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EXCHANGE RATE PASS-THROUGH WHEN MARKET SHARE MATTERS

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ABSTRACT

We investigate pricing to market when the exchange rate changes in cases where firms' future demands depend on their current market shares. We show that i) profit maximizing foreign firms may either raise or lower their domestic currency export prices when the domestic exchange rate appreciates temporarily (i.e. the "pass-through" from exchange rate changes to import prices may be perverse); ii) current import prices may be more sensitive to the expected future exchange rate than to the current exchange rate; iii) current import prices fall in response to an increase in uncertainty about the future exchange rate. We present evidence that suggests the behavior of *expected* future exchange rates may provide a clue to the puzzling behavior of U.S. import prices during the 1980s.

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With the dramatic swings in the value of the dollar over the past six years has come the observation 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 to be sensitive to the level of the exchange rate. It is well known, for example, that pricy German cars became far more expensive in the U.S. than in Europe during the 1980-84 appreciation of the dollar. Since then, as the dollar has declined substantially, U.S. prices of these cars have fallen dramatically relative to the prices of those sold in foreign markets.[1] Most of this unprecedented fluctuation in relative prices is reflected in the recent failure of foreign exporters to pass through exchange rate changes into dollar prices. Based on historical relationships, the dollar prices of U.S. imports did not fall fast enough as the dollar first appreciated, and those prices have subsequently risen by only a small fraction of what we might predict based on the decline in the dollar's value. This recent drop in the degree of pass-through has become critically important because it has halted the

[1] While luxury automobiles are perhaps the most conspicuous and exaggerated example of pricing to market, they are not unique. Giovannini (1987) presents evidence of pricing to market among more homogeneous goods, such as ball bearings.

long-awaited improvement in the U.S. trade deficit.[2] The efficacy of further attempts to push down the value of the dollar will hinge on whether the magnitude of the pass-through remains small.

Why would we expect foreign exporters to sell their goods at a higher price in the U.S. 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 selling in the U.S. market are denominated in dollars. Foreign firms must advertise, sell and distribute their goods in their overseas markets, incurring associated costs abroad.[3] A second answer is that an appreciation of the dollar may reduce foreign producers' elasticity of demand. A foreign monopolist with flat marginal costs will keep its foreign currency price constant if demand has constant elasticity, but will reduce its dollar price by a percentage that is less than half that of the exchange rate change if demand is linear. In standard oligopolistic models in which foreign firms face U.S. competition, the dollar price falls proportionately less than the dollar appreciation even with constant elasticity demand.[4] A third explanation for pricing to market, offered originally by Krugman (1986), emphasizes dynamic supply-side effects. When foreign firms gain competitive advantage through an appreciation of the dollar, it may be costly for them to step up sales quickly. Marginal costs of exports to the U.S. must rise, and, consequently, prices become higher than abroad. Baldwin and Krugman (1986) and Dixit (1987), consider adjustment behavior when foreign firms face fixed costs of entering a market that are larger than the fixed costs of remaining. In these models, a large enough exchange rate shock, even if it is temporary, results in a permanent change in the level of imports – an effect now best known as hysteresis – as well as a permanent reduction in the degree of pass-through.

[2] Recent empirical work by Mann (1987) and Mann and Hooper (1987) demonstrates that during the period of dollar appreciation 1980-84, dollar prices of many U.S. imports did not fall by as much as past experience would suggest they should, nor have they risen as rapidly as history would predict during the subsequent depreciation. In addition, foreign profit margins on exports to the U.S. seem to have absorbed an unusually large portion of the changes in the dollar's value. See Mann and Hooper (1987) for a thorough discussion of the behavior of these profit margins, and for the impact on forecasts of the trade balance deficit.

[3] Sanyal and Jones (1982) model trade flows when foreign goods can be purchased by domestic residents only after value has been added by domestic factors.

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

None of these explanations, however, offers a convincing reason for the abrupt fall in the pass-through that occurred as the dollar began to appreciate in 1981. It is hard to argue that the "domestic content" of foreign firms' production costs rose suddenly or that the elasticity of demand jumped upward, due to a change in the number of foreign and domestic firms in import-competing industries. Indeed, the "beachhead" model of Baldwin (1986), and Baldwin and Krugman (1986) predicts that competition increases in the U.S. market when the dollar appreciates, driving prices down. This effect tends to magnify, rather than reduce, the exchange rate pass-through during that period.

This paper takes a different approach by focusing on dynamic demand-side effects in an oligopolistic market. These effects can both induce hysteresis and explain why the degree of pricing to market may change substantially through time. In our model, the future demand for each firm's product depends in part on its current market share. Because demand is in a sense "sticky," firms' current strategic choices will affect future as well as current profits. The future exchange rate then becomes important because it determines the value of future profits. Thus our approach emphasizes not only the extent to which foreign firms will pass through current exchange rate changes, but also how the pass-through is affected by expected future exchange rates. Indeed, we show how the pass-through can be different in magnitude and even in sign depending 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 U.S. will reduce their dollar prices by less in our 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 will actually *raise* their dollar prices when the exchange rate appreciates. In other circumstances, perfectly flexible dollar prices will appear completely rigid in response to current exchange rate fluctuations.

Permanent dollar appreciations, on the other hand, do not create such incentives to shift profits from tomorrow to today. Instead, foreign firms' relative costs fall in both periods in response to a permanent appreciation. Foreign exporters will compete more intensely and unambiguously drive prices down. Indeed, permanent appreciations may lower prices by more in our models than in a static oligopoly model. Our results suggest that, once the temporary appreciation of the dollar has been fully unwound, further dollar depreciation that is perceived as permanent will lead to a much greater degree of pass-through and a much more rapid rate of improvement in the U.S. trade balance.

The uncertainty surrounding future exchange rates also has an effect on current prices in our model. Foreign firms' future profits are typically convex in the exchange rate since a dollar appreciation is associated with both a reduction in dollar costs and an increase in the foreign currency value of dollar profits. A more variable exchange rate therefore adds to the expected return on a (risk-neutral) foreign firm's investment in market share, and so prompts more vigorous competition for market share today. Prices in the domestic market therefore fall.

The plan of this paper is as follows. Section 1 presents a general two-period model in which market shares matter. There we emphasize that our basic results are sensitive neither to assumptions about the nature of competition (Cournot or Bertrand), nor to the precise form of demand. In section 2, we specialize the model to a simple "switching costs" model that follows Klemperer (1987a) in order to get a sense for the magnitude of the effects on the pass-through of exchange rate changes. Section 3 then turns to disaggregated bilateral export price data to investigate the sensitivity of pricing to market to the expected degree of permanence in exchange rate changes. Section 4 concludes.

1. A General Market Share Model

In this section we present a simple two-period model in which firms' second-period demands, and hence their second-period profits, depend on their first-period market shares. This dependence can arise from a number of factors.

First, consumers may face substantial costs of switching between brands of a product even if the brands are *ex ante* undifferentiated.[5] For example, consumers who have learned to use one type of computer system find it costly to learn a new one, even though the systems may be functionally identical. When they purchase more computer equipment, these consumers have a clear incentive to buy only hardware and software that are compatible with their current system. In addition to such learning costs, there may 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. Okun (1975) emphasizes the costs of breaking personal sales relationships in industrial transactions. More recently, Krugman and Baldwin (1987) have built a "book-of-the-month-club model" in which long-term contracts between buyers and sellers are costly to abrogate in the short run. Firms themselves encourage these attachments using such devices as repeat purchase discounts.

Second, a consumer may be unwilling to switch from a brand that he has tried and liked to an untested rival brand (if brands are "experience" goods in the terminology of Nelson, 1970). Indeed, consumers incur search costs even in finding out about the existence or price of a competing product.[6] Past sales also serve to 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.[7] For example, as more compact-disk players were sold, the disks themselves

[5] See Klemperer (1987a) and the references therein.
[6] See, for example, Phelps and Winter (1970).
[7] See Katz and Shapiro, (1985).

became cheaper and more abundant, raising the value of a CD 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. Corporate planning models often rest heavily on the assumption that the future demand for a product will be positively correlated with its present sales.

