NBER WORKING PAPER SERIES

EXCHANGE RATES AND CORPORATE PRICING STRATEGIES

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Working Paper No. 4151

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 1992

This paper is part of NBER's research programs in International Finance and Macroeconomics and International Trade and Investment. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

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ABSTRACT

This paper reviews the recent literature on pass-through and pricing-to-market. Pricing-to-market behavior is estimated for a new, larger data set with 60 German and 20 U.S. 7-digit industries. The results conform closely to what has been found elsewhere in smaller detailed data sets and at higher levels of aggregation. German exporters show more tendency to price-to-market than U.S. exporters for the sample of industries studied, but there is much variation across the industries. Surprisingly, pricing-to-market is more pronounced in German exports of steel and chemicals than in consumer goods.

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Exchange Rates and Corporate Pricing Strategies

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Since the breakdown of the Bretton Woods system of fixed exchange rates, firms engaged in international trade of goods and services have been confronted with relative cost shocks of unprecedented magnitudes. The wide swings in the value of the U.S. dollar against the currencies of most major industrial countries during the 1980s illustrate the point. At the beginning of the 1980s, the dollar was worth roughly 1.7 German marks. By early 1985 it had risen above 3.3 marks, an increase of nearly 100% in its value relative to the mark, in spite of the fact that U.S. inflation exceeded German inflation during this period. It then fell dramatically to less than 1.6 marks by late 1987. The changes in the yen/dollar exchange rate were nearly as large over this same time period. Research in international finance has shown that these movements in exchange rates are not easily explained by changes in observable fundamentals. Clearly, the fluctuations are too large to be consistent with the underlying differences in productivity growth across countries.[1] Consequently, these changes have induced huge shifts in the relative production costs of U.S., Japanese and German firms across the entire spectrum of traded goods industries. These shifts in relative production costs across firms provide fertile ground for empirical research on pricing behavior.

The topic of this paper is the impact exchange rate changes have on the pricing decision of firms whose factor payments are denominated primarily in the home currency and who earn at least some share of their revenue in foreign markets. Two interesting analytical issues arise with regard to pricing in the context of these huge exchange rate

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* This paper was prepared for a conference "Exchange Rates and Corporate Performance" sponsored by the NYU Salomon Center at the Stern School of Business. I would like to thank James Dana and Joe Gagnon for helpful discussions, Kristine Knetter for research assistance, and Science Center Berlin for a pleasant research environment.

[1] See for example Richard Meese's (1990) recent survey or the monograph by Paul Krugman (1989).

swings. The first is whether firms' production costs in domestic currency are sensitive to exchange rate fluctuations. This can arise if either some inputs are priced in foreign currency units or cost varies with the quantity produced which in turn varies with exchange rates. For example, since Japan imports many raw materials that are priced in dollars and traded in relatively integrated world markets (e.g., oil), an appreciation of the yen reduces input costs measured in yen. Thus, we would expect yen prices of Japanese-produced autos to fall as the yen strengthens against the dollar. It is also likely that fluctuations in the value of the yen can result in a change in total production of autos in Japan if relative prices change in foreign markets. If auto production does not exhibit constant returns to scale, then the change in the quantity produced will affect marginal (and average) cost of the Japanese producers. This will be potentially more important for exchange rate changes vis-a-vis large export destinations. Note that effects exchange rates have on costs should affect yen export prices to *all* markets. Although yen/dollar exchange rate changes may have the greatest effect on Japanese production costs relative to other currency movements, the resulting price changes via this channel are not destination-specific.

The second issue is how a change in the exchange rate affects the markup of price over cost. In order to maximize profit in either an integrated world market or segmented export markets, firms may adjust markups in response to exchange rate changes. In the segmented, imperfectly competitive markets case, which is probably applicable to most manufactured goods, destination-specific markup adjustment that is triggered by exchange rate changes is referred to as "pricing-to-market" (PTM).[2] This is a form of third-degree price discrimination in which buyers are separated by geographic, information, legal or

[2] Indeed, the notion of "pricing strategies" is only sensible if firms operate in an imperfectly competitive environment. In perfect competition, market constraints dictate that the firm's only decisions are whether and how much to produce–the environment is neutral. In imperfect competition, firms must assess the likely response of competitors and foreign governments to their range of possible actions. The first discussion of the concept of PTM appears in Krugman (1987).

other barriers.[3] Since this paper is about pricing policies, theory and evidence on PTM will be my main focus.[4]

The combined sensitivity of costs and markups to exchange rate changes ultimately determines the "pass-through" of exchange rate changes from the exporter to the importer. Pass-through is typically defined as the elasticity of the local currency price of a foreign-produced good with respect to a change in the exchange rate between the local currency and the currency of the exporter.[5] If local currency prices move in proportion to the exchange rate, then there is "full pass-through" of exchange rate changes to local currency prices. The low pass-through of exchange rate changes to dollar prices of foreign-produced goods in the United States in the 1980s stimulated new interest in goods prices and exchange rates. Since pass-through combines information about both cost and markup changes, it does not have a precise economic interpretation. Low pass-through in the 1980s could have been due to: (1) offsetting cost movements due to both the role of the dollar world commodity trade and the fact that the United States is a large country or (2) destination-specific markup adjustment in a world with segmented, imperfectly competitive markets. This may explain why PTM has become the focus of more research in recent years.

Measures of PTM can provide us with useful information on firm strategies. In particular, how do different firms/industries strike the balance between price and quantity adjustment? What industry characteristics are associated with different adjustment patterns? Are price and/or quantity adjustments consistent with the predictions of standard economic models? It also enables us to address whether behavior in a given industry is different across exporting countries. For example, is the response of markups to exchange rate

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[3] Third-degree price discrimination occurs when different buyers face different, but constant, prices for each unit of the product. It is possible that PTM involves some second-degree discrimination as well–i.e., buyers facing a non-linear pricing schedule.

[4] I will present some evidence on the sensitivity of costs to exchange rate changes, but that is a secondary issue for this paper.

[5] I will use the term local currency to refer to price in the market of final sale. Import price is the price of a tradable good in the buyer's currency. Export price is price in units of the seller's currency.

changes different for U.S. and German chemical exporters? Evidence on this point might provide some information about the importance of differences in labor market, financial market and other economy-wide institutions in determining firm behavior.[6]

This paper consists of two main sections. Section 1 summarizes theoretical issues with respect to exchange rate fluctuations and export pricing. I will also discuss some some critical assumptions of standard models of pricing that may complicate interpretation of the empirical evidence. Section 2 will summarize and extend recent empirical work on industry-level export price adjustment. In this section I will study markup adjustment using new data on shipments to a cross-section of export markets for approximately 60 German and 20 U.S. 7-digit industries. Section 3 concludes.

1. Exchange Rate Fluctuations and Export Prices in Theory

This section of the paper will show in detail the effects of exchange rate fluctuations on traded goods prices for simple non-competitive market structures, and then discuss how the relationship is complicated by more sophisticated market structures and the role of dynamic factors. I will begin by analyzing exchange rate pass-through for a monopolist selling to a single foreign market to show how pass-through depends on cost and demand functions in a precise way. Next, I analyze the pricing problem of a monopolist selling to multiple destinations. This shows how prices to multiple buyers can isolate demand characteristics in principle. Third, I discuss how more complex market structures would complicate the revenue function of the exporter and the optimal pricing policy. Fourth, I examine how dynamic factors can complicate pricing strategies. Finally, I review some

[6] This question is of particular interest given the increasingly widespread popular belief that U.S. managers suffer from "short-termism" (see, for example the study by the MIT Productivity Commission (1990)). If that were true then we might expect to observe U.S. exporter behavior that is relatively less oriented toward preserving foreign market shares by adjusting markups to stabilize foreign currency prices of exports.

important caveats that apply to almost all of the theoretical models of PTM that will be particularly important in interpreting the empirical results.

1.1 Exchange Rate Pass-Through Under Monopoly

This section derives the elasticity of import price with respect to the exchange rate for a monopolist. It can be viewed as an extension of Bulow and Pfleiderer's (1983) results on the effect of cost changes on price for a domestic monopolist and parallels Feenstra (1989). While the results are not new, they illustrate the identification and interpretation problems inherent in empirical research on goods prices and exchange rates. This analysis is partial equilibrium in nature in that the producer's actions are assumed to have no effect on the exchange rate, a standard assumption in other research on this topic. In addition, I abstract from transportation costs, trade barriers, adjustment costs and uncertainty.

