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GOODS PRICES AND EXCHANGE RATES: WHAT HAVE WE LEARNED?

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ABSTRACT

Import prices typically change by a smaller proportion than the exchange rate between the exporting and importing country. Recent research indicates that common-currency relative prices for similar goods exported to different markets are highly correlated with exchange rates between those markets. This evidence suggests that incomplete pass-through is a consequence of third-degree price discrimination. While distance matters for market segmentation, borders have independent effects. The source of the border effect has not been clearly identified. Furthermore, there is little evidence yet to suggest substantial market power is implied by the observed price discrimination.

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I. Introduction

By the standards of the post-Bretton Woods era, the 1990s have been a period of calm in foreign exchange markets. But even in this relatively quiet period, there have been some notably large fluctuations in currency values. Consider the recent swing in the Japanese Yen/U.S. $ exchange rate. On January 5, 1994, the dollar was worth 113 Yen, while by April 19, 1995, it was worth only 80 Yen. This represented a 34% appreciation of the Yen against the dollar.

An economist who hadn't lived through the turbulence of the foreign exchange market in the 1970s and 80s might worry about the implications of such a large swing in currency values for these countries. An appreciation of the Yen against the dollar of this magnitude would seem to require a dramatic change in either productivity growth or relative wages in order to avoid large fluctuations in the output of tradable goods between these two countries. In the absence of differences in productivity growth or wage inflation, labor costs in Japan relative to the U.S. would increase by the full amount of the Yen appreciation against the dollar.

So what happened? Well, industrial production per manufacturing employee in Japan and the U.S. grew by 9% and 5%, respectively, while manufacturing wages grew by 4.1% in Japan and 2.5% in the U.S.[1] These differentials in productivity growth and wage inflation, combined with the Yen appreciation imply that labor costs fell by about 30% in the U.S. relative to Japan during this period. In a world where agents respond to incentives, one might expect tremendous substitution of U.S. for Japanese labor in manufacturing. As it turns out, seasonally adjusted measures of industrial production grew by 6% in Japan compared to only 5% in the

[1] Data on indices of industrial production, manufacturing employment, and wages are from the United Nations' *Monthly Bulletin of Statistics* and the International Monetary Fund's *International Financial Statistics*.

United States over the five-quarter period of the currency swing. Why didn't Japanese output of traded goods collapse relative to the U.S. and other countries?

A large part of the answer is provided by the fact that foreign buyers of Japanese products did not experience substantial price increases in spite of the sharp increase in Japanese labor costs. For example, in 1994, a Toyota Celica ST Coupe made in Japan sold in the U.S. at $16,968. In 1995, the same Celica cost $17,285, a price increase of less than 2%.[2] Even more surprisingly, the suggested retail price of a large-screen SONY Trinitron actually *fell* by 15% in the U.S. between 1994 and 1995.[3] In the jargon of international economists, there was incomplete (or in the case of the Trinitron, negative) "pass-through" of exchange rates to imported goods prices.

Why was there so little change in the dollar price of imports associated with this Y/$ exchange rate change? Was the response simply delayed? Did Japanese exporters perceive the exchange rate change to be only temporary?[4] Does incomplete pass-through imply that Japanese producers slashed markups to the U.S.? Or did they find new ways to offset their increased dollar-equivalent costs? What happened to the prices of Japanese products sold domestically or to other countries? What can we learn about the nature of competition in international product markets from observations on prices and exchange rates? Do trade policies exert substantial influence on the equilibrium adjustment of firms? It is to these and other related questions that this article is addressed.

Empirical research on the relationship between exchange rates and goods prices has been abundant since the 1970s. After correcting for double-counting, an Econ Lit Database search turned up nearly 700 entries for articles covering a few key topics relating to exchange rates and goods prices.[5] The primary goal of this paper is to provide a unifying framework for research on

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[2] Celica prices are from *The Car Book*, by Jack Gillis.

[3] Price information provided by Michael's Radio and TV in Hanover NH. The large screen Trinitron is actually assembled in San Diego, but most parts, and thus value added, still come from Japan.

[4] Indeed, the Yen had retreated back to about 110 to the dollar as of late November 1996.

[5] Our search covered the Law of One Price, Purchasing Power Parity, Exchange Rate Pass-Through, and Pricing-to-Market.

these topics, while highlighting the unique features of each of them. A secondary goal is to examine two issues of current interest that the literature on exchange rates and goods prices has not adequately resolved: the causes of market segmentation and the measurement of market power. Since many of the issues covered in this survey overlap with similar inquiries in industrial organization, we will attempt to describe the connections between current empirical work in international product markets and related work in industrial organization.

To preview our findings, it appears that the local currency prices of foreign products do not respond fully to exchange rates. While the response varies by industry, a price response equal to one-half the exchange rate change would be near the middle of the distribution of estimated responses for shipments to the U.S. A significant portion of the muted price response can be attributed to destination-specific changes in markups on exports. Less is known about the relationship between costs and exchange rates, but increased foreign outsourcing means a decline in the share of costs incurred in the home currency, which can further mute the pass-through relationship. The adjustment of markups to exchange rates may be delayed, but recent estimates using micro data put the delays well under one year for most products. Research is ongoing to determine the sources of market segmentation and the degree of market power implied by price discrimination in international markets.

II. Integration and Segmentation: Definitions and Evidence

It matters a great deal for thinking about exchange rates and goods prices whether markets are integrated or segmented. We define an integrated market as one in which geography and/or nationality do not have systematic effects on transaction prices for otherwise identical products. Gold is a good example–the location of buyers and sellers is virtually irrelevant to the terms of the transaction.

Segmentation refers to a lack of integration. A product market is geographically segmented if the location of the buyers and sellers influences the terms of the transaction in a

substantial way (i.e., by more than the marginal cost of physically moving the good from one location to another). The market for automobiles, for example, is segmented for a variety of reasons. Automobiles purchased in a foreign market may be assessed additional taxes at the border and may not comply with safety and environmental regulations in the home market. Furthermore, warranties and service are often linked to the location of purchase. By making resale across nations costly, these factors permit nearly identical automobiles to sell for different prices in two markets without inducing profitable third-party arbitrage. The location of the buyer and the seller clearly affects the transaction beyond the marginal transportation cost.

Arthur Pigou's (1920) concept of third-degree price discrimination delineates integrated and segmented goods markets in an operational way. Third-degree price discrimination is present when different groups of consumers pay different prices for identical goods. Thus, two national markets are segmented if buyers in those markets face systematically different common currency prices for the same product.[6] If German and American customers pay different prices for similar Toyota Celicas, net of transportation costs, then the market for Celicas is segmented.[7]

It is worth emphasizing the relationship between integration and segmentation and the nature of competition. Any perfectly competitive market is characterized by the condition that price equals marginal cost. Therefore a perfectly competitive market must be integrated. A segmented market implies the existence of market power; since buyers face different prices, not all buyers face a price equal to marginal cost. However, a market that is integrated may or may not be perfectly competitive. A monopoly supplier of a commodity may charge a price above marginal cost, but be incapable of price discrimination if buyers are well organized or the product is easily transported across markets.

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[6] Conceptually, it is the *ability* to price discriminate that would dictate whether a market is segmented, not the *observation* of discrimination. We ignore cases where price discrimination is not observed (due to identical demand elasticities in the segmented markets) but could in principle occur.

[7] Our emphasis on third degree discrimination is not intended to suggest that finer degrees of price discrimination do not occur. It is quite possible there is additional discrimination among buyers within a single country, but we are not able to detect this in the international price data.

We now analyze three related strands of literature on goods prices and exchange rates: the law of one price, exchange rate pass-through, and pricing-to-market. The various phases of research resulted from theoretical advances and institutional changes which altered the research questions over time. A single empirical framework accommodates all three literatures. Distinctions among them arise from the specific price series selected as the dependent variable and the choice of independent variables that are included in addition to exchange rates.

A. The Law of One Price

Our operational definition of market integration is what international economists call the Law of One Price (LOP): identical products sell for the same common-currency price in different countries. The assumptions required for the LOP to hold are profit maximization and costless transportation, distribution, and resale. Let p denote the home currency price in country H, p^* the home currency price in country F, and E the exchange rate of H's currency per unit of F's. If the LOP holds for some good i, then:

$$(1) p_i = Ep_i^*$$

If the LOP held for all countries for some product (e.g., gold) we would characterize this as an *integrated world market*. If the LOP held for all products between two countries then the *absolute* purchasing power parity (PPP) theory of exchange rates would hold between these two countries:

$$(1') P = EP^*$$

where P and P* are price levels in countries H and F.

Since the assumptions of costless transportation, distribution, and resale are unlikely to hold in practice, the absolute versions of the LOP and PPP are often modified. Suppose costs of

transportation or resale (such as trade barriers) preclude price equalization, but that the frictions give rise to a stable price differential across two markets. In this case, we have:

(2) $p_i = \alpha E p_i^*$, and

(2') $P = \alpha E P^*$

where α is the real (product) exchange rate or, alternatively, (α x 100) is the home currency price (level) as a percentage of the foreign. If α remains constant over time, then common currency prices for a particular product (or market basket) change in the same way over time in two countries, and the *relative* LOP (PPP) holds.

The open economy monetarist model, which gained popularity in the 1960s and early 1970s, relied on an assumption like (1') or (2') to tie down the behavior of exchange rates. The emergence of global monetarism as a serious macroeconomic paradigm stimulated research on the validity of this assumption. Kenneth Rogoff (1996) provides an excellent review of theory and evidence on PPP. We concentrate here on studies of the LOP.

Consider the following generic regression model which will be used to discuss all three areas of research on prices and exchange rates:

(3) $p_t = \alpha + \delta X_t + \gamma E_t + \psi Z_t + \varepsilon_t$

where all variables are in logs and p is price for a particular product, X is the primary "control" variable (a measure of cost or price, depending on the type of study), E is the spot exchange rate, Z denotes other control variables in the model, ε is an error term, and t denotes time period.

Research on prices and exchange rates varies with respect to the choice of p , X, and Z. Tests of the LOP specify X to include another measure of price for the same product, say p^*. Distinctions among papers then center on the selection of transactions for which prices are measured and the degree to which they satisfy the identical goods assumption. The absolute

version of the LOP stated in equation (1) offers predictions for three parameters in equation (3). If the prices are measured in different currency units, then this version of the LOP implies that $\alpha = 0$, $\delta = 1$, and $\gamma = 1$, where E is the exchange rate between the two countries where prices are measured. If the price measures are already in units of the same currency, then the LOP implies $\alpha = 0$, $\delta = 1$, and $\gamma = 0$.[8]

Researchers typically test the relative version of the LOP given by (2) for three main reasons. First, arbitrage is not costless. There are costs of gathering information, transporting goods, and perhaps crossing borders. Complete equalization of prices may be implausible. A second reason concerns the validity of the "identical" goods assumption. Among the crucial characteristics of a transaction are: the seller/producer, the buyer, the location at which ownership is transferred and price is measured, the physical characteristics of the product, and other non-price terms of the transaction, such as the delivery date and the invoice currency. Ideally, a test of the LOP would compare prices for two transactions in which the nationality of the buyers is the only difference in transaction characteristics. In practice, the identical goods assumption is almost surely violated to some degree in available data. Finally, the most commonly available information on prices is in the form of price indices in different countries. When indices are used to measure p and p^*, the levels are arbitrary.

