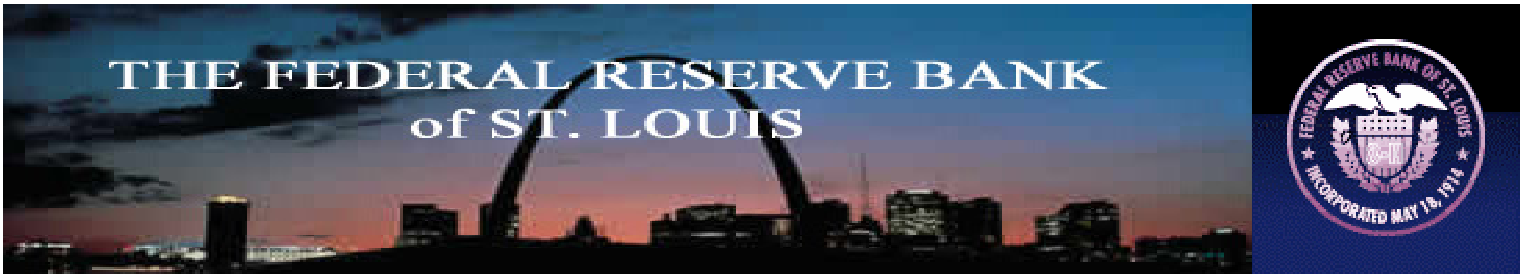

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SIZE MATTERS: ASYMMETRIC EXCHANGE RATE PASS-THROUGH AT THE INDUSTRY LEVEL

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ASYMMETRIC EXCHANGE RATE PASS-THROUGH AT THE INDUSTRY LEVEL

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Changes in costs faced by firms have direct implications for their price-cost margins. Knowing how prices respond to such cost changes is crucial for understanding how individual markets function and, in turn, for understanding the macroeconomy. We analyze exchange rate pass-through into U.S. import prices for 30 industries to address two questions related to this issue. First, does the *direction* of a change in the exchange rate affect pass-through? Second, does the *size* of a change in the exchange rate matter for pass-through? We find that firms in over half the industries studied respond asymmetrically to appreciations and depreciations, but the direction of asymmetry varies. Likewise, most firms respond asymmetrically to large and small changes in the exchange rate with pass-through positively related to the size of the change. When taking into account both direction and size effects we find that the size effect dominates.

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1. Introduction

How prices respond to changes in costs is a fundamental issue that interests economists. Because changes in the costs faced by firms have direct implications for their price-cost margins, knowledge about both the size and the speed of any price response is essential for understanding the behavior of individual markets. In turn, knowledge of the workings of individual markets provides the microeconomic foundations for macroeconomic behavior.[1] A recent article by Peltzman (2000) documented the tendency of prices to rise faster than they fall, using a large sample of consumer and producer goods.[2] On average, the immediate effect on prices of an increase in input costs was at least twice as large as the effect of a decline in input costs. Moreover, the differential was sustained for at least five to eight months. We explore the issue of price asymmetry in the context of the effect of exchange rate changes on import prices.

A well-known result of the exchange rate pass-through literature is that a change in the exchange rate is less than fully reflected in import prices. As summarized by Goldberg and Knetter (1997), studies indicate that pass-through for aggregate U.S. import prices is centered on 60 percent. Recent research by Olivei (2002) and by Pollard and Coughlin (2003) using industry level data has estimated even lower levels of pass-through. These results suggest that exchange rate changes cause exporting firms to adjust their markups of price over cost. The industry-based studies also suggest that disaggregation can provide refined estimates and additional insights into how specific markets work. A similar comment pertains to exploring the empirical importance of asymmetric exchange rate pass-through.

We explore two questions to differentiate symmetric from asymmetric pass-through. First, does the *direction* of the change in the exchange rate matter for pass-through? That is, do appreciations and depreciations of the dollar have symmetric effects on U.S. import prices? Second, does the *size* of the change in the exchange rate have an effect on the extent of pass-through into import prices?

[1] For example, the issue of sticky prices is of fundamental interest to macroeconomists. For a brief review of this literature see Davis and Hamilton (2004). For a longer discussion of price stickiness, see Blinder et al. (1998).
[2] In contrast, Blinder et al. (1998, p. 87) concluded based on interviews of firms, "There is essentially no evidence for the common belief that prices adjust more rapidly upward than downward.".

How might asymmetry arise? As Peltzman (2000) notes, standard economic theory must be modified to explain why prices tend to rise faster than they fall. In the context of exchange rate pass-through, various circumstances have been identified that could generate asymmetry. In theory, an appreciation can lead to either a higher or lower rate of pass-through than a depreciation. Thus, while prices may rise faster than they fall, prices may also fall faster than they rise. Knetter (1994), for example, has argued, if exporting firms face capacity constraints in their distribution networks, then an appreciation of the currency of the importing country might cause lower pass-through than a depreciation. The capacity constraints, because they limit potential sales, deter the lowering of the import price that an appreciation might normally induce. Meanwhile, the capacity constraints do not affect the raising of the import price that a depreciation might normally induce.

On the other hand, the relative sizes of the pass-through effects can be reversed when the exporting firms behave strategically based on certain market share objectives. If firms attempt to build market share, then an appreciation of the importing country's currency might cause higher pass-through than a depreciation. When the currency of the importing country depreciates, exporters may offset the potential increase in price by reducing their markups. With an appreciation, they maintain their markups and allow the import price to fall. This allows the exporters to gain market share when their own currencies are weakening and might deter dumping charges because the lower prices can be justified by lower costs.

Several papers, which we discuss later, have examined the behavior of the prices of traded goods under appreciations relative to depreciations. These studies have found mixed results. In addition, previous studies provide no clear evidence on the direction of asymmetry. In some cases the pass-through associated with depreciations exceeded appreciations; however, in other cases this result is reversed.

Firms may also respond asymmetrically to the size of the change in the exchange rate. Suppose a firm, because of the costs associated with changing a price, allows its markup to absorb the effect of small changes in the exchange rate by keeping its export prices constant. A large change in the exchange rate, however, may cause it to deviate from this policy and pass-through some of the change into export prices. To date, this issue has been virtually ignored in the exchange rate pass-through literature. One exception is research by Ohno (1989) that found some evidence that changes in Japanese export prices were more frequent with large exchange rate changes than with small ones.

This paper uses industry-level exchange rates to examine pass-through into U.S. import prices in the manufacturing sector, as well as 9 two-digit and 20 three-digit level manufacturing industries. Both the use of industry level exchange rates, whose advantages are argued by Goldberg (2004), and the examination of many industries with a relatively long time series are features that distinguish our research from much of the existing pass-through literature. To preview our results, in many industries, pass-through is asymmetric with respect to appreciations and depreciations. There is, however, no clear direction in this asymmetry across industries. Moreover, import prices in most industries behave asymmetrically with respect to the size of the change in the exchange rate. Pass-through is generally related positively to the size of the change in the exchange rate. This result holds even when taking into account the direction of the change. Overall, our results reveal less-than-complete pass-through of exchange rate changes. In addition, our results suggest menu costs as a potential explanation of the differential effect of large versus small exchange rate changes.

2. Model

The model follows Blonigen and Haynes (1999) and Gil-Pareja (2003). A country, Home, imports a good, x^H, from a foreign monopolist. In Home, the foreign firm faces competition from a domestic substitute good, y. Assuming that Home's import demand for this good is weakly separable from other goods in the consumer's utility function, demand in Home is: $x^H(p^H, p^y, I^H)$, where p^H is the Home currency price of good x, p^y is the Home currency price of the good y and I^H is income (or expenditures on all goods. Similarly, in the foreign firm's domestic market, demand is determined by the local (Foreign) currency price of the good and income (or expenditures on all goods): $x^F(p^F, I^F)$. Production of good x occurs only in Foreign. In contrast to Blonigen and Haynes and Gil-Pareja, in our model inputs may come from both Foreign and Home. If inputs from Home are used in the production process then factor prices, w, depend on the exchange rate, e, expressed as the Foreign currency price of the Home currency. The cost of producing the good depends on the total quantity produced, X= $x^H + x^F$, and factor prices: $c(X, w(e))$. Assuming that costs are homogeneous of degree one in factor prices then $c(X, w) = w(e)\phi(X)$.

