stabilization of prices in the local currency occurs when the exporter's currency is appreciating. Thus, we would expect to observe $\beta_2 < \beta_1$. On the contrary, the bottlenecks model (or the quantity constraints in trade scenario) predicts more PTM is observed when the exporter's currency is depreciating. Thus, we would expect to observe $\beta_1 < \beta_2$.

Since many periods of depreciation of the exporter's currency may not be periods in which distribution bottlenecks are encountered in export markets, equation (2) is not a very clean test of the bottlenecks model. By conditioning on past quantity shipments to each destination, however, it is possible to isolate those periods in which the bottlenecks model is most appropriate. Bottlenecks arise when two conditions hold: (1) the exporter's currency depreciates against a destination market currency, so that quantity expansion is desired, and (2) quantity of shipments to that destination in the previous period is at a record-high level. Therefore, define the dummy variable $d_{it}$ as follows:

$$\begin{aligned} d_{it} &= 0 \text{ if } q_{it-1} < q_{it-j} \text{ for some } j > 1. \\ &= 1 \text{ if } q_{it-1} > q_{it-j} \text{ for all } j > 1. \end{aligned}$$

Values of $d_{it}$ equal to one indicate that destination $i$ may be facing capacity constraints in period $t$ for shipments in this particular industry.[11] If in addition, the exporter's currency depreciates against destination i's currency in period t, then we might expect pricing to market to arise on account of marketing bottlenecks (or binding quantity constraints).

By interacting this dummy variable with $\Delta x_1$ it is possible to estimate a coefficient that more accurately reflects the importance of marketing bottlenecks. The model will be estimated in the following form:

$$(3)\ \ \Delta p_{it} = \theta_t + \beta_1 d_{it} \Delta x_{1it} + \beta \Delta x_{it} + \varepsilon_{it}$$

which permits assessment of the marginal impact of bottlenecks situations on the extent of pricing to market. If bottlenecks are important in generating pricing to market behavior in a particular industry, then we would expect $\beta_1$ to be negative.

## 2. Data

The data used in this study are based on the annual value and quantity of exports to selected destination countries for a number of 7-digit industries in two source countries: Japan and Germany. The sample period is 1973-1987 for Japanese exports and 1975-1987 for German exports. For each source country-industry pair, data on exports to a number of relatively large (in terms of sales) export destinations are collected. Eligible destination markets are those that have currencies that fluctuate in value against the exporter's currency, to the extent possible. The aim in choosing large export destinations is to improve the accuracy of the unit values (the value of exports divided by the quantity) as a measure of price and to minimize the number of missing observations. These criteria for data collection imply that sampling over destinations is not random. Therefore the effects in the model will be treated as fixed and inference will be conditional on the effects included in the sample. The specific industries selected and the sources for the unit value data are listed in the data appendix.

The industries were selected with several factors in mind. One aim was to provide variation in terms the types of products: durables, non-durables, intermediate goods, etc.

Another was to try to choose some products that are important export industries in the source countries being studied. For purposes of another study, there was also an attempt to select industries that exported from more than one of the source countries in the sample. This task was difficult due to the lack of harmonization of the industry classification codes across source countries. The data set includes a number of chemical products for each source country, although exact matches are rare.

The data are actually available at higher frequencies in some cases. In Germany, they are available monthly. The choice of annual frequency reflects primarily the need to economize on data collection effort. All of the data used in the study were handcopied from government publications of the respective source countries. This creates a trade-off between higher frequency information and more source country and industry variation. The latter seemed to be of greater interest and importance. Previous work (e.g., Alberto Giovannini (1988), Kasa, and Marston) has addressed the dynamics of price responses with monthly data. That will not be the focus of this work. There is also a trade-off between frequency and the length of the sample period. The lower frequency information was collected over the entire floating exchange rate period in most cases. Another reason lower frequencies may actually be preferred in constructing unit values is that erratic variation in shipments at high frequencies could increase the amount of noise in the unit value series. This is particularly likely in cases where there is heterogeneity in the product category.

The exchange rate series used as an explanatory variable is expressed in units of the buyer's currency per unit of the exporter's and is based on the annual average nominal exchange rate published in *International Financial Statistics*. The nominal rate is adjusted by dividing by the wholesale price index in the destination market. The rational for this adjustment is that the optimal export price should be neutral with respect to changes in the nominal rate that correspond to inflation in the destination market. The wholesale price indices are annual averages taken from *International Financial Statistics*.