Consider two firms, a domestic firm D and foreign firm F, each maximizing its profits over two periods of competition in the domestic (say U.S.) market. In period one, firm D chooses its first-period strategic variable, ν_1^D, to maximize its total discounted future profits:

$$\pi^D = \pi_1^D(\nu_1^D, \nu_1^F) + \lambda^D \pi_2^D(\sigma_1^D(\nu_1^D, \nu_1^F), \mathbf{e}_2) \tag{1a}$$

taking F's first-period strategic variable, ν_1^F, as given. Total profits, π^D, are the sum of the firm's first- and second-period profits, π_1^D and π_2^D, respectively. Second-period profits can be written in reduced form as a function of the firm's first-period market share, σ_1^D, and the second-period exchange rate, $\mathbf{e}_2$, expressed here in units of foreign currency per dollar. Future profits are discounted by the factor λ^D into first-period terms. It is convenient to assume that a higher value of ν_1^i represents more aggressive play, so that the firm's market share is an increasing function of ν_1^i. Thus for quantity competition we write $\nu_1^i = q_1^i$, and for price competition we have $\nu_1^i = -p_1^i$, where q_1^i and p_1^i are i's first-period quantity and dollar price, respectively, $i = D, F$. In what follows, we remain within a partial equilibrium framework, assuming that the exchange rate, as well as the aggregate price level, is exogenous to the firms.

Firm F chooses ν_1^F analogously to maximize the present discounted value of its own-currency profits:

$$\pi^F = \mathbf{e}_1 \pi_1^F(\nu_1^D, \nu_1^F, \mathbf{e}_1) + \lambda^F \mathbf{e}_2 \pi_2^F(\sigma_1^F(\nu_1^D, \nu_1^F), \mathbf{e}_2). \tag{1b}$$

π_1^F and π_2^F are the firm's first- and second-period profits in dollars, $\mathbf{e}_1$ and $\mathbf{e}_2$ are the first- and second-period price of dollars in terms of the foreign firm's currency, and λ^F is the discount factor used by the foreign firm to value second-period profits in terms of first-period profits in its own currency. Each firm's costs of production are denominated in its own currency, and its cost curve is the same in both periods.

In non-cooperative equilibrium, given $\mathbf{e}_1$ and $\mathbf{e}_2$, we have the first-order conditions:

$$\frac{\partial \pi^D}{\partial \nu_1^D} = \frac{\partial \pi_1^D}{\partial \nu_1^D} + \lambda^D \left(\frac{\partial \pi_2^D}{\partial \sigma_1^D}\right)\left(\frac{\partial \sigma_1^D}{\partial \nu_1^D}\right) = 0 \tag{2a}$$

$$\frac{\partial \pi^F}{\partial \nu_1^F} = \mathbf{e}_1 \frac{\partial \pi_1^F}{\partial \nu_1^F} + \mathbf{e}_2 \lambda^F \left(\frac{\partial \pi_2^F}{\partial \sigma_1^F}\right)\left(\frac{\partial \sigma_1^F}{\partial \nu_1^F}\right) = 0. \tag{2b}$$

Provided that a larger first-period market share increases a firm's second-period profits, i.e., $\frac{\partial \pi_2^i}{\partial \sigma_1^i} > 0$, equation (2) implies that $\frac{\partial \pi_1^i}{\partial \nu_1^i} < 0$, $i = D, F$.[8] Thus firms choose higher values of ν_1^i, that is, they compete more aggressively in the first period than they would if market share had no value (in which case $\frac{\partial \pi_2^i}{\partial \sigma_1^i} = 0$).[9] How much more aggressively they compete, however, depends on how much they value future market share, and this depends in part on the exchange rate.

Notice that firm i's discount factor is inversely proportional to the interest rate in i's home market, $\lambda^i = \beta/(1+\mathbf{r}^i)$, where β measures the duration of the second period relative to the first. More generally, we could think of β as indexing the importance of current market share for future profits. If capital is perfectly mobile internationally, the domestic and foreign interest rates will be related to expected depreciation according to Covered Interest Parity:

$$\lambda^D = \lambda^F \mathbf{e}_2/\mathbf{e}_1. \tag{3}$$

In what follows we hold constant λ^F, that is, we hold constant the interest rate in the foreign firm's home market, since our main focus is on how the foreign firm's prices will

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

[9] We assume $\frac{\partial^2 \pi_1^i}{(\partial \nu_1^i)^2} < 0$.

differ in different markets.[10]

We wish to determine the effect on firm behavior of exchange rate changes. To do this, we totally differentiate equation (2), and use equation (3) and the first-order conditions to obtain:[11]

$$\mathbf{A}d\nu_1^D + \mathbf{B}d\nu_1^F = \mathbf{E}d\mathbf{e}_1 - \mathbf{G}d\mathbf{e}_2 \tag{4a}$$

$$\mathbf{C}d\nu_1^D + \mathbf{D}d\nu_1^F = -\mathbf{F}d\mathbf{e}_1 - \mathbf{H}d\mathbf{e}_2, \tag{4b}$$

where

$$\mathbf{A} = \frac{\partial^2\pi_1^D}{(\partial\nu_1^D)^2} + \lambda^D\Big(\frac{\partial^2\pi_2^D}{(\partial\sigma_1^D)^2}\Big)\Big(\frac{\partial\sigma_1^D}{\partial\nu_1^D}\Big)^2 + \lambda^D\Big(\frac{\partial\pi_2^D}{\partial\sigma_1^D}\Big)\Big(\frac{\partial^2\sigma_1^D}{(\partial\nu_1^D)^2}\Big)$$

$$\mathbf{B} = \frac{\partial^2\pi_1^D}{\partial\nu_1^D\partial\nu_1^F} + \lambda^D\Big(\frac{\partial^2\pi_2^D}{(\partial\sigma_1^D)^2}\Big)\Big(\frac{\partial\sigma_1^D}{\partial\nu_1^D}\Big)\Big(\frac{\partial\sigma_1^D}{\partial\nu_1^F}\Big) + \lambda^D\Big(\frac{\partial\pi_2^D}{\partial\sigma_1^D}\Big)\Big(\frac{\partial^2\sigma_1^D}{\partial\nu_1^D\partial\nu_1^F}\Big)$$

$$\mathbf{C} = \frac{\partial^2\pi_1^F}{\partial\nu_1^D\partial\nu_1^F} + \frac{\lambda^F\mathbf{e}_2}{\mathbf{e}_1}\Big(\frac{\partial^2\pi_2^F}{(\partial\sigma_1^F)^2}\Big)\Big(\frac{\partial\sigma_1^F}{\partial\nu_1^D}\Big)\Big(\frac{\partial\sigma_1^F}{\partial\nu_1^F}\Big) + \frac{\lambda^F\mathbf{e}_2}{\mathbf{e}_1}\Big(\frac{\partial\pi_2^F}{\partial\sigma_1^F}\Big)\Big(\frac{\partial^2\sigma_1^F}{\partial\nu_1^D\partial\nu_1^F}\Big)$$

$$\mathbf{D} = \frac{\partial^2\pi_1^F}{(\partial\nu_1^F)^2} + \frac{\lambda^F\mathbf{e}_2}{\mathbf{e}_1}\Big(\frac{\partial^2\pi_2^F}{(\partial\sigma_1^F)^2}\Big)\Big(\frac{\partial\sigma_1^F}{\partial\nu_1^F}\Big)^2 + \frac{\lambda^F\mathbf{e}_2}{\mathbf{e}_1}\Big(\frac{\partial\pi_2^F}{\partial\sigma_1^F}\Big)\Big(\frac{\partial^2\sigma_1^F}{(\partial\nu_1^F)^2}\Big)$$

$$\mathbf{E} = \frac{\lambda^D}{\mathbf{e}_1}\Big(\frac{\partial\pi_2^D}{\partial\sigma_1^D}\Big)\Big(\frac{\partial\sigma_1^D}{\partial\nu_1^D}\Big)$$

$$\mathbf{F} = -\frac{\lambda^F\mathbf{e}_2}{\mathbf{e}_1^2}\Big(\frac{\partial\pi_2^F}{\partial\sigma_1^F}\Big)\Big(\frac{\partial\sigma_1^F}{\partial\nu_1^F}\Big) + \Big(\frac{\partial^2\pi_1^F}{\partial\nu_1^F\partial\mathbf{e}_1}\Big)$$

$$\mathbf{G} = \frac{\lambda^D}{\mathbf{e}_2}\Big(\frac{\partial\pi_2^D}{\partial\sigma_1^D}\Big)\Big(\frac{\partial\sigma_1^D}{\partial\nu_1^D}\Big) + \lambda^D\Big(\frac{\partial^2\pi_2^D}{\partial\sigma_1^D\partial\mathbf{e}_2}\Big)\Big(\frac{\partial\sigma_1^D}{\partial\nu_1^D}\Big)$$

$$\mathbf{H} = \frac{\lambda^F}{\mathbf{e}_1}\Big(\frac{\partial\pi_2^F}{\partial\sigma_1^F}\Big)\Big(\frac{\partial\sigma_1^F}{\partial\nu_1^F}\Big) + \frac{\lambda^F\mathbf{e}_2}{\mathbf{e}_1}\Big(\frac{\partial^2\pi_2^F}{\partial\sigma_1^F\partial\mathbf{e}_2}\Big)\Big(\frac{\partial\sigma_1^F}{\partial\nu_1^F}\Big).$$

Now let firm F's total costs measured in foreign currency be a function of the quantity F produces: $c = c(q_1^F)$. Profits are therefore $\pi_1^F = p_1^F q_1^F - c(q_1^F)/\mathbf{e}_1$, so $\mathbf{e}_1\frac{\partial^2\pi_1^F}{\partial\nu_1^F\partial\mathbf{e}_1} = \mathbf{e}_1^{-1}\frac{\partial c(q_1^F(\nu_1^D,\nu_1^F))}{\partial\nu_1^F}$, which is just F's first-period marginal cost in dollars in the case of Cournot competition ($\nu_1^F = q_1^F$).