It is clear how testing equation (2), which allows an arbitrary constant, alleviates the problem of using price indices. It is perhaps less evident why this modification accommodates product differentiation. Implicitly, these tests rely on George Stigler's (1987) refinement of price discrimination: Price discrimination exists when two or more similar goods are sold at prices which are in different ratios to their marginal costs. Stigler argued, for example, that binding costs were not sufficient to explain the difference in price between hardcover and paperback books. Empirical studies of the LOP are based on the same idea. If the common-currency relative price of a good fluctuates over time between two markets, that is taken as evidence

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[8] Many papers on the LOP, because they are tests of an arbitrage condition rather than estimates of a pricing model, do not include any additional controls (i.e., Z is empty).

against integration of the markets. The implicit assumption is that the relative costs are not changing enough to account for the price variation.

While an arbitrary constant can help mitigate the problems arising from the use of price indices and the possibility of non-identical goods, it may not be a good fix for the presence of trade frictions. Although some frictions, such as tariff or non-tariff trade barriers, may have the effect of inducing a stable price premium in one market, other frictions, such as transportation costs, merely allow prices to differ within some range without inducing profitable arbitrage. The hope is that frictions of the later sort will only introduce some noise into the relationship.

As noted by Rogoff (1996), researchers have tested and rejected the law of one price for a variety of products and countries, using a variety of data sources and empirical methods. The principle source of evidence against the LOP comes from the regression coefficient γ in equation (3). Irving Kravis and Robert Lipsey (1977), Peter Isard (1977), J. David Richardson (1978), and Alberto Giovannini (1988) are examples of work in this area. The LOP is rejected using price indices by all four authors, with unit values (Isard), in second difference form (Richardson), and for a variety of country pairs.[9] More recently, Kenneth Froot, Michael Kim and Rogoff (1995) document deviations from the LOP in commodity data spanning up to seven centuries.[10]

Research on the LOP has shown that, for a variety of goods and countries, relative prices of similar products sold in different countries are systematically related to exchange rate fluctuations between those countries. The main weakness of these studies is that they typically compare prices of goods that are *produced* and *sold* in different locations, both serious violations of the identical goods assumption. Goods produced in different countries are unlikely to be physically homogenous. And prices of goods sold in different locations will have different amounts of transportation, distribution, and retail "value-added" underlying them. These components are non-tradable and thus unlikely to obey the LOP. The consistent rejection of the

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[9] Unit values are period average prices constructed by dividing the value by the quantity of trade flows.

[10] Their study does not fit the structure of equation (3) due to a lack of reliable data on nominal exchange rates early in the sample. Prices are converted to silver-equivalents in both countries and it is assumed silver obeys the LOP.

LOP and PPP raised serious questions about global monetarism, but believers in an integrated, competitive paradigm viewed the evidence only as proof that goods whose prices were used in testing the LOP were not identical (McCloskey and Zecher, 1984).

B. Exchange Rate and Tariff Pass-Through

Interest in prices and exchange rates in the 1970s was motivated not only by a desire to test the foundation of global monetarism by investigating the validity of PPP and the LOP, but also to assess the effects of changes in currency values on both "external balance"–i.e., the balance of payments or the current account–and domestic inflation. Of particular interest was whether devaluation of a nation's currency would improve its trade balance. Simple textbook models with perfectly elastic export supply schedules lead to the familiar Marshall-Lerner condition: a devaluation improves a country's balance of trade if the sum of the import and export demand elasticities exceeds one. One concern about the textbook model was the premise of perfectly elastic export supplies: Would export prices really remain constant in spite of the devaluation? From the importer's perspective, this amounted to asking whether the full effect of the devaluation would be "passed-through" to local currency import prices.

The textbook definition of exchange rate pass-through (henceforth, ERPT) is the percentage change in local currency import prices resulting from a one percent change in the exchange rate between the exporting and importing countries. Textbook models of the balance of payments assumed a one-for-one response of import prices to exchange rates, known as "full" or "complete" ERPT. Two conditions are required for this result: (1) constant markups of price over cost (in the textbook model, industries are perfectly competitive and markups are constant at zero) and (2) constant marginal costs.[11] Under these conditions, the elasticity of demand for imports in the respective countries drives the response of the trade balance to exchange rate

[11] Another possibility is that changes in markups just offset changes in costs, leaving export prices constant.

changes. Research on the balance of payments problem focused on estimation of both the demand elasticities and the pass-through relationship.[12]

ERPT research focuses on the adjustment of price to an exchange rate change for transactions between an exporting and importing country. With reference to equation (3), in the typical ERPT regression, p is the local currency import price, X is a measure of exporter's cost, Z may include import demand shifters, such as competing prices or income, and E is the exchange rate (importer's currency per unit of exporter's currency). ERPT equations are export pricing equations, with prices usually measured in the importer's currency. The coefficient γ is referred to as the pass-through coefficient. ERPT is "full" or "complete" if $\gamma = 1$ and is "incomplete" if $\gamma < 1$. Provided an accurate measure of cost is in X, γ measures only the variable markup component of the textbook definition of pass-through. Unless Z includes the domestic price prevailing in the exporting country for the import good whose price is measured by p, the connection between the LOP and ERPT is unclear. In particular, incomplete ERPT is not necessarily evidence against market integration.

An early paper on pass-through noteworthy for its methodology is Mordechai Kreinin (1977). He uses a "natural experiments" approach to estimating the degree of pass-through that occurred following the currency realignments of 1971. Whereas the standard ERPT paper uses regression analysis to control for other factors, Kreinin's uses an import price from a second exporter whose exchange rate did not change relative to the importer. The difference in the change in the U.S. import prices between the two exporters is attributed to the exchange rate change and used to calculate a pass-through coefficient. Aggregating up from detailed commodity data, Kreinin estimates pass-through to U.S. import prices to be only 50%. ERPT to Germany is estimated to be 60%, Japan 70%, Canada and Belgium 90%, and Italy 100%. Kreinin interprets incomplete ERPT as a reflection of either incomplete adjustment during the

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[12] A classic example of the early research on the broader question of external adjustment is Branson's (1972) paper, which assessed the possible response of the U.S. trade deficit to the devaluation of the dollar. Magee (1973) examines the pass-through issue surrounding this episode in more detail .

sample period or "largeness" of the importer in the sense of being able to influence the world price.

Interest in the pass-through question grew following the move from fixed to floating exchange rates as it remained one component of the "external adjustment" issue and the transmission of inflation. The floating rate period which began around 1973 provided the added benefit of greater exchange rate variability with which to identify coefficients of interest, but the added complication of more subtle dynamic adjustment issues surrounding expectations about the behavior of floating exchange rates.

ERPT research in the 1980s was dominated by analysis of pass-through to the U.S. Estimation of the pass-through coefficient usually entailed more than estimating equation (3) using OLS. Unlike the simple test of an arbitrage condition like the LOP, ERPT amounted to estimation of a behavioral equation. Issues of non-stationarity, simultaneity, dynamic adjustment, and symmetric response of prices to costs, exchange rates, and competing prices were addressed in the literature (Wing Woo (1984); Peter Hooper and Catherine Mann (1989)). The range of pass-through estimates found in various studies seemed to be centered around 60% pass-through, close to the 50% pass-through to the U.S. found by Kreinin after the currency realignments.[13] This implied that 40% of the exchange rate change was offset by changes in the markup, since most papers included some cost measure as a control variable. It was not clear if the markup adjustment was destination-specific or represented a change in world prices.

The rise of imperfect competition and strategic trade theory led researchers to estimate ERPT at the industry level. The industry approach is best illustrated by Robert Feenstra (1989). Feenstra shows that the first-order conditions for a monopolist selling to a foreign market imply that there is a symmetric response of import prices to changes in the bilateral exchange rate and an import tariff. If the symmetry restriction were to be supported by empirical evidence, then ERPT studies would have applications to trade policy.

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[13] There was an active debate about whether exchange rate pass-through decreased during the 1980s. For evidence on the stability of pass-through from Japan to the U.S., see David Parsley (1993).

Feenstra uses U.S. import unit values from Japan as a measure of p for three separate industries: cars, compact trucks, and heavy motorcycles. Ad valorem tariffs on trucks and motorcycles changed substantially during the 1974:1 to 1987:1 sample period. The X control is the Japanese domestic wholesale price of the U.S. import good divided by the spot exchange rate. The Z matrix in this case includes the ad valorem tariff rates, a competing price for the import, and real income in the U.S. Estimation uses instrumental variables to account for the endogeneity of competing prices and real expenditures. A time trend is also included to capture quality change, and the period of voluntary restraints (VERs) is omitted from the car equation since quality change may have been acute in this period.

The estimated degree of ERPT ranges from 63% for trucks to nearly 100% for motorcycles, which is somewhat larger than the aggregate estimates noted earlier. It is not clear whether the differences are due to industry-specific factors or aggregation bias in the earlier studies. There is little evidence of lagged response except for motorcycles; most pass-through seems to occur within two or three quarters, which is faster than estimates from some of the aggregate studies.[14] The estimated degrees of tariff pass-through are 57% for trucks and slightly above 100% for motorcycles, which are not significantly different from the ERPT. Thus the data support the symmetry restriction imposed by the theory, at least for the industries in Feenstra's study.

Overall, the ERPT literature delivered a fairly clear consensus on important issues concerning external adjustment and the transmission of inflation across countries. For the United States, pass-through appeared to be in the neighborhood of 60% in the floating exchange rate period, although the more detailed data used by Feenstra for certain Japanese industries suggested a somewhat higher degree of pass-through. For other countries, ERPT appeared to be higher, with economic size an apparent determinant of less than full pass-through. While these empirical observations answered certain questions, the proliferation of models of imperfect

[14] This may be due to the fact that additional lags will arise when aggregation occurs over units with different adjustment costs.

competition in international trade theory in the 1980s cast industry-level pass-through research in a different light. To what extent did incomplete pass-through validate the models of imperfect competition? Research that included controls for cost and found incomplete ERPT was interpreted as showing that markups changed with exchange rates. For example, in the case of the U.S., 60% pass-through conditional on costs implies a 40% markup adjustment to offset exchange rate changes. Changes in markups imply periods in which markups are not zero and thus deviations from perfect competition. Therefore, some interpreted ERPT research as validating the shift toward models of imperfect competition.

