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Incomplete Exchange Rate Pass-Through and Hysteresis in Trade

A Survey of Recent Theories and an Empirical Study of Export Pricing of Finnish Paper Manufactures

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Abstract

This paper analyzes factors affecting the pass-through from exchange rates to import prices. The prevailing market structure, product differentiation, intertemporal optimization and the role of expectations regarding the exchange rate are the elements whose explicit modelling enable the rationalization of the empirically observed incomplete and sluggish price response to exchange rate movements. Further, recent theories concerning hysteresis in trade prices and quantities are reviewed in order to demonstrate how large exchange rate changes may cause changes in market structure through foreign entry or exit, and/or changes in distribution capacity, and market share investments. These results are then applied to examine the dynamics of price adjustment, which is shown to be the slower the higher is the level of exchange rate uncertainty and the more significant are the sunk investments required for market entry. An empirical study of export pricing of Finnish paper manufactures is carried out by estimating export price equations based on a mark-up pricing rule and a general error correction model as a dynamic empirical specification. The exchange rate pass-through estimates are significantly incomplete, also in the long run, and distinctly lower in exports to the USA than to West European markets. These results are generally consistent with the derived theoretical results. The huge appreciation of the US dollar during the first half of the 1980's seems to have evoked hysteretic effects in the US market for paper products as well as in Finnish exports to the USA, which show up as significant instabilities in the price equations. However, at the level of aggregate exports there is no clear evidence of such effects following the devaluations of the Finnish mark in the observation period 1975–1991.

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Contents

1 Introduction

The first goal of this paper is to review new theories concerning the determination of *exchange rate pass-through (EPT)*. The EPT question has been addressed by numerous authors during recent years in a wider context of reshaping theories of international trade by applying methods taken from industrial economics. Traditional theories predict or assume complete EPT, i.e. the same proportionate change in import prices as in exchange rates. By contrast, the new theories to be reviewed here imply incomplete EPT in many industries and even at the level of aggregate imports when monopolistic competition in differentiated products or oligopolistic interaction and industry-specific demand and cost conditions are explicitly modelled. A formal treatment of exchange rate uncertainty and dynamic factors causing sluggish volume and price response further accentuate the prediction of incomplete EPT.

An increase in the nominal and real variability of the major currencies (USD, DEM and JPY), and especially the huge swings in the dollar in the 1980s, have drawn attention to the EPT issue. Further, persistence of the U.S. trade deficit in spite of a sharp depreciation of the dollar in 1985–1987 has induced many authors to investigate reasons for the observed sluggish price and volume response. Hence, most studies examine the behaviour of import prices in the U.S., German or Japanese market, and present convincing evidence of incomplete pass-through both in the short and long run, most clearly in the U.S. market.

The second theoretical goal is to present results of recent research concerning *hysteresis* in trade prices and quantities and their implications for the EPT issue. Hysteresis is a key concept in new theories, providing microeconomic underpinnings to dynamic trade theories by showing how large exchange rate movements can have persistent (hysteretic) effects on market sturcture through foreign entry or exit, changes in distribution capacity or investments in consumer allegiance. This paper aims at describing the theoretical foundations of hysteresis, as well as assessing its relevance and magnitude when exchange rate uncertainty is explicitly modelled and different competitive structures applied.

Although most theoretical and empirical studies are based on the experience in the U.S. market during the 1980's the theoretical treatment in this paper is kept general enough, mostly in a two-country setting, to be widely applicable. Analyses at the level of a single firm and industry when the bilateral exchange rate floats form the body of the work. Incomplete EPT is possible not only in the case of a large domestic market, like the U.S. market, and in the case of floating exchange rates, but generally always when firms can use their profit margins as a buffer against exchange rate changes due to price setting power in monopolistic competition or oligopolistic market structure. Thus, it is justified to also consider Finnish export pricing in the general framework applied.

This paper includes an empirical study of export pricing of Finnish paper manufactures. The purpose of the estimations is to measure the magnitude of EPT in the European and the U.S. market and to investigate whether the theoretical conclusions are able to characterize Finnish export pricing as well. The paper industry was chosen, because it can be considered as having market power in international markets. The second aim is to examine whether any effects implied by the theory of hysteresis have occurred in Finnish paper exports. The movements in the dollar in the 1980's and devaluations of the Finnish Mark are considered as representing exchange rate shocks that could have caused such effects.

Analyses are limited strictly to investigating the EPT question and hysteresis in trade prices and quantities at the level of individual goods and industries. However, the implications for the trade balance and exchange rate determination itself are briefly addressed in chapter five. The impact of tariffs and other barriers to free trade on import prices is closely related with the EPT question, but it is beyond the scope of this work. One of the most important microeconomic implications of incomplete EPT is that the ensuing change in relative prices may in the case of a domestic depreciation (relative price of imports falls) lead to dumping in the juridical sense, i.e. violations of e.g. U.S. trade laws if the price of an imported good is below its production and delivery costs. This problem, referred to as "*technical dumping*", is throughly investigated in Mattila (1991) and thus not commented on here.