## 3. Estimation and Results

For each of the 32 source country-industry pairs (18 German industries and 14 Japanese), the regression equations for each destination are estimated jointly, imposing the cross equation restrictions. The errors are assumed to be independent and identically distributed. Errors must be assumed to be uncorrelated across equations, since the presence of a full set of time dummies in the model precludes estimation of an unrestricted covariance matrix. The results of estimating equation (1) for German and Japanese export industries are given in Tables 1 and 2.[12] The sign of the coefficient estimates reveals that destination-specific price adjustment in response to exchange rate changes tends to reduce fluctuations in prices measured in units of the importer's currency, which is the form of pricing to market typically emphasized in the literature. The coefficient estimates are different from zero at the 5% level of significance in about half of the cases. Most notable among the industry results are the estimates for German auto industry, which shows no evidence of pricing to market in the two large autos categories.[13]

The results of estimating equation (2) for the German and Japanese industries appear in Tables 3 and 4. The first two columns report the estimated values of $\beta_1$ and $\beta_2$ and their standard errors. The third column reports the F-statistic for the null hypothesis that destination-specific price adjustment is identical for appreciations and depreciations. Each row of each table represents a different 7-digit industry.

For the German industries reported in Table 3, the results are split evenly between industries favoring the market share model and those favoring the bottlenecks model. However, none of the industries reject the null hypothesis of symmetric response. The magnitude of the standard errors is sufficiently large with the unit value data and the split samples that even large differences in estimated coefficients are insignificant. Nonetheless, it is worth noting that the four automobile categories, two steel products and beer are consistent with the implications of the market share model. Chemical products are evenly split between the two models and both wine products are consistent with bottlenecks.

For the Japanese industries in Table 4, the results are consistent with the market share model in most cases. The null hypothesis of identical response is only rejected by the data for the case of aluminum foil (which is consistent with bottlenecks, although the parameter estimates appear to be implausible) and mid-size automobiles (consistent with market share) at the 5% level. Light manufactures and chemicals appear to be evenly split between the two models, whereas automobiles provide relatively strong support for the market share model as in the German case.

It is interesting that the evidence for all seven categories of automobiles is unanimously in favor of the market share model of asymmetric response. In other words, yen export prices to U.S. (foreign) buyers are reduced relative to prices charged to other buyers in response to appreciations of the yen against the dollar (the buyer's currency) by much larger amounts than they are increased in response to destination-specific depreciations of the yen.[14] *Ex ante*, one would think that automobiles represents an industry in which bottlenecks in distribution might constrain sales in many periods. Distribution networks play a very important role in sales and production decisions must be made before the relevant exchange rates are known. Certainly, the long term expansion of sales by Japanese producers in the United States has been facilitated by the opening of distribution outlets in new regions of the country.[15] These results are more consistent with Marston's findings for Japanese exports of small passenger cars and small trucks than with Ohno's results for machinery and equipment exports (which support the bottlenecks model). This may be a consequence of the fact that Ohno's data are at the two-digit industry level and thus may be averaging over many smaller industries which exhibit different behavior.

The results in Tables 3 and 4 are suggestive, but not statistically significant. In Tables 5 and 6, I impose additional restrictions on the data in the hope that a clearer picture will emerge.[16] Table 5 estimates equation (2) for several different groups of German industries and for the entire set of German industries. The group of auto industries comes close to rejecting the null hypothesis of a symmetric response in favor of more PTM during appreciations. The marginal significance level of .14 is not low enough to reject the null under conventional criteria, however. Alcoholic beverages (beer, white wine, and sparkling wine) indicate more PTM in appreciations as well, although the difference across regimes is small. Chemical products (which includes synthetic dyes, special dye preparations, titanium oxides, titanium oxide pigments, aluminum hydroxide, vitamin A, and vitamin C) reveal slightly more PTM in depreciations, suggesting that the capacity constraints model may be more appropriate for this group. This is consistent with the anecdotal evidence cited in the introduction regarding U.S. chemical exports. Once again, however, the differences are rather far from being statistically significant in spite of the additional restrictions imposed on the data.

Table 6 estimates equation (2) for Japanese autos and all Japanese industries. Consistent with the disaggregated results in autos, the data show somewhat more PTM in appreciations, but again the difference is not statistically significant. When the data are pooled over all industries, a surprising result is obtained: there is a statistically significant increase in PTM during depreciations as opposed to appreciations. The point estimates indicate that PTM almost completely offsets the effect of exchange rate changes during depreciations, while only 30% of an appreciation is offset by markup adjustment. This result is driven to some extent by a few industries, namely selenium, aluminum foil and fish hooks, in which the depreciation periods show substantially more PTM. That apparently is sufficient to overwhelm the larger number of industries in which PTM is greater during appreciations. However, even when these three are excluded from the model, there is still somewhat more PTM during depreciations, although the difference is not statistically significant.