This interpretation was not beyond dispute, however. The typical pass-through paper treats costs as directly observable, measured by cost indices. These indices may be reasonable measures of average cost incurred domestically, but are unlikely to be good measures of marginal cost, the concept relevant for pricing behavior of a profit maximizing firm. Furthermore, cost indices may introduce measurement error into equation (3) that is correlated with exchange rates in a way that biases the coefficients toward finding incomplete pass-through and excess markup adjustment.

This is illustrated in the following simple example. Consider pass-through by Toyota to the U.S. market. Let c^* be the true marginal cost and c be the measure of costs using a cost index. Thus, we have

$$c^*(w, q, m) = c(w) + v(q, m)$$

where v is the measurement error–the difference between true marginal cost and the cost index. True marginal cost is written to depend on wages, w, output, q, and imported input prices, m. The cost index is assumed to depend only on wages. Both imported input prices and output may depend on the value of the Yen. For example, an appreciation of the Yen will reduce Toyota's costs if imported input prices are constant, or nearly so, in dollars. This is likely to be the case for raw materials, such as oil, which tend to be priced in dollars, and may be true to a lesser extent of some components assembled in Southeast Asian countries. The appreciation may also lead to a contraction in Toyota's output due to reduced foreign demand, which would further

reduce Yen marginal costs if marginal costs were increasing in output. Exchange rate shocks may thus cause both shifts in and movements along the marginal cost curve, in addition to leading to changes in the markup.[15]

If these changes in marginal cost are not captured adequately by cost indices, then in the context of equation (3), there is measurement error in X that is negatively correlated with E (when E increases, the cost error, v, decreases) and positively correlated with p (when v decreases, so do prices, which are based on c^*). Consequently, the pass-through coefficient γ may be biased downward relative to the magnitude that would be obtained if c^* were observable. Since $(1 - \gamma)$ is normally interpreted as the degree of markup adjustment, ERPT research may overstate the magnitude of markup adjustment and thus the magnitude of departures from perfect competition. Furthermore, as foreign outsourcing becomes more prevalent, this problem becomes more acute.[16] Research on pricing-to-market tries to resolve this measurement error problem, while also providing evidence on whether markup adjustment is destination-specific.

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[15] See Anne Gron and Deborah Swenson (1996) for the ramifications of foreign sourcing on pass-through for Japanese automobiles in the U.S.

[16] Two recent papers by Jose Campa and Linda Goldberg (1995, 1996) document the changing patterns of external exposure of manufacturers in the U.S., U.K., and Canada.

C. Pricing to Market

The latest generation of studies on prices and exchange rates has focused more sharply on the issue of markup adjustment. Paul Krugman's (1987) paper labeled the phenomenon of exchange rate induced price discrimination in international markets "pricing-to-market," henceforth PTM. PTM research blends the microeconomic foundation of ERPT research such as Feenstra, with the study of multiple transactions required in testing the LOP. Ironically, it is the use of multiple transactions (as in LOP) that helps alleviate the cost measurement problem found in ERPT, while the focus on exports from a single source (as in ERPT) mitigates departures from the identical goods assumption common in tests of the LOP.

Since PTM involves behavior in multiple markets, it will be useful to specify the firm's problem more concretely. Consider a firm that sells output in n separate destination markets, indexed by i. Profits of the firm are given by:

$$(4) \qquad \Pi(p_1,\ldots,p_n) = \sum_{i=1}^{n} p_i q_i(E_i p_i;\upsilon_i) - C\left(\sum_{i=1}^{n} q_i(E_i p_i;\upsilon_i), w\right)$$

where p is the price in the exporter's currency, q is quantity demanded (a function of the price in the buyer's currency, Ep, and a demand shifter υ), E is the exchange rate (units of the destination market currency per unit of the exporter's currency), and $C(q,w)$ is the cost function where w denotes input prices.[17] 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:

$$(5) \qquad p_i = C_q\left(\frac{-\eta_i}{-\eta_i + 1}\right), \forall i$$

[17] Sales to the domestic market or to countries whose currencies are fixed to the exporters have an exchange rate equal to one.

where the arguments of the marginal cost function 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. Typically, we think of (5) as the FOC for a monopolist, although we can interpret it more generally if we consider the elasticities to be associated with a residual demand curve that takes into account the firm's perceptions of competitors responses to changes in the firm's price.

Richard Marston (1990) is a good starting point for discussing PTM since it is easily linked to simple tests of the LOP. Marston models a price discriminating monopolist selling in a domestic and an export market. By differentiating a first-order condition such as (5), he shows that the response of the export price to an exchange rate change depends on two factors: the convexity of the demand curve in the export market and any change in marginal cost that may result from changing output levels. Convexity of demand determines how demand elasticity changes with price. In general, if demand becomes more (less) elastic as local currency prices rise, then the optimal markup charged by the exporter will fall (rise) as price in the buyer's currency increases, e.g., as the buyer's currency depreciates against the exporter's.[18] Marston's model also allows exchange rate changes to have feedback effects to domestic prices through marginal cost. Changes in cost will also influence export and domestic prices, with the price adjustment again depending on the curvature of demand. The model leads to an estimating equation in which the *ratio* of export to domestic prices is a function of cost factors, national price levels, exchange rates, and real income in the two markets.

The estimating equation includes prices in two markets as well as costs, thus it has elements of both the LOP and ERPT literatures. In terms of equation (3), p is the export price, X is the domestic price of the same good and its coefficient is constrained to be one and is subtracted from both sides of the equation, and Z includes cost factors and demand shifters in the two markets.[19] It is important that the dependent variable is the export/domestic price ratio for

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[18] Constant elasticity of demand is the special case where elasticities are independent of price. Elasticities increase with price for demand schedules less convex than a constant elasticity schedule, e.g., linear demand.

[19] Note that Feenstra's (1989) ERPT paper was also a step in this direction, since his cost control variable was a domestic price index that corresponded to the export unit value.

the same good. Costs, and thus errors in costs, influence the ratio only when there is a difference in the convexity of demand between the two markets. Furthermore, the departures from identical goods are minimized relative to other types of price comparisons. Comparing prices of Japanese cars sold domestically with Japanese cars exported to other markets is probably better than comparing prices of Japanese cars in Japan to German cars in Germany.[20]

The idea that prices in closely related markets provide a way to disentangle cost changes from markup changes was more fully exploited by Michael Knetter (1989). A change in the exporter's exchange rate vis-a-vis the currency of destination market i can affect the price charged to destination i in two ways: by affecting either marginal cost or the elasticity of export demand. The former channel will affect prices to all destination markets, while the latter may be destination-specific. These potentially different implications for prices charged to other markets help distinguish marginal cost from markup responses to an exchange rate change.

Knetter estimates the following fixed-effects model of export prices across destinations for a particular industry:[21]

$$(6) \quad \ln p_{it} = \theta_t + \lambda_i + \beta_i \ln E_{it} + u_{it}$$

where p is price in units of the exporter's currency measured at the port of export, θ_t is a set of time effects, λ_i is a set of destination country effects, E is the exchange rate in units of the destination market currency per unit of the exporter's currency, u is a regression disturbance, i indexes destination, and t time period. One country effect is dropped to avoid singularity. We assume for now that the prices in (6) refer to identical goods at the port of export, distinguished only by their ultimate destination.

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[20] The notion that location of production is a source of product differentiation is often invoked in international economics as the so-called Armington assumption.

[21] In subsequent work, a variety of related specifications are explored which add more independent variables, impose parameter restrictions, or transform the model to an error correction or first difference representation.

In a competitive, integrated world market, all export prices must equal a common underlying marginal cost. In the regression model, the time effects will measure the common price in each period, which will be an exact measure of marginal cost. Under this hypothesis, there is no residual variation in prices and λ and β are zero for all destinations. Imperfectly competitive, integrated markets have similar implications. Integration requires price equalization across buyers, but the markup of price over marginal cost need not be zero with imperfect competition. In this case, the time effects will capture marginal cost plus an unidentifiable common markup. Since markups are common, the (N-1) country effects will equal zero. Hence, the empirical predictions are indistinguishable from integration with competition, although under imperfect competition the interpretation of time effects as an index of marginal cost is no longer valid. They capture any changes in the common markup as well.

Imperfect competition will typically involve market segmentation and price discrimination across the destination markets. How will market segmentation affect the interpretation of the coefficients in (6)? Suppose first that each destination market is characterized by constant elasticity of demand. In that case, the price charged to each destination market is a fixed markup over marginal cost. Variation in the price data then decomposes into time components, q_t, which give an exact index of marginal cost, and destination-specific components, λ_i, which measure differences in the markup relative to the base country (whose constant markup is inseparable from the marginal cost component of the time effects). Since the assumption of constant elasticity of demand implies constant markups, β is zero for all destinations.

Statistically significant values of λ or β would signal both market segmentation and a rejection of the constant elasticity of demand hypothesis. With segmented markets and non-constant elasticities, the time effects in (6) no longer provide an exact index of marginal cost.[22]

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[22] Essentially, the problem is that once the constant elasticity hypothesis has been rejected, cost changes, like exchange rate changes, are not fully passed-through to prices. Since the degree of cost pass-through may vary from market to market, marginal cost changes cannot simply be backed out of the behavior of prices. Knetter (1995) investigates alternative specifications in which the interpretation of the time effects as measures of change in marginal cost is robust to certain violations of the constant elasticity model. This issue is revisited in the next section when we discuss studies of excise tax pass-through in the cigarette industry.

The fact that the time effects are only a noisy measure of cost changes in this case does not alter the main result: significant λ's and β's imply price discrimination and are therefore evidence of market segmentation.

In practice, the price data used to estimate (5) are not sufficiently detailed to ensure that product qualities are identical to all export destinations, meaning that price discrimination should not be inferred on the basis of the λs alone. For example, Knetter uses annual 7-digit export unit value data to measure export prices to each destination.[23] These unit values are measured at the port of export, net of transportation costs, tariffs, and other costs of distribution in the destination market. Thus many dimensions of the transactions are identical, apart from the location of the buyers. But it is likely that there is physical product differentiation within 7-digit classifications, hence, there is no guarantee that marginal cost is common to all destinations.[24] However, (6) can reveal price discrimination in Stigler's sense that prices are in different ratios to their marginal costs provided marginal costs of goods bound for different markets change in proportion to one another over time.[25] If prices differ due to product differentiation, but are in equal ratios to their marginal costs, then estimates of λs in (6) would measure the proportionate difference in marginal costs relative to the base country. However, if destination-specific prices vary with exchange rates, then prices cannot remain in the same ratio to marginal cost. Therefore, even with product differentiation, non-zero estimates of β in (6) can reveal price discrimination under the assumption of proportionate marginal costs.