The remainder of this paper is organized as follows. Chapter two presents traditional views on EPT and both theoretical and empirical facts that dilute their validity. The determination of EPT is examined in light of static imperfect competition models in chapter three. Chapter four reviews the fundamental theory of hysteresis and presents general implications of hysteresis for trade prices and quantities that stem from the optimality of a sluggish response on the part of firms to exchange rate fluctuations. Further, various dynamic aspects such as firms' planning horizons, distribution capacity constraints and market share investments via current prices are considered. Chapter five offers some theoretical extensions. Results of the empirical study are reported in chapter six.

2 Exchange rate pass-through and shortcomings of the traditional approaches

2.1 The exchange rate pass-through concept

Broadly defined *exchange rate pass-through* (EPT) measures the extent to which the import price in domestic currency of a particular product is affected by a change in the exchange rate. *Complete EPT* results when import prices fully reflect movements in the exchange rate and exporters hold their own-currency prices constant. By contrast, *incomplete EPT* follows when exporters absorb at least partially the exchange rate fluctuations by adjusting their own-currency prices.

In the related literature EPT is most commonly defined as an elasticity of import prices with respect to the nominal or real exchange rate, α, in such manner that α is positive, as generally expected, when the domestic currency depreciates, implying a rise in the home-currency prices of imports. Thus, by letting p be the import price in home currency, p^* the export price in the exporter's (foreign) currency and e the foreign currency price of the domestic exchange, i.e. appreciation of the domestic currency appears as an increase in e. With these denotations, α becomes (see e.g. Ohno 1988):

$$\alpha = -\frac{\frac{dp}{p}}{\frac{de}{e}} = 1 - \frac{\frac{dp^*}{p^*}}{\frac{de}{e}} \tag{2.1}$$

As (2.1) shows, α can be calculated either by using home- or foreign-currency prices. By rearranging (2.1) we can conclude that the EPT-elasticity with respect to export prices (in foreign currency) α^* equals $(1-\alpha)$. Hence, α and α^* sum to unity, and the exchange rate movement is transferred into import or export prices or both. When EPT is complete α obtains the value 1 and falls in the interval $0 \leq \alpha < 1$ when EPT is incomplete. Negative α indicates *perverse EPT,* which may occur in some cases when a current exchange rate change is perceived to be temporary.[1]

In order to capture the effect of a change in competitiviness on import prices, EPT should be defined in terms of the real exchange rate. For example, if a nominal depreciation of the domestic currency is matched by a proportional increase in the inflation differential, the real exchange rate remains unaltered. Then, provided that exporters have no money illusion, domestic import prices will remain stable producing zero EPT. In effect, testing empirical hypotheses about EPT by using real exchange rates is equivalent to testing the joint hypothesis of no money illusion and some particular pricing behaviour on the part of exporters (Ohno 1988). Although the real relationship is theoretically more preferable, the

[1] Froot and Klemperer (1989) have given a theoretical explanation for the perverse EPT. It will be discussed in greater detail in section 4.5, where their market share model in described.

nominal relationship has been more widely used in the related econometric literature.[2]

In addition to individual products, EPT can be defined for aggregate import prices at the industry or national level by using a suitable price index to measure import prices. When estimating aggregate EPT-elasticity, one naturally defines it with respect to a relevant trade- or payments-weighted currency basket or to the (real) effective exchange rate (see e.g. Feinberg 1986, Hooper & Mann 1989 and Kim 1990).

2.2 Traditional models of exchange rate pass-through

2.2.1 The elasticity approach

The EPT issue was raised by trade economists when the effects of major currency realignments at the end of the Bretton Woods era were considered. The main analytical tool was the *elasticity approach,* based on conventional supply and demand analysis. The focus in this approach is on the supply response of foreign exporters whose production costs in domestic currency are affected by a change in the exchange rate. For example, a reduction in foreign costs results from a domestic appreciation to the extent that the appreciation does not have an impact on foreign producers' input prices. If some of the input prices are denominated in the appreciating currency, this "less-direct" effect on foreign costs should be accounted for.

Standard analysis considered perfectly competitive industry, where prices equal marginal costs (no mark-up) and supply curves coincide with marginal cost curves. Perfectly elastic foreign supply yields complete EPT because of a vertical shift in the foreign supply curve due to conversion of constant foreign marginal costs into domestic import prices at a different exchange rate. This represents *the small country case* in the trade literature, where domestic demand variations are assumed not to affect world prices.