Tables 7 and 8 report the results of estimating equation (3), which provides a cleaner test of the validity of the bottlenecks model. The estimates of $\beta_1$ give the marginal effect on the response of prices to exchange rates of the capacity constrained periods. If bottlenecks are important, this coefficient should be negative. In over half of the cases, it is positive for German export industries. Only for fan belts and titanium dioxide is the coefficient negative and significant. Neither of these industries seem likely to have important distribution constraints. In consumer products (beer, wine and autos) and industry durables (steel rails and containers) there is no support for the bottlenecks model. Japanese industries are only slightly more favorable to the model, with fairly strong evidence of more pricing to market in bottlenecks situations for small autos and imitation pearls used in jewelry. In general, these results are not very favorable to the bottlenecks model.

## IV. Conclusion

A number of recent theoretical models have offered reasons why pricing-to-market may be asymmetric–i.e., the response of markups to exchange rate changes may depend on the direction of the currency movement. Marketing bottlenecks and/or explicit quantity restrictions on trade flows imply more PTM during depreciations of the exporter's currency. Strategies aimed at increasing market share in a foreign market subject to constraints imposed by the threat of anti-dumping duties or other trade restrictions may lead firms to engage in more PTM during appreciations of the home currency. Other research on PTM and pass-through has been inconclusive on which, if either, of these scenarios is more important empirically.

This paper has used very disaggregated industry-level data to test for the presence of asymmetries in the response of export prices to exchange rate changes. The main result to come out of this work is that for most industries studied here, a symmetric response of prices to exchange rates is not inconsistent with the data. Given that the data set covers a wide range of industries and the entire floating exchange rate period, this finding is fairly robust.

Although the results indicate that asymmetric response is not statistically significant in most cases, the estimated coefficients provide more support for the market share model than they do for the bottlenecks model. Prices are adjusted to offset the effect of appreciations of the exporter's currency more than they are adjusted to offset the effect of depreciations. The results for automobiles are most surprising in that regard. *Ex ante*, one might expect automobiles to be a good candidate to verify the bottlenecks model for at least two reasons: the importance of distribution outlets and the necessity of production before exchange rate realizations. Nonetheless, all seven categories of automobiles in the data sample favor the market share model over the bottlenecks model. The results obtained when the German and Japanese autos categories are pooled also tend to favor the market share model, with a marginal significance level just below .15 for Germany.

The main piece of evidence favoring the bottlenecks model is the finding that when all Japanese industries are pooled in a single regression, the estimated PTM is much greater during depreciations than appreciations. This result is statistically significant. This is somewhat surprising, given that more of the individual industries appeared to favor the market share model.

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Table 1. German Exports - Estimates of $\beta$ in Equation (1)

(1) $\Delta p_{it} = \theta_t + \beta_i \Delta x_{it} + \varepsilon_{it}$

| Industry | $\beta$ (se) | F-Stat (msl) | Adj $R^2$ | DW |
|---|---|---|---|---|
| Autos over 3L. | .048 (.11) | 1.175 (.35) | 0.48 | 2.06 |
| Autos 2.1 - 3L. | .083 (.23) | 1.492 (.22) | 0.33 | 1.79 |
| Autos 1.6 - 2L. | -.356 (.25) | 2.257 (.06) | 0.28 | 1.73 |
| Aluminum Oxide | -.029 (.98) | 0.523 (.76) | 0.25 | 1.84 |
| Autos 1.1 - 1.5L. | -.542 (.30)* | 1.684 (.18) | 0.38 | 2.51 |
| Beer | -.435 (.16)* | 2.708 (.04) | 0.44 | 1.45 |
| Synthetic Dyes | -.575 (.10)* | 1.679 (.18) | 0.59 | 1.76 |
| Titanium Oxide Pigments | -.809 (.25)* | 0.331 (.85) | 0.68 | 1.75 |
| Preparations for Syn Dye | -.188 (.33) | 0.260 (.90) | 0.56 | 2.43 |
| Titanium Dioxide | -.645 (.30)* | 0.235 (.92) | 0.55 | 1.98 |
| Aluminum Hydroxide | -.724 (.42)* | 0.979 (.42) | 0.57 | 1.83 |
| Vitamin A | -.488 (.44) | 0.265 (.90) | 0.30 | 2.70 |
| Vitamin C | -.249 (.07)* | 0.059 (.99) | 0.67 | 2.37 |
| White Wine | -.021 (.14) | 3.925 (.01) | 0.89 | 1.93 |
| Sparkling Wine | -.610 (.29)* | 0.840 (.46) | 0.49 | 1.90 |
| Fan Belts | -.432 (.23)* | 0.248 (.85) | 0.58 | 2.28 |
| Steel Containers | -.359 (.23) | 0.770 (.52) | 0.68 | 1.76 |
| Steel Rails | -.774 (.98) | 0.302 (.74) | 0.41 | 1.81 |

