# Exchange Rate Pass-Through When Market Share Matters

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*We investigate the pass-through from exchange rates to import prices when firms' future demands depend on current market shares. Foreign firms may either raise or lower their dollar export prices when the dollar appreciates temporarily (i.e., the pass-through may be perverse) and import prices may be more sensitive to expected future than to current exchange rates. We explore whether expected future exchange rates provide a clue to the puzzling recent behavior of U.S. import prices.*

The dramatic swings in the dollar's value in the 1980s have made it clear that foreign producers charge different prices in U.S. markets than in other markets, that is, they "price to market." Furthermore, these price differentials appear sensitive to the level of the exchange rate. It is well known, for example, that luxury German cars became far more expensive in the United States than in Europe during the 1980–84 dollar appreciation. As the dollar subsequently fell, prices of these cars in the United States again became closer to those abroad.[1] This unprecedented fluctuation in relative prices reflects the failure of foreign exporters to pass-through exchange rate changes into dollar import prices.[2] The degree of pass-through is important not only for what it may tell us about competition in international trade, but also because of its implications for the effect of dollar depreciation on the trade balance.

Why might we expect foreign exporters to sell their goods at a higher price in the United States than abroad when the dollar appreciates? One obvious answer is that foreign producers may not be thoroughly foreign, in that some of their costs of advertising, selling, and distributing in the U.S. market are denominated in dollars. A second answer is that an appreciation of the dollar may reduce the elasticity of demand for imports. If demand is linear, for example, dollar appreciation by itself lowers the elasticity faced by foreign firms.[3] Also, in standard oligopolistic models in which foreign firms face U.S. competition, firms' own elasticities fall with an exchange rate appreciation, even when demand is of constant elasticity.[4] A third explanation for pricing to market emphasizes dynamic supply-side effects. Paul Krugman (1986) shows that if it is costly for foreign firms to expand sales rapidly, import prices will not fall much when the dollar appreciates. Richard Baldwin and Krugman (1986) and Avinash Dixit (1987a, b) consider adjustment behavior when firms face nonrecoverable fixed costs of entry. In these latter

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[1] Alberto Giovannini (1988) presents evidence of pricing to market among more homogeneous goods, such as ball bearings.

[2] See the recent empirical work by Catherine Mann (1987a, b) and Mann and Peter Hooper (1987).

[3] A foreign monopolist with constant marginal costs would reduce its dollar prices by the same percentage as the exchange rate change if demand is of constant elasticity, but by less than half that percentage if demand is linear.

[4] See Rudiger Dornbusch (1987) and Paul Krugman (1986) for an exposition of the standard Cournot oligopoly case.

models, a large enough exchange rate change, even if it is temporary, can raise *permanently* both the level of imports and the degree of pass-through—an effect now best known as hysteresis.[5]

This paper takes a different approach by focusing on dynamic demand-side effects in an oligopolistic market. These effects also can induce hysteresis and help explain both why the pass-through may be low and why it may vary through time. We study a model in which firms' future demands depend on current market shares. Expected future exchange rates therefore affect the value of current market share, and so affect current pricing strategies. We show this type of intertemporal dependence implies that the magnitude and even the sign of the pass-through will depend on whether exchange rate changes are thought to be temporary or permanent.

In response to a temporary appreciation of the dollar, for example, foreign exporters to the United States will reduce their dollar prices by less in this model than in the standard static oligopoly framework. This occurs because the appreciation increases the value of current, relative to future, dollar profits expressed in foreign currency. When the value of the dollar is temporarily high, foreign firms will find investments in market share less attractive, and will prefer instead to let their current profit margins grow. In fact, the expectation that the dollar will depreciate over time may erode the value of future profits so much that foreign firms could conceivably *raise* their dollar prices when the exchange rate appreciates.

Permanent dollar appreciations, on the other hand, do not create such incentives to shift profits from tomorrow to today. Since foreigners' current and future costs (expressed in dollars) fall as the dollar undergoes permanent appreciation, foreign firms compete more vigorously, unambiguously driving current prices down. Indeed, prices may fall more than in a static oligopoly model.

The demand-side model we study is actually closely related to the supply-side models of Baldwin and Krugman (1986) and Dixit (1987b). In both types of dynamic models, firms can make initial investments in foreign markets which give them the opportunity to earn future profits. In supply-side models these investments take the form of a sales infrastructure, whereas in our model investments purchase consumer allegiance. Both of these can be interpreted as firm-specific investments in either invisible assets or future demand. The demand-side approach, however, leads to somewhat different conclusions about pass-through. This is because current prices are the means by which firms make investments in market share. First-period prices are in a sense net—rather than gross—of investment expenditures. As a consequence, the pass-through relationship incorporates directly any changes in firms' investment decisions.

The plan of this paper is as follows. Section I presents a simple two-period model in which market shares matter. We show that the two effects that drive our results, *cost* and *interest-rate* effects, are very general: our results do not depend critically on the nature of competition (Cournot or Bertrand), the form of demand, the number of periods, or the reason why market share matters.[6] Section II then turns to disaggregated bilateral export price data to investigate the sensitivity of the pass-through to the expected permanence of exchange rate changes. We also explore the extent to which the perceived permanence of exchange rate fluctuations may have been a factor in the pass-through during the 1980s. Section III concludes.

[5] In these models, the permanent effects come from permanent changes in the number of foreign firms competing in the U.S. market.

[6] In the NBER Working Paper version (section 2), we specialize the model below to a simple "switching costs" model that follows Paul Klemperer (1987a) in order to present rough computations of the magnitude of pass-through.

## I. A General Market Share Model

This section analyzes a simple two-period duopoly competing in a domestic (U.S.) market. Firms' second-period demands, and hence their second-period profits, depend on first-period market shares.[7]

There are a number of ways that this dependence can arise. First, consumers may face substantial costs of switching between brands of a product even if the brands are functionally identical.[8] For example, consumers who have learned to use one type of videocassette recorder find it costly to learn a new one with identical capabilities. There may also be transactions costs of switching suppliers. An example would be the costs of returning rented equipment to one firm and then renting identical equipment from a competitor. Arthur Okun (1975) emphasizes the costs of breaking personal sales relationships in industrial transactions. Firms themselves can create relationships with customers by using repeat-purchase discounts or by making accessories incompatible with other brands. Second, a consumer may be unwilling to switch from a brand that he has tried and liked to an untested rival brand.[9] Indeed, consumers incur search costs even in finding out about the existence or price of a competing product.[10] Past sales also advertise a firm's product to those consumers who have not previously purchased its product. Another reason why past market share matters is provided by network externalities, which give consumers incentives to purchase products that other consumers have purchased previously.[11] For example, as more compact disk players were sold, the disks themselves became cheaper and more abundant, raising the value of a player to new and old users alike. That these or other effects—including perhaps "irrational" brand loyalty— make market share important is attested to by the emphasis placed by many business executives and corporate strategy educators on market share as a goal and a measure of corporate success.[12]

Suppose that in period one, a domestic firm, $D$, chooses its first-period price $p^D$, to maximize its total discounted future profits:

$$\text{(1a)}\quad \pi^D = \pi_1^D(p^D, p^F) + \lambda^D \pi_2^D(\sigma^D(p^D, p^F), \mathbf{e}_2)$$

taking the foreign firm $F$'s first-period price, $p^F$, as given. We choose price competition for expositional convenience and show below that our results do not depend importantly either on this assumption or on the restriction to two periods. $D$'s total profits, $\pi^D$, are the sum of its first- and second-period profits, $\pi_1^D$ and $\pi_2^D$, respectively. Its second-period profits are a function of its first-period market share, $\sigma^D$, and the second-period exchange rate, $\mathbf{e}_2$, expressed in units of foreign currency per dollar. Future profits are discounted by the factor $\lambda^D$ into first-period terms.