Let q denote the quantity produced for sale in the foreign market, p^* the price in foreign currency (referred to as the import price), and e the exchange rate (in units of foreign currency per unit of the exporter's currency). Without loss of generality, assume the monopolist employs a single factor of production at domestic currency price w. The inverse demand function which gives the import price as a function of the quantity sold will be denoted by $p^*(q)$. The domestic currency profits, Π, from sales in the foreign market are given by:

$$(1.1)\ \Pi(q) = \frac{p^*(q)\, q}{e} - C(q, w)$$

where $C(q,w)$ is the firm's cost function. The optimal export quantity must satisfy the first-order condition:

$$(1.2)\quad \frac{d\Pi}{dq} = \frac{p^{*\prime}(q)\, q + p^*}{e} - C_q(q,w) = 0$$

Assuming that the cost and demand functions are twice continuously differentiable, one can apply the implicit function theorem to the first-order condition to determine the response of import price with respect to a change in the exchange rate:

$$(1.3)\quad \frac{dp^*}{de} = \frac{dp^*}{dq}\frac{dq}{de} = -p^{*\prime}\,\frac{\Pi_{qe}}{\Pi_{qq}}$$

where Π_x denotes the derivative of the profit function with respect to x. Exchange rate pass-through is defined to be the elasticity representation of this derivative. Letting η ($1 < \eta < \infty$) denote the absolute value of the elasticity of demand with respect to price and assuming for the moment that factor prices are independent of the exchange rate, the pass-through coefficient can be expressed as[7]:

$$(1.4)\quad \frac{d\, ln\, p^*}{d\, ln\, e} = \frac{-\eta + 1}{-\eta + 1 - \frac{d\, ln\, \eta}{d\, ln\, p^*} - \eta\,\frac{eC_{qq}}{p^{*\prime}}}$$

This expression reveals the channels affecting the pass-through relationship for a monopolist. Both the slope and the degree of convexity of the import demand schedule are important, indicated by the presence of both the elasticity of demand and the *elasticity of the elasticity* with respect to import price. In addition, the denominator is a function of the slope of marginal cost. If the domestic factor price faced by the monopolist were affected by the exchange rate (as in the case of an imported input), then the resulting shift in the cost

[7] Factors other than own price that may affect the elasticity of demand are suppressed for current purposes. They will be considered in empirical implementation of the model.

function would further complicate the pass-through relationship. In reality, all of these effects are likely to be operative to some extent.

There are several points worth noting about the implications of equation (1.4) for exchange rate pass-through. First, with constant marginal cost and constant elasticity of demand the monopolist will fully pass-through exchange rate changes to import prices. This can be seen by noting that the last two terms in the denominator are zero under the stated conditions. The result is independent of the particular value of elasticity and thus, of the markup of price over marginal cost. Consequently, even under these restrictive assumptions about functional form, the pass-through coefficient reveals nothing about the degree of market power for a monopolist.[8]

Second, with constant marginal cost, the convexity of the demand schedule dictates whether pass-through exceeds, equals, or is less than one.[9] The pass-through coefficient would exceed one for demand schedules more convex than a constant elasticity schedule with equivalent slope. Pass-through is less than one for demand schedules less convex than the constant elasticity schedule. This would include the linear case.

Third, if the slope of marginal cost is not known, knowledge of the pass-through coefficient alone is insufficient to determine even the convexity of the demand schedule.[10] Even when demand is less convex than a constant elasticity schedule, pass-through could exceed one if marginal costs were falling sufficiently in the neighborhood of the optimum. On the other hand, pass-through may be incomplete in spite of demand schedules having more convexity than a constant elasticity schedule provided marginal costs were increasing sufficiently at the optimal output level. This suggests that pass-through could vary

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[8] This point is analogous to that made in Bulow and Pfleiderer's critique of Sumner's (1981) investigation of the cigarette industry.

[9] This result is related to Brander and Spencer's (1984) analysis of the effect of tariff changes on import prices.

[10] Klein and Murphy (1988) explore the ramifications of non-constant marginal cost for exchange rate pass-through in more detail.

dramatically across industries and within a particular industry over time as capacity utilization changes.[11]

1.2 Multi-Market Monopoly and Pricing-to-Market[12]

Consider a firm that produces goods for sale in n separate destination markets, indexed by i. The profits of the firm are given by:

$$(2.1)\ \Pi(p_1,\ldots,p_n) = \sum_{i=1}^{n} p_i q(e_i p_i) - C\left(\sum_{i=1}^{n} q(e_i p_i),\, w\right)$$

where p is the export price (i.e., price in the exporter's currency), q is quantity demanded (a function of the price in the buyer's currency), and e , w and $C(q,w)$ are defined as in the previous section.[13] The first order conditions for profit maximization imply that the firm equates the marginal revenue from sales in each market to the common marginal cost. Alternatively, the export price to each destination is the product of the common marginal cost and a destination-specific markup:

$$(2.2)\ p_i = C_q \left(\frac{-\eta_i}{-\eta_i + 1}\right) \quad \forall i$$

where the arguments of C_q are suppressed and η is the absolute value of the elasticity of demand in the foreign market with respect to changes in price. A change in the exchange

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11 Sensitivity of pass-through to capacity utilization might provide an alternative explanation for structural breaks in the pass-through relationship that have been documented by Baldwin (1988) for U.S. imports in the 1980's. His preferred interpretation is that large exchange rate swings change market structure by affecting entry and exit in markets.

12 This section borrows extensively from Knetter (1992).

13 This maximization could easily be recast in terms of real prices and profits without affecting any of the main results or empirical implications.

rate vis-a-vis the currency of country *i* can affect the price charged to market *i* in two ways: by affecting either marginal cost (through changes in quantity or input prices) or the elasticity of import demand. The former effect will spillover to the other destination markets as well, while the latter is destination-specific. Both effects determine pass-through, while PTM refers to the second effect only.

These two effects are revealed more clearly by taking the log of (2.2) and totally differentiating the resulting expression with respect to export prices, input prices and exchange rates:

$$(2.3)\ \frac{dp_i}{p_i} = \frac{C_{qq}\left(\Sigma q_j'\,(p_j de_j + e_j dp_j)\right) + C_{qw}dw}{C_q} + \frac{\eta_i'\,e_i p_i}{\eta_i(-\eta_i+1)}\left(\frac{dp_i}{p_i} + \frac{de_i}{e_i}\right) \quad , \forall i$$

where the arguments of q' and η' are suppressed. Defining:

$$\beta_i = \left(\frac{\dfrac{\partial ln\ \eta_i}{\partial ln\ p^*_i}}{(-\eta_i+1) - \dfrac{\partial ln\ \eta_i}{\partial ln\ p^*_i}} \right)$$

where $p^*=ep$ is the price in the buyer's currency and letting (dC_q/C_q) equal the total differential of the log of marginal cost, equation (2.3) simplifies to:

$$(2.4)\ \frac{dp_i}{p_i} = (1+\beta_i)\frac{dC_q}{C_q} + \beta_i\frac{de_i}{e_i},\ \ \forall i$$

Two important observations can be made about export price elasticities on the basis of (2.4). The first is stated in the following proposition.

Proposition. *The elasticity of export price with respect to the exchange rate, net of the effect of any associated changes in marginal cost, is less than (greater than) zero as demand is less (more) convex than the constant elasticity form.*

This follows by inspection of the simplification of the total differential in equation (2.3) and the relationship between convexity and the response of elasticities to changes in price. For demand schedules less convex than the constant elasticity class, elasticity of demand increases with price causing the numerator to be positive and the denominator negative in the expression for β. The intuition is the same as in the problem of Section 1.1.

The simplification given by (2.4) also reveals an implication for the relationship between the effect of marginal cost changes and exchange rate changes on the export prices. Changes in marginal cost and changes in exchange rates *net of their effect on marginal cost* have an identical effect on prices in the importer's currency. Equation (2.4) is in terms of the export price changes, so the coefficients on changes in exchange rates and marginal cost differ by one since exchange rate movements automatically change import prices proportionately. This is intuitively appealing. Since it is the interplay with arguments of the cost function that in general causes exchange rates to have potentially different effects than pure input price shocks, it is reasonable that when they are accounted for separately, marginal cost changes and exchange rate changes have symmetric effects on import prices.

Sections 1.1 and 1.2 illustrate two things: (1) even with simple market structures, the relationship between exchange rates and goods prices is complicated and depends on the functional forms of cost and demand as well as the sensitivity of input prices to exchange rates, and (2) by introducing multiple markets and focusing on relative export prices, it may be possible to isolate the "demand-side" effects of exchange rates from those effects that work through the cost function. In other words, PTM may in principle provide more useful information than a simple pass-through coefficient.[14]

1.3 Alternative Market Structures

Moving from monopoly to other imperfectly competitive market structures further complicates the relationship between prices and exchange rates. In the multi-market framework, the same principles concerning the convexity of demand will apply to price adjustment, but the demand schedule must now be thought of as a residual demand which incorporates the response of competitors to changes in the exchange rate (or other factors that affect the export price). Unfortunately, obtaining closed form solutions for the pricing equation based on the properties of residual demand is typically not possible. Nonetheless, the link between market demand and residual demand will vary with the number of firms, where they are located and the nature of strategic interaction. I will focus on how price adjustment varies with these factors for a given market demand schedule.