The findings on PTM are quite consistent across studies. Marston's study uses monthly data on domestic wholesale and FOB export (measured in Yen net of transportation, insurance, and tariff costs) price indices from 1980 through 1987 for 17 4-digit Japanese industries. Only

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[23] Unit values are the only measure of price that are available on a destination-specific basis. This is similar to the data used by Isard (1977) to investigate the LOP. Whereas Isard compared U.S. import unit values from Germany, Japan, and Canada in a given industry to the aggregate U.S. export unit values in the same industry, Knetter compares export unit values from a single source country across multiple destination markets.

[24] The range of product differentiation can be quite large at the 7-digit level. For example, "Vitamin C" or "kraft linerboard paper" may be fairly homogenous, while "automobiles under 2 liter engine size" can be quite different.

[25] For example, otherwise identical cars might include air conditioning when shipped to the U.S., but not when shipped to Sweden. In this case, the level of marginal cost will differ across destinations, but changes in marginal cost are likely to be very similar over time.

two of the 17 industries lack statistically significant evidence of PTM: small trucks and cameras. The range of PTM for the other 15 industries is quite wide. The estimates imply that the relative price of exports to domestic sales of microwave ovens falls by 30% of any appreciation of the Yen. This implies 70% pass-through for a given marginal cost. At the other end of the spectrum, the relative prices of amplifiers and tires change approximately one-for-one with movements in the real exchange rate. This implies *no pass-through* of exchange rate changes to import prices apart from the possibility that exchange rates influence prices through their effect on marginal cost. Overall, the average degree of PTM found in the transport, equipment, and consumer goods industries studied by Marston is in the neighborhood of 50%.

In a series of papers, Knetter finds that export unit values are sensitive to destination-specific exchange rate fluctuations for the majority of cases. The range of estimated PTM found using the multidestination framework is very similar to that found by Marston. For example, in a study of PTM in the auto industry, Joseph Gagnon and Knetter (1995) estimate that Japanese auto exporters offset approximately 70 percent of the effect of exchange rate changes on buyer's prices through markup adjustment. This finding is in line with Marston's estimates for Japanese auto exports, which range from 52% to 89% depending on size and whether the U.S. VER was in place, in spite of the different data sources (unit values vs. price indices), sample period (1973-87 vs. 1980-87), and estimation techniques. These results imply only about a 30% pass-through given constant costs, quite different from Feenstra's estimated pass-through of about 70% (although Feenstra's sample period was 1974-81).

Knetter's sample includes U.S., U.K., Japanese, and German exports to a variety of destination markets. Although PTM by U.S. exporters appears to be systematically low, the hypothesis that markup adjustment is the same across export source countries within a given industry cannot be rejected in the seven industries with multiple source countries in the sample.[26] Subramanian Rangan and Robert Lawrence (1994) show that the lack of PTM (i.e.,

[26] Industry classifications for purposes of collecting information on the value and quantity of exports and imports were only harmonized across the industrial countries in 1988. Therefore, industry comparisons across export source countries are never exact and often impossible.

full pass-through) in U.S. export industries is related to the presence of multinational operations, suggesting that transfer pricing could be partly to blame. They argue that PTM might still be accomplished through fluctuations in subsidiaries margins. Knetter also finds little evidence that PTM is unusually high on shipments to the U.S., in spite of the fact that earlier studies systematically found U.S. pass-through to be relatively low. One possible explanation is that movements in the dollar have larger effects on foreign firms' costs than movements in any other currency. Even though markup adjustment to the U.S. is not extraordinary, if changes in the value of the home currency against the dollar influence exporters' marginal costs by inducing substantial quantity or imported input price changes, pass-through to the U.S. could be muted relative to other markets.

The estimated degrees of PTM combined with the magnitude of fluctuations in exchange rates can be used to construct a lower bound on the maximum implied price (or markup, if marginal costs are not equal) differential across markets. For example, a 70% PTM coefficient by Japanese auto exporters combined with a 50% swing in the DM/$ exchange rate implies a 35% change in the relative price of exports to U.S. and German buyers of Japanese autos. This implies that price (or markup) differentials must be at least as large as 17.5% at the beginning or end of the exchange rate swing. Swings of this magnitude in relative prices would seem difficult to reconcile with a simple competitive paradigm.

Interestingly, PTM is prevalent not only in industries such as automobiles, where price discrimination seems plausible, *ex ante*, but even for some more homogeneous goods, such as linerboard paper or *The Economist* magazine.[27] Figures 1 and 2 illustrate the evidence for linerboard paper. Figure 1 shows dollar unit values on a log scale for U.S. exports of kraft linerboard paper to Canada, Germany, and Japan from 1973 to 1987. The unit values exhibit high correlation over time, as would be expected in the case of an integrated market for a reasonably homogeneous product. However, dollar export unit values to Canada are lower in most years, with sizable differences in the late 1970s. Figure 2 plots the difference in the log of

[27] Linerboard paper is the thin sheet attached to each side of corrugated paper to form the wall of a cardboard box.

export unit values between Canada and Japan against the C$/Yen exchange rate. There is a marked negative correlation between these two series: Unit values on shipments to Canada are relatively higher when the Canadian dollar is relatively strong vis-a-vis the Yen. It is precisely this pattern which generates statistically significant evidence of PTM across markets. When equation (6) is estimated across six destinations for U.S. linerboard exports, the average degree of PTM is about 30-35%. Notice the margin of PTM in linerboard does not imply relative price fluctuations as large as those in Japanese autos. A PTM coefficient of 0.3 combined with a 50% swing in exchange rates generates a 15% change in relative prices.

Prices from the cover of *The Economist* reveal a similar story, with the added twist that these prices are quoted in the local currency for each market. Figure 3 plots the pound-equivalents of the local currency cover price of *The Economist* in four markets, France, Germany, the U.S., and the U.K. from January 1973 through July 1996. Because cover prices are quoted in local currency, changes in the local currency exchange rate against the pound cause immediate changes in the pound-equivalent prices. Hence, the stickiness of nominal cover prices in local currencies can lead to a spurious finding of PTM, as pointed out by Atish Ghosh and Holger Wolf (1994). Figure 4 illustrates the problem well. The difference in common-currency cover prices between France and Germany moves 1:1 with the DM/Ff. exchange rate in almost every month. The only exceptions are those months in which local currency cover prices are adjusted (identified by the sharp jumps in the price differential). But notice that the periodic price adjustments typically bring prices back together in the two markets. Indeed, the figure is an advertisement for European integration: since 1983, exchange rates and relative prices of *The Economist* between France and Germany have stabilized relative to the 1973-83 period.

Relative price comparisons between Germany and the U.S. reveal a very different story. Figure 5 shows that cover price adjustments undo remarkably little of the exchange rate induced changes in common-currency prices. From January 1981 to March 1985, the dollar appreciated by 49% against the DM. In order for the LOP to hold in relative terms, DM cover prices would need to rise 49% more than dollar cover prices over this period. In fact, dollar cover prices rose

nearly 10%, while DM cover prices rose only 6%. Cover price adjustments have also moved the relative prices away from parity on three separate occasions since July of 1991. The price differences across these markets are large and persistent. Prices in the U.S. were at least 20% higher than prices in Germany from February 1982 until October 1985. Prices in Germany were at least 30% above prices in the U.S. from July 1994 until July 1996. The signs of integration evident between Germany and France are completely lacking between Germany and the U.S. Rather, there appears to be conscious price discrimination between European and American markets, dictated undoubtedly by distinct competitive conditions in those markets. Apparently, the costs of arbitrage are great enough that newsstand price differentials of 20-30% in either direction can persist for fairly long periods of time.

Figures 3-5 do illustrate that dynamics in general, and invoicing in particular, can complicate the study of pricing in international markets. If exporters invoice in the buyer's currency and price adjustment is infrequent, as with *The Economist*, then one must be careful to distinguish between short-run and long-run common currency price changes. Most studies of PTM use international price data which do not reveal the invoice currency. In assessing the possible importance of dynamics to explain the findings, it is first important to ask: How pervasive is invoicing in the buyer's currency?[28] S.A.B. Page (1981) is the most recent evidence on invoicing we have seen. Page finds that 98% of U.S. exports were invoiced in dollars. German exporters used the DM for over 82% of all exports, with about half the remainder in dollars. British exporters used the pound for 76% of exports and the dollar for another 17%. Japan was unique among the large economies in that 62% of its exports were invoiced in dollars and only 32% in Yen. For cases where invoicing is in the exporter's currency, infrequent price adjustment leads to a bias against finding PTM–common currency relative prices will be sticky. Thus, in studies of U.S. exports, and probably German and British exports, biases are likely to go against finding PTM, at least in the short run.

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[28] Technically, invoicing in *different* currencies generates the problem, although that typically means invoicing in the buyer's currency.

Because they compared Japanese exports and domestic prices, Marston (1990) and Giovannini (1988) had to allow for the possible effects of foreign currency invoicing. In the context of his model, Marston shows that movements in the price ratio that are due to unanticipated exchange rate changes in the presence of pre-set prices (where the pre-setting must be in different currencies for different buyers) will be a function of *changes* in the *nominal* exchange, whereas the "intended" price ratio will depend on the *level* of the *real* exchange rate.[29] Giovannini and Marston both find that for Japanese exports, pre-set prices in foreign currencies contribute to PTM in the short run, but that substantial PTM persists beyond the period in which invoice prices are sticky. Error correction methods have also been used to distinguish short run and long run PTM by Kenneth Kasa (1992) and Gagnon and Knetter (1995).[30] An alternative approach in multidestination studies is to remove destinations, such as the United States, which account for most invoicing in the buyer's currency. Knetter (1994) finds that dropping the U.S. destination from a sample of 60 German industries has little systematic impact on the estimated degree of PTM to other markets in the sample.

A second aspect of dynamic adjustment concerns the distinction between temporary and permanent exchange rate changes. Froot and Paul Klemperer (1989) show that a model with consumer switching costs will lead exporters to respond differently to temporary and permanent changes in the exchange rate.[31] They test for the presence of cost effects (the 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.

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[29] This decomposition relies in part on the assumption that exchange rates are a random walk.

[30] Interestingly, Gagnon and Knetter find that short-run PTM is higher than long run PTM for only two destinations of German auto exports: the U.S. and Canada. This result would follow naturally from invoicing in dollars for shipments to North America and in DM elsewhere, a pattern which is consistent with Page's (1981) evidence.

[31] A related dynamic issue which has been studied in the literature but is not addressed here is the effect of exchange rate expectations on the pricing of imported durables (Jaewoo Lee, 1996).