Firm $F$ chooses $p^F$ analogously to maximize the present discounted value of its own-currency profits:

$$\text{(1b)}\quad \pi^F = \mathbf{e}_1 \pi_1^F(p^D, p^F, \mathbf{e}_1) + \lambda^F \mathbf{e}_2 \pi_2^F(\sigma^F(p^D, p^F), \mathbf{e}_2),$$

where $\pi_1^F$ and $\pi_2^F$ are its first- and second-period profits in dollars, $\mathbf{e}_1$ and $\mathbf{e}_2$ are the first- and second-period price of dollars in

[7]The analysis below emphasizes that market share may affect a firm's future profits through future demand. Market share may also influence a firm's future profits through its future costs if, for example, firms have learning curves (see Michael Spence, 1981). With minor changes, the model below will apply to this case also.

[8]See Joseph Farrell (1986), Klemperer (1987a,b,c), and Christian von Weizsäcker (1984).

[9]This applies when brands are "experience" goods in the terminology of Phillip Nelson (1970).

[10]See, for example, Edmund Phelps and Sidney Winter (1970). Nils Gottfries (1986) explores the implications of cost and demand shocks in international competition in a version of their model.

[11]See Michael Katz and Carl Shapiro (1985).

[12]Harry Foster (1988) provides a case study of the construction machinery industry in the 1980s. He identifies several reasons why the market shares of two rival brands, Komatsu and Caterpillar, matter for profits.

terms of $F$'s own currency, and $\lambda^F$ is $F$'s own-currency discount factor.

Firm $i$'s discount factor is inversely proportional to the interest rate in $i$'s home market, $\lambda^i = \beta/(1+r^i)$, where $\beta$ measures the duration of the second period relative to the first. If capital is perfectly mobile internationally, domestic and foreign interest rates will be related to future depreciation according to uncovered interest parity:[13]

$$\lambda^D = \lambda^F \mathbf{e}_2/\mathbf{e}_1 = \lambda. \tag{2}$$

In what follows we hold constant the interest rate in the foreign firm's home market, that is, we hold $\lambda^F$ constant, since our main focus is on how the foreign firm's prices differ in different markets.[14]

We assume for simplicity that $F$ has constant marginal costs, $\gamma^F$, expressed in its own currency. In terms of the domestic currency, $F$'s costs in the first and second periods are then given by $c_1^F = \gamma^F/\mathbf{e}_1$ and $c_2^F = \gamma^F/\mathbf{e}_2$, respectively.[15] We also assume that the exchange rate, as well as the aggregate price level, is given exogenously. In noncooperative equilibrium the first-order conditions are thus:[16]

$$\frac{\partial \pi^D}{\partial p^D} = \frac{\partial \pi_1^D}{\partial p^D} + \lambda\left(\frac{\partial \pi_2^D}{\partial \sigma^D}\right)\left(\frac{\partial \sigma^D}{\partial p^D}\right) = 0, \tag{3a}$$

$$\frac{\partial \pi^F}{\partial p^F} = \mathbf{e}_1\left[\frac{\partial \pi_1^F}{\partial p^F} + \lambda\left(\frac{\partial \pi_2^F}{\partial \sigma^F}\right)\left(\frac{\partial \sigma^F}{\partial p^F}\right)\right] = 0. \tag{3b}$$

Since a lower price increases a firm's first-period market share, $(\partial\sigma^i/\partial p^i < 0)$, and provided that a larger market share increases a firm's second-period profits, $(\partial\pi_2^i/\partial\sigma^i > 0)$, (3a) and (3b) imply that $(\partial\pi_1^i/\partial p^i) > 0$, $i = D, F$.[17] Firms therefore choose lower prices than they would if market share had no value (in which case $\partial\pi_2^i/\partial\sigma^i = 0$). Naturally, the level of prices depends on the value of market share. Equations (3a) and (3b) balance the marginal cost of further market-share investment through lower prices $(\partial\pi_1^i/\partial p^i)$, against the marginal return from this investment tomorrow

$$\left(\lambda \frac{\partial \pi_2^i}{\partial \sigma^i}\frac{\partial \sigma^i}{\partial p^i}\right).$$

The marginal return is the effect of price on market share $(\partial\sigma^i/\partial p^i)$ times the effect of current market share on future profits $(\partial\pi_2^i/\partial\sigma^i)$ times the current dollar value of future dollar profits $(\lambda)$. The last two of these terms depend on the future exchange rate.

Note also that our formulation allows for the possibility that firms enter period 1 with extant market shares, $\sigma_0^i$. Naturally, the price levels determined in (3a) and (3b) will depend importantly on initial conditions: firms which have already built large market shares may capitalize on their investments by setting higher prices. This does not affect the qualitative analysis below, however, which focuses on the *response* of prices to exchange rate changes, and not on the *initial levels* of prices. To analyze the effect of exchange rate changes, we do comparative statics on the first-order conditions (3a,b). This strategy allows us to retain the generality of our formulation: we need not impose a specific demand function or reason why market share matters. The effects that we isolate in this way are therefore very general and transcend the particularities of simple models that can be solved explicitly.

[13] Under perfect capital mobility, equation (2) is a natural assumption because, without it, riskless arbitrage would be possible. We could, however, assume that barriers to international capital mobility invalidate (2). Such a change would have only a minor effect on our results. See fn. 24 below.

[14] This is for simplicity only, since our qualitative conclusions about pricing to market depend only on changes in the interest rate *differential*.

[15] In the NBER Working Paper version, we allow for general cost curves.

[16] We assume that the second-order conditions are satisfied, $(\partial^2\pi^i/(\partial p^i)^2) < 0$.

[17] Klemperer (1987a,c) explains why a larger market share in the first period may sometimes reduce profits in the second period.

Totally differentiating (3a) and (3b), and relegating the algebra to the Appendix, we can write firm $i$'s price in reduced form as:

$$p^i = p^i\left(c_1^F, c_2^F, \lambda\right), \tag{4}$$

since $c_1^F$, $c_2^F$, and $\lambda$ are the only variables that depend directly on exchange rates.[18] The effect of a proportional change in the period-$t$ exchange rate is therefore:[19]

$$\frac{dp^i}{d\mathbf{e}_t} = \left(\frac{\partial p^i}{\partial c_t^F}\right)\left(\frac{dc_t^F}{d\mathbf{e}_t}\right) + \left(\frac{\partial p^i}{\partial \lambda}\right)\left(\frac{d\lambda}{d\mathbf{e}_t}\right), \tag{5}$$

where $\mathbf{e}_t = \ln(\mathrm{e}_t)$. From the definitions above we have $\mathrm{e}_t(dc_t^F/d\mathrm{e}_t) = \mathrm{e}_t(-\gamma^F/\mathrm{e}_t^2) = -c_t^F$, $\mathrm{e}_1(d\lambda/d\mathrm{e}_1) = \mathrm{e}_1(-\lambda F_{\mathrm{e}_2}/\mathrm{e}_1^2) = -\lambda$, and $\mathrm{e}_2(d\lambda/d\mathrm{e}_2) = \mathrm{e}_2(\lambda^F/\mathrm{e}_1) = \lambda$. Thus, the effect of a current, temporary and proportional appreciation of the domestic currency is:

$$\frac{dp^i}{d\mathbf{e}_1} = -c_1^F\left(\frac{\partial p^i}{\partial c_1^F}\right) - \lambda\left(\frac{\partial p^i}{\partial \lambda}\right), \tag{5a}$$

while the effect of a future proportional appreciation is:

$$\frac{dp^i}{d\mathbf{e}_2} = -c_2^F\left(\frac{\partial p^i}{\partial c_2^F}\right) + \lambda\left(\frac{\partial p^i}{\partial \lambda}\right). \tag{5b}$$

These equations separate price changes into two terms, which we call *cost effects* and *real interest rate effects*.

In a standard static model of international competition, prices are unaffected by future costs or by discount factors ($\partial p^i/\partial c_2^F = \partial p^i/\partial\lambda = 0$). In such models the only effect is the first-period *cost effect*, $-c_1^F(\partial p^i/\partial c_1^F) < 0$. An appreciation of the dollar—an increase in $\mathbf{e}_1$—decreases $F$'s dollar costs and encourages $F$ to reduce its price. $D$'s optimal response is, in general, to reduce its price as well (see the Appendix).