Dornbusch (1987) provides a clear analysis of the pass-through problem for a number of models of market structure. These models can easily be extended to multiple segmented markets to consider the implications for PTM. I will focus my discussion on the Cournot oligopoly model.

The Cournot model reinforces the points made in Sections 1.1 and 1.2 and illustrates how the location and number of firms affects pass-through and PTM. Dornbusch's version of the model is geared toward studying pass-through to the "home" market. I will change the orientation of the model to study pass-through from home firms to a foreign market, in order to be consistent with notation from the previous sections and in the empirical work to follow. The foreign market is assumed to be perfectly sealed from

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[14] Econometric research on pass-through has always introduced cost measures in addition to exchange rates in regression equations. Nonetheless, considering relative export price behavior instead of single bilateral pass-through relationships may provide a superior method of controlling for the effect of cost changes on prices.

other markets for the output of n identical home and n* identical foreign firms. To keep things simple, Dornbusch initially assumes constant marginal cost (w for home firms and w* for foreign firms in units of their local currencies) and linear market demand. Given these cost and demand conditions, we know from Section 1.1 that if the foreign market were served by a home monopolist, then pass-through of exchange rate changes to goods prices in the foreign market would be incomplete. With linear demand, markups increase proportionately less than costs.

In the homogeneous products Cournot model with quantity as the strategic variable, Dornbusch shows that pass-through can be expressed as:

$$\frac{\partial \ln p^*}{\partial \ln e} = \varphi = \left(\frac{n}{N}\right)\left(\frac{ew}{p^*}\right)$$

where $N=n^*+n$ is the total number of firms serving the market. Both terms are fractions, so pass-through is less than one.

Since the equilibrium markup is a decreasing function of the total number of firms, one must be careful in interpreting how the pass-through expression is affected by changes in market structure. The effect of the location of firms is seen by holding N (and thus the markup) constant, but increasing the share of home firms. Pass-through increases since the first term gets larger while the second remains constant. Home firms have greater influence on foreign price as their share of the market increases. To see the role of the number of firms, we allow the total number of firms to increase (which will decrease the markup), while holding the market share of the home firms (n/N) constant. It is clear that this will increase pass-through. Prices become more sensitive to costs when markups are small.

The extension of this framework to the study of PTM is straightforward. Since the model assumes constant marginal costs and no imported inputs in production, the translation from pass-through to PTM only requires that we shift focus to how export prices measured in the home currency change with exchange rate changes. Clearly, full pass-through implies that export prices are unaffected by exchange rate changes, while low pass-through implies exchange rates have a relatively large effect on export prices. Consequently, low pass-through is synonymous with a high degree of PTM. Therefore we expect to observe a great deal of PTM when either: (1) the domestic firms have a small share of the foreign market(s) or (2) the market is not very competitive in the sense that markups are large.

In thinking about these two principles, note the ambiguity in the relationship between "market power" and PTM. PTM is greatest if the industry as a whole has a great deal of monopoly power (high markups over cost), but the home firms have a relatively small share of the foreign market and thus less influence over the equilibrium price. PTM is lowest when the industry as a whole is rather competitive (markups are small), but home firms tend to dominate the industry (they have relatively more market power), so that pass-through is nearly complete to all markets.[15]

1.4. Dynamic Models

Krugman (1987) rightly pointed out that most observers intuitively sense that both the actual and expected duration of an exchange rate change has an important effect on the degree of PTM. The models I outlined in Sections 1.1 – 1.3 do not have this property. In order for PTM to be duration-dependent, models must have intertemporal linkages in demand or supply–today's prices somehow affect tomorrow's demand or cost. I will briefly review two models to illustrate supply- and demand-side dynamics, respectively .

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[15] While these results are for the given linear market demand schedule, Dornbusch shows how general functional forms of demand will alter the basic relationship. For any given market demand, the qualitative relationships between pass-through (or PTM) and market structure described here still hold.

Baldwin and Foster (1986) and Krugman (1987) have emphasized the potential role of *market-specific* distribution costs in explaining PTM. Baldwin and Foster refer to it as the "marketing bottlenecks" model. Suppose an exporter faces identical constant elastic demand in several foreign markets so that normally full pass-through (or no PTM) would be expected in the absence of capacity constraints. Further assume that distribution outlets, each having a fixed capacity, are required to sell output for the product. If the exporter's currency depreciates relative to one destination market, he would leave the export price unchanged and allow the destination market currency price to fall proportionately provided there was sufficient capacity. If capacity constraints are binding however, the exporter would only pass-through the exchange rate change to the point where demand equalled capacity. The export price would be increased temporarily to this destination until more capacity could be put in place. Thus, PTM might be observed vis-a-vis other export destinations until capacity expanded sufficiently to meet the demand that would result with full pass-through.

The example implicitly assumes that the exchange rate change is permanent, or at least perceived to be so by the exporter. If the exporter believes the exchange rate change to be temporary or that it will at least partly reverse itself, then additions to capacity may be smaller or non-existent. We would then expect to observe PTM lasting until the exchange rate returned to a level at which sales in the foreign market did not exceed capacity at the original export price. It is not immediately obvious how the bottlenecks model generates PTM for permanent appreciations of the exporter's currency, since constraints on decreasing shipments are harder to justify.[16]

Froot and Klemperer (1989) present a model in which demand-side dynamics influence the pass-through relationship. One motivation is Klemperer's (1987) switching cost model which has the implication that current profits are a function of past sales, i.e.,

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[16] With temporary appreciations, one can imagine that a certain volume of shipments must be maintained in order to keep distributors either in business or carrying the product line.

market share matters. This concern about market share affects the pricing strategy, since the optimal price today depends on all past prices. In an international context this model has an additional implication: because of the effect exchange rates have on the home-currency value of foreign-currency profits, firms' expectations about future exchange rates will affect the value of today's market share. Consequently, currency fluctuations that are expected to be reversed in the future will have a different impact on pricing behavior than those that are expected to be permanent. The degree of pass-through and thus PTM may be related to expectations about future exchange rates, as well as present.

1.5 Some Caveats

In this section I will briefly discuss a number of factors likely to affect pricing behavior which are typically not addressed in models of PTM or pass-through.

Invoicing Decisions

Models of pass-through or PTM typically ignore the choice of invoice currency. In practice, trade requires the parties involved to choose an invoice currency and specify the value and quantity of goods in advance of actual exchange. Baron (1976) has analyzed the problem of choosing the optimal invoice currency as a function of supply and demand uncertainty. If contracts specify the invoice currency and a price that is not contingent on the exchange rate, then the invoice currency obviously matters a great deal for the observed pass-through of exchange rate changes. If the exporter invoices in his own currency, then pass-through is complete. If the exporter invoices in the foreign currency, then there is no pass-through.

If contract prices can be adjusted frequently, then the choice of invoice currency is of little consequence for pass-through or PTM. No matter which currency is chosen, the appropriate adjustment of the contract price could yield identical outcomes. To the extent that desired pass-through dictated by market constraints is near one extreme or the other, the optimal invoice currency would seem to be the one that necessitated the least adjustment of the contract price. In other words, if full (no) pass-through is optimal, this can be achieved by invoicing in the exporter's (importer's) currency. If some intermediate level of pass-through is desired, this could in principle be achieved by invoicing in a combination of the two currencies. I am not aware of such contracts in practice, although Whitaker (this volume) notes that GE Medical Systems invoices in the ECU for some transactions. This has apparently become a more common practice in recent years.[17] Choice of invoice currency should depend on the same factors that determine pass-through. It should not have unintended effects on pass-through apart from the very short run.

Foreign Subsidiaries and Transfer Pricing

Another issue that is typically ignored in the literature on pass-through and PTM is the possibility that multinational firms sell output to a foreign subsidiary. In this case, the price may reflect the firms preferences over where it realizes profits which will depend on tax laws in different countries. For example, a firm that wished to realize all profits in the market of final sale would charge a price equal to unit cost in the domestic currency and let the subsidiary adjust the markup over cost. In this case we would expect to see full pass-through (or no PTM) with respect to the transaction between the home firm and foreign subsidiary. If we measured prices at the consumer level, however, we may see that the subsidiary does adjust markups, so that pass-through is not full. In general, transfer pricing, where it exists would probably bias measures of PTM downward since some markup adjustment may occur between the subsidiary and the ultimate customer that is not captured in the international transaction.