The Foreign firm is engaged in Bertrand competition and hence treats p^y as exogenous. It sets the export price in the Home currency, but maximizes profits in its own currency, as given by equation (1).

$$\max_{p^F, p^H} \Pi = p^F x^F + ep^H x^H - w\phi(X), \tag{1}$$

The first order conditions from the profit maximization are[3]:

$$p^F = w\phi' * \upsilon^F \tag{2}$$

$$p^H = w\phi' * \upsilon^H \tag{3}$$

where $\upsilon^a = \left(\frac{1}{1 - 1/\varepsilon^a}\right)$ and $\varepsilon^a = -\left(\frac{\delta x^a}{\delta p^a}\frac{x^a}{p^a}\right)$ for a=F,H.

Profit maximization produces the standard condition that the price in each market is determined by a market specific markup, υ^a, over the common marginal cost, $w\phi'$.

Suppose that marginal costs are constant, $w\phi'' = 0$. Then the exchange rate pass-through elasticity is given by

$$\text{ERPT} \equiv \frac{\delta p^H}{\delta e}\frac{e}{p^H} = -\frac{(1 - \eta^{we})}{(1 - \eta^{\upsilon H})} \leq 0 \tag{4}$$

where $\eta^{we} = \frac{\delta w}{\delta e}\frac{e}{w} \geq 0$, and $\eta^{\upsilon H} = \frac{\delta \upsilon^H}{\delta p^H}\frac{p^H}{\upsilon^H} \leq 0$.

Pass-through elasticity is determined by the responsiveness of marginal cost to a change in the exchange rate and the responsiveness of the markup to a change in price. Pass-through is always nonpositive. An appreciation of Home's currency (↑e) decreases the import price of good x^H and a depreciation of Home's currency (↓e) increases the import price of good x^H. This result generalizes as long as marginal costs are nondecreasing in output, $\phi'' \geq 0$. If $\phi'' < 0$ and $\eta^{we} \Rightarrow 1$ then pass-through may be positive

[3] All derivations are given in the appendix.

In general $-1 \leq \text{ERPT} \leq 0$. If Foreign uses only domestic inputs in the production process, $(\eta^{we} = 0)$ and if markup is constant $(\eta^{\upsilon H} = 0)$, then pass-through is complete; ERPT=-1. If $\eta^{we} = 1$ pass-through is zero.

3. Asymmetry of Pass-through

Most studies assume that the extent of pass-through is independent of the direction of the change in the exchange rate. There are, however, circumstances under which firms may vary pass-through depending on whether the importer's currency is appreciating or depreciating. After briefly reviewing the pricing decisions that exporters face as a result of exchange rate changes, we summarize the three major explanations for asymmetric pass-through.

When production occurs only with domestic inputs, a depreciation of Home's currency leaves the Foreign firm with undesirable choices — either decrease its markup to maintain the Home currency price of its product (no pass-through) or maintain its markup, increasing the Home currency price to reflect fully the depreciation and likely lose some market share (complete pass-through) or some combination of both (partial pass-through). If there is no pass-through, then the Foreign firm's sales in Home, x^H, remain unchanged but the price received by the firm, ep^H, falls resulting in a decline in its profits. If pass-through is complete, ep^H remains unchanged, but sales in Home decline, resulting in a fall in revenue and hence profit. The extent to which profits fall is determined by the elasticity of demand for good x in Home, ε^H. With partial pass-through both ep^H and x^H decline, with the corresponding decline in profits again being determined by ε^H.

The effect of a depreciation in Home's currency on the profits of the Foreign firm may be tempered by the use of both local (i.e. Foreign) and Home inputs in the production process. In this case the depreciation of Home's currency has a more muted effect on the price, ep^H, and/or sales to Home. As long as $\eta^{we} < 1$, the depreciation still will have a negative effect on profits.

An appreciation of the Home currency presents desirable options for the Foreign firm. The firm can either increase markup by maintaining p^H (no pass-through) or decrease p^H in accordance with the appreciation hoping to increase market share (complete pass-through) or some combination of both. In the case of no pass-through, ep^H rises and x^H is unchanged, raising the profits of the Foreign firm. In the case of complete pass-through, ep^H remains unchanged and x^H rises, again raising the profits of the Foreign firm. If partial pass-through occurs, both ep^H and x^H rise so profits increase. As in the case of a depreciation, the extent of the change in the Foreign firm's profits when pass-through occurs depends on ε^H. Likewise, using inputs from Home in the production process moderates the effect of a rise in e on profits, unless $\eta^{we} = 1$.

Models of Asymmetric Pass-through

Market share

Pricing to market is often given as an explanation for less than complete pass-through. Suppose for example, that the goal of a firm is to maintain market share. It may aim to keep p^H constant despite fluctuations in e. In such a case, falling profits during periods of a decline in e may be offset by rising profits during periods of a rise in e. Another possibility is that the Foreign firm adjusts its markup to increase its market share when Home's currency appreciates and hold on to market share when Home's currency depreciates, as in Marston (1990) and Knetter (1994).[4] Under this latter strategy pass-through is asymmetric. Pass-through into p^H is greater when Home's currency appreciates than when it depreciates. In the first case pricing to market implies symmetric pass-through. In the second case pass-through is asymmetric.

To examine the latter case, suppose that the Foreign firm never raises the price of good x in Home's market above the price of the substitute good, y. The Foreign firm chooses p^F and p^H to maximize prices conditional on $p^H \leq p^y$. The elasticity of exchange rate pass-through becomes

$$ERPT \equiv \frac{\delta p^H}{\delta e}\frac{e}{p^H} = \begin{cases} 0 & \text{when } p^H = p^y \\ -\dfrac{1-\eta^{we}}{1-\eta^{\upsilon H}} & \text{when } p^H < p^y \end{cases} \tag{4a}$$

[4] As shown by Froot and Klemperer (1989), permanent and temporary exchange rate changes can have different pass-through effects in a model in which a firm's future demand depends on current market shares.

Suppose that $p^H = p^y$. When Home's currency depreciates (↓e) the firm reduces its markup to hold p^H fixed, so that pass-through is zero. If, however, Home's currency appreciates (↑e) the firm can hold or increase slightly its markup so that p^H falls, pass-through occurs and market share rises.

Production Switching

Another route for asymmetries in pass-through comes from the use of imported inputs in the Foreign firm's production process, as discussed by Webber (2000). Suppose the Foreign firm switches between imported inputs and domestically produced inputs depending on the price of the two.[5] Pass-through then depends solely on the elasticity of markup, as shown in equation (4b).

$$\text{ERPT} \equiv \frac{\delta p^H}{\delta e}\frac{e}{p^H} = \begin{cases} -\frac{1}{1-\eta^{\upsilon H}} & \text{when } \eta^{we} = 0 \\ 0 & \text{when } \eta^{we} = 1 \end{cases} \tag{4b}$$

When the Home currency is appreciating the Foreign firm only uses domestic (Foreign) inputs, so $\eta^{we} = 0$. The extent of pass-through thus depends on $\eta^{\upsilon H}$. When the Home currency is depreciating the Foreign firm uses only inputs from Home, so $\eta^{we} = 1$; no pass-through occurs.

Binding Quantity Constraints

In both the market share and production switching models, pass-through is greater when the importer's currency is appreciating than when it is depreciating. If the exporter is subject to binding quantity constraints, pass-through will be higher when the importer's currency is depreciating.

Binding quantity constraints occur when the ability of the Foreign firm to increase sales as Home's currency appreciates is limited. Under this scenario when e increases the Foreign firm raises its markup to hold p^H fixed. Rather than increasing sales the firm raises its profit margins. When e decreases the quantity

[5] The production switching argument can be found in Ware and Winter (1988).

constraint is not binding. The firm may reduce its markup but still allows p^H to rise. Pass-through is thus higher when Home's currency depreciates than when it appreciates.