The main hurdle to implementation of the model is distinguishing temporary from permanent exchange rate changes. The literature on exchange rate determination shows only very weak evidence in favor of reversion to PPP, meaning that most changes might be best viewed as permanent. Froot and Klemperer use survey data on expectations to construct their measures of the two components. Whatever the limitations of such data, that is probably the best solution to the problem of measuring expected exchange rates. Their parameter estimates imply that *purely* temporary exchange rate changes lead to an unusually high degree of PTM: 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.[32]

Although dynamic issues certainly complicate the study of the PTM (and are hard to resolve due to data limitations), they do not alter the main conclusion that for many products rather large common-currency price differentials exist across countries and, as seen with *The Economist*, these price differences can be quite persistent. Conscious price discrimination on the part of exporters appears to be part of the economic landscape. At first blush, this suggests "globalization" of goods markets may have far to go. An important caveat is in order, however. Most evidence on PTM (or against the LOP) comes from *changes* in common currency *relative* prices that are associated with exchange rate changes. Data on price levels for a specific product are the exception and not the rule. A period of convergence from price dispersion to price equalization (think of this as a secular decline of α in equation (2)) requires changes in common currency relative prices. Hence, a finding of PTM is quite possible over a period of time in which price convergence is occurring in product markets. How likely is it that we are mistakenly viewing PTM as evidence of segmentation when in fact it is a consequence of the process of integration? From the data presented on cover prices from *The Economist*, there is evidence of integration within continental Europe (Germany and France), but little evidence that continental Europe, the U.K., and the U.S. are moving toward a single market. It is tempting to assume that

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[32] Notice that this might help explain the puzzling behavior of prices for the SONY Trinitron or the Toyota Celica discussed in the introduction to this paper.

PTM in other product markets is also a manifestation of market segmentation, but we cannot be sure based on available research.

While the PTM literature has delivered convincing evidence of price discrimination, there have been fewer attempts to identify the determinants of the magnitude of PTM across industries. Since PTM is just evidence of systematic price discrimination across markets, it is useful to return to the basics of price discrimination in thinking about other inferences that we can draw about the workings of product markets. Hal Varian (1989) argues that three conditions are necessary for price discrimination to be a solution to the firm's maximization problem: (i) sorting of customers, (ii) prevention of resale, and (iii) the presence of market power. PTM presumes that sorting of customers is done with respect to location. Deeper understanding of PTM requires investigation of the other necessary conditions for price discrimination.

III. Measurement and Sources of Market Power in International Markets

The price discrimination documented by PTM research implies the existence of market power, but does not quantify its economic significance, nor does it explain its sources. Current research in international economics is moving towards more structural approaches that both measure and explain deviations from perfect competition. How large are markups in export markets? Are the cross-country differences economically significant? If so, what are the sources of the markup variation? Are the differences driven by differences in the demand elasticities, or are they caused by different market structures and regulatory regimes? What is the role of trade policies? These questions are now becoming the focus of research. Because many of these issues have been studied in the context of domestic markets in industrial organization, it is useful to draw some parallels to this literature.

The limitations of research on ERPT and PTM for determining the degree of market power are revealed by a series of empirical papers which attempt to measure market power in the cigarette industry. Daniel Sumner (1981) attempted to measure the degree of monopoly power in

the cigarette industry by examining the pass-through of excise taxes to prices. Sumner's dependent variable was the retail price of cigarettes across states from 1954 to 1978. Assuming a common underlying marginal cost, the major source of state variation in prices was excise tax differentials. Sumner argued that the state-specific price changes resulting from state-specific tax changes would permit an inference about the elasticity of demand and thus markup for cigarettes. But as was argued earlier in this survey, the price response to a cost shock depends not only on the level of the demand elasticity, but also on how elasticity changes along the demand schedule (i.e., it depends on the convexity of demand, not just the slope). Jeremy Bulow and Paul Pfleiderer (1983) pointed out that Sumner's inference about demand elasticities, and thus monopoly power, was only valid for the special case of constant elasticity of demand. Outside of that special class of demand functions, no inference about the level of the elasticity and the degree of monopoly power is possible.[33]

Nonetheless, the question Sumner sought to address remains an important one for international markets: Do the data allow us to infer anything more than a deviation from perfect competition? In a sequel to Sumner's research on the cigarette industry, Daniel Sullivan (1985) made further progress in the measurement of market power in the cigarette industry, by testing (and rejecting) the hypothesis that the industry was a perfect cartel. Sullivan's inference was based on estimating the elasticity of demand facing the industry and testing the hypothesis that this elasticity was–consistent with a monopolistic equilibrium–greater than one. His approach did not provide a precise measure of the markup, but the elasticity estimate, in conjunction with the modest assumption that marginal costs are positive, allowed him to derive upper and lower bounds for the "numbers equivalent" of firms in a Cournot industry.[34] In order to estimate an elasticity, Sullivan employed an additional dependent variable: quantity.

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[33] In fairness to Sumner, the multidestination dimension of his data makes his approach similar to the framework adopted by Knetter and Marston in the study of PTM. Just as in PTM, a general inference of imperfect competition could have been based on a price discrimination argument (i.e., prices were in different ratios to marginal cost).

[34] A low numbers equivalent of firms corresponds to greater market power (one firm equals a monopoly), while the market approaches perfect competition as the numbers equivalent tends towards infinity.

The lessons learned from the work on the cigarette industry apply equally well to the measurement of markups in international markets. Analysis of prices alone can give only minimal information about market power. A more quantitative assessment of market power requires analysis of quantity responses. While this insight can be directly adopted from studies of the cigarette industry, there is a difference in the comparative statics exercises provided by excise taxes and exchange rates. Changes in excise tax rates shift the supply curve, allowing one to derive bounds on, but not a precise measure of, market power. In contrast, exchange rate changes rotate the demand curves facing suppliers of foreign markets. As Timothy Bresnahan (1989) showed, it is this type of comparative statics in demand that allow one to identify the magnitude of the markup. The role of exchange rates as natural demand rotators is an attractive feature of international studies in the measurement of market power.[35]

To make this argument explicit, consider a firm selling to a foreign destination. To simplify a bit, we ignore the subscript denoting the country of destination, and assume linear demand and marginal cost functions:

$$(7)\quad q_t = \alpha_0 + \alpha_1 E_t p_t + \alpha_2 I_t + \varepsilon_{dt}$$

$$(8)\quad c_t = \beta_0 + \beta_1 W_t + \beta_2 q_t + \varepsilon_{st}$$

where I is a vector of demand shifters (income, prices of substitute products, etc.), W is a vector of cost shifters (typically input prices), and the Greek letters denote parameters. The price p is expressed in the exporter's currency, although demand in the destination country depends on the local price, which is given by the product of the exporter price and the exchange rate. This system is identical to the supply and demand equations estimated for domestic markets, except for the exchange rate in the demand equation. The profit maximizing exporter will set marginal

[35] Exchange rates are not the only source of econometric identification of market power in international markets, but we have restricted our focus to those approaches since they are in the domain of research on prices and exchange rates, the topic of our review. Studies that have used alternative identification assumptions (e.g., Schembri (1989), Goldberg (1995), Verboven (1996)) have also offered convincing explanations of pass-through, pricing to market, and international price discrimination.

cost equal to perceived marginal revenue. In the case of perfect competition, the perceived marginal revenue is equal to price, and the first order condition reduces to price equals marginal cost. Under imperfect competition, the first order condition can generally be written as:

$$(9)\quad p_t = \beta_0 + \beta_1 W_t + \beta_2 q_t + \left(\frac{\theta}{\alpha_1 E_t}\right) q_t + \varepsilon_{st}$$

which allows for a markup over marginal cost equal to $\left(\frac{\theta}{\alpha_1 E_t}\right) q_t$. The markup depends on both the curvature of the demand function given by α_1, and the degree of competitive conduct captured by the parameter θ. To estimate the markup and identify its sources, it is necessary to separately identify the parameters α_1, β_2, and θ.

To identify the parameter of main interest, θ, (7) and (9) are estimated jointly. The parameter α_1 is clearly identified; the cost shifters W shift the marginal cost curve along the demand curve, allowing us to identify the demand parameters. The identification of the conduct parameter θ, however, is less straightforward. As discussed in Bresnahan (1989), identification of θ requires, for the general case of non-constant marginal costs, the availability of a demand rotator that changes the slope of the demand curve. From equation (9) is evident that the exchange rate plays exactly this role: Because E_t is interacted with q_t in the supply relation, the parameter θ is identified separately from β_2.

An early application of this idea is provided by Bee-Yan Aw (1993), in a study of Taiwanese footwear exports. Aw considers 4 destination markets, the U.S., Germany, Saudi Arabia and Hong Kong, which account for approximately 80% of total Taiwan footwear exports, over the 1974 to 1985 period. The empirical analysis documents large price differences across countries, with the U.S. and Germany being substantially more expensive than the two developing countries. Aw's model explicitly allows for differences in marginal costs–unlike PTM studies which assume at least proportional costs across destinations–as a potential source of price differences across markets. Hence, three sources of international price differences are built

into the model: differences in marginal costs, differences in conduct, and differences in price elasticities of demand. In addition, Taiwanese exporters faced VERs in the U.S. from 1977 to 1981; these are accounted for by appropriately modifying the supply relation for the U.S. during these years.

Aw estimates equations (7)-(9), allowing for the demand and supply parameters to vary across destinations. The vector of demand shifters includes per capita income and prices of substitutes, while the vector of cost shifters consists of input prices. Identification of the conduct parameters is achieved by including exchange rates and prices of Taiwanese footwear substitutes as demand rotators in each market. The results indicate significant differences in both the price elasticities of demand and conduct. The hypothesis of perfect competition (zero markups over marginal cost) cannot be rejected in three out of the four cases: the U.S., Hong Kong, and Saudi Arabia. The significant, positive markup in Germany is primarily explained by collusion among Taiwanese exporters in this market. Aw also finds that the VERs in the U.S. allowed Taiwan to capture the rents; the trade restrictions resulted in a positive markup of about 18% between 1977 and 1981.

The advantage of this approach is that to the extent price discrimination is present, it is not only diagnosed, but also explained by some combination of demand conditions and conduct. Furthermore, the role of quantitative trade restrictions is made explicit. A perhaps less satisfactory aspect of the approach concerns the market definition. The problems associated with defining the "relevant" market are well known from domestic antitrust analysis; but they are more pronounced in international applications where market boundaries potentially cross national borders. To make the problem of estimating competition tractable, international economists typically impose the Armington assumption–i.e., they assume that products within an industry are differentiated according to the country of production. An extreme interpretation of the Armington assumption implies that goods produced in different countries represent different markets. Aw's market definition includes only Taiwanese footwear sold in each destination market–imports from other countries and domestic sales are treated as a different market. The

competition from these other sources is accounted for by including the prices of substitutes in the set of demand shifters and rotators; but this treatment fails to capture the strategic interaction between footwear producers of different nationalities, as only the interaction among Taiwanese is built into the model.