When market share matters, however, the other terms in (5) are no longer zero.[20] $F$'s second-period costs (in dollars) affect both firms' second-period profit functions and so influence first-period pricing decisions. If lower second-period costs increase the marginal value of market share to $F$,[21] that is, increase $(\partial\pi_2^F/\partial\sigma^F)$, then $F$ increases market-share investment by lowering its price. In terms of (3b), $(\partial\pi_1^F/\partial p^F)$ increases, so $p^F$ falls. Thus we expect that the second-period cost effect on $F$'s price is negative, $-c_2^F(\partial p^F/\partial c_2^F) < 0$: expected future dollar appreciation lowers $p^F$.[22]

In addition to cost effects this model gives rise to *real interest rate effects*, which correspond to the second terms in (5). A temporary appreciation makes future dollar profits relatively less valuable than current dollar profits. The return on market-share investment therefore falls. When firms invest less, they raise current prices and let their profit margins grow. Specifically, an increase in $\mathbf{e}_1$ lowers $\lambda$, hence lowers $(\partial\pi_1^i/\partial p^i)$, and so raises $p^i$. Thus we expect $-\lambda(\partial p^i/\partial\lambda) > 0$: interest rate effects tend to *increase* import prices when the dollar appreciates.

[18] The domestic firm's costs are not altered by exchange rate changes. This is a result of our assumption that $c_t^D$ is fixed in domestic currency. This assumption is, however, not crucial. As long as domestic costs remain relatively unaffected by exchange rate changes in comparison with foreign costs expressed in domestic currency, we would obtain qualitatively similar results.

[19] We write $(dp^i/d\mathbf{e}_t)$ here, and similar expressions below, to reduce notational complexity. Strictly, since we have previously defined $p^i(\cdot)$ as a function of $c_1^F$, $c_2^F$, and $\lambda$, we should give a different name to the function relating $p^i$ and $\mathbf{e}_1$ and $\mathbf{e}_2$: $p^i = \tilde{p}^i(\mathbf{e}_1, \mathbf{e}_2)$, and write $(\partial\tilde{p}^i/\partial\mathbf{e}_t)$ here.

[20] The presence of market share effects also alters the magnitude of the first-period cost effect. This occurs because a change in current costs alters the return on investment in market share, and because the slopes of firms' reaction functions are determined in part by the importance of market share.

[21] This will always be true in the limiting case when market shares are so important that in the second period each firm is a monopolist in its first-period share of the market, and in general the term will be larger (more positive) the more market share matters.

[22] The second-period cost effect on $D$'s price is hard to sign. See the Appendix for more detail.

We show in the Appendix that the interest rate effect on $i$'s price can be written as

$$\lambda\left(\frac{\partial\pi_2^F}{\partial\sigma^F}\right)\left(\frac{-\partial\sigma^F}{\partial p^F}\right)\phi^i + \lambda\left(\frac{\partial\pi_2^D}{\partial\sigma^D}\right)\left(\frac{-\partial\sigma^D}{\partial p^D}\right)\psi^i.$$

The terms $\phi^i$ and $\psi^i$ are generally positive and depend on the second derivatives of the profit functions, $\pi^F$ and $\pi^D$. (For firm $F$, the second part of the expression arises from its response to $D$'s changed behavior, and conversely for $D$). The greater in magnitude the effect of price on today's market share ($\partial\sigma^i/\partial p^i$), or the greater the effect of market share on second-period profits ($\partial\pi_2^i/\partial\sigma^i$), or the greater the value of second-period dollar profits in terms of current dollars ($\lambda$), the greater we expect the interest rate effects to be.

Note that the interest rate effects operate even in thoroughly domestic industries. Indeed, this type of effect is general to any model in which prices can fall as firms shift profits over time in response to interest rate changes.[23] An important feature of this model is that lower prices are not just the result of a change in competition; they are the *mechanism* by which investments are made.

Of course, if we had held constant the U.S. interest rate instead of the foreign interest rate, then the interest rate effect would be absent in the U.S. market. From (2), the required fall in the foreign interest rate would, however, raise the return on investments in foreign market share, and therefore lower dollar prices in the foreign market. Thus, regardless of the change in either country's interest rate, as long as the interest differential increases with the temporary dollar appreciation, the differential between U.S. and foreign prices increases as well.[24]

In fact, in a model more general than this one, we would see interest rate effects in the U.S. market even if only the foreign interest rate moved in response to the increase in expected dollar depreciation. Assume firms produce for both the U.S. and foreign markets and have increasing marginal costs in the short run due, for example, to capacity constraints. Then a temporary dollar appreciation which leaves U.S. interest rates unchanged but reduces foreign interest rates makes foreign market share relatively more valuable than U.S. market share. It follows that firms will reallocate output toward the foreign market and away from the U.S. market, thereby raising U.S. prices.

In the current model, the total effect of a temporary exchange rate appreciation on prices is ambiguous, since the interest rate and cost effects are opposed. If the two effects are of similar magnitudes, dollar import prices will appear to be sticky in response to exchange rate changes that are

[23] For example, lower real interest rates may lower prices by encouraging capital investment that lowers marginal costs (although investments in durable advertising might raise prices). In Dixit (1987b) lower real interest rates encourage more firms to pay the fixed costs of entering a market, leading to greater competition and so also to lower prices. See Joseph Stiglitz (1984) for other possible relationships between real interest rates and prices. Phelps and Winter (1970), and Phelps (1986) discuss the tendency for high real interest rates to raise markups in a single-economy model, and Jean-Paul Fitoussi and Phelps (1986) place much of the blame for the persistently high rates of unemployment in Europe on this kind of mechanism. John Maynard Keynes (1930) refers to a similar effect, which posits positive correlation between the level of prices and the nominal interest rate, as Gibson's paradox. See also Robert Barsky and Lawrence Summers (1985).

[24] To see how the results are affected by relaxing uncovered interest parity, suppose that domestic interest rates are independent of expected exchange rate changes. In that case, our analysis would be unchanged except that $D$'s marginal incentive to invest in market share would not be affected by exchange rate changes: the interest rate effect would not include the term

$$\lambda\left(\frac{\partial\pi_2^D}{\partial\sigma^D}\right)\left(\frac{\partial\sigma^D}{\partial p^D}\right).$$

The value to $F$ of second-period dollar profits relative to first-period dollar profits would remain $\lambda F_{e_2}/e_1$, and would depend on exchange rates exactly as above. Thus, the first term of the interest rate effect—which is proportional to $\lambda(\partial\pi_2^F/\partial\sigma^F)(\partial\sigma^F/\partial p^F)$—would be unaffected. The cost effects would be completely unchanged.

perceived to be temporary, despite the fact that prices are perfectly flexible. Interest rate effects will be relatively more important in markets in which profits, and hence the values of market shares, are large relative to costs. In the NBER Working Paper version, we show in an example that the interest rate effect can easily dominate, in which case import prices respond perversely to exchange rate changes.[25] Note that if only a fraction of $F$'s costs are incurred outside the United States, the cost effect (but not the interest rate effect) is multiplied by that fraction. In general, under a purely temporary exchange rate change, the real interest rate effect *must* dominate if firms' costs are sufficiently low, or if a sufficiently small fraction of costs are fixed in $F$'s own currency.[26]

The effect of a permanent percentage change in the exchange rate (i.e., $d\mathbf{e}_1 = d\mathbf{e}_2$) is simply the sum of (5a) and (5b):

$$\text{(5c)} \quad \frac{dp^i}{d\mathbf{e}_1} + \frac{dp^i}{d\mathbf{e}_2} = -c_1^F\left(\frac{\partial p^i}{\partial c_1^F}\right) - c_2^F\left(\frac{\partial p^i}{\partial c_2^F}\right).$$

For a permanent exchange rate change, the interest rate effects cancel: the *relative* values of current and future profits do not change. Equation (5c) is therefore just the sum of the cost effects. Since the cost effects have the same sign, and since the cost and interest rate effects under temporary exchange rate changes are opposed, a permanent dollar appreciation lowers dollar prices more than a temporary appreciation.[27]

Since an expected future exchange rate change gives rise to an interest rate effect that is equal and opposite to a temporary change, the cost and interest rate effects are in the same direction. Current prices may therefore be more sensitive to expected future exchange rate changes than they are to contemporaneous changes.