Less than infinitely elastic foreign supply gives rise to incomplete EPT, since now its magnitude depends both on the shift in the foreign supply curve and on the movement along it. These effects can be measured by equation (2.2) (Veneables 1990a, p.20):

$$\alpha = \frac{\eta^f \theta}{\varepsilon + \eta^d(1-\theta) + \eta^f \theta}, \qquad (2.2)$$

where ε, η^f and η^d are the price elasticities of domestic demand, foreign and domestic supply, respectively, and θ is the share of imports in the home market. All elasticities are assumed to be constant. Thus, equation (2.2) can be derived directly from the slopes of demand and supply curves using the share of imports as a weight-factor. In terms of equation (2.2), infinite η^f implies complete EPT

[2] See e.g. Branson (1972), Magee (1974), Krugman & Baldwin (1987), Baldwin (1988a), Hooper & Mann (1989), Moffet (1989) and Kim (1990)

while smaller values of η^f reduce it. The effects of domestic demand and supply elasticities on EPT are also straightforward: it falls as ε increases (in absolute value) and η^d rises, *ceteris paribus*. The change in the quantity of imports, M, is the larger the greater are the absolute values of all elasticities.

According to the elasticity approach, the case where foreign exporters absorb an exchange rate change in their sales margins is regarded only as a short-run phenomenon. Thus, the pass-through question governs only the timing of its effect. Attempts to absorb exchange rate changes would produce lags in EPT, but in the long-run it needs to be complete because of variations in export volume (and reallocations of capital and labour in the forign export industry). For example, a domestic revaluation would generate profits for foreign exporters if it were absorbed, and hence would eventually draw entrants into the industry and cause import volume to rise and prices to fall through the increase in the number of exporting firms. This reasoning requires, of course, the presumption that no overwhelming trade barriers exist. (Branson 1972)

2.2.2 Standard open economy models of price relationships

The two extreme models of price relationships in the open economy literature are *the monetary flexible-price* and *the "Keynesian" sticky-price model.* The corner-stone of the monetary approach is the "law of one price", which implies that prices are equalized in different locations through effective spatial arbitrage. Even the threat of arbitrage is regarded as sufficient enough to keep prices uniform. Product homogenity, perfect competition and informationally efficient markets are the crucial assumptions that assure this result. (Dornbusch 1987, Hallwood and MacDonald 1986, ch.4)

The "law of one price" is asserted by the PPP, which gives a direct link between prices in home and foreign countries for the good in question: $p=p^*/e$.[3] This is considered to hold particularly among industrialized countries as product substitutability is assumed to be high. Thus, foreign and domestic firms are regarded as takers of world market prices, which results in complete EPT in domestic currency import prices (Kravis & Lipsey 1978).

The monetary model also assumes full price flexibility and perfectly integrated world capital markets, which allow financial surpluses to be transferred across borders without changes in relative prices. Thus, changes in exchange rates offset divergent national price trends, and relative prices can deviate only temporarily. Or more generally, pure monetary disturbances leave the real exchange rate unaffected, and PPP ensures that it is preserved at its equilibrium level. (Krugman 1989, ch 1, Mark 1990)

By contrast, the "Keynesian" approach assumes that internationally traded goods are imperfect substitutes, i.e. to some extent heterogeneous, and that wages are fixed or at least sticky in national currencies. The "Keynesian" view assumes further a constant mark-up over marginal costs, which together with sticky wages yields sticky prices for the industry output. Hence, national price levels also tend

[3] Transaction costs, tariffs and transport costs will modify the strict equality by creating a "neutral band" around it within which arbitrage is unprofitable. The other commonly applied assertion is the first-difference version of Cassel (Hallwood & MacDonald 1986, ch4).

to be inflexible. Therefore, exchange rate movements alter relative prices, i.e. the real exchange rate, and hence the relative competitiviness of domestic and foreign producers. Traditional analyses assume complete EPT. Thus, competitiviness of domestic firms can be increased via a devaluation, at least temporarily. This kind of "Keynesian" reasoning is used in the open economy IS–LM framework, e.g. in the Mundell-Fleming model, in which the price level is given simply by an exogenously fixed index (Copeland 1989, ch.6). (Dornbusch 1987)

2.3 Critique of the traditional models

2.3.1 Imperfect competition and "pricing to market"

The first type of criticism stems from the fact that the assumptions the traditional approaches make are inappropriate for modern industries. Among industrialized countries most trade takes place in differentiated manufactures rather than in homogeneous goods where prices of raw materials constitute a large part of the production costs. Thus, to a considerable extent, industries engaged in international trade are imperfectly competitive and incorporate firms that possess price-setting power. Therefore, the analysis of EPT should contain elements from models of industrial economics.[4] The most relevant factors are the degree of product substitutability between domestic and foreign variants, the market organization and the oligopolistic interaction of firms in the domestic market. The effects of these factors will be discussed in turn in the next chapter (Dornbusch 1987, Krugman 1989, ch.1).