Extending a framework introduced by Jonathan Baker and Bresnahan (1988), Pinelopi Goldberg and Knetter (1996) propose an approach to estimate exporters' market power which avoids these difficulties provided we are interested in estimating the market power of only one firm (or group of firms) in a setting where the market boundaries are ambiguous and product differentiation is extensive. Rather than estimating all the parameters of the structural model, the system is manipulated so that only one equation has to be estimated: the firm's residual demand curve.[36] The elasticity of the residual demand curve is a proxy for market power since it tells us how much power the firm has over price, taking into account the price/quantity response of all other firms. Generally, the residual demand elasticity will depend on the properties of the market demand schedule and the supply schedules of other competitors in the market. If market demand elasticities are not very different across markets (which follows from the standard assumption in international economics that preferences are identical and homothetic across countries), then differences in residual demand elasticities across destinations reflect differences in the elasticity of competitor's supply across destinations. More elastic schedules reflect the presence of many close substitutes and intense competition from outside the exporter group.

The residual demand approach entails loss of a significant amount of information (for example, price elasticities of demand, marginal costs and conduct parameters are not identified), but it offers the advantage of providing a measure of market power with modest data requirements and computational burden. Application of this methodology in the international context seems promising for three reasons. First, by reducing the data requirements, it makes estimation of market power in a multidestination framework a tractable problem. It is seldom

[36] The firm's residual demand is the demand curve that takes into account the strategic responses of competitors to changes in the firm's price.

feasible to obtain information on all competitors in all markets. Second, in practical applications, we are often interested in measuring the markups of just one exporter or exporter group (in Aw's work, for example, the focus is on Taiwanese footwear exporters alone), even though there are more firm's in the market. Instead of using exporters' nationality as the market definition criterion, the concept of the residual demand elasticity allows one to adopt a more realistic market definition that incorporates the strategic interaction among producers from different countries. Third, the condition required for identification of the residual demand curve–that a firm's costs move independently of all other firms' costs–is easily met in international markets. Exchange rate changes move the relative costs of producers, expressed in destination currency, providing a powerful comparative statics exercise for estimating the residual demand elasticity. Goldberg and Knetter employ this approach to study German exports of beer and U.S. exports of linerboard to several destinations.

The Aw and Goldberg and Knetter studies are indicative of a new direction in international industrial organization: the attempt to exploit the identification power of exchange rates in a framework that jointly analyzes price and quantity responses to exchange rate fluctuations. Two features of exchange rates make this direction particularly promising: (1) exchange rates are plausibly exogenous to industry events and (2) exchange rates exhibit substantial variation in the post Bretton Woods era. Nevertheless, this work also faces several challenges. The relevant institutional details, which are essential to proper interpretation of empirical results, are more complex and difficult to measure in international settings. For example, the expansion of foreign direct investment (FDI) and non-tariff trade barriers in recent years can be hard to account for in an empirical framework.[37] Yet the lack of a price response to exchange rate changes in some markets may be due to the existence of trade barriers that restrict import quantities, rather than collusion among firms in the industry.

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[37] As an example, anti-dumping law is a frequently used tool to protect industries under duress in the United States. The existence of this law may inhibit foreign firms from passing a depreciation through to dollar prices. There is no obvious way to introduce this type of constraint into an empirical model.

A perhaps greater challenge concerns the quality and proper interpretation of the quantity data. Studies that employ data on export quantities often report imprecise estimates of export demand elasticities (Aw (1993), Goldberg and Knetter (1996)). This lack of precision is surprising given the enormous exchange rate variation in the data sample. Moreover, it is clearly at odds with the precision with which pass-through or PTM coefficients are usually estimated in price equations. Figure 6 plots the unit values and quantities of German beer exports to Japan. While unit values are relatively stable from period to period, the bilateral export quantities are extremely volatile. The case of German beer exports to Japan is by no means exceptional. Graphs of unit values and quantities for other exported commodities and destinations exhibit the same general tendency. Quantity fluctuations seem too great to represent true fluctuations in demand or consumption of the export good in the corresponding period.

One possible general explanation is that a fairly high fraction of export shipments go unrecorded, which could introduce a great deal of noise into quantities that is not present in unit values.[38] A recent U.S. Customs report lends support to this explanation, claiming that monitoring of exports is much more lax than imports, since no revenues are at stake. There may also be industry-specific reasons for noise in quantity data. In durable goods sectors, inventories may fluctuate a great deal, and quantity flows along with them. In other cases, shipping patterns change and goods are routed to intermediate destinations. Export data record the intermediate destination, so we lose the connection between destination market and the ultimate source of demand.

This problem will be difficult to resolve. For example, using import data to get quantity information for each destination is undermined by the fact that countries only adopted a 10-digit harmonized classification scheme as of 1989. Prior to that, industry definitions are not comparable across countries, and thus only export data will be defined consistently across destinations. Using a higher level of aggregation might reduce the noise in the quantity data, but it is almost sure to introduce more noise in the measurement of prices as unit values, introducing

[38] Since missing shipments reduce value and quantity equally, their quotient would be unaffected.

a trade-off between the quality of price and quantity data. Attention to industry detail can minimize some of the industry-specific data problems. In general, the quantity movements appear to be more erratic when the markets involved are new or in transition phase. An example of such a transition market is the Japanese beer market (Figure 6), in which buyers are learning about new products, sellers have not yet established their positions, and the set of competitors changes rapidly. The techniques described above work better for mature markets where equilibria are perturbed mainly by changes in relative costs or demand shifts.

In summary, exchange rate fluctuations appear to provide the ideal comparative statics exercise for measuring market power: a rotation of the demand curve. Several recent papers have implemented standard techniques from the industrial organization literature with mixed results, in the sense that elasticity and markup estimates are not very precise. The lack of precision seems to be a function of volatile quantity data. Progress in measuring market power in international markets will require either better quantity data or better understanding of how existing export flows are related to underlying demand or consumption.

IV. Sources of International Market Segmentation

While recent research has made progress in measuring and explaining market power in international markets, the sources of international market segmentation are still not well understood. What factors make arbitrage costly and thus enable substantial price discrimination in international markets? In principle, one would expect the answer to be country- and industry-specific. Just as in domestic markets, laws regulating the distribution and resale of commodities, information and transportation costs, and other transactions costs may inhibit or even prevent resale. Detailed case studies of industries and countries where segmentation is prevalent can shed light into the relative importance of these factors. A more general, and perhaps more interesting, question is whether there is a pure "border" effect in international price

discrimination. In other words: Is price discrimination across markets greater than discrimination within them after controlling for the distance effect? If so, why?

A recent paper by Charles Engel and John Rogers (1996) answers the first of these questions very clearly. Engel and Rogers use fairly detailed CPI data for U.S. and Canadian cities to study two potentially important determinants of relative price volatility across locations: distance and the border. While distance does help explain the degree of price variation between city pairs, the U.S.-Canadian border is also very important. In fact, they find the border to be equivalent to approximately 1,780 miles in terms of its effect on relative price variability. The underlying reasons for the border effect are harder to pin down. Perhaps surprisingly, Engel and Rogers find that the border effect does not seem to be influenced by the U.S.-Canada free trade agreement. This does not completely exonerate trade frictions as a contributing factor, since many informal barriers to commerce between these countries remain. In a sequel, Engel and Rogers (1995), the authors find that monthly volatility of common-currency relative prices are better explained by nominal exchange rate volatilities than by measures of trade barriers. Their preferred explanation for the border effect appears to be nominal price stickiness, combined with volatile exchange rates.

Shang-Jin Wei and Parsley (1995) is another recent paper that attempts to tackle the sources of market segmentation implied by PTM and the violations of PPP. They explore violations of PPP in a panel of 12 tradables sectors in 14 OECD countries. They find evidence that the deviations from PPP are related to both transportation costs (as in Engel and Rogers) and exchange rate volatility. Beyond these two factors, the presence of free trade areas such as the EC and EFTA contribute little to explaining the deviations. It is likely, however, that free trade areas and exchange rate volatility are highly correlated in this sample of countries, which could make it difficult to separate their respective contributions. Furthermore, as in the case of the U.S. and Canada, zero tariffs and free trade are not the same thing.

The findings of both these papers contrast with the results of some recent micro-data studies which identify trade policies as a major source of cross-country price differentials. As an

example, consider Frank Verboven's (1996) study of the European car market. The study employed disaggregated data consisting of market shares, characteristics and prices of every vehicle make sold in 1990 in Belgium, France, Germany, Italy and the U.K. The data indicate significant price differences across markets, which cannot be fully accounted for by cost or quality differences. In particular, Belgium is the lowest-priced market, while Italy and the U.K. are associated with the highest prices. Verboven estimates a structural oligopoly model with product differentiation to uncover the sources of the cross-country price variation. He finds that binding quota constraints are found to significantly increase prices of Japanese cars in France and Italy compared to the other destinations.[39]

How can we reconcile the different findings regarding the importance of trade barriers in explaining deviations from the LOP and price discrimination? The simplest explanation might be that trade barriers are important for autos and footwear, but not so important in the aggregate. On the other hand, it is hard to identify what the impediment to arbitrage would be across borders if it is not lack of information or trade barriers. Since exchange rate volatility is so easily observed, it is hard to imagine that the price differentials it induces could go unnoticed for very long. One possible resolution of these differences is that Verboven's work tries to explain level differences in prices, while Engel and Rogers, and Wei and Parsley try to explain relative price volatility. Trade barriers may be a crucial determinant of persistent deviations from the absolute LOP, while nominal exchange rate volatility dominates any measure of aggregate trade barriers in explaining common currency relative price volatility.

To understand the sources of long-run market segmentation, it may be necessary to study detailed information on price levels, product by product. Only at this level can we also come up with meaningful measures of trade barriers. Average tariff rates or coverage ratios for broad sectors may not be able to reflect the degree to which trade is restricted between countries. Unfortunately, information on price levels is difficult to obtain for most products, which is why

[40] Other micro studies yielding similar results with respect to the role of trade policies include Aw (1993), and several studies on the effects of the VERs in the U.S. auto market.

indices are used in studies that try to be more comprehensive in scope. At present, it seems premature to speculate about the relative importance of various frictions in facilitating market segmentation and price discrimination. This is clearly an area that cries out for more research.