Finally, this model provides a reason why greater uncertainty about future exchange rates may affect current prices. A foreign firm's future profitability in the U.S. market is typically a convex function of the exchange rate: when dollar costs are lower, dollar profits are higher exactly when dollars are more valuable. Therefore greater exchange rate uncertainty increases the expected value of U.S. market share to a risk-neutral foreign firm, and so tends to reduce $F$'s prices.[28] If, however, $F$ were sufficiently risk averse, greater exchange rate uncertainty would reduce the value to $F$ of investment in U.S. market share. In such a case $F$ would prefer to take profits, and would tend to *raise* its price.

*Quantity Competition.* Since our main interest is in prices, our analysis has assumed for simplicity that firms compete on price. It is straightforward, however, to reinterpret our model as a quantity-competition model. To do so, just redefine $p^i$ as firm $i$'s first-period quantity. Then equations (3)–(5) are unchanged, but $(\partial\sigma^i/\partial p^i) > 0$ (a larger quantity increases market share), so (3) implies $(\partial\pi_1^i/\partial p^i) < 0$ and the signs of $(\partial p^F/\partial c_1^F)$, $(\partial p^F/\partial c_2^F)$, and $(\partial p^i/\partial\lambda)$ in (5)

[25] This example assumes homogeneous products, quantity competition, and linear demand in the first period and large enough consumer switching costs that in the second period each firm behaves as a monopolist over its first-period share of the market. The condition for the interest rate effect to dominate is approximately:

$$\lambda \times \text{percent profit margin of a monopolist}$$
$$> (5\alpha/2) \times \text{foreign firms' market share},$$

in which $\alpha$ is the fraction of the foreign firms' costs incurred outside the United States.

[26] In reality, of course, expected future exchange rates move strongly with current rates: exchange rate changes are predominantly permanent. Thus, even if the theory were to predict that interest rate effects would dominate in a certain industry, we would not usually expect to see a perverse pass-through in the data.

[27] This suggests a presumption that the effects of a permanent exchange rate change are greater here than in a standard model in which market share is unimportant, and in which the only effect present is the first-period cost effect. This presumption is justified in the example of section 2 of the NBER Working Paper version. Generally, however, we should be cautious on this point because incorporating the market-share effects changes firms' first-period behavior and so changes the magnitudes of the first-period cost effects.

[28] To save space, we omit a formal derivation. See the NBER Working Paper version for details.

are similarly usually reversed. Thus, exchange rate changes that lower prices in price competition raise quantities in quantity competition: in both cases prices fall. In this sense, our results do not depend importantly on the price-competition assumption. The Appendix gives details.

*More Than Two Periods*. We have discussed the effects of exchange rate changes on the first period of this two-period model. The effects we identified are also present in every period, except the last, of a multiperiod model.[29] To form a multiperiod model we could replace the current-period profit functions $\pi_1^i(p^D, p^F, \mathbf{e}_1)$, by the functions $\pi_t^i(p_t^D, p_t^F, \mathbf{e}_t)$, and replace the future-period profit functions, $\pi_2^i(\sigma^i, \mathbf{e}_2)$, by the value functions $V_{t+1}^i(\sigma_t^i, \mathbf{e}_{t+1})$. The analysis would proceed as above.[30] Every period $t$ has the characteristics of the first period of our two-period model: each firm trades off the benefits of cutting price to win new market share against the costs of reducing period-$t$ profit margins. Cost effects and interest rate effects arise exactly as in the model above. Thus we expect our qualitative conclusions to hold good in a many-period model.[31]

## II. Data Analysis

Naturally, the stylized model above is likely to be only one explanation among many for actual pass-through behavior. In this section, we nevertheless look to the data to test a simple but important implication of our model: that the degree of pricing to market depends on the perceived permanence of exchange rate changes. While it is not in itself surprising that permanent appreciations exert more downward pressure on prices than temporary appreciations,[32] such a distinction might help explain the puzzling fall in the 1980s in the pass-through from the dollar exchange rate to U.S. import prices.[33]

One way to view pass-through behavior over this period is to compare foreign exporters' profit margins with the real exchange rate, as shown in Figure 1.[34] The graph traces out a cycle in profit margins to match the dollar cycle in the 1980s, with a large bulge in profits peaking in early 1985. On average over the sample, 50 percent of real exchange rate changes are passed through into profit margins.[35] One cannot

[29] The effect of an exchange rate change in the last period is just the cost effect that is present in a standard oligopoly model. (In the last period there is no future so market share is no longer valuable). The magnitude of this effect will of course depend on the form of last-period demand which will be different from that in a standard oligopoly model, and will be affected by previous periods' outcomes.

[30] In our analysis we did not derive firms' optimal pricing functions. Instead, our strategy was to characterize the behavior of the first-order conditions in (3a) and (3b), which are necessary for an optimum. The same strategy can be used for examining pass-through in a multiperiod model.

[31] The quantitative results will of course depend on how past market shares affect current profit functions, $\pi_t^i$. However, although the levels of prices are likely to be higher in the general period of a multiperiod model (if firms develop some monopoly power over their previous market shares) than in our first period, the derivatives of these prices with respect to costs and interest rates, and hence the sizes of the pass-through, may not be very different from those our model would suggest. See Alan Beggs and Klemperer (1989) and Farrell and Shapiro (1988) for multiperiod models of switching.

[32] In any dynamic model with costly adjustment, a temporary exchange rate change produces less adjustment than a permanent change. The hysteresis models of Dixit (1987a, b), Baldwin and Krugman (1987), and Baldwin (1988), as well as the model in Section I of this paper, could all be supported over standard static models if the permanence of exchange rate changes were found to affect systematically pricing to market. Thus these models as well as ours might explain the empirical results presented below, even though the test below is not really appropriate for a supply-side hysteresis model, which would imply that firms make discrete (as opposed to purely continuous) adjustments.

[33] Disaggregated data in Mann (1987b) and Helkie and Hooper (1988) indicate that U.S. import prices have moved too little in response to exchange rate changes to be consistent with historical experience.

[34] The real exchange rate is calculated using U.S. trade weights with 10 major industrial trading partners. Profit margins are the U.S. fixed-weight import price index (excluding business machines) divided by the Federal Reserve Board's index of foreign production costs across the same 10 countries.

[35] A regression of the change in the profit margin on the change in the real exchange rate yields: $\Delta pm_t =$

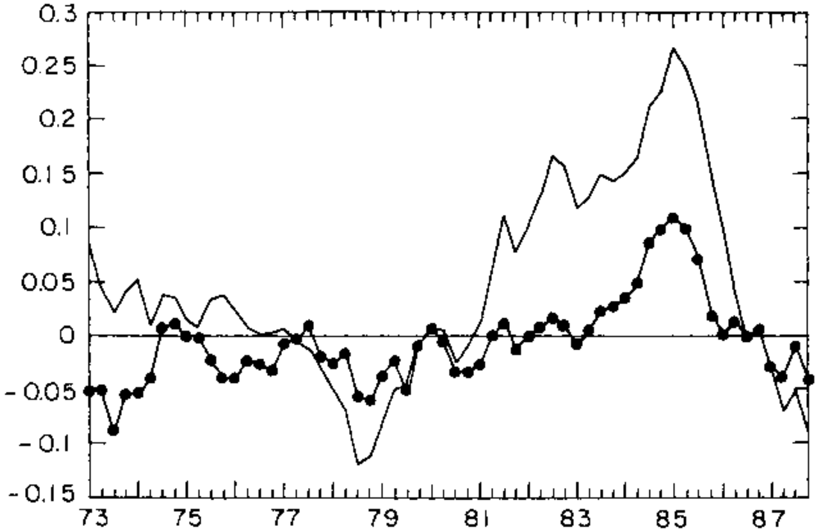


FIGURE 1. FOREIGN PROFIT MARGINS ON EXPORTS TO THE UNITED STATES AND THE VALUE OF THE DOLLAR. DOLLAR (LOG INDEX).—IS AN INDEX REAL VALUE OF THE DOLLAR; ··· IS THE FOREIGN PROFIT MARGINS.
*SOURCES*: BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM AND AUTHORS' CALCULATIONS

reject the hypothesis that the pass-through remained the same during the recent appreciation (1981–84) and depreciation (1985–1987) phases, but during the second half of the appreciation (1983:1 to 1984:4) and the first half of the following depreciation (1985:1 to 1986:1) the pass-through from real exchange rate changes to profit margins rose to 79 and 65 percent, respectively. This implies a detectable (although not statistically significant) *reduction* in the pass-through from exchange rate changes to dollar import prices.[36] This reduction is the more dramatic if the increase in competitiveness in the U.S. market predicted by many dynamic supply-side models has in fact occurred.