Imperfectly competitive markets entail a mark-up over marginal costs. Thus, the EPT issue boils down to finding out how the mark-up varies in response to exchange rate fluctuations, i.e. to what extent exporters absorb exchange rate movements in their profit margins by "passing-through" incompletely. The behaviour whereby prices are held stable in the purchaser's currency is referred to as *"pricing to market"* (PTM) behaviour by Krugman (1986), since export prices are now determined by competitive conditions in the destination market. PTM may result from active international price discrimination across different national markets, but more generally the recognition of PTM behaviour offers evidence of the role of market structure in international trade. This is best displayed by the fact that even in the case of homogeneous products oligopolistic competition can lead to incomplete EPT when different national markets are segmented[5]. Thus, the "law of one price" need not hold for homogeneous goods either, and oligopolistic

[4] Static models of imperfect competition and game-theoretic frameworks have been applied by numerous authors in recent years. A partial list includes: Dornbusch 1987, Feenstra 1989, Feinberg 1986, Fisher 1989, Giovannini 1988, Helpman & Krugman 1985, Knetter 1989, Krugman 1986 and 1990, Marston 1990 and Veneables 1990a.

[5] Various national markets are segmented if it is not possible to engage in spatial arbitrage (e.g. to reimport goods from other countries). When markets are segmented firms can set their strategic variables separately for different markets, whereas in an integrated market they are forced to choose a single value for the variable in question. Segmented markets are, of course, also a condition for successful price discrimination. (Veneables 1990b)

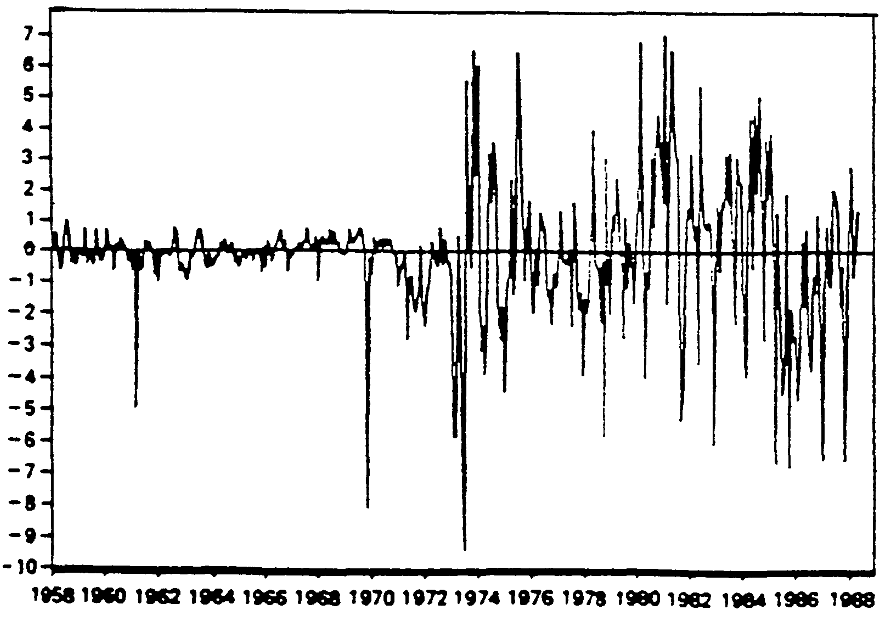
interaction can lead to the PTM phenomenon without active price discrimination (Knetter 1989, Veneables 1990a).

Strict dependence on exact demand and supply schedules constitutes a severe problem in explaining PTM with static frameworks, as will be demonstrated in the next chapter. More profound rationalizations can be uncovered in dynamic analyses by considering intertemporal optimization, expectations formation and various kinds of supply and demand side stickinesses. Formal treatment of these factors further accentuates the prediction of incomplete EPT. Moreover, it has been shown that large exchange rate variations can have persistent real effects on market structure and the firm's pricing policies referred to as the *hysteresis* phenomenon. The sluggish response of import prices and volumes is a central outcome in all dynamic analyses, implying incomplete EPT in the long-run as well. Chapter four is devoted to these issues.

2.3.2 Stickiness of domestic prices and the behaviour of exchange rates

The observation that firms tend to fix their prices and wage offers for rather long periods of time dilutes the fundamental flexible-price assumption of the basic monetary approach. Dornbusch (1989) has given convincing evidence of sticky nominal goods prices by showing that the variability of bilateral real exchange rates among industrial countries and the USA has been far greater under flexible exchange rates than under fixed exchange rates (see figure 2.1).[6] Thus, national price levels have not been able to adjust to nominal exchange rate changes, which has also led to greater volatility of real exchange rates.

Figure 2.1 **Monthly Changes in the USD–DEM Real Exchange Rate (per cent), CPI data (Dornbusch 1989, p. 419)**



[6] For example, measured by variance, the variability of the real USD–DEM rate was nine and that of the real USD–FRF rate eight times higher during 1973–1987 than 1958–1972. (Dornbusch 1989, pp. 418–420)

Recent literature on the validity of the PPP in the regime of floating exchange rates concludes that it does not seem to hold even in the long run[7] (see e.g. Hallwood & MacDonald 1986, ch. 4, and Mark 1990). Thus, commodity price levels and nominal exchange rates are unrelated and nominal and real exchange rates move closely together. According to Krugman (1989, ch. 1 and 2) imperfect integration of world markets causes the "law of one price" to fail both at the level of aggregate national price indices and individual goods. The main reasons for the imperfections are: limited economic integration (goods, services and factors of production do not move completely freely at the global level), imperfect information and diverse spending patterns (marginal propensities to spend on imported goods).