[10] The foreign firm's prices in its own market will differ from those in the U.S. market as a function of the interest differential. In order to avoid explicit analysis of the foreign market, however, we make the simplifying assumption that foreign interest rates remain fixed. See the discussion below for more detail.

[11] In equations (4a) and (4b), we assume that firms' first-period profits do not depend directly on $\mathbf{e}_2$. See footnote 24 below.

To see how current and future exchange rate changes affect the equilibrium, we use equation (4) to examine changes in firms' strategic choices:

$$\mathbf{e}_1 \frac{d\nu_1^D}{d\mathbf{e}_1} = (C_1^D - I_1^D)/\Delta \tag{5a}$$

$$\mathbf{e}_1 \frac{d\nu_1^F}{d\mathbf{e}_1} = (C_1^F - I_1^F)/\Delta \tag{5b}$$

$$\mathbf{e}_2 \frac{d\nu_1^D}{d\mathbf{e}_2} = (C_2^D + I_2^D)/\Delta \tag{5c}$$

$$\mathbf{e}_2 \frac{d\nu_1^F}{d\mathbf{e}_2} = (C_2^F + I_2^F)/\Delta \tag{5d}$$

where

$$C_1^D = \rho^D C_1^F$$

$$C_1^F = -\mathbf{e}_1^{-1}\Big(\frac{\partial c^F(q_1^F)}{\partial \nu_1^F}\Big)\mathbf{A}$$

$$C_2^D = \gamma^D + \rho^D \gamma^F$$

$$C_2^F = \gamma^F + \rho^F \gamma^D$$

$$I_1^D = I_2^D = \Gamma^D + \rho^D \Gamma^F$$

$$I_1^F = I_2^F = \Gamma^F + \rho^F \Gamma^D$$

$$\gamma^D = -\lambda^D \mathbf{e}_2 \Big(\frac{\partial^2 \pi_2^D}{\partial \sigma_1^D \partial \mathbf{e}_2}\Big)\Big(\frac{\partial \sigma_1^D}{\partial \nu_1^D}\Big)\mathbf{D}$$

$$\gamma^F = -\lambda^D \mathbf{e}_2 \Big(\frac{\partial^2 \pi_2^F}{\partial \sigma_1^F \partial \mathbf{e}_2}\Big)\Big(\frac{\partial \sigma_1^F}{\partial \nu_1^F}\Big)\mathbf{A}$$

$$\Gamma^D = -\lambda^D \Big(\frac{\partial \pi_2^D}{\partial \sigma_1^D}\Big)\Big(\frac{\partial \sigma_1^D}{\partial \nu_1^D}\Big)\mathbf{D}$$

$$\Gamma^F = -\lambda^D \Big(\frac{\partial \pi_2^F}{\partial \sigma_1^F}\Big)\Big(\frac{\partial \sigma_1^F}{\partial \nu_1^F}\Big)\mathbf{A}$$

The term ρ^D is the slope of D's reaction function:

$$\rho^D = \frac{d\nu_1^D}{d\nu_1^F} = -\frac{\mathbf{B}}{\mathbf{A}};$$

and similarly, ρ^F is the slope of F's reaction function:

$$\rho^F = \frac{d\nu_1^F}{d\nu_1^D} = -\frac{\mathbf{C}}{\mathbf{D}}.$$

The second-order conditions imply that $\mathbf{A}$ and $\mathbf{D}$ are negative. In a stable equilibrium, $\rho^D \rho^F < 1$, so that $\Delta = \mathbf{AD}(1 - \rho^D \rho^F) > 0$.[12]

Equations (5a)-(5d) tell us the effect of changes in exchange rates on firms' first-period choices ν_1^D and ν_1^F. In each case we have separated the overall effect into two components: a *cost effect*, C, and a *real interest rate effect*, I.

The first-period cost effects, C_1^F and C_1^D, are familiar from the standard static duopoly model. A temporary appreciation of the dollar exchange rate – an increase in $\mathbf{e}_1$ – results in a proportionate decrease in the foreign firm's first-period costs measured in dollars. (Note that from the second-order conditions, C_1^F is unambiguously positive and proportional to F's marginal costs). Even if market share did not matter, the foreign firm would translate this competitive advantage into more aggressive play. The term C_1^D measures D's response to F's more aggressive behavior: with a positively (negatively) sloped reaction curve D behaves more (less) aggressively. With price competition these effects unambiguously lower F's dollar price (raise ν_1^F) and with quantity competition they usually do so. (With quantity competition and homogeneous products, they do so if $\rho^D > -1$, which is true for any stable symmetric equilibrium.)

Note that the cost effect is the *only* effect present when future profitability is independent of market share, since then $\frac{\partial \pi_2^D}{\partial \sigma_1^D} = \frac{\partial \pi_2^F}{\partial \sigma_1^F} = 0$ and therefore $I_1^D = I_1^F = I_2^D = I_2^F = C_2^D = C_2^F = 0$. Indeed, the first-period cost effects are the only effects present in

[12] Note that if firms set prices, the effect of a proportional exchange rate change in period j on F's first-period dollar price is $\mathbf{e}_j \frac{dp_1^F}{d\mathbf{e}_j} = -\mathbf{e}_j \frac{d\nu_1^F}{d\mathbf{e}_j}$, since $\nu_1^F = -p_1^F$. In quantity competition, $\nu_1^i = q_1^i$, so that

$$\mathbf{e}_j \frac{dp_1^F}{d\mathbf{e}_j} = \frac{\partial p_1^F}{\partial q_1^F} \mathbf{e}_j \frac{d\nu_1^F}{d\mathbf{e}_j} + \frac{\partial p_1^F}{\partial q_1^D} \mathbf{e}_j \frac{d\nu_1^D}{d\mathbf{e}_j}.$$

With homogeneous products this last expression can be written as $f'\left(\mathbf{e}_j \frac{d\nu_1^F}{d\mathbf{e}_j} + \mathbf{e}_j \frac{d\nu_1^D}{d\mathbf{e}_j}\right)$, in which $f' < 0$ is the slope of the inverse demand curve.

the standard models of exchange rate pass-through in oligopoly by Dornbusch (1987) and Krugman (1986).[13]

The terms C_2^D and C_2^F are the second-period cost effects. They measure the impact on firms' first-period behavior of the reduction in F's second-period costs brought about by a future appreciation of the dollar. Such a change in costs affects the intensity of second-period competition, changing the marginal value of market share to both firms and, therefore, the aggressiveness with which firms compete for market share in the first period. In γ^F, the term $\mathbf{e}_2 \frac{\partial^2 \pi_2^F}{\partial \sigma_1^F \partial \mathbf{e}_2}$ is precisely the change in the marginal value of market share to F caused by its dollar cost reduction resulting from a change in $\mathbf{e}_2$. While we cannot be definite about its sign (for example, market share might be an important determinant of the second-period outcome only when firms' costs are similar) we expect it to be positive, that is, we expect market share to be more valuable to a firm when its costs are lower.[14] Assuming this term is positive, γ^F is positive and also proportional to the sensitivity of first-period market share to F's first-period strategic variable, $\frac{\partial \sigma_1^F}{\partial \nu_1^F}$. Similarly, the sign of γ^D is the sign of $\mathbf{e}_2 \frac{\partial^2 \pi_2^D}{\partial \sigma_1^D \partial \mathbf{e}_2}$, which measures the change in the marginal value of market share to D caused by a change in F's costs resulting from the exchange rate change. We expect this term to be smaller in magnitude than the corresponding term for F (since customer loyalty and other market-share effects tend to insulate D from effects resulting from changes in F's costs) and negative. Thus we expect $\gamma^D < 0$ and $|\gamma^D| < |\gamma^F|$, at least around the symmetric equilibrium. Hence we also expect C_2^F to be positive,[15] and C_2^D to be smaller in absolute value than C_2^F. It follows that with either price or quantity competition, this cost effect acts to lower prices in the first period. The intuition for this fall in prices is that a future appreciation of the dollar lowers F's second-period costs and

[13] When market share matters, however, the magnitude of this standard cost effect is somewhat altered because a change in current costs alters firms' costs of investing in market share, and because the slopes of firms' reaction functions are different. In the example of the next section, the first-period cost effect is slightly smaller in our model than in the standard model.