If the unusual rise in the dollar's value in the 1980s was believed to be more temporary than prior appreciations, profit-maximizing firms in our model would have let their profit margins rise by more than historical experience would suggest.[37] There is, in fact, some evidence that suggests the recent appreciation was viewed as a temporary phenomenon by historical standards. Survey data on exchange rate expectations, for example, show that during the period from 1982 to 1985, respondents consistently believed the dollar would begin to depreciate rapidly within the next twelve months.[38] In-

$0.504\Delta rer_t + \varepsilon_t$, with standard error of the coefficient of 0.072, $\bar{R}^2 = 0.45$, $\sigma = 0.0163$, $DW = 1.95$. Adding lags and/or a constant term has little effect on these results.

[36]Mann (1987b) discusses the pitfalls in using aggregate data to infer the behavior of foreign producers' profit margins.

[37]To be sure, over the floating rate period it is difficult, if not impossible, to reject the hypothesis that the real exchange rate follows a random walk over relatively short forecast horizons—see, for example, Richard Meese and Kenneth Rogoff (1988). Newer evidence for the longer intervals which are more relevant to our analysis, however, suggests that as much as 50 percent of real exchange rate changes are temporary. See John Huizinga (1986).

[38]See Jeffrey Frankel and Kenneth Froot (1987) for a description of this survey data.

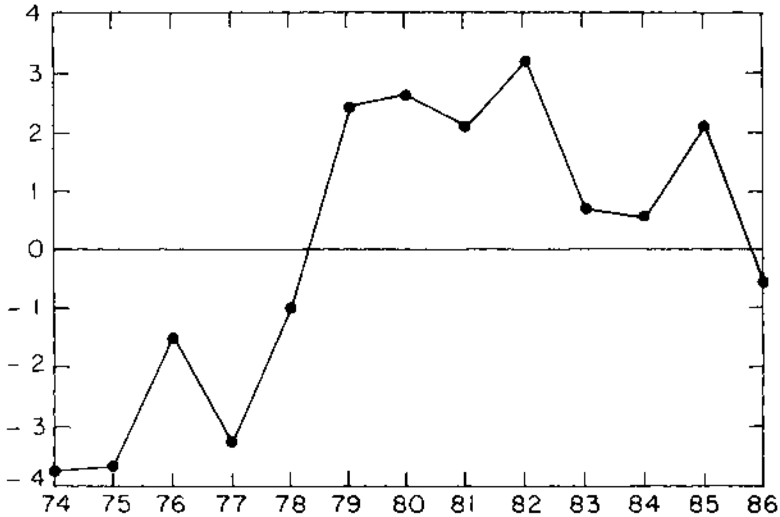


FIGURE 2. TWELVE-MONTH DOLLAR DEPOSIT RATE LESS AVERAGE TWELVE-MONTH RATE FOR THE POUND, MARK, YEN, AND FRANC.
*SOURCES*: DATA RESOURCES, INC., AND AUTHORS' CALCULATIONS

deed, nominal depreciation at an annual rate of 7 to 10 percent was expected on average by this measure.

A more common measure of expected depreciation, the nominal interest differential between U.S. and foreign eurocurrency deposits, yields the same qualitative conclusion. Figure 2 shows a simple average of the differences between twelve-month eurodollar deposits and similar deposits for the pound, mark, yen, and French franc. By this measure, the dollar was expected to depreciate most rapidly in the early 1980s, just when the rate of appreciation was also the greatest.[39]

Of course, our model focuses on real and not nominal magnitudes. Calculation of expected real depreciation, however, is further hindered by the inability to observe expected inflation. Nevertheless, expected real depreciation appears to be positively correlated with our estimates of expected nominal depreciation. Table 1 presents estimates of both expected nominal depreciation of the dollar and expected inflation in the United States relative to that in several of its major trading partners. We have chosen a variety of measures to ensure that the behavior of expected real depreciation is not due to the peculiarities of any one measure. We report three (out of many possible) ways of calculating expected real depreciation in the bottom portion of Table 1. Regardless of the precise measures used, the early 1980s were characterized by expectations of unusually large future real depreciation.

To investigate the role of expected depreciation more closely, we examine the differential effect of exchange rate changes on prices charged by foreign exporters in different markets. Consider as an example, the one-period percentage change in a British exporter's dollar price on exports to the United States less the percentage change in its dollar price on exports to Japan:

$$\Delta p_t^{UK,US} - \Delta p_t^{UK,JA}. \tag{5}$$

If there is pricing to market, a current appreciation of the dollar relative to the yen will raise the relative price of exports to the U.S. market, so that expression (5) will be positive.

[39] The interest differential is not a perfect measure of expected depreciation because it is contaminated by the exchange risk premium. However, the alternative survey measure, which is free from this kind of contamination, shows expected depreciation to be *greater* during this period. Thus the interest differential in Figure 2 may well understate expected depreciation.

TABLE 1—MEASURES OF EXPECTED REAL DEPRECIATION OF THE DOLLAR (PERCENT PER ANNUM)

| | Years | | | | |
|---|---|---|---|---|---|
| Measures of Expected Nominal Depreciation[a] | 1976–78 | 1979–80 | 1981–82 | 1983–84 | 1985–86 |
| 1. One-Year Forward Discount | 0.18 | 2.57 | 3.34 | 1.85 | 0.10 |
| 2. Expected Depreciation from Surveys | | | | | |
| a. Economist 12 Month | NA | NA | 8.57 | 8.60 | 1.03 |
| b. Amex 12 Month | 0.61 | NA | 6.67 | 6.99 | 3.72 |
| Measures of Expected Inflation Differential[b] | | | | | |
| 3. One-Year Lag | −1.01 | 3.54 | 0.88 | −0.35 | 0.62 |
| 4. Three-Year Distributed Lag | −1.96 | 2.70 | 1.89 | −0.18 | 0.41 |
| 5. DRI Three-Year Forecast[c,d] | NA | 2.20 | 0.96 | 0.23 | 0.15 |
| 6. OECD Two-Year Forecast[e] | 1.42 | 2.24 | 0.62 | 0.61 | 0.91 |
| Measures of Expected Real Depreciation | | | | | |
| 7. One-Year Forward Lag (1–3) | 1.19 | −0.97 | 2.46 | 2.20 | −0.52 |
| 8. Economist/One-Year (2a-3) | NA | NA | 7.69 | 8.95 | 0.41 |
| 9. Average (1,2)-Average (3,...,6) | 0.91 | −0.10 | 5.11 | 5.74 | 1.09 |

*Notes:* [a] Measures of expected nominal depreciation calculated using a GNP-weighted average of the pound, franc, mark, and yen against the dollar.
[b] Measures of expected inflation differential calculated as United States minus a GNP-weighted average of the UK, France, West Germany, and Japan.
[c] Available during 1985–86 for 1985 only.
[d] Averages of various forecast dates beginning March 1978.
[e] OEDC forecasts available during 1976–78 only for December 1978.
*Sources:* IMF International Financial Statistics, DRI FACS financial database and forecasts, OECD Economic Outlook, Amex Bank Review, and Economist Financial Report.