Thus, the "Keynesian" approach is more realistic than the monetary approach in that it recognizes mark-up pricing and sticky prices. However, by assuming constant mark-ups, it does not take into account the strategic interaction of firms (Dornbusch 1987). Therefore, a model of imperfect competition which accounts for the ability of firms to make decisions on a country-by-country basis is needed.

2.3.3 Empirical evidence[8]

The second source of criticism is that actual observations of EPT and trade quantity changes during the 1980's are much smaller than the predictions of the traditional models. Empirical literature, which has grown substantially during recent years, has addressed the EPT question either directly or through its implications for the trade balance. The major part of the literature considers US import prices and export pricing of US, Japanese and German firms. Huge swings in the real US dollar effective exchange rate and their puzzling effects on the US trade balance have drawn attention to the subject. For example, during the two years of continuous fall in the real value of the dollar after its peak in 1985, there was only a slight increase in real import prices and no reduction in the growth of import volume. Hence, the US trade balance was not able to improve (Baldwin 1988a, Krugman & Baldwin 1987, pp. 5–7).

Evidence suggests that EPT is significantly incomplete for many countries and industries. Further, there are considerable observed lags in EPT to import prices and EPT is found significantly incomplete even in the long run. Further, the EPT relation has been discovered to vary considerably across different products and

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[7] Krugman (1989) and Dixit (1989b) argue that there is an unquestionable tendency for real exchange rates to revert to equilibrium values, which are, however, difficult to capture statistically due to high volatility and structural changes which alter equilibrium values over time. According to Krugman, a pure random walk pattern is possible only if technological shocks occur randomly, which is unrealistic on the whole. Frankel & Meese (1987, pp. 122–125) present evidence of real exchange rates regressing towards long-term equilibrium when the time sample is very long.

[8] EPT to aggregate US nonoil import prices is studied by e.g. Krugman & Baldwin (1987), Hooper & Mann (1989), Moffet (1989), Ohno (1989) and Kim (1990). Dornbusch (1987) also considers aggregate US export prices. Industry level data is used by e.g. Giovannini (1988), Feenstra (1989), Knetter 1989, Ohno 1988 and 1989, and Marston 1990 to detect asymmetries between US, Japanese and German export pricing. Hysteresis hypothesis is explicitly tested in Baldwin 1988a. See Vesala (1992) for a detailed review of the empirical results.

industries when disaggregated data are used, which supports the role of market structure in determining the magnitude of EPT.

There also exists an apparent *asymmetry* in export and import price pass-throughs as well as in the pricing behaviour of exporters of different nationality. The PTM phenomenon implies that the relative prices in disparate markets change and that the "law of one price" in international trade fails to hold. Many authors have discovered asymmetric pricing behaviour among Japanese and German firms in their home and export markets during the 1980's, while US firms seem to follow the same policies at home and abroad. Thus, significantly incomplete EPT characterizes Japanese and German exports while in US exports EPT is typically nearly complete.

There is evidence that both the magnitude and timing of the pass-through effects have changed during the recent decade (Baldwin 1988a and 1988b, pp. 782–784). This is referred to as a structural break, or a shift in the EPT relationship. Structural breaks constitute evidence in support of hysteresis models in which EPT hinges on the evolution of the industry concerned (EPT is path-dependent). These models imply that large exchange rate shocks can provoke changes in industry structure that do not reverse themselves when the exchange rate returns to its original level. For example, foreign firms entered the US market during the dollar appreciation, but did not exit when it fell to the level prevailing at the beginning of the rise (Dixit 1989a). In fact, the models producing hysteretic effects have been put forward to explain the recent puzzling US observations mentioned above.

3 Implications of imperfect competition for exchange rate pass-through

3.1 Exchange rate pass-through in case of homogeneous products

As mentioned earlier, even in case of homogeneous products oligopolistic market structure is able to explain incomplete EPT when international markets are segmented. When the markets are integrated the analysis diverges little from that of the pefect competition case. By contrast, effective spatial separation allows a separate game played in each individual market in sales volumes or prices[9]. (Veneables 1990a and 1990c)