*: denotes the estimate of $\beta$ is significant at the 5% level for a one-tailed test.

Notes: Specific destinations for each industry are listed in the appendix. There are NT observations for each industry, where T=12 and N (number of destinations) can be determined from the appendix. Standard errors of $\beta$ in parentheses are robust to heteroscedasticity. The marginal significance level (msl) for the F-test represents the probability of observing an F-statistic larger than the sample value given that the null hypothesis ($\beta$ is the same across destinations) is true. The null is typically rejected for an msl below .05. The adjusted $R^2$ and the Durbin-Watson statistics are averages across the destinations for each industry.

Table 2. Japanese Exports - Estimates of $\beta$ in Equation (1)

$$(1)\ \Delta p_{it} = \theta_t + \beta_i \Delta x_{it} + \varepsilon_{it}$$

| Industry | $\beta$(se) | F-Stat (msl) | Adj $R^2$ | DW |
|---|---|---|---|---|
| Color Film | -.940 (.28)* | 1.500 (.20) | 0.62 | 2.01 |
| Photo Paper | -.611 (.37)* | 0.599 (.71) | 0.52 | 2.39 |
| Aluminum Foil | -1.385 (.81)* | 0.794 (.59) | 0.29 | 2.18 |
| Fish Hooks | .854 (.60) | 1.678 (.18) | 0.39 | 2.51 |
| Tires | -.167 (.57) | 0.332 (.88) | 0.25 | 2.99 |
| Autos 1.1 - 2L | -.615 (.10)* | 3.375 (.02) | 0.63 | 1.94 |
| Autos 1L or less | -.182 (.24) | 1.282 (.30) | 0.38 | 1.72 |
| Autos over 2L | -.689 (.22)* | 2.589 (.05) | 0.65 | 2.23 |
| Inner Tubes | -2.26 (1.18)* | 2.938 (.04) | 0.43 | 2.59 |
| Imitation Pearls | -.484 (.37) | 2.637 (.07) | 0.44 | 2.46 |
| Portland Cement | -.570 (.64) | 1.601 (.20) | 0.46 | 2.83 |
| Titanium Dioxide | -1.533 (.64)* | 0.251 (.87) | 0.55 | 1.66 |
| Selenium | .545 (.62) | 0.157 (.85) | 0.76 | 1.72 |
| Golf Balls | 1.42 (1.16) | 10.575 (.01) | 0.69 | 2.01 |

*: denotes the estimate of $\beta$ is significant at the 5% level for a one-tailed test.

Notes: Specific destinations for each industry are listed in the appendix. There are NT observations for each industry, where T=14 and N (number of destinations) can be determined from the appendix. Standard errors of $\beta$ in parentheses are robust to heteroscedasticity. The marginal significance level (msl) for the F-test represents the probability of observing an F-statistic larger than the sample value given that the null hypothesis ($\beta$ is the same across destinations) is true. The null is typically rejected for an msl below .05. The adjusted $R^2$ and the Durbin-Watson statistics are averages across the destinations for each industry.