A simple way to capture pricing to market and its sensitivity to exchange rate expectations is to project a measure of (5) onto the change in expected future depreciation of the real dollar/yen exchange rate and the contemporaneous change in the real exchange rate:[40]

$$(6)\quad \Delta p_t^{i,UK,US} - \Delta p_t^{i,UK,JA} = \beta_1 \Delta E_t\left(\Delta e_{t+1}^{US,JA}\right) + \beta_2 \Delta \mathbf{e}_t^{US,JA} + \varepsilon_t^{i,US,JA},$$

where the superscript $i$ represents the $i$th industry, $\Delta \mathbf{e}_t^{US,JA}$ is the change from period $t-1$ to $t$ in the log of the real dollar/yen rate, and $\Delta E_t(\Delta \mathbf{e}_{t+1}^{US,JA})$ is the percentage-point change from period $t-1$ to $t$ in expected depreciation of the real dollar/yen rate over the following period. If there were no pricing to market, both sides of (6) would on average be zero. If there were pricing to market but all industries behaved in exactly the same way, then (to a first-order approximation) the error term, $\varepsilon_t^i$, would be zero. Finally, with pricing to market and diversity across markets, the error term would appear random over $i$. Thus (6) represents a crude but informative test of a basic property of our model.[41]

[40] In the model of Section I, the relationship between discrete percentage changes in price and changes in exchange rates is not necessarily linear, so that (6) is only a first-order approximation.

[41] Note that under the null hypothesis that the model in Section I is true, the coefficients would be industry-specific:

$$\Delta p_t^{i,UK,US} - \Delta p_t^{i,UK,JA} = \beta^i X_t^{UK,US} + \eta_t^{i,US,JA},$$

The coefficient $\beta_1$ in (6) measures the degree of pricing to market that occurs in response to an expected future depreciation in the dollar/yen rate. That is, a 1 percentage point increase in the expected future depreciation of the dollar, $(\Delta E_t(\Delta \mathbf{e}_{t+1}^{US,JA}) = 1)$, given no change in the current spot rate, $(\Delta \mathbf{e}_t^{US,JA} = 0)$, results in a proportional increase of $\beta_1$ in the relative price of exports sent to the United States versus exports sent to Japan.[42] Conventional static models would yield $\beta_1 = 0$, while our model predicts $\beta_1 > 0$. Similarly, the coefficient $\beta_2$ measures the effect of a permanent depreciation of the dollar on pricing to market. If, for example, changes in the dollar/yen rate are passed through one-for-one into dollar import prices (so that there is no pricing to market) we would expect $\beta_2 = 0$. If, on the other hand there is no pass-through at all, we would expect $\beta_2 = -0.01$. Finally, the pass-through from a current depreciation that is expected to be purely temporary is given by $\beta_2 - \beta_1$. If, for example, $\beta_2 - \beta_1 = 0$, there is no pricing to market in response to temporary exchange rate changes. If $\beta_2 - \beta_1 = -0.01$, the *dollar* prices of U.S. imports are insensitive to temporary exchange rate changes. If $\beta_2 - \beta_1 < -0.01$, the pass-through for temporary exchange rate changes tends to be perverse: in response to a current appreciation of the dollar, foreign exporters raise their dollar prices on exports to the United States.

To measure the price term on the left-hand side of (6), we use highly disaggregated bilateral export unit value data from the U.N. Our sample covers annual exports (1981–86) of 65 industries *from* each of the UK, West Germany (*WG*), France (*FR*), and Japan (JA) *to* each of the United States, JA, and the UK. The term $\Delta \mathbf{e}_t^{US,JA}$ is measured by the change over the last twelve months of the dollar/yen rate, adjusted by the CPI in the United States and Japan (and similarly for other currencies). In the regressions that follow, we used the two measures of expected real depreciation given in lines 7 and 8 of Table 1. Thus the term $\Delta E(\Delta \mathbf{e}_{t+1}^{US,JA})$ is either the change in the twelve-month forward discount or the survey expected depreciation of the dollar/yen rate, plus a proxy for expected inflation (the change in inflation in Japan over the previous twelve months less the change in inflation in the United States over the previous twelve months).

It is well known that the bilateral unit value indexes we use are subject to substantial measurement errors. Nevertheless in this context, their problems are attenuated. First, by using bilateral export data we ensure that the exchange rate changes on the right-hand side of the equation can be measured with precision. When using multilateral data, for example, it is difficult to know the precise weights that should be applied to measure "the" exchange rate change. Second, the potentially large measurement errors contained in the price data themselves are less of a problem here because they are on the left-hand side of the equation. Thus by selecting noisier measures of price changes, we are able to use cleaner measures of the explanatory variables.

Tables 2a and 2b present estimates of (6) using the interest differential and the survey measures of expected depreciation, respectively. The estimates were performed using OLS. We used the averaged data for all variables over the two-year periods reported in Table 1.[43] We report the usual OLS stan-

where $X_t^{UK,US} = [E_t(\Delta \mathbf{e}_{t+1}^{US,JA})\Delta \mathbf{e}_t^{US,JA}]$, $\beta^i = [\beta_1^i \beta_2^i]$, and $\eta_t^{i,US,JA}$ represents measurement error in the dependent variable (see the discussion in the text below). Equation (6) constrains the coefficients to be equal across industries. Because the regressors are not industry-specific, it is easy to show that the coefficients estimated in (6) are averages of the coefficients for the $N$ individual industries:

$$\hat{\beta} = \frac{1}{N}\sum_{i=1}^{N} \hat{\beta}^i,$$

where $\beta = [\beta_1 \beta_2]$. A randomly drawn industry thus behaves on average according to the constrained coefficients, $\beta$. To see that the industry-average interpretation in (6) satisfies the Gauss-Markov assumptions, note that the error term can be written:

$$\varepsilon_t^{i,UK,US} = \eta_t^{i,UK,US} + (\beta^i - \beta)X_t.$$

The expectation of $\varepsilon_t^{i,US,JA}$ conditional on the regressors is zero, since the regressors do not provide information about a specific $\beta^i$ relative to the mean, $\beta$.

[42] The regression results are reported in a manner that permits exactly this type of calculation.

[43] Initially we estimated (6) on the original annual data. The resulting parameter estimates were similar to

TABLE 2a—EXCHANGE RATE PASS-THROUGH AND THE EFFECTS OF EXPECTED DEPRECIATION
$\Delta p_t^{i,j,k} - \Delta p_t^{i,j,l} = \beta_1 \Delta E_t(\Delta e_{t+1}^{k,l}) + \beta_2 \Delta e_t^{k,l} + \varepsilon_t^i$

| Dependent Variable | $\beta_1$ | $\beta_2$ | $SE$ | $DF$ | $F$-test $\beta_1 = \beta_2 = 0$ | $F$-test $\beta_2 - \beta_1 = 0$ |
|---|---|---|---|---|---|---|
| $\Delta p_t^{i,UK,US} - \Delta p_t^{i,UK,JA}$ | 0.1399** | 0.0135** | 0.33 | 126 | 4.88** | 8.58** |
| | (0.0463) | (0.0046) | | | | |
| $\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,JA}$ | 0.0173 | −0.0013 | 0.30 | 146 | 0.87 | 0.27 |
| | (0.0380) | (0.0038) | | | | |
| $\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,UK}$ | −0.0071 | −0.0026 | 0.40 | 167 | 0.25 | 0.03 |
| | (0.0240) | (0.0033) | | | | |
| $\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,JA}$ | 0.0126 | −0.0003 | 0.32 | 154 | 0.24 | 0.12 |
| | (0.0400) | (0.0040) | | | | |
| $\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,UK}$ | 0.0154 | −0.0016 | 0.28 | 166 | 0.67 | 1.01 |
| | (0.0169) | (0.0026) | | | | |
| $\Delta p_t^{i,JA,US} - \Delta p_t^{i,JA,UK}$ | 0.0048 | −0.0031 | 0.29 | 115 | 0.51 | 0.14 |
| | (0.0208) | (0.0032) | | | | |
| All Countries | 0.0437* | 0.0026 | 0.32 | 884 | 1.64 | 3.68** |
| | (0.0232) | (0.0020) | | | | |

*Notes:* Expected depreciation is measured using the appropriate 12-month Eurointerest differential. **, *represent statistical significance at the 5 and 10 percent levels, respectively. $i$ indexes the industry exports. Data set includes 65 industries for each country, annually from 1981–86. Equations estimated using OLS. Standard errors are in parentheses.