Dixit (1986, p. 115) demonstrates that oligopoly models are highly sensitive to the exact curvature of the domestic demand function, since it affects the slopes of the reaction functions. Therefore, the determination of EPT varies across different demand specifications. However, the principal result from the basic two-country oligopoly models remains unaffected, namely, that the size of EPT depends positively on the relative market share of foreign firms. This can be demostrated by adhering to a basic Cournot competition model and a linear domestic demand curve: $p=f(X)=a-bX$, where p denotes the common domestic market price, and X the the total domestic demand. Assume further that n domestic firms are identical, as well as n^* foreign firms active in the domestic market, but the home and foreign firms are permitted to differ. Marginal costs of all firms are assumed constant, c and c^* respectively, which allows us to examine exporters' sales decisions in the domestic and foreign market independently. (Although sales volumes are set separately the outcome is optimal through the common marginal cost: $eMR=c^*=MR^*$). Profit maximization leads to a Cournot-Nash equilibrium with an unique equilibrium price whose elasticity with respect to the bilateral exchange rate is:[10]

$$\alpha = -\frac{dp}{de}\frac{e}{p} = \left(\frac{n^*}{n+n^*}\right)\left(\frac{(c^*/e)}{p}\right) \tag{3.1}$$

Thus, when linear demand is assumed EPT depends further negatively on the mark-up over marginal costs. Obviously EPT is always incomplete as both of its determinants are fractions.

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[9] Veneables (1990c) argues that a more reasonable formulation of the trade game, resulting in a lower trade volume than the one implied by the basic Cournot model, is in two stages: firms choose first capacity at the world level and then play a separate price game in various national markets.

[10] Profits of the representative domestic and foreign firms in domestic currency are: $\pi_i=f(X)x_i-x_ic$ and $\pi_j=f(X)x_j-x_j(c^*/e)$. Adding together all first order conditions yields: $(n+n^*)f(X)+Xf'=nc+n^*(c^*/e)$, where the total industry sales X equal $nx_i+n^*x_j$. Solving $p=f(X)=a-bX$ from the previous equation, differentiating it with respect to e, and forming the elasticity expression gives (3.1). Corresponding formulations can be found in Krugman 1986, Dornbusch 1987 and Veneables 1990a.

If the domestic demand has constant elasticity, e.g. p=f(X)=Aexp(−B), EPT depends no longer on the mark-up, since if there were no domestic competitors foreign firms would not have any incentive to "pass-through" incompletely and adjust their mark-up (Krugman 1986, p. 18). Thus, with initially equal marginal costs the exchange rate impact on the equilibrium price reduces just to a function of the relative market share.[11]

The two limiting cases of the trade literature can be interpreted in terms of (3.1). Namely, the *"small country case"* where a nation is a price taker in world markets, and exchange rate movements alter domestic prices in the same proportion, accords with a large number of foreign firms relative to home firms *and* perfect competition (no mark-up). At the other extreme, when most firms are domestic, exchange rate movements do not have virtually any effect on domestic prices. Hence, the fact that the USA has a large domestic component in most industries explains in part the observations of low EPT to US import prices discussed earlier. Thus, considering Finnish exports to large markets like the EC and the US market, EPT is likely to be significantly incomplete.

If producers of homogeneous goods act as Bertrand competitors all demand is typically assumed to be allocated to the seller declaring the lowest offer in common currency. Since the announcements of prices are binding commitments, and they are usually made before the exchange rate is realized, the analysis of Bertrand competition must incorporate the expectations of firms about the exchange rate evolution. Due to the demand allocation assumption there is a need to examine only the most competitive offers. Fisher presents a partial equilibrium model of the EPT in Bertrand competition based on the assumption that firms anticipate correctly the probability distribution of the exchange rate. As in the Cournot case, EPT is shown to depend on the domestic and foreign market shares in such way that EPT is the higher the more competitive is the foreign market and the less competitive the domestic market. (Fisher 1989)

When the product substitutability is high as e.g. in paper products, some plastics and chemicals, the results of this section can be applied. The obvious shortcoming is, however, the strict reliance on the form of domestic demand. Further, the assumption of constant marginal costs simplifies the derivation of the central results, but it appears to be justified only in the short-run (Dornbusch 1987).[12]

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[11] (3.1) becomes in the constant elasticity case: $\alpha = \frac{n^*}{(n+n^*)}\left[\frac{\left(\frac{c^*}{e}\right)}{\frac{n}{(n+n^*)}c + \frac{n^*}{(n+n^*)}\left(\frac{c^*}{e}\right)}\right]$. With initially equal marginal costs the term in [ ] equals 1. (Dornbusch 1987, Veneables 1990a)

[12] The assumption of constant marginal costs becomes unrealistic in the long-run. A persistent real exchange rate movement changes the relative competitiviness of domestic and foreign firms causing unemployment and expansion making n and n^* endogeneous in the long-run. Also a persistent change in the import price index leads to a macroeconomic adjustment of domestic prices, wages and other production costs. E.g. a domestic appreciation tends to raise domestic market prices, and thus increase EPT in the long-run. The macroeconomic adjustment can be considered as a dynamic aspect affecting EPT not considered in this paper as focus is on the examination of firms' behaviour. (Dornbusch 1987)