[14] 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.

[15] This follows from $\gamma^D < 0 < \gamma^F$, if reaction curves are downward sloping as is usual in quantity competition, and using $|\gamma^D| < |\gamma^F|$ if reaction curves are upward sloping as is usual in price competition, provided $\rho^F < 1$ as must be the case at least in symmetric, stable equilibrium.

therefore raises the value to F of market share today. This effect does not arise in standard static models.

Observe that the effects of a permanent percentage change in the exchange rate (i.e., $d\mathbf{e}_1/\mathbf{e}_1 = d\mathbf{e}_2/\mathbf{e}_2$) are simply the sums of the cost effects:

$$\mathbf{e}_1 \frac{d\nu_1^D}{d\mathbf{e}_1} + \mathbf{e}_2 \frac{d\nu_1^D}{d\mathbf{e}_2} = (C_1^D + C_2^D)/\Delta \tag{5e}$$

$$\mathbf{e}_1 \frac{d\nu_1^F}{d\mathbf{e}_1} + \mathbf{e}_2 \frac{d\nu_1^F}{d\mathbf{e}_2} = (C_1^F + C_2^F)/\Delta \tag{5f}$$

Thus the effects of a permanent exchange rate change exceed the cost effects of a temporary exchange rate change.[16]

In addition to cost effects, this model gives rise to what we call real interest rate effects. A temporary appreciation of the dollar makes future dollar profits relatively less valuable than current dollar profits. Firms therefore place less emphasis on market share and instead let their current profit margins grow. This effect not only tends to raise the price of exports to the U.S. relative to other markets, but also raises the absolute dollar price of exports to the U.S. when the dollar appreciates. Note that from equation (4), a temporary appreciation of the dollar is associated with a rise in the U.S. interest differential. The impact on domestic firms is exactly the same as on foreign firms; more precisely, in a symmetric equilibrium $I_1^F = I_1^D$. Provided that the firms are not too asymmetric (and always if reaction curves are upward sloping) these terms are positive.[17]

While the real interest effect leads to very substantial pricing to market by a foreign exporter, it also implies that the same price changes will occur even in thoroughly domestic industries. Such an outcome is general to any model of intertemporal profit maximization

[16] 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 effects present are C_1^D and C_1^F. There are reasons for caution on this point, however. First, incorporating the market-share effects changes firms' value functions – in the special model of the next section, it is as if we included an additional segment of demand of constant elasticity -1 – hence directly changes behavior and the magnitudes of C_1^F, C_1^D, ρ^D, ρ^F, and Δ. (It may also affect first-period demand.) Second, the effects of an exchange rate change on the second period of a market share model are likely to be smaller than in a standard oligopoly model, so with overlapping generations (so that every period has some of the characteristics of both the first and the last period of our model) the size of the effect is unclear.

[17] Since $\frac{\partial \pi_2^i}{\partial \sigma_1^i} > 0$, $\frac{\partial \sigma_1^i}{\partial \nu_1^i} > 0$, $\mathbf{A} < 0$ and $\mathbf{D} < 0$, we have $\Gamma^D > 0$ and $\Gamma^F > 0$.

in which firms have some ability to shift profits over time. Keynes refers to a similar effect, which posits positive correlation between the level of prices and the nominal interest rate, as Gibson's paradox.[18] Phelps and Winter (1970), Phelps (1986) and Fitoussi and Phelps (1986) discuss the tendency for high real interest rates to raise markups in a single-economy model. Indeed, Fitoussi and Phelps (1986) place much of the blame for the persistently high rates of unemployment in Europe on this kind of mechanism.

Of course, if we had fixed the U.S. interest rate instead, then the effect of a temporary exchange rate change would be absent in the absolute level of dollar prices in the U.S. market. The required fall in the foreign interest rate, however, would raise the return on investments in *foreign* market share, and the relative dollar price of the identical good in the foreign market would nevertheless fall. 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.

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. market and the foreign market and are capacity constrained, or, more generally, have increasing marginal costs in the short run. Then a temporary dollar appreciation which leaves the U.S. interest rate 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 real interest rate and cost effects are opposed. It is quite plausible that the two effects are of similar magnitudes, so that import prices will appear to be sticky in response to changes in the value of the dollar that are perceived to be

[18] See Keynes (1930). See also Barsky and Summers (1985) for empirical evidence of Gibson's paradox. Lower real interest rates may also lower prices by encouraging capital investment that lowers current marginal costs (although investments in durable advertising would probably raise current prices). See Stiglitz (1984) for other possible explanations of this phenomenon.

temporary. This stickiness arises despite the fact that prices are perfectly flexible. In the example of the next section, the real interest rate effect can easily dominate, leading to a perverse response of import prices to exchange rate changes: dollar import prices may *rise* when the dollar appreciates. In general, the real interest rate effect *must* dominate if firms' costs are sufficiently low.

An expected future exchange rate change gives rise to an interest rate effect that is equal and opposite to a temporary change. To see this, observe that a permanent appreciation is equivalent to the sum of a temporary appreciation and an expected future appreciation of equal amounts. The relative values of future profits do not change in this case. Since, therefore, for future exchange rate changes the cost effect and real interest rate effect are in the same direction, current prices may be more sensitive to expected future exchange rate changes than they are to contemporaneous changes.

Finally, we consider an implication of uncertainty about future exchange rates in our model. If firms are risk neutral, then D chooses ν_1^D to maximize:

$$E(\pi^D) = \pi_1^D(\nu_1^D, \nu_1^F) + \lambda^D E\Big(\pi_2^D(\sigma_1^D(\nu_1^D, \nu_1^F), \mathbf{e}_2)\Big). \tag{1a'}$$

Similarly, F chooses ν_1^F to maximize:

$$E(\pi^F) = \mathbf{e}_1 \pi_1^F(\nu_1^D, \nu_1^F, \mathbf{e}_1) + \lambda^F E\Big(\mathbf{e}_2 \pi_2^F(\sigma_1^F(\nu_1^D, \nu_1^F), \mathbf{e}_2)\Big). \tag{1b'}$$

We assume that Uncovered Interest Parity holds, so that equation (3) becomes:

$$\lambda^D = \lambda^F E(\mathbf{e}_2)/\mathbf{e}_1.$$

Proceeding as before, we can derive the effect of a small increase in the variance of $\mathbf{e}_2$ by considering a family of distributions of $\mathbf{e}_2$, f_δ, with variance δ and constant mean; members of the family are derived from one another by mean-preserving spreads. We then have:

$$\frac{d\nu_1^D}{d\delta} = (V^F + \tilde{\rho}^F V^D)/\tilde{\Delta} \tag{5g}$$

$$\frac{d\nu_1^F}{d\delta} = (V^D + \tilde{\rho}^D V^F)/\tilde{\Delta} \tag{5h}$$

$$V^D = -\lambda^D\Big(\frac{\partial^2}{\partial\sigma_1^D\partial\delta}E\Big(\pi_2^D\Big)\Big)\frac{\partial\sigma_1^D}{\partial\nu_1^D}\tilde{\mathbf{D}}$$

$$V^F = -\frac{\lambda^F}{\mathbf{e}_1}\Big(\frac{\partial^2}{\partial\sigma_1^F\partial\delta}E\Big(\mathbf{e}_2\pi_2^F\Big)\Big)\frac{\partial\sigma_1^F}{\partial\nu_1^F}\tilde{\mathbf{A}}$$

where $\tilde{\rho}^D = -\tilde{\mathbf{B}}/\tilde{\mathbf{A}}$ and $\tilde{\rho}^F = -\tilde{\mathbf{C}}/\tilde{\mathbf{D}}$, $\tilde{\Delta} = \tilde{\mathbf{A}}\tilde{\mathbf{D}}(1 - \tilde{\rho}^D\tilde{\rho}^F)$, and $\tilde{\mathbf{A}}$, $\tilde{\mathbf{B}}$, $\tilde{\mathbf{C}}$, and $\tilde{\mathbf{D}}$ are the expectations taken with respect to $\mathbf{e}_2$ of $\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$, and $\mathbf{D}$, respectively.