[17] See Reboul (1987) and Jozzo (1987).

Endogenous Market Structure and Hysteresis

In recent research, Baldwin (1988) and Dixit (1989) among others, have considered the possibility that market structure itself depends on realizations of exchange rates, since exchange rates will affect the entry and exit decisions of firms. More significantly, if there are sunk costs associated with these decisions, then temporary swings in exchange rates can have permanent effects on market structure and thus on the relationship between prices and exchange rates. Baldwin (1988) presented some empirical support for this idea in his work. The data were consistent with the hypothesis that U.S. product markets became somewhat more competitive as a result of the overvaluation of the dollar in the early to mid 1980s. Subsequent research by Hooper and Mann (1989), Ohno (1989), Knetter (1991b) and Parsley (1991) has shown less support for this proposition. For investigations with long time series data sets structural breaks may be an important issue, but it does not appear to be a significant factor for empirical work with post-Bretton Woods data.

Trade Policy

Another issue that may affect the data, but has received little attention empirically is the notion that there may be significant feedback between firms' pricing policies and governments' trade policies. Feenstra's (1988, 1989) work is one example where exchange rates are trade policy are both taken into account. He has documented the quality upgrading of Japanese auto exports in response to VERs (and its associated effect on unit values of exports to the United States) and the symmetric pass-through of tariff and exchange rate changes.

There are two levels at which trade policy will affect PTM. First, binding quantity restrictions would give rise to rigid prices in the buyer's currency and therefore a high degree of PTM. This is something that seems very evident in the data on Japanese auto exports to European and North American markets as shown in Gagnon and Knetter (1991).

More subtle is the notion that the mere threat of trade restrictions may alter the pricing strategy of firms engaged in trade. Anti-dumping law in the United States, for example, may serve to constrain the extent to which foreign firms choose to pass-through depreciations of their currency against the dollar. In general, protectionist pressure seems to increase most in countries whose currency has appreciated against its trading partners. If true, there may be an asymmetry in pass-through: firms may be reluctant to pass-through devaluations for fear of provoking trade restrictions in the importing country which may be hard to reverse.[18] Knetter (1991b) finds weak support for such asymmetries in the data.

Imperfectly Sealed Markets

Perhaps the most important qualification to bear in mind before moving to empirical work is that national markets are not perfectly sealed, as is typically assumed in theoretical models of pass-through and PTM . While it is possible to price discriminate between different markets of final sale in most manufactured goods industries, there may be bounds on how large price differentials can become before arbitrage becomes a profitable activity or new entry is encouraged in some markets. The characteristics that determine the ability of a firm to segment foreign markets are also important determinants of the competitiveness of the industry. Product differentiation and geographic and legal barriers to arbitrage tend to permit discrimination across markets and increase the market power of firms in the industry.

Empirically, we might expect to observe that price differentials across buyers in different markets are closely related to exchange rate changes as long as exchange rates stay within some band. Once exchange rates wander outside the band, the price differentials cannot increase further and the relationship with exchange rates thus breaks down in this region. The band width itself should depend on characteristics of the product.

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[18] This impact of anti-dumping law on PTM was first suggested in Marston (1990).

Automobiles should have a much wider band than Vitamin C, since the degree of product differentiation and barriers to arbitrage are much greater in the automobile industry.

1.6 Pricing Strategies and Observed Behavior

While economists are most interested in whether evidence on pricing to market can be used to support particular models of market organization, perhaps business people are more concerned with what the data say about "strategies" that firms use to cope with exchange rate fluctuations. In theory, once a model is fully-articulated, choosing the optimal pricing policy is a matter of maximizing the present discounted value of the stream of profits the firm expects under alternative policies.

Although there may be a single optimal strategy in theory, we may expect to observe different behavior in practice. Does different behavior imply different strategies? Suppose we observe Toyota and BMW engaging in different pricing responses to exchange rate changes. One possibility is that the firms face objectively similar situations (e.g., number of competitors, market demand schedule, etc.) but choose different courses of action based on different subjective factors such as beliefs about the responses of foreign government policy, consumers or competitors or discount rates. Another possibility is that the situations are not objectively similar (BMW may face less competition than Toyota in most markets), and that Toyota would choose the same strategy as BMW were it confronted with the same objective situation, and vice-versa. In the former case, we might think of the different behavior as resulting from firms pursuing different strategies, whereas in the latter case the different behavior results from a different environment.

In reality, firms are probably very uncertain about the reaction of competitors, consumers and government policies to price changes. Firms that give more weight to the potential impact of price changes on future demand and cost and/or those that have lower discount rates are more likely to choose pricing strategies that involve relatively more PTM and less pass-through, all else equal. But the "all else equal" qualification looms large, given the variety of "objective" factors that can influence optimal behavior. By careful organization of empirical evidence, it may be possible to determine whether firms facing basically similar market constraints are choosing different strategies. Different behavior across industries may be more likely to reflect different objective environments, whereas different behavior across countries within an industry may reveal differences in strategies.

2. Empirical Evidence on Export Prices and Exchange Rates

Empirical studies of how exchange rates affect prices have a much longer tradition than the theoretical work surveyed in the previous section. The period of volatile exchange rates in the early and mid 1980s and the coincident incorporation of imperfect competition into trade theory has led to a new burst of empirical research in this area. Progress in the more recent work shows up on three fronts: (1) measurement and interpretation have been sharpened by the shift from pass-through to PTM, (2) more sophisticated methods in time series econometrics have been brought to bear on the data, and (3) more detailed data, especially in terms of country and industry variation, has been examined.

While these advances have been important, it remains true that econometric research to date has not been successful in measuring the influence of all of the possible channels through which exchange rates might affect goods prices under imperfect competition. Disentangling the separate roles of market demand, strategic interaction, and intertemporal linkages (let alone the factors theory has largely neglected) in the price adjustment process will require industry studies at a level of detail not yet seen in the literature on pass-through or PTM. Nonetheless, the reduced-form equations that have been estimated do provide general information about the relationship between exchange rates and prices for specific industries and therefore shed some light on pricing strategies.

This section of the paper is divided into four sub-sections. I first summarize recent evidence on exchange rates and prices at the industry level. Next, I discuss the empirical framework used in this paper to study export price adjustment to exchange rate changes. Third, the data are described. Fourth, I present the results of estimation and offer some interpretations of the main findings.

2.1 Recent studies

At the macroeconomic level, empirical research on exchange rate pass-through flourished around the collapse of the Bretton Woods system, although evidence from aggregate data says little about pricing strategies. Dunn's (1970) paper on Canadian prices was one of the earliest studies at the industry-level, and was followed by Isard (1977), Kravis and Lipsey (1977) and Richardson (1978). While much interesting work was done in the 1970s and early 80s, I will concentrate on industry-level research that has been done since Goldstein and Kahn's (1985) article, which reviews the earlier work in great detail. There have been many new studies since 1985, stimulated in part, no doubt, by the large swings in the value of the dollar and the puzzling behavior of the U.S. current account in this period.

Based on the movement in various 4-digit industry U.S. import prices relative to a trade-weighted average of foreign production costs, Mann (1986) concluded that foreign profit margins are adjusted to mitigate the impact of exchange rate changes on dollar prices of U.S. imports. Somewhat surprisingly, a sample of U.S. exporters showed no tendency to adjust markups in response to exchange rate changes.[19]

Giovannini (1988) shows large deviations from the law of one price are correlated with exchange rate changes for monthly export and domestic prices of narrowly defined Japanese manufactured goods–ball bearings, screws, and nuts and bolts. The deviations in some cases exceed 20% of the mean levels for the sample period, and persist for well over one year. Using monthly price indices for Japanese export and domestic prices from 1980-

[19] If anything, the data suggested markup adjustment on U.S. exports amplified the effect of exchange rate changes on prices measured in the buyer's currency.

87, Marston (1990) finds strong evidence of PTM in a sample of eight transport equipment and nine consumer goods industries at the 4-digit level. The degree of PTM (the change in domestic/export price ratio in response to an exchange rate change) is over 50% for both sets of goods on average.

Knetter's (1989) study of export pricing in U.S. and German 7-digit industries documents evidence of PTM on German exports to a variety of destinations. As in the work of Mann, there is no evidence of PTM for U.S. exports. In a comparative analysis of PTM in autos, Gagnon and Knetter (1991) estimate Japanese auto exporters offset approximately 70 percent of the effect of exchange rate changes on buyer's prices through markup adjustment. The comparable number for German auto exports varies by engine size: for small autos, about 40 percent of the effect of exchange rate changes are offset by destination-specific markup changes, whereas for large autos adjustment is minimal. They find no evidence of PTM for U.S. auto exports.