V. Conclusion

Research on exchange rates and goods prices has moved from macro analyses aimed at examining the underpinnings of global monetarism, to the study of external adjustment, and more recently to an examination of the importance of imperfect competition in international markets. Not surprisingly, this shift in emphasis has paralleled both institutional changes (the switch from fixed to floating exchange rates) and theoretical developments (the emergence of imperfectly competitive models in international trade). With each generation of studies, the economic interpretation of the evidence on prices and exchange rates has become clearer. We are increasingly certain that deviations in the law of one price are not just an artifact of non-identical goods, and incomplete pass-through is not just a result of changes in world prices. Rather, they both appear to be largely a result of third-degree price discrimination. Although there is substantial variation across industries, in many cases half or more of the effect of an exchange rate change is offset by destination-specific adjustments of markups over cost. Given the behavior of exchange rates in recent years, this means that large and persistent deviations from the law of one price occur on a regular basis. There are many interesting subsidiary issues in the study of international pricing, but the conclusion from this research that ought to affect the way we think is simply this: National markets for goods are better viewed as segmented than integrated.

Establishing the factors responsible for segmentation and determining the extent of market power in international product markets are the next items on the agenda in this area of research. Trade and regulatory policies seem, a priori, to be the leading candidates in the search for factors that facilitate segmentation of markets. However, research to date has not generated a

consensus on these issues. Studies of the behavior of price indices across many industries tend to find no role for measures of trade barriers in explaining the volatility of deviations from the law of one price. Studies of specific products, such as automobiles in European countries, do find that discrepancies in prices across markets can be attributed to trade policies. At this point, it is not clear whether aggregation problems have obscured the importance of trade barriers in the macro studies, or whether the micro studies are an unrepresentative sample of industries. Better data will be necessary to resolve these issues.

Recent research that uses exchange rates in an attempt to measure market power might also be useful in understanding the effect of trade and other competition policies. Variation in market power across countries and industries could help us understand the economic significance of policies that regulate trade and competition. These studies must also overcome substantial hurdles in data collection. The lack of historical data using harmonized industry classification systems across countries is a major one. Furthermore, the tools used to measure departures from competition may not be well suited to an environment in which competitors are changing rapidly, consumers are learning about new products, and markets are far from a long run equilibrium state. That appears to be the state of affairs in many international markets. It remains to be seen if future research will meet these challenges.

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Figure 1. U.S. Linerboard Export Unit Values, 1973-87