Quantity constraints may arise because of trade restrictions that limit imports, such as quotas or voluntary export restraints.[6] Quantity constraints may also arise because of limitations on a firm's ability to expand its capacity, as in the bottleneck model of Baldwin (1988). As noted by Knetter (1994) and Gil-Pareja (2000) if the Foreign firm is operating at capacity, a rise in e will not be met with a lower p^H. The firm instead will increase its markup to limit pass-through. No such constraint applies when e falls. In this case

$$\text{ERPT} = \frac{\delta p^H}{\delta e}\frac{e}{p^H} = \begin{cases} -\dfrac{1-\eta^{we}}{1-\eta^{\upsilon H}} & \text{when } e\downarrow, \text{ or } e\uparrow \text{ and } X < \overline{X} \\ 0 & \text{when } e\uparrow \text{ and } X = \overline{X} \end{cases} \tag{4c}$$

Table 1 summarizes the direction of the asymmetry implied by these three theories. Both the market share and the production switching explanations imply that pass-through will be higher when the importer's currency is appreciating than when it is depreciating. The quantity constraint analysis produces the opposite result: pass-through is highest when the importer's currency is depreciating. The contrasting direction of the results highlights the importance of analyzing pass-through at the industry level. If the direction of asymmetry varies across industries then aggregation may obscure asymmetry that is present at the industry level.

Menu Costs

Firms may also respond asymmetrically with respect to the size of the change in the exchange rate. For example, the presence of menu costs may result in asymmetric pass-through of large and small exchange rate changes. The cost of changing prices increases the likelihood that firms only adjust the invoice price if the change in the exchange rate is above some threshold. The direction of the asymmetry in pass-through will depend on the currency of invoice.

6 During the time period of our study voluntary export restraints were imposed by the United States on textiles and apparel, automobiles, and steel.

Suppose, as in the model, imports are invoiced in the importer's currency. Given a small change in the exchange rate the firm holds p^H constant and absorbs the change in the exchange rate through the price it receives, ep^H. In this case pass-through is zero. If the change in the exchange rate is large, the Foreign firm does adjust p^H. If partial pass-through occurs both p^H and ep^H change. If pass-through is complete, ep^H does not change. Thus, with invoicing in the importer's currency, pass-through will be greater when exchange rate changes are large than when they are small.

If, however, imports are invoiced in the exporter's currency then a small change in the exchange rate has no effect on ep^H (the invoice price) but fully affects p^H – pass-through is complete. When the exchange rate change is large the exporter adjusts ep^H, reducing the amount of pass-through. In this case pass-through is greater when exchange rate changes are small.

Our interpretation of menu costs and pass-through differs from that of Ghosh and Wolf (2001). In their model menu costs imply that a sequence of observations of zero exchange rate pass-through will be followed by an observation of more than complete pass-through. Pass-through of the cumulative change in the exchange rate, however, will be complete. Because our dataset precludes us from a similar analysis we use the size of the change in the exchange rate to differentiate between the cases in which menu costs might inhibit pass-through from those in which menus costs would not inhibit pass-through.

Previous Empirical Studies

Previous studies of asymmetry have concentrated almost entirely on testing for asymmetry in the direction of the change in the exchange rate. These studies have taken two different approaches. One set has looked at whether pass-through differed during general periods of appreciation and depreciation. Mann (1986), for example, examined whether the degree of pass-through into U.S. import prices differed over the period 1977 through 1980, a period of overall depreciation of the dollar, and 1981 through early 1985, a period of overall appreciation. The other set of studies incorporated dummy variables to identify each time the dollar appreciated or depreciated.

Two studies, Mann (1986) and Webber (2000), used aggregate trade data, whereas the remainder of the studies were conducted at the industry or product level.[7] Mann argued that pass-through into U.S. import prices was greater during the period of the dollar's appreciation than during the period of depreciation, although the difference in pass-through estimates was not statistically significant.[8] Webber found strong support for asymmetric pass-through into import prices in five of seven Asian countries. In contrast to Mann, he found pass-through was higher when the importer's currency depreciated than when it appreciated. This result supports the binding quantity constraint explanation.

Kadiyali (1997) and Goldberg (1995) focused on a single industry. Kadiyali examined U.S. imports of photographic film from Japan while Goldberg (1995) examined U.S. automobile imports from Germany and Japan. Both found that pass-through was higher when the dollar depreciated, consistent with the binding quantity constraint theory.[9]

In studies that considered a range of industries, only Feinberg's (1989) study of U.S import prices and Athukorala's (1991) study of Korean export prices failed to find any evidence of asymmetry. All other studies found support for asymmetry in one or more industries. Ohno (1989), for example, found evidence of pass-through asymmetry in Japanese machinery and equipment exports. His work also supported the binding quantity constraint explanation. In contrast, Marston (1990) found support for the market share explanation in his study of Japanese transportation and electrical machinery exports. Knetter's (1994) study of German and Japanese exports found relatively more support for the market share theory than the quantity constraint theory.[10]

Gil-Pareja (2000) examined the differences in pass-through in a range of industries across a sample of European countries. He found that the degree and direction of asymmetry varied across industries and

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[7] Lawrence (1990), in a study of U.S. current account adjustment during the 1980s, also used aggregate trade data. He found that trade prices moved symmetrically in periods when the dollar appreciated relative to periods when the dollar depreciated.

[8] Mann (1986) also examined a small number of industries and found similar results.

[9] Goldberg's sample period covered the voluntary export restraints on Japanese automobiles. However, in simulations of pass-through without the import restrictions she found a similar direction of asymmetry.

[10] Marston's and Knetter's results are also consistent with the production switching explanation, but neither paper considered this explanation.

countries. Moreover, within an industry there were also differences in the direction of the asymmetry across countries. His results found no clear-cut direction of the asymmetry.

Mahdavi (2002) examined pass-through in a range of U.S. export industries, while Olivei (2002) did the same for U.S. import industries.[11] Mahdavi found evidence of an asymmetric response in 7 of the 12 industries he studied but with no clear direction in the asymmetry. In Olivei's analysis, 9 of the 34 industries studied exhibited some degree of asymmetry and most were consistent with the binding quantity constraint explanation.[12]

Kanas (1997) also found support for the binding quantity constraint explanation. In a study of eight goods exported form the United Kingdom to the United States, he found asymmetric responses in six cases. Four of these six cases were consistent with the existence of quantity constraints.

Ohno's (1989) study is the only one among this group that also considered asymmetry based on the size of the exchange rate change. In his study, changes in Japanese export prices occurred more often when exchange rate changes were large than when they were small; a result consistent with prices invoiced in the exporter's currency. The differential effects of large versus small exchange rate changes suggest a role for menu costs. In their study examining the cover prices of two weekly magazines, Ghosh and Wolf (2001) found support for the role of menu costs in exchange rate pass-through.

4. Estimation

Our empirical analysis follows directly from the profit maximization model discussed previously. We modify this empirical model to examine asymmetric pass-through. Our basic regression equation is

$$\Delta \ln p_{i,t}^{US} = \underset{-}{\beta_{1,i}}\Delta \ln e_{i,t} + \underset{+}{\beta_{2,i}}\Delta \ln p_{i,t}^{y} + \underset{+}{\beta_{3,i}}\Delta \ln w_{i,t} + \underset{?}{\beta_{4,i}}\Delta \ln I_{i,t}^{US} + \text{quarterly dummies} \tag{5}$$

[11] Kreinin *et al*. (1987) was one of the first pass-through studies covering a range of industries. In a cross-industry analysis of U.S. industries, they generated indirect evidence of asymmetry.
[12] Affirmative antidumping cases can also yield relative pass-through rates similar to that of binding quantity constraints. However, Blonigen and Hayes (2002) found little evidence of asymmetric pass-through in such cases.

where i is the industry, t is the quarter, and the United States is the Home country. The expected signs of the regressors are given under the equation. An increase in e (appreciation of the dollar) at time t should lower the import price of good i. An increase in the dollar price of the U.S. substitute good, p^y, should raise the import price, as should an increase in the foreign marginal cost of production, w. The theoretical link between the expenditure (income) measure, I^{US}, and the import price is less certain. Because the data are not seasonally adjusted, quarterly dummy variables are included to capture any seasonal effects.

Data

The dataset covers 30 International Standard Industrial Classification (ISIC) revision 2 manufacturing industries: 9 industries at the two-digit and 20 industries at the three-digit level of classification, as well as the total manufacturing sector. The industries covered are listed in Table 2.[13] The sample period is 1978.q1 through 2000.q4 for all industries except the following, which start at later dates: 322 (1980.q4), 352 (1979.q3), 353 (1981.q3) and 356 (1980.q4).

The exchange rate is calculated on an industry basis, as a weighted average of the bilateral exchange rates between the United States and 17 countries. Pollard and Coughlin (2003) show that an industry level exchange rate index is more appropriate for measuring industry level pass-through than a typical aggregate trade-weighted exchange rate index. In addition their results indicate that a 17-country index performs as well as a more inclusive index.