Knetter (1992) addresses the issue of whether there are country-specific differences the degree of PTM. In a sample of U.S., U.K., Japanese and German industries, I find that within a particular industry, the hypothesis that behavior is the same across exporting countries cannot be rejected. While most U.S. industries in the sample again show little evidence of PTM, corresponding industries in the other countries behave similarly. There is little statistically significant evidence that PTM varies by destination, either. In particular, the United States does not appear to experience more PTM as a buyer than other destinations for Japanese and German exports.

Regarding the appropriate dynamic specification of prices and exchange rates, the evidence is much harder to read. There seem to be three separate issues. First, does the law of one price hold in the long run, so that PTM is merely a short-run phenomenon? Second, are there important lags in the price adjustment process that must be recognized in estimation? Third, does the price response to exchange rate changes depend on whether the changes are perceived to be temporary or permanent? Under certain conditions, the dynamic models described in Section 1 imply that this distinction matters a great deal. If those conditions hold and exchange rate changes differ greatly in terms of the permanence of an innovation, then it is important to account for this empirically.

While the first question may appear to be more basic, it is probably the one which we can say least about. Price discrimination based on age of consumer, time of day, and bundling of products is pervasive and persistent, but can geographic price discrimination persist over the long run? The existence of firms selling output at uniform delivered prices within domestic markets attests to the possibility, provided differentials do not exceed transport costs.[20] It is certainly easier for differentials to persist across countries than within them, since differences in customs, language and regulations as well as fluctuations in currency values increase the cost of arbitrage. Fluctuations in currency values over the floating rate period are such that we cannot hope to get reliable sample information about whether PTM-induced price differentials across countries would vanish if exchange rates stopped changing. In a sense, volatile exchange rates have probably facilitated the segmentation of national markets while making it difficult for research to determine if that segmentation can persist.[21]

Regarding lags in price adjustment, the work of Giovannini (1988) and Marston (1990) provides the most thorough evidence. Giovannini explicitly allows for the possibility that prices may be set in advance of sales and that price discrimination may be observed simply due to exchange rate surprises. He finds that preset prices alone cannot account for the violations in the law of one price, although they appear to be part of the story. Marston also finds price pre-setting to characterize a number of the transport equipment categories, but that it is less important for consumer goods. The estimated share

20 Varian (1989) identifies cement in Belgium and plasterboard in the United Kingdom as examples.

21 The issue of whether PTM is temporary or permanent arises when error correction models are estimated. Kasa (1990) explicitly assumes the law of one price holds in the long run. Gagnon and Knetter (1991) consider both possibilities. Tests cannot determine which assumption is more appropriate.

of exports with pre-set prices exceeds 50% in only three of the 17 industries in Marston's study. Given the monthly frequency, it is somewhat surprising a larger share of products do not exhibit preset prices.

Froot and Klemperer's (1989) empirical framework can address both the first and third issues raised above. They test for the presence of cost effects (the only channel by which exchange rates affect prices in static models) and "interest rate effects" in price adjustment. The latter arise from dynamic considerations alone and exist only in the event of temporary exchange rate changes. The interest rate and cost effects work in opposite directions, so the fall in the dollar price of imports after a temporary appreciation will be less than after a permanent appreciation. The parameter estimates imply that *purely* temporary exchange rate changes lead to perverse price adjustment: as the dollar appreciates temporarily, foreign firms increase profit margins enough to more than offset the effect of the depreciation, leading to an increase in dollar import prices in this case. The authors cannot reject the null hypothesis that permanent changes in exchange rates leave relative prices across export markets unaffected, i.e., there is no PTM in the long run. It is fair to say that the evidence for both of these propositions is rather weak, given that very few specifications yield significant coefficients. The 1981-86 sample of annual observations may be too short to uncover true long run relationships, but provides the best chance for identifying the temporary/permanent distinction.

2.2 The multi-market framework

The empirical framework adopted here follows Knetter (1989). It is motivated by the first-order conditions of a monopolist selling to multiple 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 estimate for a 7-digit industry in a given source country can be written as follows:

$$(1)\ p_{it} = \theta_t + \lambda_i + \beta_i x_{it} + \gamma_i y_{it} + \varepsilon_{it}$$

where $i = 1,...,N$ and $t = 1,...,T$ index the destination market for exports and time, respectively, p is the log of destination-specific export price (measured in units of the exporter's currency at the port of export), x is 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), y is the log of income in the destination market and θ_t, λ_i, γ_i and β_i are (T+3N-1) parameters to be estimated.[22] The θ_t are coefficients corresponding to a set of time effects and the λ_i are coefficients corresponding to a set of destination market effects.[23] The error term, ε_{it}, is assumed to be independent and identically distributed with mean zero and variance σ^2_ε.

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 θ's) and unobservable factors that are constant over time but vary across individuals (captured by the λ's). The primary factor underlying the time

[22] 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. Both the exchange rate and income series for each destination is normalized around its mean before taking logs. Thus at the average values for these series, the (log of) price charged to any destination is given by the sum of the time and country effects.

[23] In estimation one of the time or destination effects must be dropped to avoid singularity. In this case, the destination effect for the U.S. will be dropped, thus the magnitude of the time effects will be normalized around the level of unit values of shipments to the United States. The country effects for other destinations will indicate the difference in unit values relative to the United States at average levels of the exchange rate and income.

effects is marginal cost of the exporter. It is likely that some common movement in prices is due to changes in the markup over marginal cost that are common to all destination markets.[24] The primary factor underlying the destination effects will be geography, trade policy and other institutional features of destinations that vary across countries but are constant over time. One can think of these factors as determining the "competitiveness" of the destination market and thus its average level of markup over cost. As written in equation (1), the model allows for the destination-specific response of prices to exchange rate and income changes to vary across destinations. Knetter (1992) shows that it is almost never possible to reject the hypothesis that the export price response to exchange rates is identical across destinations for a given industry. In accordance with that finding, equality constraints will be imposed on these coefficients in most of the estimation which follows.

The errors in equation (1) can arise for many reasons. Measurement error in the dependent variable is perhaps the primary source, since unit value data will be used to measure prices. Many of the theoretical models mentioned in Section 1 of the paper imply either non-linearities in the relationship between exchange rates and prices or that responses are conditional on the nature of exchange rate changes, so (1) may suffer from mis-specification as well. Nonetheless, the linear fixed effects model seems to be a sensible first pass at data from a wide range of industries. No single specification is likely to be best for all of them.

The statistical interpretation of the β'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

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[24] The model is linear in the parameters, whereas the equation (2.4) derived in Section 1.2 suggests an interaction between the time effects used to control for cost and the elasticity of price with respect to exchange rate changes. I have evaluated the non-linear version of equation (1) in Knetter (1991) and found the results to be similar to those obtained with the linear model. There were instances of convergence problems and implausible parameter estimates with the non-linear model, which may be attributable to the relatively high frequency of outliers in the unit-value data used in estimation. Thus, I will concentrate on the linear model in this paper.

through to the buyer apart from any possible impact they may have on the common marginal cost. Negative values of β 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, the exporter would reduce (increase) his markup by 5%. Assuming constant costs, the price paid in units of the buyer's currency would rise (fall) by only 5%. Positive values of β 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. The estimated value of γ would be interpreted similarly. It gives the destination-specific response of price to changes in destination market income. I will constrain the response of prices to real income changes to be identical across countries, in part to conserve on degrees of freedom.

The economic interpretation of the β's depends on what one assumes about market structure. Obviously, PTM cannot occur in a frictionless, competitive model of trade. Export market segmentation is a necessary condition for the existence of price discrimination in general and PTM in particular. Some possible explanations for segmentation were discussed in Section 1. Estimates of β reveal whether exporters in a given industry are attempting to offset the effects of currency fluctuations on prices, but we cannot be certain of the underlying reason for the behavior. The explanation is likely to differ by industry.

Before presenting the data and estimation, some discussion of dynamic and time series issues is in order. Work by Giovannini (1988), Kasa (1990) and Marston (1990) has addressed the dynamics of price responses with monthly data. Since annual data will contribute little to that debate, I ignore price adjustment lags. The appropriate dynamic specification of the model depends on the true time series properties of the variables. With only thirteen annual observations on price to each destination in each industry, it is impossible to uncover the true time series relationship between the variables. Here I will present the regressions in log levels. Two caveats should be kept in mind: (1) strictly speaking, these results should be interpreted as long-run relationships and (2) standard errors are suspect. The relationships are quite robust–similar estimates have been obtained using differenced data. Thus, we can be confident these are not spurious relationships, although we may not know the exact dynamic specification.[25]

2.3 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 from two source countries: the United States and Germany. The sample period is 1973-1987 for U.S. exports and 1975-1987 for German exports.[26] The data are taken from customs declaration forms at the port of export. The values are in units of the exporter's currency net of transportation, insurance and tariffs. That makes them ideal measures for price comparisons, provided the level of aggregation is fine enough. Data in the markets of final sale for the product may seem a better source of detailed price information, but price differentials on products in different locations do not provide good evidence on PTM, since trade barriers and transportation costs can inhibit arbitrage within a range of prices and retail competition may differ across countries.