Table 3. German Exports - Results of Equation (2)

$$(2)\ \Delta p_{it} = \theta_t + \beta_1 \Delta x_{1it} + \beta_2 \Delta x_{2it} + \varepsilon_{it}$$

| Industry | $\beta_1$ | $\beta_2$ | F-Stat (msl) |
|---|---|---|---|
| Autos over 3 L | .27 (.26) | -.13 (.07) | 0.55 (.47) |
| Autos 2 - 3 L | .10 (.25) | .07 (.34) | 0.01 (.90) |
| Autos 1.5 - 2 L | -.10 (.24) | -.56 (.32) | 0.69 (.44) |
| Aluminum Oxide | -.03 (1.70) | -.03 (1.08) | 0.00 (.95) |
| Autos 1 - 1.5 L | -.25 (.40) | -.80 (.39) | 0.26 (.65) |
| Beer | .06 (.11) | -.81 (.14) | 3.39 (.07) |
| Synthetic Dyes | -.69 (.14) | -.49 (.10) | 0.27 (.65) |
| Titanium Oxide Pigmt. | -1.04 (.42) | -.60 (.14) | 0.40 (.55) |
| Special Dyes | -.22 (.42) | -.16 (.46) | 0.00 (.95) |
| Titanium Oxides | -.33 (.56) | -.93 (.08) | 0.32 (.60) |
| Alum. Hydroxide | -.59 (.81) | -.84 (.46) | 0.03 (.85) |
| Vitamin A | -1.57 (.77) | .33 (.36) | 0.90 (.38) |
| Vitamin C | -.17 (.12) | -.31 (.07) | 0.09 (.77) |
| White Wine | -.18 (.35) | .10 (.11) | 0.38 (.58) |
| Sparkling Wine | -.78 (.68) | -.48 (.09) | 0.04 (.85) |
| Fan Belts | -.52 (.48) | -.36 (.24) | 0.06 (.83) |
| Steel Containers | -.07 (.31) | -.59 (.34) | 0.37 (.57) |
| Steel Rails | 1.04 (.71) | -2.19 (.70) | 3.23 (.09) |

Notes: Standard errors in parentheses are robust to heteroscedasticity. The F-statistic tests the model with separate responses for appreciations ($\beta_2$) and depreciations ($\beta_1$) against the null that responses are identical across periods (i.e., the estimates of $\beta$ in Table 2).

Table 4. Japanese Exports - Results of Equation (2)

$$(2)\ \Delta p_{it} = \theta_t + \beta_1 \Delta x_{1it} + \beta_2 \Delta x_{2it} + \varepsilon_{it}$$

| Industry | $\beta_1$ | $\beta_2$ | F-Stat (msl) |
|---|---|---|---|
| Color Film | -1.64 (.88) | -.63 (.14) | 2.67 (.11) |
| Photo Paper | -0.08 (.76) | -.85 (.37) | 0.11 (.74) |
| Aluminum Foil | -4.04 (.71) | .09 (.71) | 4.05 (.05) |
| Fish Hooks | -.27 (.66) | 1.47 (.55) | 1.97 (.19) |
| Tires | -.17 (2.24) | -.16 (.63) | 0.00 (.95) |
| Autos 1 - 2L | -.18 (.25) | -.77 (.08) | 5.18 (.03) |
| Autos under 1L | -.13 (.66) | -.20 (.25) | 0.00 (.95) |
| Autos over 2L | -.36 (.45) | -.80 (.20) | 1.04 (.35) |
| Inner Tubes | -1.12 (1.11) | -2.76 (1.87) | 0.27 (.68) |
| Imitation Pearls | -.24 (.87) | -.56 (.49) | 0.05 (.84) |
| Portland Cement | -.16 (.64) | -1.49 (1.00) | 0.26 (.68) |
| Titanium Dioxide | -1.14 (.79) | -2.26 (1.73) | 0.16 (.70) |
| Selenium | -.45 (.56) | 1.00 (.75) | 0.77 (.45) |
| Golf Balls | 1.22 (1.45) | 1.46 (1.21) | 0.02 (.86) |

Notes: Standard errors in parentheses are robust to heteroscedasticity. The F-statistic tests the model with separate responses for appreciations ($\beta_2$) and depreciations ($\beta_1$) against the null that responses are identical across periods (i.e., the estimates of $\beta$ in Table 2).

Table 5. German Exports - Results of Equation (2) with pooled industries

$$(2)\ \Delta p_{it} = \theta_t + \beta_1 \Delta x_{1it} + \beta_2 \Delta x_{2it} + \varepsilon_{it}$$

| Industry | $\beta_1$ | $\beta_2$ | F-Stat (msl) |
|---|---|---|---|
| Autos | .02 (.19) | -.32 (.22) | 2.35 (.14) |
| Alcoholic Beverages | -.28 (.21) | -.41 (.06) | 0.14 (.72) |
| Chemical Products | -.57 (.36) | -.33 (.27) | 0.35 (.57) |
| All Industries | -.28 (.22) | -.42 (.18) | 0.38 (.55) |