At this level of generality, we cannot unambiguously sign V^F and V^D. However, in the limiting case in which switching costs, customer loyalty, etc., are so strong that in the second period each firm acts as a monopolist in its first-period share of the market, π_2^F is a convex function of $\mathbf{e}_2^{-1}$ (since a monopolist's profits are a convex function of its costs). It follows that $\mathbf{e}_2\pi_2^F$ is a convex function of $\mathbf{e}_2$, and this is sufficient to show that $\frac{\partial^2}{\partial\delta\partial\sigma_1^F}E(\mathbf{e}_2\pi_2^F) > 0$. Also in this case, π_2^D is independent of the future exchange rate, so that $V^D = 0$ and $V^F > 0$. Hence in either price competition or quantity competition in the limiting case, adding a mean-preserving spread to the distribution of the future exchange rate lowers first-period prices.[19]

The intuition for this result is that the future profitability of an overseas market is typically a convex function of the exchange rate: dollar costs are lower and so dollar profits are higher exactly when dollars are more valuable. Therefore greater exchange rate uncertainty increases the value of overseas market shares, hence lowers current prices in these markets.[20]

It is important to note that this result may be reversed if firms are sufficiently risk-averse. Even though an increase in the variance of the future exchange rate raises foreign

[19] An exception is quantity competition with extreme negative values of $\tilde{\rho}^D$, but this could not arise in stable, symmetric equilibrium.

[20] To see one aspect of this convexity, consider the marginal consumer in the second period when the exchange rate takes its expected value. With a variable exchange rate, the foreign firm will sell to this consumer only if such a sale turns out to be profitable. As the variability increases, this *option* to sell becomes more valuable and so an investment in market share yields a higher expected return. (This intuition is only partial since it ignores inframarginal consumers.) Similarly, Dixit (1987) studies how the option value of remaining in a market depends on the variability of the exchange rate. In our model, however, unlike Dixit's, participation in the market is not an either/or proposition. In our model, foreign firms increase their participation in a continuous way by competing more aggressively as variability of the exchange rate, and hence the option value of market share, increases.

firms' expected returns on investments in market share, it also makes these returns more risky. For firms that are highly risk-averse, the increase in expected return will be insufficient to offset the added variability. They will therefore be less willing to sacrifice certain first-period profits for a risky investment in market share, and so they will raise prices.

So far, we have discussed the effects of exchange rate changes on only the first period of our model. The effect of an unanticipated exchange rate change that occurs in the last period is just the cost effect that is present in a standard oligopoly model.[21] (In the last period there is no future, so that market share is no longer valuable.) If the reason that market share matters is that each firm has some monopoly power over its previous market share, then the second period will in general be less competitive than a standard oligopoly model, and the cost effect may be smaller. Thus, exchange rate pass-through in the last period of a model in which market share matters seems likely to be smaller than in a standard oligopoly model, and, indeed, this is the case in the example of Section 2.[22]

In reality, we are rarely in either the first or last period of any market. In a multiperiod version of this model, each period will have some characteristics of the first and last periods: we expect that the effects of exchange rate changes on first-period prices, on which we have focused, will be present but perhaps diluted.[23]

2. An Example: Quantity Competition Among Producers of Perfect Substitutes with Consumer Switching Costs

We illustrate the preceding analysis by considering a simple example: in the first period producers selling a homogeneous product engage in Cournot competition, and in the

[21] The second-period equilibrium may also be affected by temporary changes in first-period exchange rates. A change in e_1 affects first-period market shares, and this may have an effect on second-period competition.

[22] This comparison is ambiguous for two reasons. First, the last period of a market-share model is not always less competitive than a standard oligopoly model (see Klemperer, 1987b). Second, even in a monopoly, the cost effect is not necessarily smaller than in a standard oligopoly.

[23] In a multiperiod model, firms will have the (first-period) incentive we have emphasized to invest in capturing market share that will be valuable in the future, but the (last-period) incentive to price high to exploit market share may keep prices from falling too far. In the following multiperiod model, the effects of exchange rates on average prices in any period will simply be the average of the effects on our "first period," and the fairly standard effects on our "second period." Let there be overlapping generations of customers who each live two periods, let the conditions of the model in the text apply to each generation of consumers, and let firms be able to discriminate on price perfectly between generations. Farrell and Shapiro (1987) provide a cleverly constructed multiperiod model of switching costs but make a number of very special assumptions. To our knowledge, no satisfying and tractable multiperiod model of market-share competition exists.

second period each firm behaves as a monopolist on its share of the first-period market. A simple interpretation of this model would be that first-period consumers have costs of switching between firms in the second period. It is clear that with large enough switching costs, in the non-cooperative second-period equilibrium, each firm will behave as a monopolist within the segment of the market that bought from it in the first period. Klemperer (1987a) shows that the same result can arise with relatively small second-period switching costs.[24]

We make the model somewhat more general than that of the previous section by allowing n^* foreign firms and n domestic firms, with $N = n^* + n$. The representative foreign and domestic firms produce outputs q^F and q^D, respectively, in the first period. In equilibrium all firms of a given type will produce the same output, so that total industry output is $Q = n^*q^F + nq^D$. For simplicity, we assume linear demand, $p = A - Q$, in both periods. We also assume that all firms have constant marginal costs of c units of their own currency. A foreign firm's second-period dollar profits are then just $\frac{q^F}{Q}\left(\frac{(A-c/e_2)^2}{4}\right)$ since the term in brackets, $\left(\frac{(A-c/e_2)^2}{4}\right)$, is the profit a monopolist with costs c/e_2 would earn in the second period.

It is now straightforward to derive the response of the first-period dollar price, p_1, to a change in both the first- and second-period exchange rates around the symmetric equilibrium:

$$\frac{dp_1}{de_1} = \frac{1}{N+1}\left(\frac{X}{2X-1}\right)\Big((X-1)N(A-c) - n^*c\Big)$$

$$\frac{dp_1}{de_2} = \frac{1}{N+1}\left(\frac{X}{2X-1}\right)\Big(-(X-1)N(A-c) - (X-1)2n^*c\Big),$$

[24] To be consistent with the model of the previous section, we require that the structure of first-period demand is independent of the second-period exchange rate. This is not necessarily the case in a model of switching costs since first-period consumers who anticipate purchasing again in the second period should consider second-period prices (which depend on the second-period exchange rate) in making their first-period purchase decisions. This additional linkage between e_2 and the first period would make no difference to the equilibrium of the example of this section – under the switching-cost interpretation – if we interpret the inverse demand function $f(q)$ as meaning the qth consumer has reservation price $f(q)$ and assume consumers' reservation prices are identically ordered in the two periods (see Klemperer, 1987a). However, it would affect the comparative statics results. Therefore, the example of market share competition in this section should be interpreted as applying strictly to a model of switching costs when either consumers are naïve or (more reasonably) second-period consumers face switching costs because they are exposed to first-period consumers' purchases, but their preferences are not taken into account by first-period consumers. An example might be universities that buy computers in the first period, which are used by students, who are themselves consumers in the second period.

where for convenience we have set $e_1 = e_2 = 1$, and $X = (1/2)(1+(1+\lambda(N^2-1)/N^2)^{1/2})$.[25] It follows that the effect of a permanent exchange rate change is:

$$\frac{dp_1}{de_1} + \frac{dp_1}{de_2} = -\frac{Xn^*c}{N+1}$$

The economic significance of X is that in the unique equilibrium each firm produces a first-period output $\left(\frac{A-c}{N+1}\right)X$. Thus, in the standard model in which market share is unimportant to firms, $X = 1$. Note that this is also the case here if either $\lambda = 0$ (firms place no value on the future) or if $N = 1$ (a monopolist always captures the whole first-period market and so can ignore market share effects in choosing its first-period output). With $X = 1$ we have the standard Cournot oligopoly results. Future exchange rate changes have no effect ($\frac{dp_1}{de_2} = 0$) and the effect of a current change, $\frac{dp_1}{de_1} = -n^*c/(N+1)$, derives purely from the impact on foreign firms' costs expressed in dollars and, for a given size oligopoly N, is proportional to foreign firms' market share, n^*/N, and the foreign firms' costs, c. With linear demand the price elasticity with respect to the current exchange rate is $-\frac{n^*c}{(N+1)p}$, which is less than one, even when all firms are foreign.

More generally, X is the fraction of the standard single-period Cournot output that each firm produces, and so can be thought of as a measure of competitiveness in the first period. Provided that $\lambda > 0$ and $N > 1$, we have that $X > 1$, and that X is increasing in both λ and N. In fact, X is relatively insensitive to N for $N \geq 2$,[26] but it is more sensitive to λ.[27] For reasonable values of λ, X is approximately linear in λ, which is sensible since the value that firms place on future market share is linear in λ.

Note that λ need not be less than 1. If the "second period" consists of several subperiods, in all of which first-period market share matters, then λ may be substantially larger.[28]

[25] Note that with $N > 2$ firms we have:

$$\frac{dp_1}{de_j} = -\left(n\frac{dq^D}{de_j} + n^*\frac{dq^F}{de_j}\right).$$

[26] With $\lambda = 1$, $X = 1.16$, 1.19, and 1.21, for $N = 2$, 3, and ∞, respectively.