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.[27] The aim in choosing large export destinations is to improve the accuracy

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[25] Gagnon and Knetter (1991) have estimated an error correction version of equation (1) for the auto industry and found the short run and long run estimates of PTM to be similar.
[26] The only important exceptions are U.S. exports of photographic film and switches, which are for the period 1978-87. Changes in product categories precluded a longer sample.
[27] For German exports the destination markets always include the United States. Other common destinations are France, the United Kingdom, Japan, Canada, Sweden, and Italy. For U.S. exports the most common destinations are Canada, United Kingdom, Germany, Japan, Australia and Sweden.

of the unit values (the value of exports divided by the quantity) as a measure of price and to minimize the number of periods in which price is not observed because of a lack of shipments. These criteria for data collection imply that sampling over destinations is not random. As a result, caution should be taken in drawing inferences about other trading relationships.

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. The data are available at higher frequencies in some cases. In the United States and Germany, they are available monthly. The choice of annual frequency reflects primarily the need to economize on data collection effort. Lower frequencies may actually be preferred in constructing unit values, since 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 independent 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 rationale 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 and real GDP data (used for the income series) are annual averages taken from *International Financial Statistics*. The specific industries selected and the data sources for the unit value data are listed in the data appendix.

2.4 Estimation and Results

Equation (1) is estimated by pooling the data across destination markets for a given export industry in the source country. Thus, each of the 60 German industries and 18

U.S. industries constitutes a separate panel on which pricing behavior across markets is estimated. A Gauss-Newton procedure is used which minimizes the total sum of squared residuals across time and destinations. The method is equivalent to maximum likelihood provided that the errors are assumed to be normally distributed, uncorrelated across equations and over time, and have equal variances. Estimation of an unrestricted covariance matrix is precluded by the presence of a full set of time dummies in estimation.

I will estimate three separate versions of Equation (1) for the German industries. Model (1) imposes the constraint that the response of prices to exchange rate innovations is identical for all destinations, i.e., the degree of PTM is independent of destination. Model (2) imposes the same constraint, but drops the U.S. data from the sample of German destinations in each industry. Model (3) relaxes the constraint of identical price adjustment across destination markets and uses data for all destinations. My reasons for considering these different versions of Equation (1) are to examine the robustness of the findings on PTM and to focus on whether the U.S. data in particular drives the results, either due to the comparatively large fluctuations in the dollar against the D-Mark or because pricing behavior differs.[28]

The results for the German industries are presented in four Tables, 1A-1D. I have grouped the industries into four categories: consumer products (Table 1A), steel and other metal products (1B), other industrial products (1C), and chemical products (1D). The divisions are not always clear, but may nonetheless be useful in organizing the evidence and helping connect the results on PTM to the theories discussed in Section 1. In order to keep the focus on how exchange rates affect pricing, I report only the estimates of β and a

[28] The results of previous research by Mann (1986), Giovannini (1988), Knetter (1989), Marston (1990) and Ohno (1989) taken together suggested much more PTM by non-U.S. exporters than by U.S. exporters. While this may suggest different behavior, it may also be due to a U.S. "destination effect". Knetter (1992) finds no real evidence of a U.S. effect on a smaller data set than that considered here.

couple of diagnostic statistics for each model in each industry. It is impractical to report all of the time and country effects for each industry.

Choosing Between the Models

First, consider the difference in results across the alternative models that are estimated. In comparing the estimates of PTM obtained with and without the U.S. data (i.e., Model 1 vs. Model 2), there do not appear to be important systematic differences between the two. Although the estimated values of β in Model 1 reveal more evidence of PTM, there are only five instances of sign reversals in the four tables, only two of which are of substantial magnitude (two chemicals: hydrocarbons and hydrogen). The inclusion of U.S. data appears to sharpen the finding of PTM for consumer products, steel, and chemicals, but not for other industrial products. Most striking is consumer products, in which, absent the U.S.data, there is hardly any evidence of PTM in the standard sense (i.e., negative βs indicating stabilization of prices in local currency).

To the extent the U.S. data increase measured PTM in steel, it may be due to the fact that trade restrictions on various steel products in the U.S. market during this period caused dollar prices of imports to be more rigid than otherwise, necessitating PTM on the part of German exporters. In chemicals, geographically distinct regions may be a necessary condition for price differentials to arise. Products may be sufficiently homogeneous that without the U.S. market in the sample, correlation between price differentials and exchange rates is weakened.[29] Although trade policy and geography might explain the differences in these categories, in consumer products that seems less likely. The United States is not noted for particularly restrictive quantitative policies on consumer products, nor does the Atlantic Ocean seem necessary to maintain price differentials across countries–as it may be in primary chemical products.

[29] Note, however, that the evidence of PTM remains quite strong even without U.S. data.

In comparing Model 1 against Model 3, where β can vary by destination, the F-statistic reported beneath the parameter estimate for Model 2 allows a direct test between the two models. In consumer and other industrial products, the data reject the constraint in most cases. In steel products the industries are split evenly across the alternatives, whereas most chemical products accept the restriction.[30] The ramifications of choosing one model over the other are not great, except for consumer goods and steel, where the preponderance of products point toward the unrestricted Model 3, which in turn usually implies more PTM in the U.S. market than the common estimate from Model 1.

Beneath the estimates of β from Model 3, I report the Durbin-Watson statistic from the residuals in the U.S. destination pricing equation. Under the null hypothesis, the autocorrelation pattern should not differ across destinations, but since DW statistics are calculated for each destination in regression output, I report the U.S. DW statistic in all cases.[31] There is fairly strong evidence of positive autocorrelation in the residuals for some consumer and industrial products, but little in steel and chemicals.

There are a number of possible reasons why one might expect autocorrelation of residuals to arise. First, it could result from measurement error in the dependent variable. A sporadic outlier that is correlated with a large exchange rate movement may cause positive autocorrelation. Second, unmodelled dynamics in price adjustment may cause price adjustment to be related to past exchange rate changes. This might be particularly important in products like autos with infrequent price adjustment.[32] Since positive autocorrelation does not seem to be a pervasive problem, I have not attempted to correct for

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30 These results differ from Knetter (1992), in which the constraint of a common β was nearly always accepted by the data. Those tests were based on data in first-differences. Part of the change in results may be due to a weaker relationship in the differenced data, since there is more noise in the short-run than the long-run response to exchange rate changes.

31 I have used a small sample correction factor of (t/(t-1)) to the d-statistic since there are only 13 time series observations.

32 The observation of positive autocorrelation for auto pricing equations across a number of source countries was the motivation for Gagnon and Knetter's (1991) error correction estimation.

it in this work. The appropriate response is likely to vary by industry, so that a serious pursuit of this issue would detract from discussion of pricing policies in the large. The DW stats are not so low as to raise concern that the regressions are spurious.

Evidence on Pricing to Market

Let me now consider what the data seem to show about the pattern of pricing to market across industries. I will begin with the parameter estimates for the German data. For Germany, I will concentrate most of my discussion on the parameter estimates for the constrained model, with the caution that in some cases that model is rejected by the data.[33] Recall that negative values of β 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% depreciation (appreciation) of the buyer's currency, the exporter would reduce (increase) his markup by 5% relative to the markup charged to other destination markets. Positive values of β imply that destination-specific markup adjustment amplifies the effect of exchange rate changes on the local currency price.

The evidence for conventional PTM is remarkably weak in consumer goods industries for German exports. By "conventional PTM" I mean markup adjustment that would stabilize prices in the local currency relative to a constant markup policy. Notice that for large autos, markup adjustment has a destabilizing effect on price. This is also true for several other products, although we should note that the U.S. βs in Model 3 for alcoholic beverages tends to show more PTM than those in the constrained model.

Let me offer three reasons why we might observe positive βs. First, measurement error may bias β upward. If product categories include many varieties and more expensive varieties have less elastic demand, β's will be biased upward by measurement error that is

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[33] Even in cases of rejection, the coefficient still captures a rough average of the degree of PTM across destinations, with the country-specific estimates being somewhat more disperse around the average in those cases.

correlated with exchange rates. When the exporter's currency is weak, cheaper varieties make up a larger share of export quantities, by assumption of more elastic demand. Unit values would give the appearance of destabilizing markup adjustment even if all varieties have constant elastic demand and therefore constant DM prices. Second, if market share matters and much of the movement in exchange rates is temporary, then interest rate effects dominate cost effects, and we may observe positive βs. Third, under some demand conditions an "opportunistic" pricing strategy is optimal. Suppose there are "Beck's drinkers" and "beer drinkers", the former with inelastic demand for Beck's and the latter which view it as having close substitutes. When the DM is weak, Beck's lowers its markup to sell to beer drinkers. When the DM is dear, they sell only to Beck's drinkers at a high price.