Table 6. Japanese Exports - Results of Equation (2) with pooled industries

$$(2)\ \Delta p_{it} = \theta_t + \beta_1 \Delta x_{1it} + \beta_2 \Delta x_{2it} + \varepsilon_{it}$$

| Industry | $\beta_1$ | $\beta_2$ | F-Stat (msl) |
|---|---|---|---|
| Autos | -.38 (.16) | -.49 (.15) | 0.13 (.73) |
| All Industries | -1.05 (.28) | -.31 (.19) | 4.28 (.04) |

Notes: Standard errors in parentheses are robust to heteroscedasticity. The F-statistic in column 3 tests the model with separate responses for appreciations ($\beta_2$) and depreciations ($\beta_1$) against the null that responses are identical across periods. In all cases, pooling across industries is not rejected for the model with a single response coefficient at the 5% level. The only case in which the marginal significance level is below 30% is in German autos, with an msl of 8%.

Table 7. German Exports - Results of Equation (3)

$$(3)\quad \Delta p_{it} = \theta_t + \beta_1 d_{it} \Delta x_{1it} + \beta \Delta x_{it} + \varepsilon_{it}$$

| Industry | $\beta_1$ | $\beta$ | F-Stat (msl) |
|---|---|---|---|
| Autos over 3 L | 1.19 (.64) | -.21 (.16) | 18.6 (.01) |
| Autos 2 - 3 L | .11 (.15) | .03 (.27) | 0.24 (.65) |
| Autos 1.5 - 2 L | -.05 (.18) | -.34 (.28) | 0.05 (.83) |
| Aluminum Oxide | -.78 (1.27) | .14 (.99) | 0.30 (.61) |
| Autos 1 - 1.5 L | -.52 (.54) | -.54 (.30) | 0.97 (.36) |
| Beer | .32 (.19) | -.56 (.16) | 2.98 (.09) |
| Synthetic Dyes | .15 (.35) | -.60 (.12) | 0.39 (.55) |
| Titan Oxide Pigmt. | .05 (.45) | -.82 (.26) | 0.02 (.89) |
| Special Dyes | -.24 (.63) | -.13 (.38) | 0.07 (.80) |
| Titanium Oxides | -.45 (.18) | -.59 (.30) | 0.81 (.39) |
| Alum. Hydroxide | -.28 (.90) | -.67 (.48) | 0.14 (.70) |
| Vitamin A | .12 (.69) | -.51 (.51) | 0.02 (.89) |
| Vitamin C | .28 (.14) | -.27 (.07) | 1.15 (.31) |
| White Wine | .25 (.23) | -.12 (.11) | 2.18 (.16) |
| Sparkling Wine | -.10 (.50) | -.60 (.26) | 0.02 (.89) |
| Fan Belts | -.75 (.28) | -.23 (.19) | 4.62 (.04) |
| Steel Containers | .45 (.39) | -.41 (.23) | 0.82 (.39) |
| Steel Rails | 1.15 (.90) | -.95 (1.00) | 0.85 (.38) |

Notes: Standard errors in parentheses are robust to heteroscedasticity. The F-statistic tests the model with a separate response for capacity-constrained depreciation periods (see text) against the null that PTM is the same across all periods.

Table 8. Japanese Exports - Results of Equation (3)

$$(3)\ \Delta p_{it} = \theta_t + \beta_1 d_{it} \Delta x_{1it} + \beta \Delta x_{it} + \varepsilon_{it}$$

| Industry | $\beta_1$ | $\beta$ | F-Stat (msl) |
|---|---|---|---|
| Color Film | .12 (.20) | -.96 (.29) | 0.12 (.74) |
| Photo Paper | .25 (.52) | -.66 (30) | 0.02 (.89) |
| Aluminum Foil | 2.18 (1.18) | -1.59 (.83) | 0.96 (.37) |
| Fish Hooks | -.75 (.57) | .92 (.61) | 0.81 (.39) |
| Tires | -.86 (1.42) | .02 (.54) | 0.45 (.51) |
| Autos 1 - 2L | .15 (.07) | -.65 (.11) | 1.24 (.28) |
| Autos under 1L | -.60 (.24) | -.08 (.25) | 1.06 (.33) |
| Autos over 2L | -.24 (.31) | -.66 (.22) | 1.29 (.27) |
| Inner Tubes | -.15 (.79) | -2.22 (1.26) | 0.01 (.92) |
| Imitation Pearls | -.97 (.42) | -.32 (.38) | 1.38 (.24) |
| Portland Cement | .27 (1.13) | -.76 (1.01) | 0.02 (.89) |
| Titanium Dioxide | -.37 (.71) | -1.40 (.78) | 0.05 (.83) |
| Selenium | .36 (.85) | .49 (.65) | 0.11 (.74) |
| Golf Balls | .09 (.82) | 1.41 (1.24) | 0.01 (.88) |

Notes: Standard errors in parentheses are robust to heteroscedasticity. The F-statistic tests the model with a separate response for capacity-constrained depreciation periods (see text) against the null that PTM is the same across all periods.