The general formula for each industry i's exchange rate is

$$e_{i,t} = e_{i,t-1} \prod_{j=1}^{n} \left(\frac{s_{j,t}}{s_{j,t-1}} \right)^{\omega_{i,j,t}},$$

where t is the time period, j is the foreign currency (country), s is the foreign currency/U.S. dollar bilateral exchange rate, and ω is the weight assigned to each foreign currency in the index. The index uses annual chain-weights where the weights are based on each country's trade (exports and imports) in industry i with the United States relative to U.S. trade with all countries in the index:

$$\omega_{i,j,t} = \frac{X_{i,j,t} + M_{i,j,t}}{\sum_{j=1}^{17}\left(X_{i,j,t} + M_{i,j,t}\right)}$$

where X and M are U.S. exports and imports, respectively. The 17 countries in the index are the 11 original euro-area countries plus Australia, Canada, Japan, Sweden, Switzerland and the United Kingdom.

Ohno (1989), Mahdavi (2002) and Olivei (2002) also used industry-specific exchange rate indexes in their asymmetry studies.[14] All of these studies, however, used fixed weight indexes. Using a chain weight index is preferred as it takes into account shifts throughout the sample period in the source of imports. Goldberg and Tracy (2003) use similar industry-specific exchange rate indexes to study the effect of exchange rate changes on industry level wages.

U.S. import prices are from the U.S. Bureau of Labor Statistics (BLS) and are based on dollar prices paid by the U.S. importer. Most of the prices are calculated on a free on board basis that excludes freight, insurance and duties.[15] The use of import price data avoids the measurement problems associated with unit value data. As Alterman (1991) notes, unit values do not take into account differences in product composition or quality

The prices for the U.S. substitute goods and the foreign marginal production costs were proxied by producer price indexes. Industry level (ISIC) data were obtained from the OECD Indicators of Industrial Activity database and Eurostat.[16] When industry-level data were unavailable, a general producer price index was used; lacking that, the consumer price index was used.

Foreign cost of production indexes are calculated to match the exchange rate index. The weight given to the cost data for each of the countries is identical to that used in the exchange rate index. So that for each industry i

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[13] The data set and construction details are available from the authors.
[14] Ohno's index includes 16 countries, Mahdavi's 41 and Olivei's 5.
[15] The BLS data are based on the Standard International Trade Classification (SITC) revision 3 and were converted to ISIC revision 2 codes.
[16] Data for 1999 and 2000 are available only on an ISIC revision 3 basis. These were converted to an ISIC revision 2 basis.

$$w_{i,t} = \sum_{j=1}^{17} \omega_{i,j,t} PPI_{i,j,t}$$

where PPI is the producer price index with 1978 as the base year for each index.

U.S. domestic expenditures are measured by output plus imports minus exports, on an industry level basis. Output is measured by industry shipments data obtained from the U.S. Census Bureau. Industry trade data were obtained from the Census Bureau and the U.S. International Trade Commission. Data were converted from a SIC basis to an ISIC basis.

Behavior of the Dollar

Table 3 examines the behavior of the exchange rate over the sample period. Appreciations were more common than depreciations in every industry. The share of quarters in which the dollar appreciated ranged from 56 to 63 percent. Although appreciations and deprecations are easily defined, there is no corresponding definition to distinguish a large from a small change in the exchange rate. We denote "small" changes as quarterly changes in the exchange rate that were less than 3 percent in absolute value, although we consider alternative measures, as discussed in section 5. In all industries the 3 percent breakpoint was above the median of the absolute value of the quarterly change in the exchange rate, which ranged from 1.4 to 2.8 percent for both the two-digit and the three-digit industries. As table 3 shows, small changes accounted for between 54 and 88 percent of all quarterly changes in the exchange rate using two-digit industries and between 54 and 91 percent of all quarterly changes using three-digit industries.

The last four columns of Table 3 decompose the appreciations and depreciations into large and small changes. Small appreciations are the most frequent occurrence, accounting for between 35 and 55 percent of the exchange rate changes over the sample period. Small depreciations are the next most frequent occurrence in most of the industries: 6 of the 9 two-digit industries and 12 of the 20 three-digit industries.

5. Results

The results from estimating equation (5) are given in Table 4. The pass-through coefficient, β_1, is always negative as expected, and is statistically significant in 17 of the 20 three-digit industries. For these industries we rejected the hypothesis that $\beta_1 = -1$ (at the 5 percent level) in all except five of the three-digit industries. The industries for which complete pass-through could not be rejected are: refined petroleum products (353), nonferrous metals (372), machinery (382 and 383), and other manufactured goods (390). In each of these industries the point estimate was above 50 percent. Our results indicate that pass-through is incomplete in total manufacturing, all two-digit manufacturing industries and 12 three-digit manufacturing industries. Pass-through is zero in three of the three-digit industries and complete in five of the three-digit industries.

Pass-through was lower on average as the level of aggregation increased. Pass-through in total manufacturing was 28 percent, while pass-through at the two-digit level industry level averaged 30 percent, and averaged 38 percent at the three-digit level.

The coefficients on the other variables in equation (5) were statistically significant much less frequently. The proxies for the U.S prices of domestic substitute goods and for foreign marginal production costs, β_2 and β_3, respectively, were generally positive as expected but were statistically significant in about half of the industries. Changes in U.S. domestic expenditures, β_4, were also generally positive but were statistically significant in only industries 35 and 354. The quarterly dummy variables were statistically significant for only a few industries and are not reported in Table 4.

A common assumption in the pass-through literature is that foreign firms respond symmetrically to changes in their input costs, *w*, and the exchange rate, *e*. As a result the estimated pass-through coefficients should be the same regardless of whether *w* and *e* are estimated separately, as in this paper and Blonigen and Haynes (2002), or jointly, as in Feenstra (1989) and Gron and Swenson (1996). Blonigen and Haynes fail to reject the symmetry restriction, as does Feenstra in most industries. Gross and Schmitt (2000), however, find no evidence of symmetric pass-through of costs and exchange rate changes. For the industries under study in this paper, a Wald test rejected the symmetry hypothesis in three industries at the two-digit level and five industries at the three-digit level, all at the 5 percent significance level. These results support our specification.

We also estimated long-run pass-through by adding four lagged changes in the exchange rate to equation (5), and summing the coefficients on the contemporaneous and lagged changes. In most industries pass-through was incomplete even in the long run. Only in 2 two-digit industries (35 and 37) and 6 three-digit industries (351, 353, 354, 372, 382, and 390) did a Wald test fail to reject the hypothesis that pass-through was complete in the long-run. At the three-digit level, all except industries 351 and 354 showed evidence of complete pass-through in the short-run.

Asymmetry in Pass-through: Appreciations and Depreciations

Equation (5) restricts pass-through to be identical regardless of whether the dollar is appreciating or depreciating. If pass-through is asymmetric with respect to the change in the exchange rate, then the estimates of pass-through from this specification are misleading. To determine if pass-through is asymmetric with respect to the direction of the change in the exchange rate, two dummy variables are created that separate quarters in which the dollar appreciated from those in which it depreciated. Specifically, for each industry i, let

$$A_t = \begin{matrix} 1 \text{ when } \Delta \ln e_t > 0 \\ 0 \text{ otherwise} \end{matrix} \quad \text{and} \quad D_t = \begin{matrix} 1 \text{ when } \Delta \ln e_t < 0 \\ 0 \text{ otherwise} \end{matrix}$$

Interacting these dummy variables with the exchange rate index and replacing $\beta_1 \Delta \ln e_t$ in equation (5) with $\beta_{1A}(A_t \Delta \ln e_t) + \beta_{1D}(D_t \Delta \ln e_t)$, provides separate estimates for pass-through under appreciations and depreciations.

The results from this modified regression are shown in Table 5. Pass-through in 1 two-digit industry (35) and in 6 three-digit industries (341, 351, 354, 371, 384, and 390) was not statistically significant either when the dollar was appreciating or depreciating. In four of these industries (35, 354, 371 and 390) pass-through was statistically significant when the symmetric restriction was imposed, as in equation (5).