TABLE 2b—EXCHANGE RATE PASS-THROUGH AND THE EFFECTS OF EXPECTED DEPRECIATION
$\Delta p_t^{i,j,k} - \Delta p_t^{i,j,l} = \beta_1 \Delta E_t(\Delta e_{t+1}^{k,l}) + \beta_2 \Delta e_t^{k,l} + \varepsilon_t^i$

| Dependent Variable | $\beta_1$ | $\beta_2$ | $SE$ | $DF$ | $F$-test $\beta_1 = \beta_2 = 0$ | $F$-test $\beta_2 - \beta_1 = 0$ |
|---|---|---|---|---|---|---|
| $\Delta p_t^{i,UK,US} - \Delta p_t^{i,UK,JA}$ | −0.0824 | −0.0159 | 0.34 | 126 | 1.20 | 1.91 |
| | (0.0614) | (0.0137) | | | | |
| $\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,JA}$ | −0.0022 | −0.0022 | 0.30 | 146 | 0.77 | 0.01 |
| | (0.0500) | (0.0111) | | | | |
| $\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,UK}$ | 0.0198 | 0.0026 | 0.40 | 167 | 0.57 | 0.91 |
| | (0.0235) | (0.0070) | | | | |
| $\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,JA}$ | 0.0096 | 0.0007 | 0.32 | 154 | 0.20 | 0.05 |
| | (0.0515) | (0.0115) | | | | |
| $\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,UK}$ | 0.0094 | 0.0004 | 0.28 | 166 | 0.42 | 0.50 |
| | (0.0165) | (0.0048) | | | | |
| $\Delta p_t^{i,JA,US} - \Delta p_t^{i,JA,UK}$ | 0.0472** | 0.0086 | 0.28 | 115 | 3.37** | 6.39** |
| | (0.0197) | (0.0058) | | | | |
| All Countries | 0.0171* | 0.0032 | 0.32 | 884 | 1.95 | 3.80** |
| | (0.0093) | (0.0024) | | | | |

*Notes:* Expected depreciation is measured using survey data on exchange rate expectations over a twelve-month forecast horizon. **, *represent statistical significance at the 5 and 10 percent levels, respectively. $i$ indexes the industry exports. Data set includes 65 industries for each country, over the 1981–86 period. Equations estimated using OLS. Standard errors are in parentheses.

dard errors in Tables 2a and 2b, as we discovered that the standard errors calculated using a heteroscedasticity-consistent covariance estimate were smaller. Each table gives regression results for six sets of relative bilateral export price changes; the last set of regressions combines all the individual bilateral regressions.

There is no overwhelming evidence that expected future depreciation influences the degree of pricing to market. Nevertheless,

those reported in Table 2, but the standard errors were large. On the assumption that the imprecision was attributable to both measurement error in the data and lags in response to exchange rate changes, we used two averages of the data over two-year nonoverlapping intervals.

the magnitude and sign of the estimates of both coefficients have interesting interpretations in terms of our model, and may shed light on the recent behavior of the pass-through relationship.

The estimates of $\beta_1$ are not always the same sign, but whenever they are statistically different from zero, they are positive: higher expected future dollar depreciation implies increasing prices in the U.S. market relative to other export markets. In the combined regression, the point estimates are statistically positive at the 10 percent level. In addition, the magnitude of these effects is impressive. For example, the last point estimate of $\beta_1$ in Table 2a implies that, given the current spot rate, a 1 percent increase in expected dollar depreciation is on average associated with an increase of about 4 percent in the price of exports sent to the United States relative to similar exports sent to Japan and the U.K. Of course, if current market share affects firms' profits more than one year into the future, then a 1 percent increase in expected depreciation over the next twelve months is likely to be associated with a larger cumulative expected depreciation over a longer, more relevant horizon. The estimated magnitudes of $\beta_1$ in Table 2b are similar to those in Table 2a. If the survey data contain measurement error, however, these estimates are biased in magnitude and statistical significance toward zero.[44]

The estimates of $\beta_2$ are usually more than an order of magnitude smaller than the estimates of $\beta_1$, and in only one case in fourteen regressions is an estimate statistically different from zero. We therefore cannot reject the hypothesis that permanent changes in the value of the dollar have *no* effect on the ratio of export prices to different countries. The standard errors are small enough, however, that we can reject the hypothesis that there is any substantial degree of pricing to market in response to permanent exchange rate changes. This suggests that fully permanent depreciations are passed through into import prices one-for-one.

Estimates of the difference, $\beta_2 - \beta_1$, are almost always negative and usually less than $-0.01$: a completely temporary appreciation of the dollar is associated with a *rise* in import prices. The right-most column of Tables 2a and 2b tests the hypothesis that $\beta_2 - \beta_1 = 0$. In several cases, including the combined regressions, this difference is statistically negative at the 5 percent level. In the last regression of Table 2a, the estimates imply that a 1 percent temporary appreciation leads on average to an increase of $4.4 - 0.3 = 4.1$ percent in relative prices of exports sent to U.S. markets. The corresponding number in Table 2b is 1.4. These results illustrate the case of perverse pass-through we discussed above.

Naturally, one rarely sees such large effects in practice because most exchange rate changes include a substantial permanent component. In fact, our estimates in Table 2a imply that the combination of a contemporaneous appreciation of 3.5 percent and an increase of 1 percent in expected depreciation over the following 12 months would leave dollar import prices constant.[45] These figures suggest that the 4 percentage point rise in the real interest differential witnessed during the 1980s would cancel the effect on dollar import prices of the first 14 percentage points of dollar appreciation.

## III. Conclusions

We have constructed a model in which market share matters in order to study the effects of exchange rate changes on international pricing. We stressed that the return a firm expects to earn on its current investment in market share is sensitive to the expected future exchange rate. Thus we found that foreign firms price more aggressively in the domestic market, attempting to gain more market share, when the price of the domestic currency is expected to remain

[44]See Froot and Frankel (1989) for a discussion of measurement error in these data.

[45]The last regression in Table 2a implies that an increase of 1 percent in expected dollar depreciation raises dollar import prices by 4.37 percent, and that a 3.5 percent current appreciation lowers dollar import prices by $3.5 + 3.5(0.26) = 4.41$ percent.

permanently higher. Conversely, when a current exchange rate appreciation is thought to be temporary, foreign firms will behave less aggressively, perhaps even *raising* prices denominated in the domestic currency.

We also explored some tentative empirical evidence that suggests a possible relationship between the degree of pricing to market and expected future depreciation. If producers regarded each year's appreciation during 1981–85 as more temporary than past appreciations, our model suggests that the pass-through of exchange rate changes into dollar import prices should have been lower than historical experience would predict. Indeed, our empirical results suggest that if we were to observe a purely temporary dollar appreciation, it could conceivably be associated with an *increase* in dollar import prices. Expected depreciation may help in understanding foreign exporters' decisions to raise prices in the U.S. market relative to those in other markets in the 1980s.

## Appendix. Comparative Statics

*Expressions for the Cost and Interest Rate Effects.* Totally differentiating (3a) and (3b) with respect to $x = c_1^F, c_2^F$, or $\lambda$ and writing $\pi^i_{jk}$ for $(\partial^2\pi^i/\partial p^j \partial p^k)$ yields:

$$\pi^D_{DD}\,dp^D + \pi^D_{DF}\,dp^F = -\frac{\partial}{\partial x}\left(\frac{\partial \pi^D}{\partial p^D}\right)dx$$

$$\pi^F_{FD}\,dp^D + \pi^F_{FF}\,dp^F = -\frac{\partial}{\partial x}\left(\frac{\partial \pi^F}{\partial p^F}\right)dx,$$

hence,

$$\frac{\partial p^F}{\partial x} = \frac{\Phi}{e_1}\frac{\partial}{\partial x}\left(\frac{\partial \pi^F}{\partial p^F}\right) + \rho^F\Psi\frac{\partial}{\partial x}\left(\frac{\partial \pi^D}{\partial p^D}\right),$$

$$\frac{\partial p^D}{\partial x} = \rho^D\frac{\Phi}{e_1}\frac{\partial}{\partial x}\left(\frac{\partial \pi^F}{\partial p^F}\right) + \Psi\frac{\partial}{\partial x}\left(\frac{\partial \pi^D}{\partial p^D}\right),$$

where $\Phi = -e_1\pi^D_{DD}/\Delta$, $\Psi = -\pi^F_{FF}/\Delta$, $\rho^F = -\pi^F_{FD}/\pi^F_{FF}$, $\rho^D = -\pi^D_{DF}/\pi^D_{DD}$, and $\Delta = \pi^D_{DD}\pi^F_{FF} - \pi^D_{DF}\pi^F_{FD}$.