# DATA APPENDIX

The export unit value data used in this study are based on customs declarations in the respective countries of export. The values reported are FAS (free alongside ship) which measures the transactions value at the port of export and is exclusive of transportation and tariff wedges. Although values are always reported in units of the exporter's currency, it is not clear which currency is used in the trade invoices themselves. German data are published by Statistisches Bundesamt under the title *Aussenhandel nach Waren und Laendern Fachserie 7, Reihe 2*. Japanese data are published by the Japan Tariff Association under the title *Japan Exports and Imports*. The specific product categories of exports for country and their classification codes are listed below. Listed in parentheses after each product category are the specific destination markets for exports that used in estimation. The countries and the abbreviations used are as follows: United States (US), United Kingdom (UK), Sweden (SD), Canada (CN), France (FR), Japan (JP), West Germany (WG), Denmark (DN), Australia (AS), Norway (NO), India (IN), Switzerland (SZ), Korea (KO), Netherlands (NE), Phillipines (PH), and Saudi Arabia (SA).

German Export Data

| Code | Product (destination markets) |
|---|---|
| 2203900 | beer in containers under 10 liters (US, CN, FR, UK, JP) |
| 2205090 | sparkling wine other than champagne (US, CN, FR, UK) |
| 2205160 | white wine below 13% alcohol in containers under 2 liters (US, CN, DN, UK, JP) |
| 2820110 | aluminum oxide (US, CN, FR, UK, JP, SD) |
| 2820150 | aluminum hydroxide (US, FR, UK, JP, SD) |
| 2825000 | titanium oxide (US, FR, UK, JP, SD) |
| 2938210 | vitamin A (US, CN, FR, UK, JP) |
| 2938500 | vitamin C (US, CN, FR, UK, JP) |
| 3205100 | synthetic dyes (US, CN, FR, UK, JP) |
| 3205200 | preparations used in synthetic dyes (US, CN, FR, UK, JP) |
| 3207400 | titanium oxide pigment (US, FR, UK, JP, SD) |
| 4010300 | fan belts of soft rubber (US, SD, FR, UK) |
| 7316140 | steel rails over 20 kg/m. (US, FR, UK) |
| 7320420 | steel containers (US, CN, FR, UK) |
| 8702216 | autos from 1 - 1.5 liter engine size (US, FR, UK, JP, SD) |
| 8702232 | autos from 1.6 - 2 liter engine size (US, CN, FR, UK, JP, SD) |
| 8702234 | autos from 2.1 - 3 liter engine size (US, CN, FR, UK, JP, SD) |
| 8702250 | autos over 3 liter engine size (US, CN, FR, UK, JP, SD) |

Japanese Export Data

| | |
|---|---|
| 2825000 | titanium oxides (US, KO, PH, NE) |
| 9706051 | golf balls (US, UK, SD) |
| 3702092 | photographic film in rolls, unexposed (US, CN, UK, WG, SD, AS, KO) |
| 3703010 | color photographic paper, not developed (US, CN, UK, WG, AS, KO) |
| 7604000 | aluminum foil of a thickness not exceeding 0.2 mm (US, CN, WG, PH, AS, KO) |
| 2804220 | selenium (US, IN, KO) |
| 8702191 | autos with engine size 1 liter or less (US, AS, UK, WG, SZ) |
| 8702192 | autos with engine size 1.1 - 2 liters (US, CN, UK, WG, SD) |
| 8702193 | autos with engine size over 2 liters (US, CN, UK, WG, NO) |
| 4011620 | inner tubes for bicycles, of rubber (US, CN, UK, AS) |
| 7019010 | imitation pearls of glass (US, CN, UK, WG) |
| 2523010 | portland cement (US, CN, AS, PH) |
| 9707020 | fishing hooks (US, CN, AS, WG, KO, PH) |
| 4011420 | pneumatic tires for bicycles, of rubber (US, CN, UK, WG, SD, AS) |

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1 See for example Catherine Mann (1986), Paul Krugman (1987), Michael Knetter (1989,1991,1992), Kenichi Ohno (1989), Kenneth Kasa (1990), Richard Marston (1990), and Joseph Gagnon and Knetter (1991).