Pass-through in total manufacturing, 3 two-digit industries and 4 three-digit industries was statistically significant both during appreciations and depreciations. In none of these industries could the restriction that $\beta_{1A} = \beta_{1D}$ be rejected at the 5 percent level. These industries included: textiles, apparel and leather products (32, 321, and 323), nonmetallic minerals excluding coal and petroleum products (36), fabricated metals, machinery and equipment (38, 381 and 385). The pass-through estimates during appreciations were nearly identical to those during depreciations for industry 32, its sub-industry 323 and industry 385. For these industries the pass-through estimates given in Table 4 provide an accurate measure of pass-through regardless of whether the dollar is appreciating or depreciating. The coefficient estimates for industries 36 and 381 however, show sharp differences in pass-through during appreciations and depreciations. Thus, despite the inability to discriminate statistically between the estimates for an appreciation and depreciation, the size of the differences for some of the industries suggests caution in accepting the estimates in Table 4 as an accurate pass-through measure.

Pass-through in 3 two-digit and 6 three-digit industries was significant only when the dollar was appreciating. In 2 two-digit and 4 three-digit industries pass-through was significant only when the dollar was depreciating. Pass-through occurred only during appreciations in apparel (322), wood products (33 and 331), metals (37 and 372), machinery (382 and 383), and other manufactured goods (39). Pass-through occurred only when the dollar was depreciating in food beverages and tobacco (31), paper and publishing (34), chemicals (352), refined petroleum products (353), rubber (355) and plastics (356).

The pass-through estimates in Table 4 provide a misleading picture for the 15 industries in which pass-through is sensitive to the direction of the change in the exchange rate. For the3 two-digit and 6 three-digit industries in which pass-through occurs only when the dollar is appreciating, the estimates from a symmetry restriction underestimate the effect of changes in the exchange rate on import prices during an appreciation of the dollar and overestimate the effect on import prices during a depreciation. For the 2 two-digit and 4 three-digit industries in which pass-through only occurs during depreciations, the estimates in Table 4 overestimate the effect of changes in the exchange rate on import prices during a dollar appreciation and underestimate the effect on prices during a dollar depreciation.

The degree of pass-through in the industries that only pass-through appreciations is typically larger than in those that only pass-through deprecations. The average pass-through in the nine appreciation-only industries was 81 percent compared to a 52 percent pass-through rate in the six depreciation only industries. Indeed, the hypothesis that pass-through is complete could not be rejected in five of the nine appreciation-only industries (33, 39, 372, 382, and 383) but in only one of the six depreciation-only industries (353). These results are consistent with the argument that firms that attempt to increase market share when the dollar is appreciating act more aggressively than firms that operate under binding quantity constraints.

It is not surprising that the refined petroleum products industry (353) is the one industry where pass-through is complete when the dollar is depreciating and is not statistically significant when the dollar is appreciating. This industry is likely to operate under binding quantity constraints while facing an inelastic demand curve allowing firms to fully pass-through a depreciation.

Asymmetry with respect to the size of the exchange rate change

Tavlas (1997) estimated that 85 percent of U.S. imports in 1980 and 89 percent in 1996 were invoiced in dollars. Thus, if menu costs are important we would expect the size of pass-through to be positively correlated with the size of the exchange rate change. To test this, for each industry i, let

$$L_t = \begin{matrix} 1 & \text{when } |\Delta \ln e_t| \geq 3\% \\ 0 & \text{otherwise} \end{matrix} \quad \text{and} \quad S_t = \begin{matrix} 1 & \text{when } |\Delta \ln e_t| < 3\% \\ 0 & \text{otherwise} \end{matrix}$$

Interacting these two dummy variables with the exchange rate variables and then replacing $\beta_1 \Delta \ln e_t$ in equation (5) with $\beta_{1L}(L_t \, \Delta \ln e_t) + \beta_{1S}(S_t \, \Delta \ln e_t)$ provides separate estimates for pass-through under large and small changes in the exchange rate. The results of this estimation are shown in Table 6.

Pass-through is not statistically significant in 3 three-digit industries (341, 351 and 384). These are the same three industries in which pass-through is insignificant in the basic regression equation reported in Table 4. In 5 two-digit and 13 three-digit industries pass-through occurred only when there were large changes in the exchange rate. In total manufacturing, and the remaining 4 two-digit (32, 33, 36, and 38) and 4 three-digit (323, 356, 381, and 385) industries, pass-through occurs both when changes in the exchange rate are small and large. Only in industry 381 were we able to reject the hypothesis that pass-through was symmetric.

There is considerable variation in the degree of pass-through of large changes across industries, particularly at the three-digit level. Pass-through in total manufacturing was 31 percent. At the two-digit level, pass-through ranged from 11 percent in the textiles, wearing apparel and leather industry (32) to 44 percent in the miscellaneous manufactured goods industry (39). At the three-digit level, pass-through in the iron and steel (371) industry was 11 percent while pass-through in the refined petroleum products industry (353) and the nonferrous metals (372) was 127 percent and 98 percent, respectively.[17]

For the industries where pass-through was greater when there were large changes in the exchange rate, the imposition of symmetry (as in Table 4) underestimates the effect of a large change in the exchange rate on import prices and overestimates the effect of a small change in the exchange rate.

As Ghosh and Wolf (2001) show, if menu costs alone drive pass-through then in the long-run pass-through is complete. As noted above, in only 2 two-digit and 6 three-digit industries do we find evidence of complete pass-through in the long run. All of these industries, however, only pass-through large exchange rate changes. Thus, although both strategic factors and menu costs appear to play a role in determining pass-through in most industries, our results provide evidence that menu costs are the key determinant in a few industries.

[17] In neither industry could the restriction that pass-through is complete be rejected.

Asymmetry with respect to the size and direction of the exchange rate change

A final specification creates four dummy variables to combine the size of the change in the exchange rate with the direction of the change in the exchange rate. For each industry i, let

$$LA_t = \begin{matrix} 1 \text{ when } L_t = 1 \text{ and } A_t = 1 \\ 0 \text{ otherwise} \end{matrix}, \qquad SA_t = \begin{matrix} 1 \text{ when } S_t = 1 \text{ and } A_t = 1 \\ 0 \text{ otherwise} \end{matrix}$$

$$LD_t = \begin{matrix} 1 \text{ when } L_t = 1 \text{ and } D_t = 1 \\ 0 \text{ otherwise} \end{matrix} \text{ and}, \qquad SD_t = \begin{matrix} 1 \text{ when } S_t = 1 \text{ and } D_t = 1 \\ 0 \text{ otherwise} \end{matrix}$$

Interacting these four dummy variables with the exchange rate variable and replacing $\beta_1 \Delta \ln e_t$ in equation (5) with $\beta_{1LA}(LA_t \, \Delta \ln e_t) + \beta_{1SA}(SA_t \, \Delta \ln e_t) + \beta_{1LD}(LD_t \, \Delta \ln e_t) + \beta_{1SD}(SD_t \, \Delta \ln e_t)$ provides separate estimates for pass-through under large appreciations, small appreciations, large depreciations and small depreciations of the U.S. dollar. The results are reported in Table 7.

Large changes in the exchange rate continue to be the key determinant of pass-through. Pass-through is never significant in four industries: 341, 351, 371 and 390. There is no evidence that firms pass-through only small changes. In contrast, firms in total manufacturing, as well as 5 two-digit and 10 three-digit industries, pass-through changes in the exchange rate only when the change is large. In five of these industries (32, 321, 322, 355 and 372) and total manufacturing pass-through occurs both during appreciations and depreciations.

In all of the industries where firms pass-through a small change in the exchange rate they also pass-through the corresponding large change in the exchange rate. For example in industries 33, 331, 382, 383 and 39 firms pass-through changes in the exchange rate when the dollar is appreciating regardless of whether the appreciation is large or small, but do not pass-through deprecations of the dollar. In a few industries firms pass-through all large changes plus small appreciations or depreciations. There is no industry in which firms pass-through both small appreciations and small deprecations.

Davis and Hamilton (2004) find that in the U.S. wholesale gasoline market firms are more reluctant to increase prices than decrease them when changes are big, but are more reluctant to decrease prices than to increase them when changes are small. In our model such behavior would imply that $|\beta_{1LA}| > |\beta_{1LD}|$ and $|\beta_{1SD}| > |\beta_{1SA}|$. We find no industry where both of these conditions hold.