[27] With $N = 2$, $X = 1.09$, 1.16, 1.29, and 1.50 for $\lambda = 1/2$, 1, 2, and 4, respectively.

[28] This would be the case if, for example, consumers develop switching costs that lock them into a product for several repeat purchases.

More generally, we can simply think of λ as representing the importance of current market share for future profits.

We can now isolate the different effects discussed in the preceding section, and give a sense for their relative importance. As we saw in the foregoing section, the effect of changing either the current or future exchange rate consists of two parts, the cost effect and the real interest rate effect.

We discuss first the cost effects. The effect on price of a change in the current exchange rate that operates purely through lowering foreign firms' costs in dollars is the last term of $\frac{dp_1}{de_1}$, which in this example can be written $-\frac{1}{N+1}(\frac{X}{2X-1})(n^*c)$. We note that this term is directly proportional to the number of foreign firms, n^*, for given N, and to first-period costs, c. It is not very sensitive to the number of firms N, given the share held by foreign firms, n^*/N, or to the value of future market share, which is proportional to λ. As we mentioned earlier, the effect is solely that of the exchange rate on price in any single-period Cournot model.

The effect on current price of a change in future costs caused by a future exchange rate change is the second-period cost effect. As the dollar appreciates in the second period, foreign firms' dollar costs fall, causing F's return on an investment in market share to rise. (The return to D on an investment in market share does not change with the exchange rate in this example.) Competition becomes more vigorous in the first-period equilibrium. As a result, p_1 falls by $\frac{1}{N+1}(\frac{X}{2X-1})((X-1)2n^*c)$. Like the first-period cost effect, this cost effect is directly proportional to the fraction of foreign firms (since only foreign firms' costs are affected) and to second-period costs, c, and is not very sensitive to N. However this cost effect is very roughly proportional to λ: the more firms care about market share, the more a change in its value affects current behavior.

The cost effect generated by a permanent change in the exchange rate, $\frac{dp_1}{de_1} + \frac{dp_1}{de_2}$, is just the sum of the cost effects, here given by $-\frac{Xn^*c}{N+1}$. For the demand structure in this example, the effect of a permanent exchange rate change is always greater than the analogous effect in the standard Cournot model; for $\lambda = 1$ the effect is about 20 percent larger than in the standard model, whereas for $\lambda = 4$ (which could represent the case in which the "second period" was actually several repeated periods, or a two-period model in which firms cared even more about market share than in our model) the effect is about 60 percent larger than in the standard model.[29] Observe, on the other hand, that the cost effect of a temporary exchange rate change is always less than the effect of a temporary change in the standard model (since $X/(2X-1) < 1$). Also note that if a fraction $(1-\alpha)$ of foreign firms' marginal costs are actually incurred in the U.S., the cost effects (but not the interest rate effects) would be multiplied by α. The model in the previous section and our example have assumed $\alpha = 1$.

The impacts on current prices of the first- and second-period real interest rate effects in this example are, respectively, $\frac{1}{N+1}(\frac{X}{2X-1})N(A-c)$ and $-\frac{1}{N+1}(\frac{X}{2X-1})N(A-c)$. As noted in the previous section, they are equal and opposite, and therefore cancel for permanent exchange rate changes. Because the interest rate effects influence domestic as well as foreign firms, these effects are independent of the degree of foreign penetration into the domestic market. In addition, the real interest rate effects grow slightly more important as the total number of firms, N, increases,[30] and are approximately linear in λ. Recall that these effects arise even if firms have zero costs.

The overall effect of a temporary exchange rate change is the sum of the cost and real interest rate effects. As shown earlier, these effects oppose each other, and either can dominate. Indeed, a temporary appreciation of the dollar would actually be associated with an increase in the dollar price of U.S. imports, if $(X-1)N(A-c) > n^*c$. If a fraction $(1-\alpha)$ of foreign firms' marginal costs are incurred in the U.S., then the condition becomes $(X-1)N(A-c) > \alpha n^*c$. To understand when a temporary appreciation will raise prices,

[29] Note, however, that the effect in the second period of an unanticipated change in the exchange rate is $\frac{dp_1}{de_2} = -\frac{n^*c}{2N}$, which is a fraction $(N+1)/2N$ of that in the standard model. Thus in a world in which all periods have some of the characteristics of each of our two periods, the effect of a permanent change in the exchange rate would be more similar to that in a standard oligopoly model.

[30] For $\lambda = 1$ the magnitudes are $.09(A-c)$, $.12(A-c)$, and $.18(A-c)$ for $N = 2$, 3, and ∞, respectively.

note that a monopolist's markup with linear demand is $(A-c)/2$. A rough approximation of $(X-1)$ is $\lambda/5$, so the condition for a temporary dollar appreciation to have no effect at all on dollar import prices is approximately:

$$\lambda = \alpha(5/2)\left(\frac{\text{foreign firms}' \text{ share of market}}{\text{percent profit margin of a monopolist in the market}}\right)$$

which is not unreasonable.

A short appendix summarizes these results on the sensitivity of dollar import prices to exchange rate changes.

To gain a sense for the magnitude of the pass-through elasticities for the model of this section, we present in Table 1 computations of the percentage change in dollar import prices in response to a one percent temporary appreciation of the dollar. Table 1a shows the values of the elasticity, $\frac{dp_1}{de_1}\frac{e_1}{p_1}$, for different values of λ and different fractions of costs that are denominated in foreign currency. The top row of the table ($\lambda = 0$) gives the standard Cournot pass-through. Tables 1b and 1c separate this elasticity into the cost and real interest rate effects, respectively. In the tables that follow, we assume that 50 percent of the foreign firm's costs are denominated in dollars. Table 1d shows the effect on the pass-through of different levels of foreign penetration into the domestic market (holding the total number of firms constant). Table 1e allows N to increase, holding constant instead the fraction of the market controlled by foreign firms at one half. Finally, Table 1f shows the impact of higher costs on the sensitivity of price changes to the exchange rate. The tables illustrate the results discussed above. They also show that the degree of pass-through attributable to both the cost effect and the interest rate effect are larger, *ceteris paribus*, when prices are lower, i.e., for larger λ, larger N, and larger c.

It is clear from these tables that the pass-through from a temporary exchange rate change may easily be perverse: a temporary appreciation can reduce the profitability of a marginal investment in market share enough to *increase* the current dollar price. Notice that in these cases, pricing to market will be most extreme, since foreign currency prices of foreign exports will rise proportionately more than the exchange rate.

The elasticities reported in Table 2 are for an analogous set of computations, except that here the dollar appreciation is assumed to be permanent. As we saw above, a permanent dollar appreciation tends to make the dollar price of U.S. imports fall more rapidly than does a temporary appreciation. Comparing the elasticities reported in Tables 1 and 2 makes clear that expected future exchange rate changes can easily have a much greater effect than current exchange rate changes on current prices.

Finally, we consider the effect of increasing the variance of the future exchange rate. A Taylor series approximation to future expected profits for the foreign firm yields:

$$\frac{\partial}{\partial \delta}\Big(E(\mathbf{e}_2\pi_2^F(\mathbf{e}_2)\Big) \approx (1/2)\frac{d^2(\bar{\mathbf{e}}_2\pi_2^F(\bar{\mathbf{e}}_2))}{(d\mathbf{e}_2)^2} > 0$$

where the middle expression is evaluated at the expected future exchange rate, $\bar{\mathbf{e}}_2$. We can compute that around the symmetric equilibrium an increase in the variance, δ, of future exchange rates lowers dollar import prices:

$$\frac{dp_1}{d\delta} = -\frac{1}{N+1}\Big(\frac{X}{2X-1}\Big)\Big(\frac{(X-1)c^2}{A-c}\Big) < 0$$

Thus with risk-neutral firms, an increase in uncertainty about future exchange rates lowers current prices.