Regarding the results for German consumer products, the possibility of bias must be taken seriously, especially in autos where product heterogeneity is greatest. Even so, other evidence on prices and sales in the U.S. auto market confirm a basic qualitative finding of the table. Market shares of German producers have fallen much more in the large, high-quality end of the auto market (e.g., Porsche) with the fall in the dollar since 1985. This is consistent with the estimated degree of PTM near zero in Table 1A combined with the entry of new Japanese producers in that segment of the market. German cars in the smaller end of the market have not lost as much market share, again consistent with the markedly higher degree of PTM in those categories.[34]

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[34] Since people often associate PTM with German auto pricing due to an anecdote by Krugman (1987) regarding gray markets, I feel compelled to point out that these estimates only imply that price differentials between the U.S. and *other export markets* do not appear to be sensitive to exchange rates. It is entirely possible that (1) differentials between the U.S. and German domestic price fluctuate with exchange rates (the domestic market is not part of my comparisons here) and/or (2) differentials exist that are not related to exchange rates. The fact that one can still find advertising for "chop shops" to modify autos produced for sale in Europe suggests that the gray markets of the mid-80s may have been more than an exchange rate-induced phenomenon.

There is robust evidence of PTM in two auto accessory categories: tires and fan belts. PTM in sandals and blouses seems to be a robust finding across specifications as well. The positive estimates of PTM in cocoa, olive oil, and razor blades are puzzling. The correlations are robust across specifications for the most part and it is not obvious that the explanations for positive βs are relevant. Generally speaking, this evidence is weaker than the evidence of PTM in Japanese consumer goods exports that is presented in Marston (1990) or Knetter (1992). Since the market constraints are likely to be similar, this may be a sign of different pricing strategies across Japanese and German consumer goods exporters.[35] Perhaps Japanese consumer goods exporters take a longer view than their German counterparts, using pricing strategies that stabilize local currency prices. On the other hand, they may simply face (or fear) more trade restrictions.

Moving to Table 1B, there is rather strong evidence of PTM in steel products. Products are more narrowly defined in these cases, so measurement error is much less of an issue. Parameter estimates appear to exhibit more stability across the models, with the exception that PTM to the U.S. market may be more pronounced. Nonetheless, for a large share of the industries, price adjustment offsets 50% or more of the effect of exchange rate changes on prices. In 13 of 14 cases, the estimated value of β for the U.S. is negative, while β is negative in 10 of 14 industries in Model 1. As noted earlier, the disparity across those specifications may be a consequence of trade restrictions that were prevalent in the U.S. steel market beginning in the 1970s and continuing into the 80s.

The results in Table 1C show less evidence of PTM. Ceramic tile, glazed and unglazed, ornamental ceramics, and unprocessed glass balls and tubes all have robust estimates of PTM in the neighborhood of 50% or more. The estimates for most other products are indistinguishable from zero.

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35 I should note that Marston's evidence comes from price indices in which the upward bias described for unit values could not apply.

Table 1D reports PTM for 17 chemical products. The evidence clearly indicates that PTM is an important phenomenon. This is surprising, since we think of many of these products as relatively homogeneous and easy to transport. The observation that price differentials can vary with exchange rates as much as the data suggest signals market segmentation. Those skeptical of this evidence need only consult issues of *Chemical Marketing Reporter* or other trade publications during the mid 1980s. Reports of price differentials between the European and North American markets were numerous and usually attributed to exchange rates. These findings are probably no more surprising than Giovannini's estimates of price discrimination in Japanese ball bearings, nuts and bolts, etc.

Table 2 presents the estimated values of β for 18 U.S. export products. Two raw commodities, yellow corn and raw cotton, are included in part as a check on the method. We would be skeptical of the data or method if these industries revealed large price differentials on average or strong evidence of PTM. In fact, the estimated country effects for these products reveal average price differentials across destinations of no more than 5%. The estimates of PTM are virtually zero, as reported in the table. This is the answer one would expect for a homogeneous agricultural commodity.

Both the consumer and chemical/industrial products categories tell a very similar story. There is almost no evidence of PTM in the data. The exceptions are photographic film, industrial lacquers and two types of paper. For nearly all other categories, the estimated values of β are positive or virtually zero. This is consistent with Mann's (1986) work and subsequent work of my own on U.S. exporter behavior. I have argued elsewhere that although nearly all studies are in agreement on this basic fact, there is very little evidence that U.S. firms behave differently than foreign firms in the same industry. Formal statistical tests in Knetter (1992) cannot reject identical price adjustment to exchange rate changes across source countries within an industry.

Exact industry matches are rare when comparing the U.S. and German data presented here, although a few comparisons are possible. U.S. price adjustment behavior in bourbon is similar to what I find in alcoholic beverages generally for Germany. The estimated behavior in autos is also indistinguishable from what we find for large German autos. Aluminum oxide and titanium oxide price adjustment in the U.S. does differ markedly from the estimated behavior for German exports.

While it may be tempting at first glance to conclude that the evidence confirms the view that U.S. export pricing policies validate the thesis of "short-term" behavior of American industry, that is not a legitimate conclusion. These results do not say anything very conclusive about *country-specific* differences in pricing "strategies" across U.S. and German exporters. It is clear, however, that pricing behavior in the U.S. industries studied here is quite different than what we observe in the German export industries. PTM does not appear to be commonplace in U.S. manufacturing exports.[36] That may only suggest that U.S. manufacturing exports are concentrated in industries in which little PTM is possible. Industry-mix effects may explain low pass-through on U.S. imports and relatively high pass-through on U.S. exports.

3. Conclusion

In summary, the data show that PTM is a strategy that is widely adopted in manufacturing exports in a sample of German export industries, but far less common in U.S. export industries. Within the German export industry sample, PTM was lower than expected in consumer goods industries and relatively high in steel and chemicals. Given that price discrimination can be maintained in the latter categories, it is quite possible that

[36] Regrettably, the unit value data are at a severe comparative disadvantage vis-a-vis price indices for examining PTM in high technology industries. The quality change and product innovation in those fields makes unit values poor measures of price. As a result, such industries are not considered in the data set.

measurement error due to quality change that is correlated with exchange rate fluctuations may bias the unit value data against the finding of PTM in consumer goods. Within the sample of U.S. export industries, only four of 18 showed any indication of PTM. Whether there is any country-specific relationship is not clear, since there is wide variation in behavior across industries and little overlap of industries across countries in the data sample.

The mapping between theoretical models of PTM and empirical estimates is very difficult. At present, the literatures are far apart. Empirical work has primarily assembled facts that can be compared with implications of various theories, without providing conclusive tests of them. While this is useful, future empirical research on PTM and pass-through should take the form of detailed studies of individual industries that attempt to account for trade restrictions and other factors that have been largely ignored in the literature to date.

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TABLE 1A. Estimates of PTM Coefficient β: Results for German Exports

Industry	Model 2 β(s.e.)	Model 1 β(s.e.)	Model 3 β_{US}(s.e.)
CONSUMER PRODUCTS			
Beer	-0.09(0.21)	-0.19(0.21) F=14.03*	-0.57(0.17) DW=0.75
White wine	0.10(0.10)	0.01(0.08) F=7.45*	-0.22(0.02) DW=1.08
Sparkling wine	0.68(0.35)	0.42(0.33) F=2.55	-0.18(0.32) DW=1.77
Olive oil	0.36(0.23)	0.36(0.17) F=4.44*	0.02(0.20) DW=0.93
Cocoa powder	0.46(0.14)	0.15(0.19) F=1.87	-0.21(0.23) DW=1.08
Sandals	-0.48(0.49)	-0.34(0.26) F=6.56*	-0.57(0.15) DW=0.52
Blouses	-0.26(0.31)	-0.20(0.27) F=9.88*	-0.27(0.14) DW=1.87
Record players	0.12(0.35)	-0.06(0.34) F=0.35	-0.02(0.45) DW=1.08
Razor blades	0.72(0.46)	0.60(0.39) F=1.65	0.08(0.27) DW=2.20
Fan belts	-0.76(0.15)	-0.43(0.12) F=7.74*	-0.56(0.12) DW=1.77
Autos under 1L.	-0.63(0.18)	-1.06(0.21) F=4.30*	-1.00(0.18) DW=2.55
Autos 1.5-2 L.	-0.23(0.21)	-0.56(0.20) F=3.94*	-0.65(0.22) DW=0.85
Autos 2-3 L.	0.12(0.15)	-0.05(0.14) F=9.14*	0.03(0.11) DW=0.97
Autos over 3 L.	0.59(0.17)	0.44(0.18) F=6.97*	0.03(0.13) DW=1.48
Pneumatic tires	-0.33(0.12)	-0.47(0.11) F=1.16	-0.66(0.14) DW=2.29

* : reject constraint at 5% level.