In many industries the nature of pass-through is the same regardless of the level of aggregation. In a few industries, however, the level of aggregation matters for the behavior of pass-through. For example, pass-through occurred only during depreciations in the food, beverage and tobacco (31) industry but only during appreciations when the food (311) industry was separated from the other two components. Separate data for the beverage and tobacco industries are not available on the to determine whether pass-through does indeed behave differently in these industries than in the food products industry. The contrast is more apparent for the chemicals, petroleum, coal, rubber and plastics (35) industry. At the two-digit level firms pass-through only large appreciations. In most of the three-digit industries (352, 353, 354 and 356) firms pass-through only large deprecations. Indeed, in none of the three-digit industries are only large appreciations significant.

Robustness

Because there is no standard measure of a "large" or "small" change in the exchange rate, we applied alternative measures to test the robustness of our results. First we looked at alternative values of the threshold for a large change: 3.5, 4.0 and 5.0 percent.[18] As the threshold increases, the frequency of small changes necessarily increases. Quarterly changes in the exchange rate that were less than 3.5 percent occurred between 62 and 96 percent of the time. Quarterly changes in the exchange rate less than 4 percent occurred between 65 and 98 percent of the time, and changes that were less than 5 percent occurred between 73 and 99 percent of the time. The strength of the results decreases as the size of a large change rises. The number of industries for which pass-through only occurs when the change in the exchange rate is large declines. When a small change is defined as either less than 3.5 percent or less than 4 percent, the basic result holds that more industries show pass-through with large changes than with small changes. At the 5 percent threshold level

[18] All changes in the exchange rate are measured in absolute value.

pass-through is statistically significant more frequently with small changes than with large changes. It is not clear however whether these results indicate that firms do not pass-through very large changes in the exchange rate or if the infrequency of such changes makes statistical significance difficult. Indeed, in more than half the industries at the two-digit level and three-quarters of the industries at the three-digit level the point estimate of pass-through is greater for large changes in the exchange rate than for small changes.

Second, we used the distribution of exchange rate changes in each industry to define a large and small change. We did this in two ways. First we defined large as a change that is greater than the sample standard deviation, the measure used by Ohno (1989). Using this definition reduces the dispersion of the frequency of small changes across industries. At the two-digit industry level small changes range from 63 to 67 percent. At the three-digit industry level between 62 and 71 percent of all quarterly changes are small. Next, for each industry, we sorted the absolute values of the exchange rate changes and defined large as any change in the highest quartile. The threshold for this quartile ranged from 2.2 percent to 5.2 percent.

The results using either of these two measures were similar to those using the 3 percent threshold measure. Pass-through occurred in nearly every industry when the change in the exchange rate was large but in fewer industries when the change was small. Using measures of large and small based on the properties of the distribution of exchange rate changes in each industry, however, has its drawbacks. Most importantly, it requires firms in each industry to have knowledge of the underlying distribution of exchange rate changes. The single threshold level, e.g. 3 percent, requires no such sophistication on the part of the firm.

Our results indicate that firms react quickly to large changes in the exchange rate. A final robustness test looked at whether firms react similarly to accumulated large changes in the exchange rate. To test this we calculated a 4-quarter moving average of changes in the exchange rate for each industry. We then used a 2 percent threshold measure and the standard deviation measure to define a large change in the exchange rate.[19] Using either method we found that pass-through occurred most often when the 4-quarter moving average

[19] Because the 4-quarter moving average typically attenuated exchange rate changes, some industries never had exchange rate changes above the 3 percent threshold used to define a large quarter to quarter change.

change in the exchange rate was large. However, we found evidence of some degree of pass-through in fewer industries than when looking only at a quarter-to-quarter change in the exchange rate.

6. Conclusion

Most studies of exchange rate pass-through assume that firms behave symmetrically with respect to the direction of the change in the exchange rate. Theory, however, provides several explanations for why firms may behave asymmetrically. As part of a strategy of pricing to market, firms attempting to increase their market share may increase pass-through when the importer's currency is appreciating and decrease pass-through when the importer's currency is depreciating. Firms using both local and imported inputs may act in a similar manner. On the other hand firms operating under quantity constraints, either because of trade restrictions or production bottlenecks, may increase pass-through when the importer's currency depreciates and reduce pass-through when the importer's currency appreciates.

We analyze pass-through in total manufacturing, 9 two-digit and 20 three-digit ISIC manufacturing industries using industry level exchange rate data to determine if firms behave asymmetrically. When allowing appreciations and depreciations to have dissimilar effects on import prices, we find evidence of asymmetric behavior in 5 two-digit and 10 three-digit industries, but not in total manufacturing. Not surprisingly, the direction of the asymmetry varies across industries. These results imply that in the case of exchange rate changes Peltzman's (2000) "prices rise faster than they fall" does not have general applicability. For example, the quantity constraint explanation fits with chemical and petroleum related industries. The market share or production switching theory fits with wood and metal products, machinery and miscellaneous manufactured goods. These results indicate that imposing symmetrical pass-through may provide biased estimates for many manufacturing industries. In addition, because of differences in the direction of asymmetrical responses across industries, aggregate data may show no evidence of asymmetry despite its existence at the industry level.

Firms may also respond asymmetrically with respect to the size of the change in the exchange rate, adjusting their invoice prices only when there are large changes in the exchange rate. In this case the direction of the asymmetry depends on whether a firm invoices prices in its own or the importer's currency

In 5 two-digit and 14 three-digit industries in our study pass-through was statistically greater when there were large changes in the exchange rate. In no industry did firms pass-through more of the change in the exchange rate when the change was small. The direction of the asymmetry in our results is consistent with studies indicating that most U.S. imports are invoiced in dollars. The size effect dominates even when taking into account the direction of the change in the exchange rate. This result holds across all levels of aggregation.

To the extent that our size variables capture menu costs behavior, our results indicate that menu costs are an important factor in determining exchange rate pass-through. If only menu costs matter for pass-through then in the long-run pass-through is complete. If long-run pass-through is incomplete then strategic factors, such as pricing to market, also affect pass-through. We find that even after allowing for lagged effects of the exchange rate pass-through is rarely complete. Thus our results provide general support for concluding that both strategic factors and menu costs play a role in determining pass-through.

One area for future research is to determine the characteristics that explain the different behavior of the industries in our study, particularly with respect to pass-through differences during appreciations and depreciations. However, as demonstrated by Peltzman (2000) finding industry characteristics that explain price asymmetry in a statistical sense is likely to be a major challenge.

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Table 1
Direction of Asymmetry in Exchange Rate Pass-through

Explanation	Pass-through
Market Share	Appreciation > Depreciation
Production Switching	Appreciation > Depreciation
Quantity Constraints	Depreciation > Appreciation

Table 2
Manufacturing Industries in Pass-through Regressions

ISIC rev. 2	Description
3	Manufacturing
31	Manufacture of food, beverages and tobacco
32	Textiles, wearing apparel and leather industries
33	Wood and wood products, including furniture
34	Paper and paper products, printing and publishing
35	Chemicals, chemical, petroleum, coal, rubber and plastic products
36	Non-metallic mineral products, except coal and petroleum
37	Basic metals
38	Fabricated metal products, machinery and equipment
39	Other manufactured goods
311	Food products
321	Textiles
322	Wearing apparel except footwear
323	Leather products
331	Wood products except furniture
341	Paper and paper products
351	Industrial chemicals
352	Other chemicals
353	Refined petroleum products
354	Misc. petroleum and coal products
355	Rubber products
356	Plastic products
371	Iron and steel
372	Non-ferrous metals
381	Fabricated metal products
382	Machinery except electrical
383	Electrical machinery
384	Transport equipment
385	Professional and scientific equipment
390	Other manufactured goods

Table 3

Behavior of the Dollar: 1978.2 - 2000.4

(Percent of total changes)

ISIC	**Overall**		**Appreciations**		**Depreciations**	
	Appreciations	Small Change	Large	Small	Large	Small
3	58	66	13	45	21	21
31	58	62	18	41	21	21
32	62	62	20	42	19	20
33	56	88	7	49	5	38
34	56	87	8	48	5	38
35	57	65	15	42	20	23
36	57	65	18	40	18	25
37	56	67	14	42	19	25
38	58	63	14	44	23	19
39	60	54	22	38	24	15
311	58	64	16	42	20	22
321	57	63	18	40	20	23
322	63	56	23	40	21	16
323	58	57	23	35	20	22
331	59	91	4	55	4	36
341	56	89	7	49	4	40
351	57	65	16	41	19	24
352	60	61	18	42	21	19
353	57	65	18	39	17	26
354	59	71	12	47	16	24
355	59	69	13	46	18	23
356	60	64	18	43	19	21
371	58	57	19	40	24	18
372	60	78	12	48	10	30
381	57	67	13	44	20	23
382	57	63	15	42	22	21
383	57	60	15	42	24	19
384	59	68	13	46	19	22
385	58	60	14	44	25	16
390	60	54	22	38	24	15

Note: A large change is 3 percent or more in absolute value.