3. Data Analysis

It is beyond the scope of this paper to test comprehensively the model above. In this section, we look instead at aspects of a simple but important implication of our model: that the degree of pricing to market depends on the perceived permanence of exchange rate changes.[31] While it is not in itself surprising that permanent appreciations exert more downward pressure on prices than temporary appreciations, such a distinction might help explain the puzzling behavior of U.S. import prices during the 1980s. There is now

[31] The permanence of exchange rate changes can also affect the degree of pricing to market in models where there is a cost of adjusting supply. Krugman (1986) discusses an example in which there are increasing marginal costs of expanding sales in a firm's overseas market. A model of this type might explain the empirical results presented below; note, however, that such a model would not generate the perverse response, discussed in the foregoing sections, of dollar import prices to temporary exchange rate changes.

a growing consensus that the dollar prices of U.S. imports during this period have moved too little in response to exchange rate changes to be consistent with historical experience. To the extent that the unprecedented rise in the dollar's value was believed to be more temporary than prior appreciations, profit-maximizing firms in our model would cut prices to the U.S. market by little, if at all.[32]

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.[33] Indeed, 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 euro-currency deposits, yields the same qualitative conclusion. Figure 1 shows a simple average of the differences between twelve-month euro-dollar 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.[34]

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 3 presents estimates of both expected nominal depreciation of the dollar and expected inflation in the U.S. relative to several of its major trading partners. We have chosen a variety of measures to ensure

[32] 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, Meese and Rogoff, 1986). 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 Huizinga, 1986).

[33] See Frankel and Froot (1987) and Froot and Frankel (1986) for a description of this survey data.

[34] 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 may well understate expected depreciation.

that the appearance of a substantial increase in 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 3. 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 the one-period percentage change in a British exporter's dollar price on exports to the U.S. less the percentage change in his dollar price on exports to Japan:

$$\Delta p_t^{UK,US} - \Delta p_t^{UK,JA}. \tag{6}$$

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 (6) will be positive. Note the effect of a temporary versus permanent appreciation. The model above would predict that the more the dollar is expected to depreciate in the future, the greater the quantity given in (6) will be. Indeed, prices in our model may often be more sensitive to expected future exchange rate changes than to current changes.

A simple way to capture pricing to market and its sensitivity to exchange rate expectations is to project a measure of expression (6) onto the change in expected future depreciation of the real dollar/yen exchange rate and the contemporaneous change in the real exchange rate:[35]

$$\Delta p_t^{i,UK,US} - \Delta p_t^{i,UK,JA} = \beta_1 \Delta E_t(\Delta \mathbf{e}_{t+1}^{US,JA}) + \beta_2 \Delta \mathbf{e}_t^{US,JA} + \epsilon_t^i. \tag{7}$$

where the superscript i represents the ith 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 change from period $t-1$ to t in expected depreciation of the real dollar/yen rate over the following

[35] In general, the relationship between discrete percentage changes in price and changes in exchange rates is not linear, so that equation (7) is only a first-order approximation.

period. If there were no pricing to market, we would expect all the terms in equation (7) to 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, ϵ_t^i, would be zero. Finally, with pricing to market and diversity across markets, the error term would appear random over i. (Notice that any such variation across industries is independent of the exchange rate terms, so that the Gauss-Markov assumptions are satisfied.) Thus equation (7) represents a crude but informative test of a basic property of our model.

The coefficient β_1 in equation (7) 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 β_1 in the relative price of exports sent to the U.S. versus exports sent to Japan.[36] Conventional static models would yield $\beta_1 = 0$, while our model predicts $\beta_1 > 0$. Similarly, the coefficient β_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 $\beta_2 = -.01$. 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 $\beta_2 - \beta_1 = -.01$, the *dollar* prices of U.S. imports are insensitive to temporary exchange rate changes. If $\beta_2 - \beta_1 < -.01$, 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 U.S.

To measure the price term on the left-hand side of equation (7), 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 JA

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

to each of the US, JA, and the UK.[37] 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 US and Japan. In the regressions that follow, we used the two relatively standard measures of expected real depreciation given in lines 7 and 8 of Table 3. 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 the change in inflation in Japan over the previous twelve months less the change in inflation in the U.S. 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 4a and 4b present estimates of equation (7) 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 3.[38] We report the usual OLS standard errors in Tables 4a and 4b, as we discovered that the standard errors calculated using a heteroskedasticity-consistent covariance estimate were smaller. Each table gives regression results for six sets of relative bilateral export price changes; the last set of regressions combine all the individual bilateral regressions.

[37] In some cases these unit value data show sudden, huge jumps in level from one year to the next. We have eliminated industries which contained one-year jumps of more than 400 percent, which were most likely to be data errors.

[38] Initially we estimated equation (7) on the original annual data. The resulting parameter estimates were similar to those reported in Table 4, 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.

There is no overwhelming evidence that expected future depreciation influences the degree of pricing to market. Nevertheless, 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 β_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 β_1 in Table 4a 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 U.S. 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 β_1 in Table 4b are similar to those in Table 4a. If the survey data contain measurement error, however, these estimates are biased in magnitude and statistical significance toward zero.[39]

The estimates of β_2 are usually more than an order of magnitude smaller than the estimates of β_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 degree pricing to market. 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. Thus, fully permanent depreciations appear to be passed through into import prices one-for-one.

Estimates of the difference, $\beta_2 - \beta_1$, are almost always negative and less than $-.01$: a

[39] See Froot and Frankel (1986) for a discussion of the measurement errors in these data.

completely temporary appreciation of the dollar is associated with a *rise* in import prices. The right-most column of Tables 4a and 4b 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 4a, 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 4b 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 have a substantial permanent component. In fact, our estimates in Table 4a 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.[40] 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.

Our findings suggest that one must know how much of a given exchange rate change is expected to be permanent in order to determine the magnitude and even the sign of the effect on dollar import prices. In sum, the estimates reported in Tables 4a and 4b provide some support for the view that expected depreciation may have a large role to play in explaining the pricing behavior of foreign exporters to the U.S. market during the 1980s.

[40] The last regression in Table 4a 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.

4. Conclusion

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 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. Finally, we found that an uncertain future exchange rate is likely to make market share more valuable, and so drive down current prices.

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 1981-5 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 investigation suggests that purely temporary dollar appreciations are associated with an *increase* in dollar import prices. Expected depreciation may have played a substantial role in foreign exporters' recent decisions to raise prices in the U.S. market relative to those in other markets.

5. Appendix

The following expressions summarize the results of Section 2.

For $\lambda = 0$ (i.e. in a standard single-period Cournot model):

$$\frac{dp_1}{de_1} = -\Big(\frac{n * c}{N+1}\Big)$$

$$\frac{dp_1}{de_2} = 0.$$

For $\lambda = 1$, $N \geq 2$,[41]

$$\frac{dp_1}{de_1} \approx \frac{6}{7}\Big(\frac{1}{N+1}\Big)\Big(\frac{N(A-c)}{5} - n^*c\Big)$$

$$\frac{dp_1}{de_2} \approx \frac{6}{7}\Big(\frac{1}{N+1}\Big)\Big(\frac{-N(A-c)}{5} - \frac{2n^*c}{5}\Big)$$

$$\frac{dp_1}{de_1} + \frac{dp_1}{de_2} \approx -\frac{6}{5}\Big(\frac{n^*c}{N+1}\Big).$$

For $\lambda = 3\Big(\frac{N^2}{N^2-1}\Big)$, $N \geq 2$ (i.e., $\lambda \approx 3.2$ for $3 \leq N \leq \infty$, $\lambda = 4$ for $N = 2$):

$$\frac{dp_1}{de_1} = \frac{3}{4}\Big(\frac{1}{N+1}\Big)\Big(\frac{-N(A-c)}{2} - n^*c\Big)$$

$$\frac{dp_1}{de_2} = \frac{3}{4}\Big(\frac{1}{N+1}\Big)\Big(\frac{N(A-c)}{2} - n^*c\Big)$$

$$\frac{dp_1}{de_1} + \frac{dp_1}{de_2} = -\frac{3}{2}\Big(\frac{n^*c}{N+1}\Big)$$

[41] These approximations use the result that for $\lambda = 1$, $X - 1 \approx 1/5$. (For $N = 2$, $X = 1.10$; for $3 \leq N \leq \infty$, $1.18 \leq X \leq 1.21$.)

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Elasticity of the Price with Respect
to a Temporary Exchange Rate Change

Table 1a

λ	fraction of foreign costs denominated in domestic currency 0	.2	.5	.9
0	-.17	-.13	-.08	-.02
.4	-.10	-.06	-.01	.05
.8	-.04	-.00	.05	.12
1.2	.02	.06	.11	.18
2.0	.14	.18	.24	.32

Table 1b

The Cost Effect

λ	fraction of foreign costs denominated in domestic currency 0	.2	.5	.9
0	-.17	-.13	-.08	-.02
.4	-.17	-.13	-.08	-.02
.8	-.17	-.14	-.09	-.02
1.2	-.18	-.14	-.09	-.02
2.0	-.19	-.15	-.10	-.02

Table 1c

The Real Interest Rate Effect

λ	fraction of foreign costs denominated in domestic currency 0	.2	.5	.9
0	.00	.00	.00	.00
.4	.07	.07	.07	.07
.8	.14	.14	.14	.14
1.2	.20	.20	.20	.20
2.0	.33	.33	.33	.33

Parameters: $N = 2$, $A = 4$, $C = 1$, $n^* = 1$

Elasticity of the Price with Respect to a Temporary Exchange Rate Change

Table 1d
The Impact of Foreign Penetration

λ	number of foreign firms, n^* 1	3	5
0	-.05	-.15	-.25
.4	.12	.01	-.10
.8	.32	.19	.06
1.2	.56	.41	.26
2.0	1.36	1.13	.90

Parameters: N = 6, A = 4, c = 1, fraction of foreign costs denominated in domestic currency = .5.