2 These facts are based on the evidence in Mann, Marston, and Knetter (1989,1992).

3 Richard Baldwin (1988) and Avinash Dixit (1989) have developed models in which other forms of non-linearities arise in the relationship between exchange rates and prices due to the existence of sunk costs of entry into new markets. This paper does not attempt to test the more general implications of those models.

4 See "Chemical Firms Resist Lures to Expand", *Wall Street Journal*, January 12, 1988, p.6.

5 Krugman and Kenneth Froot and Paul Klemperer (1989) have investigated the impact of market share motives on traded goods prices. Marston (1990) noted that market share objectives in an environment with threats of trade restrictions may lead to asymmetries in PTM.

6 Since his tests are aimed at detecting only "market share" asymmetries, it is not clear whether any of the industries in his sample were consistent with the bottlenecks model.

7 Both features are quite important. Since one explanation for the disparate findings on export price adjustment is that they employ different measures of cost (see Baldwin (1988) or Peter Hooper and Mann (1989)), this new approach to cost measurement may be able to mediate the difference of opinion in earlier studies. Furthermore, the patterns across industries may be a function of industry characteristics. A finer level of disaggregation permits an evaluation of whether the results are consistent across groups of industries with similar characteristics.

8 Adjusting the nominal exchange rate for changes in the price level in the destination market imposes the condition that export prices are unaffected by changes in currency values that leave the relative price in units of foreign currency unchanged.

9 See Richard Meese and Kenneth Rogoff's (1983) original paper or the more recent survey by Meese (1990). In a dynamic model that attempts to measure the impact of

temporary exchange rate changes on export pricing, Froot and Klemperer (1989) find little evidence to suggest that this is an important phenomenon.

10 The economic interpretation of the $\beta$'s depends on what one assumes about market structure. If the exporter is a monopolist, the value of $\beta$ is determined by the convexity of the demand schedule in the destination market. The class of demand schedules having constant elasticity with respect to price imply a value of $\beta$ equal to zero. $\beta$ is negative provided demand is less convex than a constant elasticity demand schedule. When the export sector consists of multiple firms that compete with firms located in other countries (the typical case), the interpretation of $\beta$ is more complicated–it hinges on factors that influence residual demand. In general, exact aggregation holds only if the export markets are divided among the firms in the export sector or if they collude perfectly and thus behave as a single monopolist would. The results with industry data should be thought of as the reduced form response of a representative firm. See Knetter (1991) for more discussion of these issues.

11 Obviously, it is possible that the variable will equal one in some periods in which capacity constraints are not binding. Lacking actual data on distribution capacity for each industry by destination country, this admittedly imperfect filter is the best screening device available.

12 These two tables are taken from Knetter (1992). That paper shows that this pattern of export price adjustment is not typical of a sample of similar U.S. and U.K. industries. The reader is referred to that paper for further discussion of the results in relation to existing theories of pricing to market.

13 Gagnon and Knetter (1992) estimate a number of different models for German, Japanese and U.S. auto prices and find the differences between German and Japanese price adjustment to be robust. They speculate that for the sample period in question, large German autos faced less competition from other suppliers (compared to small German autos and Japanese autos), enabling greater pass-through of exchange rate changes to buyers (i.e., less PTM). The lack of PTM seems to have hurt German firms in the high quality end of the market during the recent period of weaker dollar. Porsche, BMW and Mercedes have all experienced large decreases in market share, in part due to new Japanese entrants in the high-quality segment of the market.

14 It is important to note that the effects of exchange rates on prices measured in this framework are net of any impact exchange rate changes have on production cost. Yen appreciations are likely to reduce yen costs of production since imported input prices (oil or other raw materials) will naturally fall. In addition to the downward pressure this will exert on yen prices to all buyers, destination-specific markup adjustment further insulates prices paid by buyers. Any effects exchange rates have on the common production cost will be absorbed by the time effects in the model. This is discussed in greater detail in Knetter (1989,1991a).

15 Hideki Yamawaki (1989) has demonstrated the importance of distribution networks in the success of Japanese exports to the United States in a broad range of industries.

16 I am grateful to an anonymous referee for suggesting these restrictions. In all cases, the data accept the additional restrictions at conventional levels of significance.