Table 4

Regression Coefficients – Basic Model

ISIC	β_1	β_2	β_3	β_4	$\overline{R}^2$
3	-0.280 **	0.446 **	0.307 **	0.055	0.54
31	-0.244 **	0.111	0.529	-0.040	0.09
32	-0.112 **	0.733 **	-0.032	0.018	0.50
33	-0.488 **	-0.045	0.518 **	0.045	0.45
34	-0.172 *	0.996 **	0.494 **	0.163	0.73
35	-0.219 *	-0.210	0.629 **	0.360 ++	0.42
36	-0.410 **	-0.049	0.512 *	-0.065	0.41
37	-0.259 **	0.653 **	0.333 *	0.154	0.50
38	-0.384 **	0.143	0.521 **	-0.033	0.63
39	-0.427 **	0.166	1.486 **	0.046	0.36
311	-0.249 **	0.143	0.098	-0.129	0.20
321	-0.223 **	0.696 **	-0.063	0.059	0.55
322	-0.262 **	0.814 *	0.030	-0.015	0.21
323	-0.264 **	0.055	0.420 **	-0.047	0.49
331	-0.333 **	0.193	0.324 **	0.054	0.42
341	-0.061	-0.097	0.635 **	0.043	0.57
351	-0.038	0.697	-0.015	0.246	0.04
352	-0.335 **	0.259	-0.772 *	-0.172	0.16
353	-1.112 **	-0.272	1.449 **	0.435	0.50
354	-0.341 *	0.028	0.052	0.164 +	0.22
355	-0.176 **	-0.001	0.355 **	0.062	0.37
356	-0.265 **	0.035	-0.007	0.005	0.19
371	-0.125 *	0.864 **	0.092	-0.036	0.47
372	-0.784 **	-0.258	0.777 **	0.215	0.50
381	-0.410 **	0.276 *	0.252	-0.024	0.56
382	-0.589 *	2.457 **	-0.371	0.214	0.15
383	-0.534 *	4.168 **	-0.975	0.468	0.20
384	-0.392	0.138	0.111	0.166	-0.05
385	-0.573 **	-0.299	-1.213 *	0.204	0.27
390	-0.562 *	0.576	0.593	-0.131	0.01

* denotes significance at the 5 percent level based on a one-tailed test.
** denotes significance at the 1 percent level based on a one-tailed test.
+ denotes significance at the 5 percent level based on a two-tailed test.
++ denotes significance at the 1 percent level based on a two-tailed test.

Table 5
Pass-through with Appreciation and Depreciation Dummy Variables

	Appreciation		Depreciation	
	Estimate	Std. Error	Estimate	Std. Error
3	-0.243 **	0.086	-0.311 **	0.073
31	-0.186	0.167	-0.297 *	0.154
32	-0.115 *	0.049	-0.108 *	0.052
33	-0.871 **	0.215	-0.020	0.249
34	-0.052	0.151	-0.315 *	0.172
35	-0.313	0.191	-0.128	0.185
36	-0.549 **	0.129	-0.275 *	0.127
37	-0.419 *	0.181	-0.111	0.171
38	-0.340 **	0.079	-0.416 **	0.062
39	-0.663 **	0.182	-0.234	0.158
311	-0.384 *	0.176	-0.136	0.153
321	-0.256 **	0.065	-0.191 **	0.063
322	-0.349 **	0.108	-0.175	0.107
323	-0.266 **	0.075	-0.262 **	0.084
331	-0.493 *	0.239	-0.145	0.271
341	0.030	0.183	-0.174	0.213
351	0.038	0.485	-0.105	0.448
352	-0.208	0.254	-0.447 *	0.230
353	-0.876	0.745	-1.380 *	0.816
354	-0.282	0.332	-0.392	0.300
355	-0.162	0.100	-0.188 *	0.086
356	-0.025	0.133	-0.495 **	0.128
371	-0.159	0.119	-0.098	0.099
372	-1.002 **	0.340	-0.561	0.345
381	-0.326 **	0.089	-0.481 **	0.078
382	-1.257 *	0.595	-0.062	0.497
383	-1.893 **	0.578	0.320	0.409
384	0.204	0.745	-0.828	0.588
385	-0.583 *	0.249	-0.565 **	0.195
390	-0.482	0.583	-0.628	0.505

* denotes significance at the 5% level based on a one-tailed test.
** denotes significance at the 1% level based on a one-tailed test.

Table 6
Pass-through with Large and Small Dummy Variables

ISIC	Large Dummy Estimate	Large Dummy Std. Error	Small Dummy Estimate	Small Dummy Std.Error
3	-0.306 **	0.044	-0.170 *	0.093
31	-0.252 **	0.088	-0.208	0.200
32	-0.111 **	0.029	-0.118 *	0.070
33	-0.431 **	0.177	-0.537 **	0.166
34	-0.234 *	0.118	-0.112	0.116
35	-0.233 *	0.106	-0.150	0.228
36	-0.412 **	0.073	-0.399 **	0.155
37	-0.294 **	0.103	-0.127	0.199
38	-0.372 **	0.039	-0.444 **	0.093
39	-0.442 **	0.096	-0.274	0.277
311	-0.305 **	0.090	-0.034	0.182
321	-0.249 **	0.035	-0.060	0.084
322	-0.282 **	0.058	-0.105	0.166
323	-0.257 **	0.045	-0.320 **	0.119
331	-0.423 *	0.206	-0.273	0.168
341	-0.191	0.161	0.029	0.134
351	0.132	0.258	-0.850	0.582
352	-0.324 **	0.134	-0.394	0.329
353	-1.268 **	0.432	-0.388	0.886
354	-0.473 **	0.182	-0.026	0.279
355	-0.184 **	0.053	-0.148	0.098
356	-0.243 **	0.076	-0.367 *	0.166
371	-0.112 *	0.060	-0.214	0.176
372	-0.984 **	0.227	-0.425	0.294
381	-0.454 **	0.047	-0.241 **	0.096
382	-0.601 *	0.305	-0.532	0.727
383	-0.550 *	0.274	-0.437	0.717
384	-0.481	0.376	-0.085	0.716
385	-0.507 **	0.116	-0.972 **	0.302
390	-0.566 *	0.303	-0.522	0.877

* denotes significance at the 5% level based on a one-tailed test.

** denotes significance at the 1% level based on a one-tailed test.

Table 7

Pass-through with Large and Small Dummy Variables

	Appreciations				Depreciations			
	Large		Small		Large		Small	
ISIC	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
3	-0.259 **	0.089	-0.089	0.181	-0.348 **	0.081	-0.253	0.217
31	-0.165	0.178	0.034	0.419	-0.340 *	0.175	-0.464	0.459
32	-0.115 *	0.052	-0.127	0.146	-0.106 *	0.058	-0.111	0.136
33	-0.762 **	0.252	-1.114 **	0.306	-0.028	0.295	0.154	0.354
34	-0.124	0.169	0.109	0.230	-0.370 *	0.210	-0.349	0.246
35	-0.345 *	0.202	-0.423	0.475	-0.116	0.207	0.114	0.491
36	-0.497 **	0.135	-0.210	0.334	-0.326 *	0.142	-0.639 *	0.316
37	-0.406 *	0.188	0.052	0.386	-0.206	0.185	-0.431	0.439
38	-0.371 **	0.084	-0.607 **	0.176	-0.358 **	0.071	-0.139	0.239
39	-0.733 **	0.193	-0.999 *	0.536	-0.170	0.181	0.400	0.579
311	-0.426 *	0.186	-0.127	0.381	-0.204	0.169	0.021	0.410
321	-0.257 **	0.066	0.009	0.169	-0.241 **	0.067	-0.142	0.169
322	-0.362 **	0.112	-0.220	0.318	-0.200 *	0.116	-0.018	0.312
323	-0.269 **	0.077	-0.386 *	0.216	-0.243 **	0.090	-0.248	0.224
331	-0.546 *	0.305	-0.528 *	0.317	-0.284	0.328	0.053	0.387
341	-0.058	0.213	0.014	0.262	-0.419	0.273	0.067	0.291
351	-0.030	0.506	-2.029	1.336	0.303	0.497	0.114	1.115
352	-0.146	0.267	0.134	0.612	-0.499 *	0.253	-1.016	0.710
353	-0.871	0.774	0.636	1.922	-1.739 *	0.890	-1.265	1.756
354	-0.382	0.345	0.320	0.596	-0.567 *	0.322	-0.372	0.587
355	-0.180 *	0.105	-0.238	0.201	-0.182 *	0.093	-0.047	0.203
356	-0.020	0.139	-0.123	0.324	-0.472 **	0.141	-0.525	0.335
371	-0.155	0.129	-0.285	0.308	-0.077	0.113	-0.134	0.438
372	-1.125 **	0.349	0.016	0.586	-0.761 *	0.374	-0.876	0.560
381	-0.358 **	0.091	-0.103	0.185	-0.538 **	0.084	-0.369 *	0.209
382	-1.490 *	0.637	-2.529 *	1.382	0.196	0.562	1.791	1.657
383	-2.017 **	0.627	-2.301 *	1.345	0.406	0.472	1.246	1.716
384	0.252	0.768	2.116	1.435	-1.146 *	0.633	-2.258	1.429
385	-0.598 *	0.265	-1.355 **	0.569	-0.409 *	0.223	-0.285	0.854
390	-0.480	0.625	-0.400	1.731	-0.641	0.584	-0.594	1.868