Table 1e
The Impact of Industry Concentration

λ	Total number of firms, N 2	6	20
0	-.08	-.15	-.21
.4	-.01	.01	.02
.8	.05	.19	.34
1.2	.11	.41	.85
2.0	.24	1.13	6.67

Parameters: c = 1, A = 4, n^* = N/2, fraction of foreign costs denominated in domestic currency = .5.

Table 1f
The Impact of Marginal Costs

λ	c 1	1.4	1.8
0	-.15	-.17	-.18
.4	.01	-.06	-.10
.8	.19	.05	-.04
1.2	.41	.15	.03
2.0	1.13	.41	.16

Parameters: N = 6, A = 4, n^* = 3, fraction of foreign costs denominated in domestic currency = .5.

Elasticity of the Price with Respect
to a Permanent Exchange Rate Change

Table 2a

λ	fraction of foreign costs denominated in domestic currency 0	.2	.5	.9
0	-.17	-.13	-.08	-.02
.4	-.19	-.15	-.10	-.02
.8	-.22	-.17	-.11	-.02
1.2	-.24	-.20	-.12	-.02
2.0	-.30	-.24	-.15	-.03

Parameters: N=2, A=4, C=1, n^*=1

Table 2b

The Impact of Foreign Penetration

λ	number of foreign firms, n^* 1	3	5
0	-.05	-.15	-.25
.4	-.07	-.20	-.33
.8	-.08	-.25	-.42
1.2	-.11	-.33	-.55
2.0	-.20	-.59	-.98

Parameters: N=6, A=4, C=1, fraction of foreign costs denominated in foreign currency = .5.

Elasticity of the Price with Respect to a Permanent Exchange Rate Change

Table 2c

The Impact of Industry Concentration

λ	Total number of firms, N: 2	6	20
0	-.08	-.15	-.21
.4	-.10	-.20	-.30
.8	-.11	-.25	-.43
1.2	-.12	-.33	-.67
2.0	-.15	-.59	-3.41

Parameters: A=4, c=1, n^*=N/2, fraction of foreign costs denominated in domestic currency = .5.

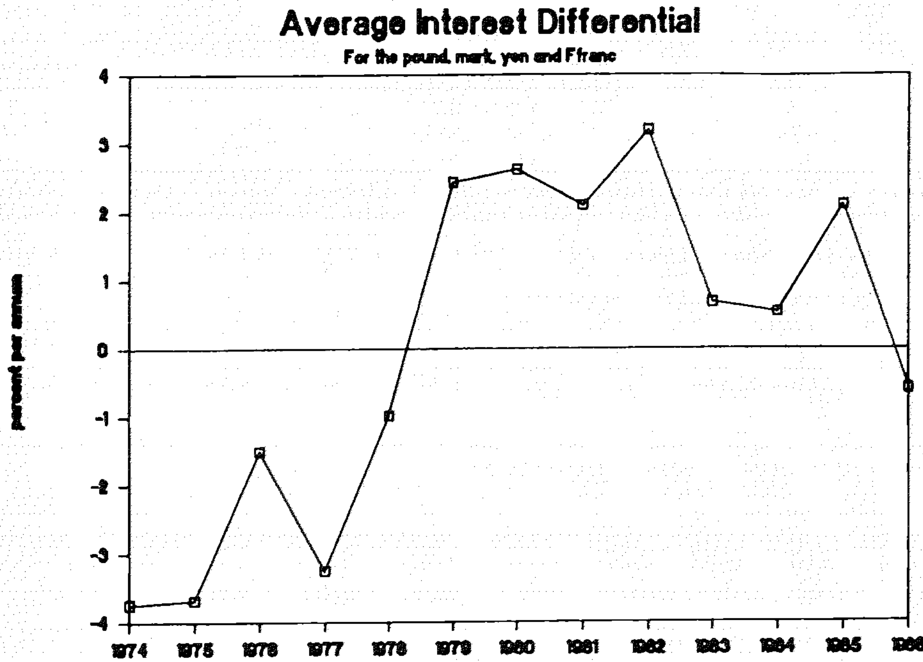
Table 2d

The Impact of Marginal Costs

λ	Marginal Costs: 1	1.4	1.8
0	-.15	-.17	-.18
.4	-.20	-.21	-.22
.8	-.25	-.25	-.25
1.2	-.33	-.30	-.29
2.0	-.59	-.43	-.37

Parameters: N=6, A=4, n^*=N/2, fraction of foreign costs denominated in foreign currency = .5.

Figure 1



Twelve-month eurodeposit interest differentials from.DRI.

Table 3
Measures of Expected Real
Depreciation of the Dollar
(% per annum)

	Years				
Measures of expected nominal depreciation #	1976-8	1979-80	1981-2	1983-84	1985-6
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 ##					
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 **	NA	2.20	0.96	0.23	0.15
6. OECD two-year forecast ***	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: # measures of expected nominal depreciation calculated using a gnp-weighted average of the pound, Ffranc, mark, and yen against the dollar.
measures of expected inflation differential calculated as US minus a gnp-weighted average of the UK, France, West Germany, and Japan.
* available during 1985-86 for 1985 only.
** averages of various forecast dates through March 1978.
*** OECD forecasts available during 1976-8 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.

Table 4a

Exchange Rate Pass Through and the Effects of Expected Depreciation

$$\Delta p_t^{i,j,k} - \Delta p_t^{i,j,l} = \beta_1 \Delta E_t(\Delta s_{t+1}^{k,l}) + \beta_2 \Delta s_t^{k,l} + \epsilon_t^i$$

Dependent Variable	β_1	β_2	SE	DF	F-test $\beta_1=\beta_2=0$	F-test $\beta_2-\beta_1=0$
$\Delta p_t^{i,UK,US} - \Delta p_t^{i,UK,JA}$	.1399** (.0463)	.0135** (.0046)	.33	126	4.88**	8.58**
$\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,JA}$	.0173 (.0380)	-.0013 (.0038)	.30	146	.87	0.27
$\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,UK}$	-.0071 (.0240)	-.0026 (.0033)	.40	167	0.25	0.03
$\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,JA}$	.0126 (.0400)	-.0003 (.0040)	.32	154	0.24	0.12
$\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,UK}$	.0154 (.0169)	-.0016 (.0026)	.28	166	0.67	1.01
$\Delta p_t^{i,JA,US} - \Delta p_t^{i,JA,UK}$	.0048 (.0208)	-.0031 (.0032)	.29	115	0.51	0.14
all countries	.0437* (.0232)	.0026 (.0020)	.32	884	1.64	3.68**

Notes: Expected depreciation is measured using the appropriate 12-month Euro-interest 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 4b

Exchange Rate Pass Through and the Effects of Expected Depreciation

$$\Delta p_t^{i,j,k} - \Delta p_t^{i,j,l} = \beta_1 \Delta E_t(\Delta s_{t+1}^{k,l}) + \beta_2 \Delta s_t^{k,l} + \epsilon_t^i$$

Dependent Variable	β_1	β_2	SE	DF	F-test $\beta_1=\beta_2=0$	F-test $\beta_2-\beta_1=0$
$\Delta p_t^{i,UK,US} - \Delta p_t^{i,UK,JA}$	-.0824 (.0614)	-.0159 (.0137)	.34	126	1.20	1.91
$\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,JA}$	.0022 (.0500)	-.0022 (.0111)	.30	146	0.77	0.01
$\Delta p_t^{i,FR,US} - \Delta p_t^{i,FR,UK}$	.0198 (.0235)	.0026 (.0070)	.40	167	0.57	0.91
$\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,JA}$	.0096 (.0515)	.0007 (.0115)	.32	154	0.20	0.05
$\Delta p_t^{i,WG,US} - \Delta p_t^{i,WG,UK}$	.0094 (.0165)	.0004 (.0048)	.28	166	0.42	0.50
$\Delta p_t^{i,JA,US} - \Delta p_t^{i,JA,UK}$	.0472** (.0197)	.0086 (.0058)	.28	115	3.37**	6.39**
all countries	.0171* (.0093)	.0032 (.0024)	.32	884	1.95	3.80**

Notes: Expected depreciation is measured using survey data on exchange rate, 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.