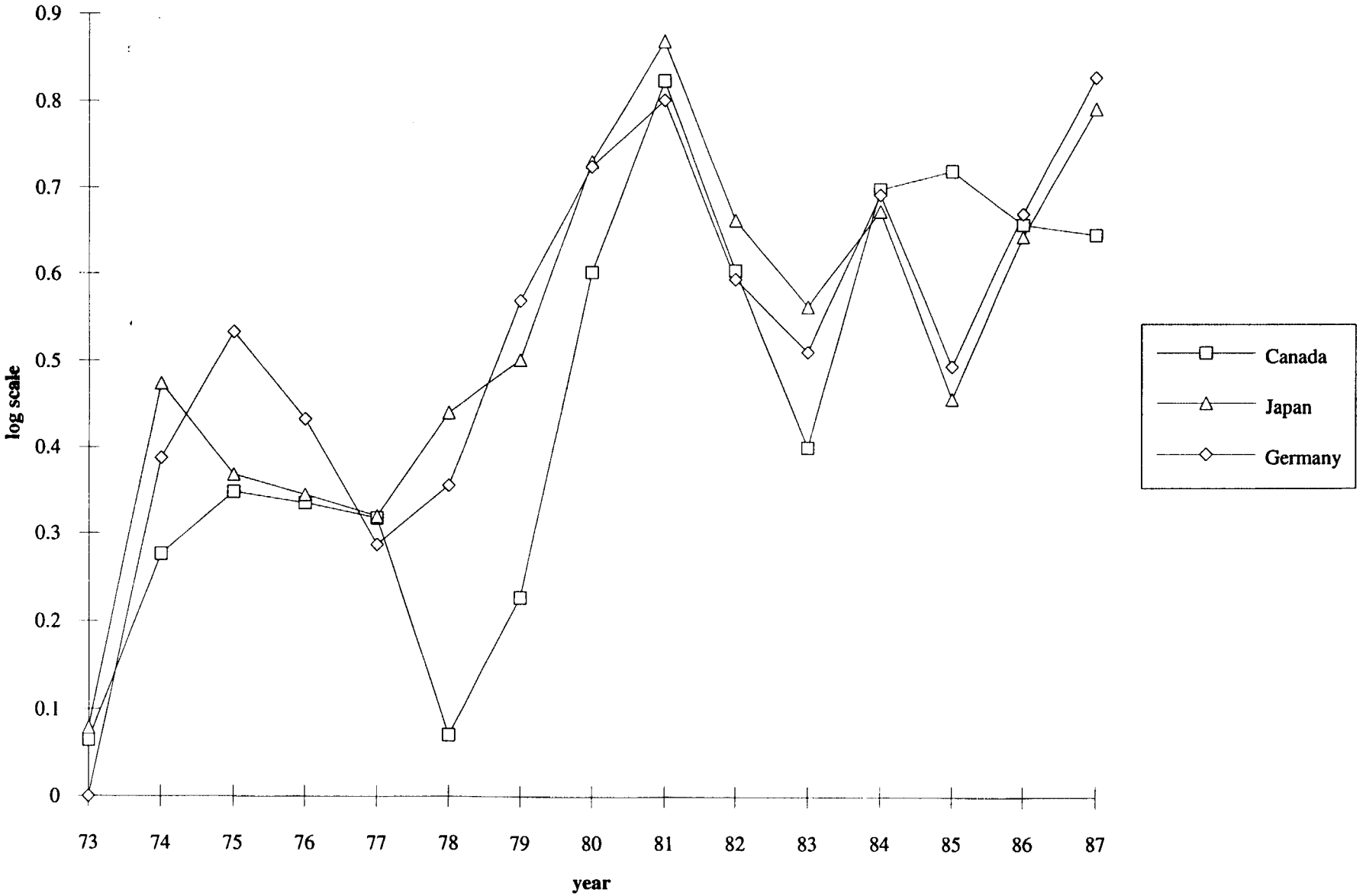

Figure 2. Canada-Japan Linerboard Unit Value Differentials and Exchange Rates

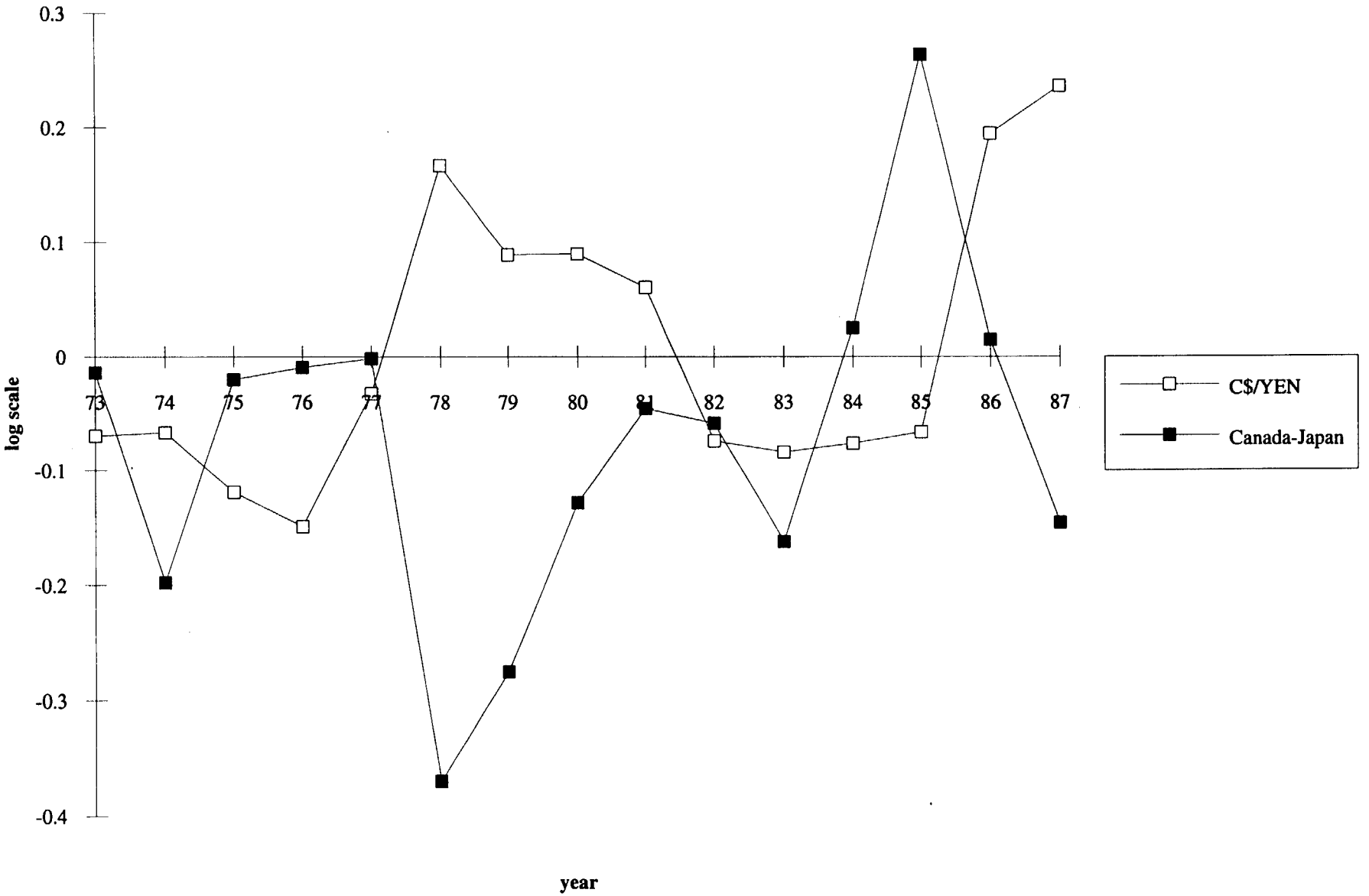

Figure 3. Pound Prices for The Economist

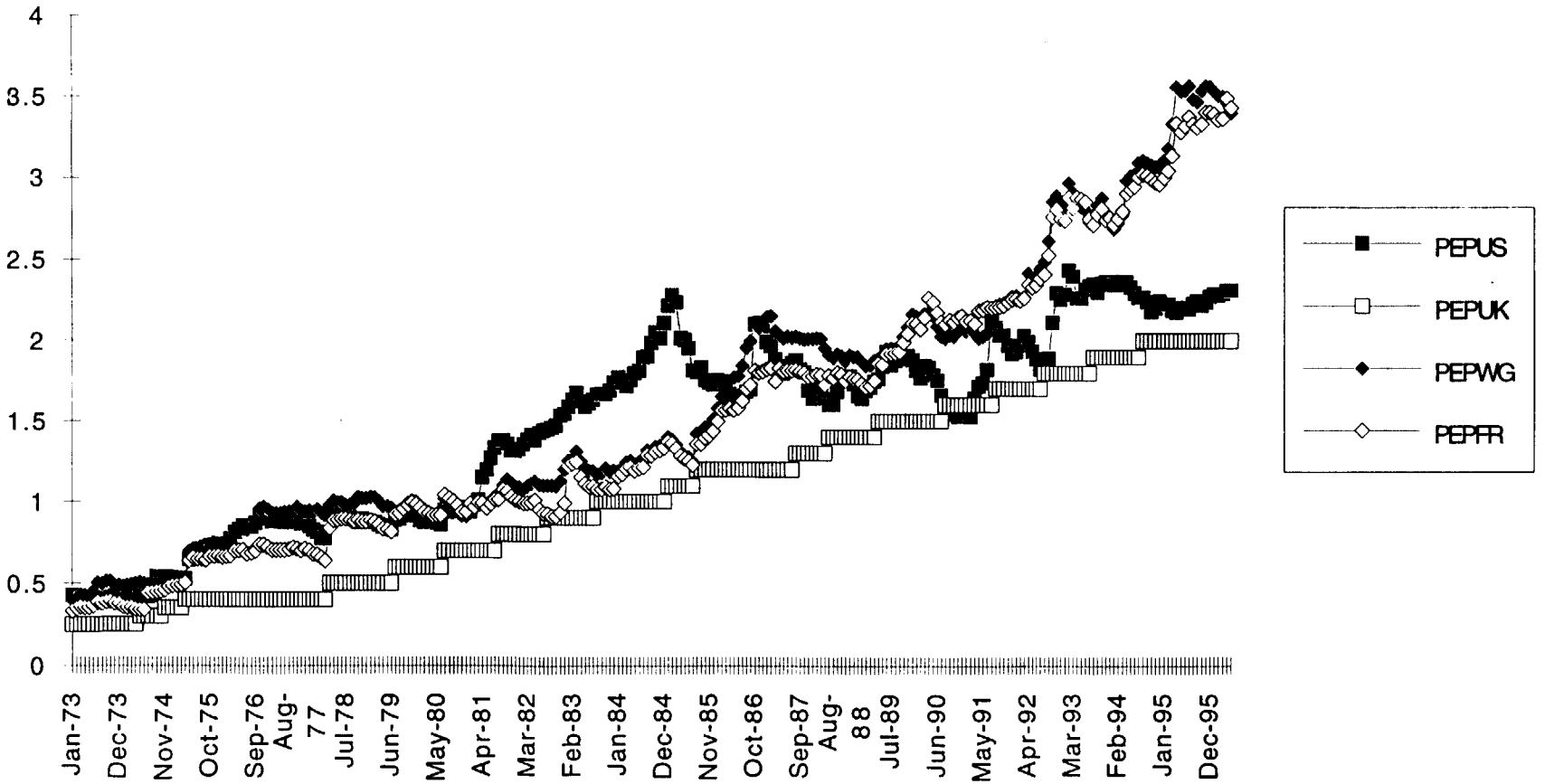

Figure 4. French-German Price Differentials and the Exchange Rate

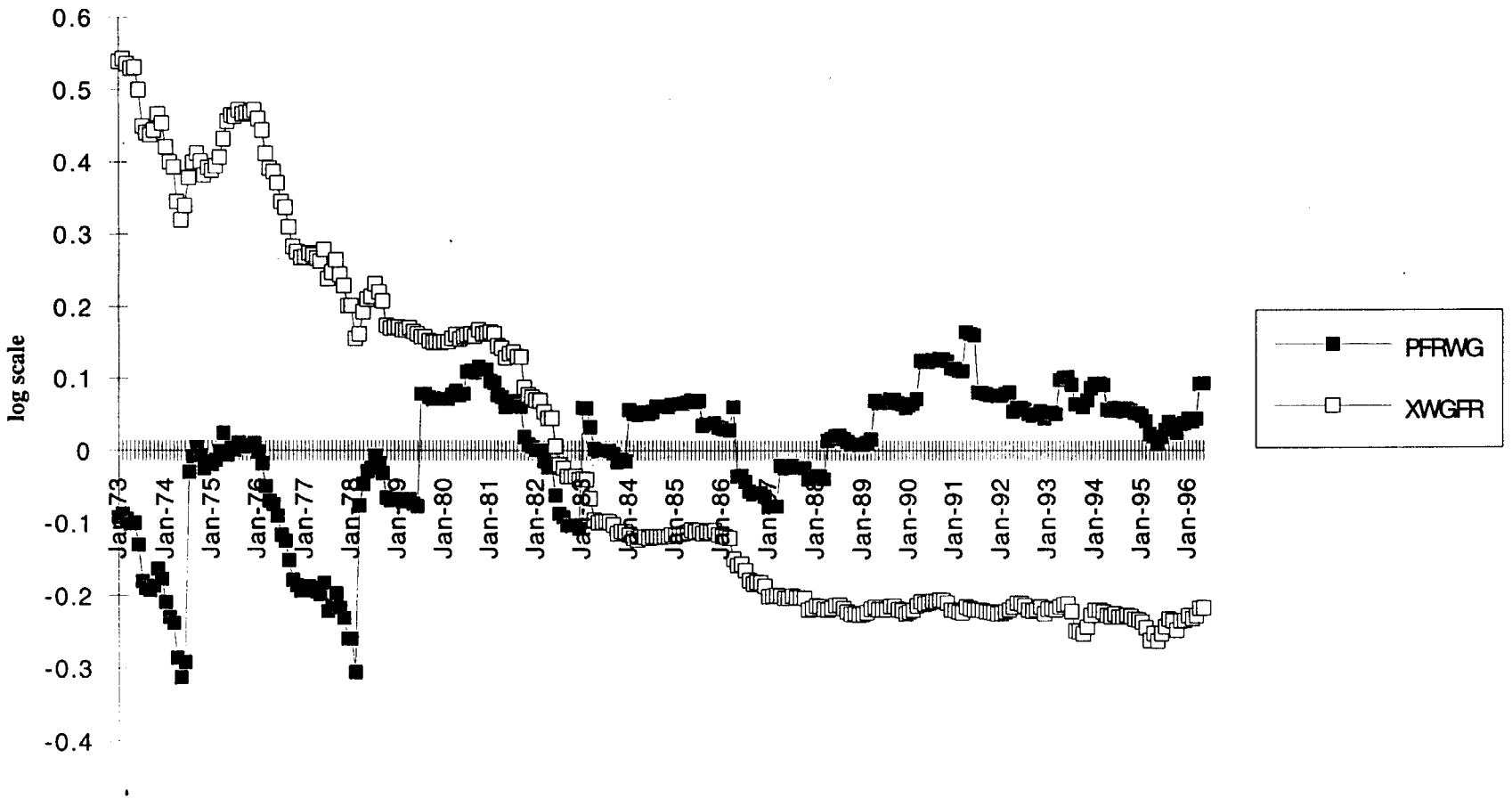

Figure 5. US-German Price Differentials and the Exchange Rate

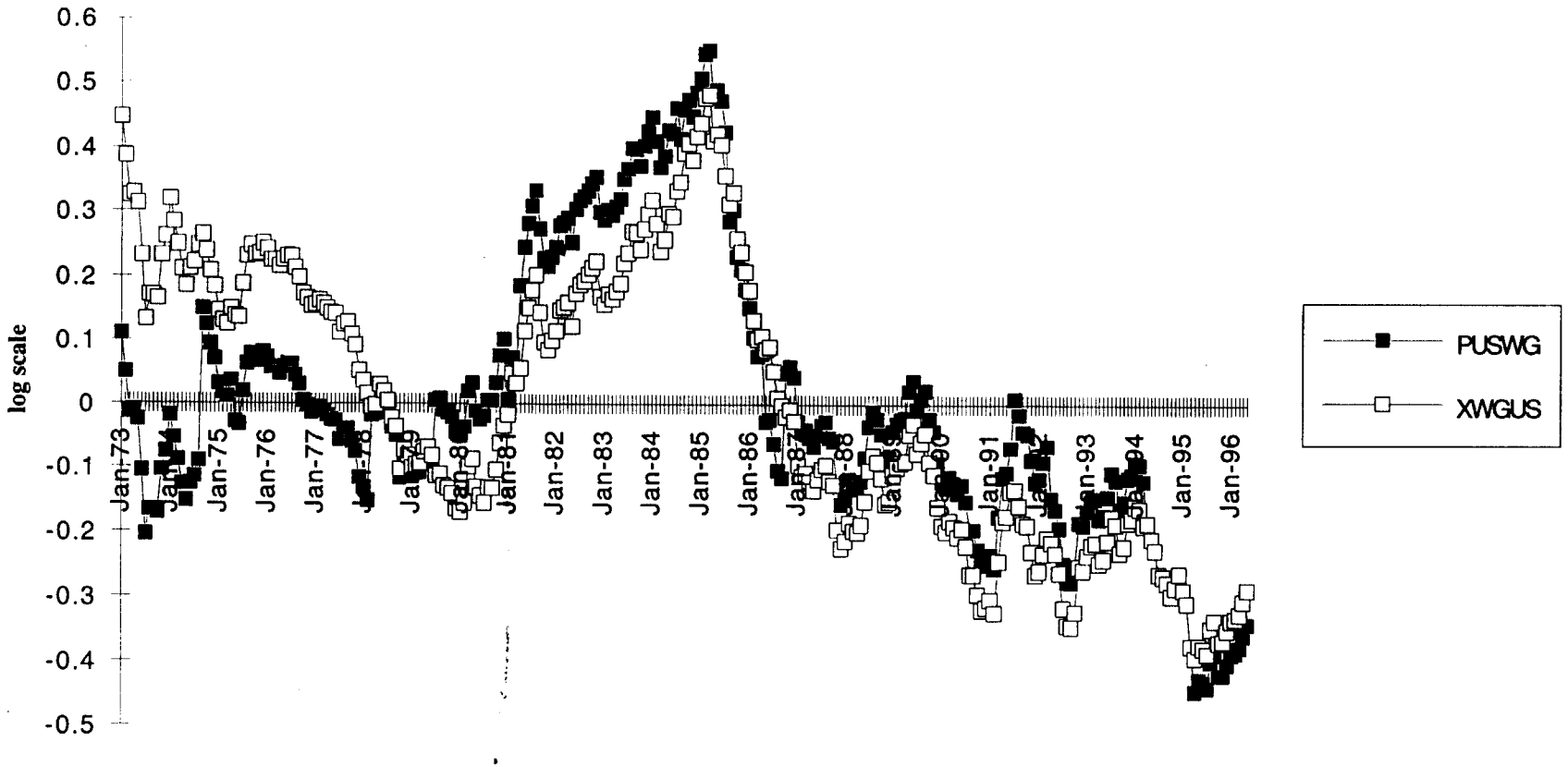

Figure 6. Price and Quantity of German Beer Exports to Japan (1975=100)