* denotes significance at the 5% level based on a one-tailed test.

** denotes significance at the 1% level based on a one-tailed test.

Appendix

First Order Conditions

Maximizing equation (1) with respect to prices in each market give the first order conditions

$$p^F: \quad x^F + p^F \frac{\delta x^F}{\delta p^F} - w\phi' \frac{\delta x^F}{\delta p^F} = 0 \tag{A1}$$

$$p^H: \quad ex^H + ep^H \frac{\delta x^H}{\delta p^H} - w\phi' \frac{\delta x^H}{\delta p^H} = 0 \tag{A2}$$

These can be rewritten as:

$$p^F: \quad \frac{\delta x^F}{\delta p^F}\left[p^F\left(1-\frac{1}{\varepsilon^F}\right) - w\phi'\right] = 0 \tag{A3}$$

$$p^H: \quad \frac{\delta x^H}{\delta p^H}\left[ep^H\left(1-\frac{1}{\varepsilon^H}\right) - w\phi'\right] = 0 \tag{A4}$$

where $\varepsilon^a \equiv -\left(\frac{\delta x^a}{\delta p^a}\frac{p^a}{x^a}\right)$ for a=H,F.

Let υ be the markup of price over marginal cost, where $\upsilon^a \equiv \frac{1}{1-1/\varepsilon^a}$ for a=H, F. Using this the first order conditions (A3) and (A4) can be rewritten as

$$p^F: \quad \frac{\delta x^F}{\delta p^F}\left[\frac{p^F}{\upsilon^F} - w\phi'\right] = 0 \tag{A5}$$

$$p^H: \quad \frac{\delta x^H}{\delta p^H}\left[e\frac{p^H}{\upsilon^H} - w\phi'\right] = 0 \tag{A6}$$

which can be rewritten as equations (2) and (3) in the text.

Second Order Conditions

The second order conditions for profit maximization are

$$\begin{vmatrix} \frac{\delta^2\Pi}{\delta p^{F^2}} & \frac{\delta^2\Pi}{\delta p^F \delta p^H} \\ \frac{\delta^2\Pi}{\delta p^H \delta p^F} & \frac{\delta^2\Pi}{\delta p^{H^2}} \end{vmatrix} > 0, \quad \frac{\delta^2\Pi}{\delta p^{F^2}} < 0, \text{ and } \frac{\delta^2\Pi}{\delta p^{H^2}} < 0,. \qquad (A7)$$

Expanding the second inequality in (A7) yields:

$$\frac{\delta^2\Pi}{\delta p^{F^2}} = \frac{\delta^2 x^F}{\delta p^{F^2}}\left(\frac{p^F}{\upsilon^F} - w\phi'\right) + \frac{\delta x^F}{\delta p^F}\left(\frac{1}{\upsilon^F}\left(1-\eta^{\upsilon F}\right) - w\phi''\frac{\delta x^F}{\delta p^F}\right) < 0 \qquad (A8)$$

where $\eta^{\upsilon F} = \frac{\delta \upsilon^F}{\delta p^F}\frac{p^F}{\upsilon^F} \leq 0$.

By the first order condition, (A5), $\left(\frac{p^F}{\upsilon^F} - w\phi'\right) = 0$. Thus the sign of (A8) depends on the sign of

$\frac{\delta x^F}{\delta p^F}\left(\frac{1}{\upsilon^F}\left(1-\eta^{\upsilon F}\right) - w\phi''\frac{\delta x^F}{\delta p^F}\right)$. If demand is well behaved, $\frac{\delta x^F}{\delta p^F} < 0$. Therefore,

$\left(\frac{1}{\upsilon^F}\left(1-\eta^{\upsilon F}\right) - w\phi''\frac{\delta x^F}{\delta p^F}\right) > 0$.

Similarly, expanding the third inequality in (A7) yields:

$$\frac{\delta^2\Pi}{\delta p^{H^2}} = \frac{\delta^2 x^H}{\delta p^{H^2}}\left(e\frac{p^H}{\upsilon^H} - w\phi'\right) + \frac{\delta x^H}{\delta p^H}\left(\frac{e}{\upsilon^H}\left(1-\eta^{\upsilon H}\right) - w\phi''\frac{\delta x^H}{\delta p^H}\right) < 0 \qquad (A9)$$

$\eta^{\upsilon H} = \frac{\delta \upsilon^H}{\delta p^H}\frac{p^H}{\upsilon^H} \leq 0$.

By the first order conditions (A6), $\left(e\frac{p^H}{\upsilon^H} - w\phi'\right) = 0$. Thus, the sign of (A9) depends on the sign

of $\frac{\delta x^H}{\delta p^H}\left(\frac{e}{\upsilon^H}\left(1-\eta^{\upsilon H}\right) - w\phi''\frac{\delta x^H}{\delta p^H}\right)$. Once again, assuming demand is well behaved, $\frac{\delta x^H}{\delta p^H} < 0$. Therefore,

$\left(\frac{e}{\upsilon^H}\left(1-\eta^{\upsilon H}\right) - w\phi''\frac{\delta x^H}{\delta p^H}\right) < 0$.

Effect of a Change in the Exchange Rate on Prices

Starting with the first order conditions given by equations (A5) and (A6), the implicit function theorem can be used to calculate the effect of a change in the exchange rate on the price of good x in Home.

$$\frac{\delta p^H}{\delta e} = \frac{-\frac{w\phi'}{e\upsilon^F}\left(1-\eta^{\upsilon F}\right)\left(1-\eta^{we}\right) - w\phi''\frac{\delta x^F}{\delta p^F}\frac{p^H}{\upsilon^H}}{\frac{e}{\upsilon^F\upsilon^H}\left(1-\eta^{\upsilon F}\right)\left(1-\eta^{\upsilon H}\right) - w\phi''\left[\frac{1}{\upsilon^F}\left(1-\eta^{\upsilon F}\right)\frac{\delta x^F}{\delta p^F} + \frac{e}{\upsilon^H}\left(1-\eta^{\upsilon H}\right)\frac{\delta x^F}{\delta p^F}\right]} \qquad \text{(A10)}$$

where $\eta^{we} = \frac{\delta w}{\delta e}\frac{e}{w}$ is the elasticity of input costs with respect to the exchange rate.

If marginal costs are constant, (A10) reduces to

$$\frac{\delta p^H}{\delta e} = \frac{-\frac{w\phi'}{e}\left(1-\eta^{we}\right)}{\frac{e}{e\upsilon^H}\left(1-\eta^{\upsilon H}\right)} = \frac{-\frac{p^H}{\upsilon^H}\left(1-\eta^{we}\right)}{\frac{1}{e\upsilon^H}\left(1-\eta^{\upsilon H}\right)} = -\frac{p^H\left(1-\eta^{we}\right)}{e\left(1-\eta^{\upsilon H}\right)} < 0 \qquad \text{(A11)}$$

Rearranging equation (A11) gives equation (4) in the text.