Incomplete EPT implies here price discriminating trade though it involves homogeneous products. In fact, analyzing trade in light of the oligopoly models as in this section points out another new explanation of trade in addition to intra-industry specialization suggested by monopolistic competition discussed in the following section. This form of trade, namely penetration of export markets via setting a lower price abroad is referred as *"reciprocal dumping"* by Brander & Krugman (1990, ch. 4). It relies crucially on the segmented markets perception, and is shown to result from conventional profit maximization in oligopolistic competition.[13]

3.2 Exchange rate pass-through and monopolistic competition

Nowdays most international trade takes place in differentiated manufactures like cars, consumer electronics, investment goods etc. Thus, a model of *monopolistic competition* needs to be applied in order to assess the determinants of EPT when products are differentiated. Each firm retains now some monopoly power and faces a downward- sloping demand curve. The framework of monopolistic competition has been recently employed in many problems of international trade, especially in *the intra-industry trade* where increasing economies of scale provide an incentive for specialization at the level of individual products. The intra-industry trade can be defined to concern goods that use factors of production in similar proportions. (Helpman & Krugman 1985, ch. 6–7)

The methods of analysing monopolistic market structure are based on the works of Chamberlin (1956), Spence (1976), Dixit & Stiglitz (1977) and Salop (1979). The two opposite ways of describing consumers' preferences are Dixit & Stiglitz's *"love of variety approach"* where consumers like to consume different brands of the same good, and Salop's *"consumption on the circle approach"* where consumers buy only one brand at a time. Here EPT question is first adressed by means of the static Spence-Dixit-Stiglitz (SDS) framework and then according to Salop's approach which enables us to evaluate the effects of brand substitutability. Dynamization of the static model is postponed to the next chapter.

3.2.1 Static Spence-Dixit-Stiglitz approach

Suppose that there are n domestic and n^* foreign firms producing each a single product variant with vectors of unit factor costs in domestic currency c and c^*/e respectively. Thus, the number of varieties sold in the domestic market ω equals $n + n^*$. Dixit & Stiglitz (1977) assume that all firms have equal marginal costs which they call a symmetric industry case. Further, the inverse demand functions,

[13] In Brander and Krugman's (1990, ch. 4) model a firm faces higher demand elasticity abroad due to a smaller market share abroad than in its home market. Therefore, the firm is willing to sell in the foreign market at a smaller mark-up and even absorb the cost of transportation. At equilibrium market share it is just profitable to incur these costs. (Hence, the model does not rely on accidental demand disturbances.)

$p_i(\omega,x_i)$[14] are assumed identical in the symmetric industry, although they represent demands for different varieties. A representative foreign firm sets its deliveries x_j to maximize profits in domestic currency:

$$\max_{x_j} \pi_j = p_j(\omega,x_j)x_j - \phi(x_j)\frac{c^*}{e} \tag{3.2}$$

The first-order condition of the maximum can be stated as:[15]

$$p_j = \frac{1}{1-\frac{1}{\varepsilon(\omega,x_j)}}\phi'(x_j)\frac{c^*}{e} = \beta\phi'(x_j)\frac{c^*}{e} \equiv \beta mr(\omega,x_j), \tag{3.3}$$

where $\varepsilon(\omega,x_j)$ is the absolute value of the perceived demand elasticity faced by the foreign firm, $mr(\omega,x_j)$ the marginal revenue, and β the mark-up over marginal costs. Representative home firm's maximization problem produces in a similar fashion: $p_i=\beta\phi'(x_i)c$. With a symmetric industry structure the above pricing rules are identical across all firms.

EPT can now be determined through examining the impact of exchange rate movements on the relative unit factor costs expressed in common (domestic currrency). In the symmetric industry case the monopolistic competition model yields similar results as the traditional "Keynesian " model predicting complete EPT, since the effect of a change in the exchange rate depends only on the change in the relative costs.[16] To be exact, crucial is the fraction of foreign firms' costs that are fixed in foreign currency. If some of the costs are denominated in other currencies the prediction of complete EPT must be adjusted downwards by their share. (Dornbusch 1987).

Relaxing strict assumptions of the basic symmetric industry model concerning equal marginal costs and constant mark-ups, allows us to derive a more general and realistic formulation of EPT in case of differentiated products. Totally differentiating the first order condition (3.3) gives the pass-through elasticity for

[14] The total number of brands ω appears as an argument in the inverse demand functions, since an increase in ω shifts down and makes more elastic the demand curve for each variety. (Chamberlin 1956, ch. 5)

[15] The foreign cost function is $C(x_j,c^*)$. By assuming that costs are homogeneous of degree one in factor prices we obtain $\phi(x_j)c^*$ where $\phi''> 0$ indicates rising marginal costs. This kind of formulation is the starting point of Feenstra's (1988), Baldwin's (1988b), Ohno's (1989) as well as Brander and Spencer's (1984) models that examine the behaviour of import prices under monopolistic market structure.