NOTES: All models are based on estimates of Equation (1) in Section 2.2. Model 1 constrains the value of β to be identical across export destinations. The reported F-values test this constraint against the unconstrained Model 3. I report the Durbin-Watson statistic for the U.S. price equation for Model 3. Model 2 is the same as Model 1 except the United States is eliminated as a destination of shipments to explore the sensitivity of PTM to the inclusion of U.S. data. In all models γ is constrained to be the same across markets.

TABLE 1B. Estimates of PTM Coefficient β: Results for German Exports (cont'd)

Industry	Model 2 β(s.e.)	Model 1 β(s.e.)	Model 3 β_{US}(s.e.)
STEEL AND OTHER METAL PRODUCTS			
Semi-gold plate	-0.63(1.60)	-0.43(0.33) F=1.49	-0.77(0.32) DW=2.67
Gas cont., steel	-0.29(0.26)	-0.60(0.09) F=6.75*	-0.49(0.10) DW=1.82
Aluminum rods	0.15(0.12)	0.01(0.11) F=4.86*	-0.03(0.15) DW=2.55
Barbed wire,thin	-0.56(0.17)	-0.80(0.10) F=2.85*	-0.94(0.12) DW=1.96
Barbed wire,med.	-0.42(0.10)	-0.76(0.09) F=6.65*	-0.72(0.09) DW=2.14
Barbed wire,thick	-0.70(0.10)	-0.80(0.25) F=0.27	-0.66(0.21) DW=1.12
Steel containers	-0.21(0.29)	-0.28(0.26) F=4.10*	-0.59(0.21) DW=1.77
Steel rails	-1.14(2.00)	-0.15(0.44) F=1.82	-0.55(0.49) DW=1.21
Iron&steel cans	-0.36(0.11)	-0.59(0.13) F=2.67	-0.72(0.16) DW=0.55
Rivets	-0.26(0.21)	-0.24(0.20) F=5.09*	-0.21(0.18) DW=1.58
Steel wire	0.22(0.20)	0.17(0.22) F=0.19	0.12(0.41) DW=1.87
Platinum plating	0.20(0.13)	0.07(0.14) F=3.91*	-0.12(0.15) DW=0.78
Platinum,semi-fin	-0.11(0.27)	-0.23(0.26) F=0.85	-0.44(0.27) DW=1.03
Nails	0.44(0.57)	0.18(0.42) F=2.80*	-0.39(0.36) DW=2.10

* : reject constraint at 5% level.
NOTES: All models are based on estimates of Equation (1) in Section 2.2. Model 1 constrains the value of β to be identical across export destinations. The reported F-values test this constraint against the unconstrained Model 3. I report the Durbin-Watson statistic for the U.S. price equation for Model 3. Model 2 is the same as Model 1 except the United States is eliminated as a destination of shipments to explore the sensitivity of PTM to the inclusion of U.S. data. In all models γ is constrained to be the same across markets.

TABLE 1C. Estimates of PTM Coefficient β: Results for German Exports (cont'd)

Industry	Model 2 β(s.e.)	Model 1 β(s.e.)	Model 3 β_{US}(s.e.)
OTHER INDUSTRIAL PRODUCTS			
Coated paper	-0.26(0.29)	0.03(0.15) F=3.78*	0.18(0.12) DW=2.81
Wicks, soaked	0.32(0.31)	0.03(0.20) F=14.78*	0.06(0.26) DW=0.47
Glass balls&tubes	-1.10(0.41)	-1.07(0.26) F=8.02*	-1.28(0.22) DW=1.32
Electric heaters	0.87(0.25)	0.51(0.22) F=11.38*	-0.02(0.14) DW=1.69
Ceramic tiles	-0.50(0.06)	-0.46(0.07) F=4.46*	-0.20(0.12) DW=2.20
Cer. tile, glazed	-0.62(0.16)	-0.36(0.13) F=3.08*	-0.15(0.15) DW=1.78
Glass panels	0.11(0.50)	0.10(0.37) F=2.67*	0.26(0.20) DW=1.54
Fireproof tiles	-0.18(0.13)	-0.13(0.15) F=3.92*	0.06(0.18) DW=0.73
Ornam. ceramics	-0.48(0.46)	-0.48(0.38) F=1.01	-0.57(0.29) DW=1.44
Induct. furnaces	-0.12(0.20)	-0.08(0.18) F=0.55	-0.17(0.17) DW=1.10

* : reject constraint at 5% level.

NOTES: All models are based on estimates of Equation (1) in Section 2.2. Model 1 constrains the value of β to be identical across export destinations. The reported F-values test this constraint against the unconstrained Model 3. I report the Durbin-Watson statistic for the U.S. price equation for Model 3. Model 2 is the same as Model 1 except the United States is eliminated as a destination of shipments. In all models γ is constrained to be the same across markets.

TABLE 1D. Estimates of PTM Coefficient β: Results for German Exports (cont'd)

Industry	Model 2 β(s.e.)	Model 1 β(s.e.)	Model 3 β_{US}(s.e.)
CHEMICAL PRODUCTS			
Organic compds.	-0.22(.25)	-0.36(0.19) F=1.11	-0.22(0.16) DW=2.21
Aluminum hyd.	-0.16(0.31)	-0.42(0.18) F=1.49	-0.41(0.27) DW=1.17
Titanium pigmt.	-0.55(0.14)	-0.69(0.12) F=1.40	-0.85(0.17) DW=1.14
Titanium diox.	-0.40(0.18)	-0.67(0.18) F=1.87	-0.96(0.15) DW=2.25
Vitamin A	-0.40(0.58)	-0.37(0.38) F=3.24*	-0.02(.30) DW=1.34
Vitamin C	-0.11(0.04)	-0.12(0.05) F=0.72	-0.15(0.07) DW=2.01
Synthetic dyes	-0.39(0.15)	-0.33(0.09) F=16.07*	-0.30(0.07) DW=1.90
Special dyes	-0.48(0.17)	-0.39(0.26) F=1.01	-0.18(0.32) DW=2.15
Aluminum ox.	-0.56(1.06)	-0.89(0.68) F=1.03	-0.48(0.50) DW=1.65
Aldehyde deriv.	1.10(0.52)	0.65(0.27) F=0.29	0.45(0.24) DW=2.08
Manganese ox.	0.55(0.24)	0.47(0.25) F=1.55	0.03(0.39) DW=1.36
Aromatic ketones	-0.26(0.27)	-0.35(0.22) F=2.20	-0.38(0.24) DW=1.85
Hydrocarbons	0.27(0.19)	-0.67(0.16) F=7.14*	-0.82(0.14) DW=2.08
Hydrogen	1.12(0.21)	-0.37(0.15) F=8.95*	-0.16(0.19) DW=1.66
Glykocides	0.07(0.17)	0.01(0.14) F=6.63*	0.04(0.12) DW=0.85
Oleic acids	-0.81(0.29)	-0.87(0.24) F=1.27	-0.96(0.26) DW=1.54
Calcium, barium	0.47(0.43)	0.36(0.17) F=4.95*	0.02(0.20) DW=0.50

NOTE: See previous page for full explanation of table entries.

TABLE 2. Estimates of PTM Coefficient β: Results for U.S. Exports

	Model 1
Industry	β(s.e.)
RAW COMMODITIES	
Yellow corn	-0.01(0.05)
Raw cotton	0.07(0.10)
CONSUMER PRODUCTS	
Cigarettes	0.32(0.15)
Bourbon whiskey	0.07(0.20)
Aluminum foil	0.10(0.49)
Photographic film	-0.33(0.38)
Autos over 8 cyl.	-0.06(0.19)
Autos under 8 cyl.	0.00(0.10)
CHEMICAL/INDUSTRIAL PRODUCTS	
Aluminum oxide	1.53(0.32)
Titanium dioxide	1.07(0.50)
Nitrile rubber	0.21(0.23)
Industial lacquers	-0.36(0.42)
Putty	-0.09(0.44)
Kraft linerboard paper	-0.24(0.11)
Photocopier paper	-0.40(0.44)
Primary cell batteries	0.22(0.63)
Integrated circuits	0.81(0.53)
Snap-action switches	1.99(0.64)

NOTES: Model (1) is based on Equation (1) in Section 2.2, but constrains the value of β to be identical across export destinations.