Note that $\rho^F$ and $\rho^D$ are the slopes of $F$'s and $D$'s first-period reaction functions which with price competition are usually positive and, if the equilibrium is (as we shall assume) stable, $\Delta > 0$, so that the second-order conditions imply $\Phi > 0$, $\Psi > 0$.

Now

$$\frac{\partial}{\partial c_1^F}\left(\frac{\partial \pi^F}{\partial p^F}\right) = \frac{\partial}{\partial p^F}\left(\frac{\partial \pi^F}{\partial c_1^F}\right) = -e_1\frac{\partial q^F}{\partial p^F} > 0$$

in which $q^F$ is $F$'s first-period output and

$$\frac{\partial}{\partial c_1^F}\left(\frac{\partial \pi^D}{\partial p^D}\right) = 0,$$

so the first-period cost effect on $p^F$ is

$$-c_1^F\frac{\partial p^F}{\partial c_1^F} = c_1^F\frac{\partial q^F}{\partial p^F}\Phi < 0.$$

The first-period cost effect on $p^D$ arises simply from $D$'s reaction to $F$'s lower costs. It is $-c_1^F(\partial p^D/\partial c_1^F) = \rho^D c_1^F(\partial q^F/\partial p^F)\Phi < 0$, and so is typically of the same sign as, but smaller in magnitude than, the effect on $p^F$.

Next, assuming that firms' first-period demands do not depend directly on their second-period costs,[46] the second-period cost effect on $p^i$ is

$$-c_2^F\frac{\partial p^i}{\partial c_2^F} = -c_2^F\left(\lambda\frac{\partial \sigma^F}{\partial p^F}\left(\frac{\partial}{\partial c_2^F}\left(\frac{\partial \pi_2^F}{\partial \sigma^F}\right)\right)\phi^i + \lambda\frac{\partial \sigma^D}{\partial p^D}\left(\frac{\partial}{\partial c_2^F}\left(\frac{\partial \pi_2^D}{\partial \sigma^D}\right)\right)\psi^i\right),$$

where $\phi^F = \Phi$, $\psi^F = \rho^F\Psi$, $\phi^D = \rho^D\Phi$, and $\psi^D = \Psi$. (The second part of the expression arises from the fact that a change in $F$'s future dollar costs affects the marginal value of market share to $D$ as well as to $F$). We expect that an increase in $F$'s future dollar costs will decrease the marginal value of market share to $F$, and increase the marginal value of market share to $D$, that is,

$$\frac{\partial}{\partial c_2^F}\left(\frac{\partial \pi_2^F}{\partial \sigma^F}\right) < 0 < \frac{\partial}{\partial c_2^F}\left(\frac{\partial \pi_2^D}{\partial \sigma^D}\right),$$

and that the magnitude of the (former) own effect is greater than that of the (latter) cross effect. Since

[46] This assumption is not always justified. If consumers' first-period consumption decisions depend on their expectations of second-period prices, then second-period costs (which affect second-period prices) affect first-period demands. In this case, additional terms including

$$\frac{\partial}{\partial c_2^F}\left(\frac{\partial \pi_1^i}{\partial p^i}\right) \text{ and } \frac{\partial}{\partial c_2^F}\left(\frac{\partial \sigma^i}{\partial p^i}\right)$$

arise in the second-period cost effect.

$(\partial \sigma^i/\partial p^i) < 0$, therefore, we expect

$$-c_2^F \frac{\partial p^F}{\partial c_2^F} < 0 \text{ and } \left| c_2^F \frac{\partial p^D}{\partial c_2^F} \right| < \left| c_2^F \frac{\partial p^F}{\partial c_2^F} \right|,$$

at least around symmetric equilibrium.[47]

Finally, assuming that firms' first-period demands do not depend directly on the domestic-currency interest rate,[48] the interest rate effect on $p^i$ is:

$$-\lambda \frac{\partial p^i}{\partial \lambda} = -\lambda \left( \frac{\partial \pi_2^F}{\partial \sigma^F} \left( \frac{\partial \sigma^F}{\partial p^F} \right) \phi^i + \frac{\partial \pi_2^D}{\partial \sigma^D} \left( \frac{\partial \sigma^D}{\partial p^D} \right) \psi^i \right).$$

These terms are unambiguously positive if, as we expect, $\rho^D$ and $\rho^F$ are both positive.[49]

*Extension to Quantity Competition.* In quantity competition, $p^i$ represents $i$'s first-period quantity, so $(\partial \sigma^i/\partial p^i) > 0$ and we expect $\rho^F$ and $\rho^D$ to be negative (downward-sloping reaction functions) in the equations above.

We can write the first-period cost effect on the quantities $p^D$ and $p^F$ more simply as $c_1^F \Phi$ and $\rho^D c_1^F \Phi$, respectively, since $q^F = p^F$ in this case.

The first-period cost effect on $p^F$ is unambiguously positive, as is the second-period cost effect on $p^F$

if

$$\frac{\partial}{\partial c_2^F} \left( \frac{\partial \pi^F}{\partial \sigma^F} \right) < 0 < \frac{\partial}{\partial c_2^F} \left( \frac{\partial \pi^D}{\partial \sigma^D} \right),$$

as we assumed above, and $\rho^F < 0$.

The interest rate effect on $p^F$ is negative, at least around symmetric equilibrium. Thus, the signs of all these effects are opposite to those in price competition: exchange rate changes that induce more aggressive behavior (lower prices) from $F$ in price competition also induce more aggressive behavior (larger quantities) from $F$ in quantity competition. The interest rate effect on $p^D$ is also typically negative (i.e., opposite to the sign in price competition) but the first-period cost effect on $p^D$ will be negative (the same as in price competition, because reaction curves slope in the opposite direction) and the second-period cost effect on $p^D$ is, as in price competition, hard to sign.

Letting $P^i$ be $i$'s first-period price resulting from the quantity choices $p^F$ and $p^D$, the effect of a proportional decrease in $x = c_1^F, c_2^F$ or $\lambda$ on $i$'s price is:

$$-x \frac{\partial P^i}{\partial x} = -x \frac{\partial p^i}{\partial x} \left( \frac{\partial P^i}{\partial p^i} \right) - x \frac{\partial p^j}{\partial x} \left( \frac{\partial P^i}{\partial p^j} \right),$$

$$i = D, F;\ i \neq j.$$

If products are homogeneous across firms in the first period, this simplifies to

$$-x \frac{\partial P^i}{\partial x} = \left( -x \frac{\partial p^i}{\partial x} - x \frac{\partial p^j}{\partial x} \right) f',$$

where $f' < 0$ is the slope of the inverse demand curve. Since the firms' products are substitutes we expect

$$\frac{\partial P^i}{\partial p^i} \le \frac{\partial P^i}{\partial p^j} < 0.$$

Since we expect the cost effects on $p^D$ to be smaller than those on $p^F$, if follows that the first-period cost effect, the second-period cost effect, and the interest rate effect on $F$'s price all have the same sign under quantity competition as under price competition.

[47]In symmetric stable equilibrium, $\rho^D = \rho^F < 1$ and $\Phi = \Psi$.

[48]If this assumption is not warranted, the interest rate effect includes terms involving

$$\frac{\partial}{\partial \lambda} \left( \frac{\partial \pi_1^i}{\partial p^i} \right) \text{ and } \frac{\partial}{\partial \lambda} \left( \frac{\partial \sigma^i}{\partial p^i} \right)$$

in addition to those we derive.

[49]Even if $\rho^F$ and $\rho^D$ are negative, the interest rate effects remain positive in any symmetric stable equilibrium.

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