[16] From (3.3) and $p_i=\beta\phi'(x_i)c$ we obtain the relative price of domestic and foreign varieties($p_i/p_j=c/(c^*/e)$) which depends only on the relative unit costs. According to SDS-methodology, maximizing utility (CES-form assumed) with respect to consumer's budget constraint produces demand for each brand as well as an utility-based industry price index $P=[(\sum p_i^h+\sum p_j^h)]^{1/h}$, where the weight h is derived from the utility function. The relative price of the imported variant in terms of the industry price index (p_j/P) becomes also just a function of the relative costs implying complete EPT (Dixit & Stiglitz (1977)).

the imported variant with respect to foreign unit factor costs in domestic currency (Feenstra 1989, p. 28):

$$\alpha = \frac{dp_j}{d(c_j^*/e)}\frac{(c_j^*/e)}{p_j} = \frac{1}{\left[\left(\frac{\phi_j''x_j}{\phi_j'}\right)\varepsilon + \left(\frac{\partial mr_j}{\partial p_j}\frac{p_j}{mr_j}\right)\right]}, \tag{3.4}$$

where the term $(\phi_j''x_j/\phi_j')$ represents the elasticity of marginal costs with respect to output with sign the same as that of ϕ_j'', and the term $((\partial mr_j/\partial p_j)p_j/mr_j)$ the price elasticity of marginal revenue. According to (3.4) the exact magnitude of EPT is jointly determined by the exact forms of the domestic demand and foreign cost functions. Therefore, it is natural to observe dissimilar EPTs in different industries (see e.g Ohno 1988 and Feenstra 1989). Negative EPT is ruled out, since (3.4) is alvays positive due to the second-order condition. The change in the demand elasticity as the price changes, $d\varepsilon/dp_j=\varepsilon_{pj}$, dictates the magnitude of $((\partial mr_j/\partial p_j)p_j/mr_j)$[17], and hence, the size of EPT along with the behaviour of marginal costs:

$$\varepsilon_{p_j}>0,\ \phi_j''\geq 0 \Rightarrow 0<\alpha<1 \tag{3.5}$$

$$\varepsilon_{p_j}\leq 0, \phi_j''<0 \Rightarrow \alpha>1 \tag{3.6}$$

A linear demand curve and constant and increasing marginal costs satisfy the condition (3.5), and thus produce incomplete EPT, which is frequently observed empirically among differentiated manufactures. Theoretically, however, EPT over unity is possible, e.g. when the elasticity of demand is constant and marginal costs are declining in output. With rising marginal costs, changes in foreign marginal revenue due to exchange rate movements lead to smaller changes in the optimal output than with constant or decreasing marginal costs. Hence, the price impact of an exchange rate change will be smaller under increasing marginal costs.

A further generalization of the model by letting the demand functions for different brands vary yields similar results as the previous formulation with identical demand functions.[18] A strong result emerges when there are no competing domestic brands. EPT is then determined solely by foreign marginal costst as the denominator in (3.4) becomes $\phi_j''x_j/\phi_j'+1$ (Feenstra 1989, p. 31). Thus, now constant marginal costst lead to complete EPT. This holds exactly true, however, only when prices of all imported brands are altered by the same proportion which leaves the demand elasticities of individual brands unaffected, and changes in marginal costs "pass-through" fully. This result is in accordance

[17] In (3.4) $((\partial mr_j/\partial p_j)p_j/mr_j)$ can be written as: $1+(p_j^2/mr_j\varepsilon^2)\varepsilon_{pj}>1$ when $\varepsilon_{pj}>0$, and <1 when $\varepsilon_{pj}<0$. By noting also that $\varepsilon=-(\partial x_j/\partial p_j)(p_j/x_j)>0$, it is possible to formulate the conditions (3.5) and (3.6) (Feenstra 1989, p. 28). Note that rather than x_j, p_j is now considered as an argument of ε.

[18] In (3.4) the term $((\partial mr_j/\partial p_j)p_j/mr_j)$ just gets a more general form: $1+(p_j^2/mr_j\varepsilon_j^2)\Sigma_{k=1}^{n+n^*}(\partial\varepsilon_j/\partial p_k)$.

with Fisher's (1989) reasoning which argues that in general the more competition there is among the foreign firms the higher EPT is predicted.

3.2.2 Salop's "consumption on the circle" approach

Apart from being a more plausible framework for many differentiated consumer and investment goods e.g. vehicles, consumer electronics and investment goods, Salop's formulation of consumers' preferences enables us to examine the effect of substitutability of different varieties. Salop depicts all competing brands as uniformly spread over the unit circle located at distance ($1/n+n^*$) from each other. Let v denote the constant reservation price describing the "surplus-utility" stemming from the fact that consumers can expend differentiated brands that match their requirements instead of all consuming a single homogeneous product. There is an utility cost of g per unit distance from the consumer's optimum location on the circle, since the characteristics of the existing brands do not meet precisely consumers' requirements. Then, an imported brand j captures all consumers within a distance τ given by the following condition (Salop 1979, p. 144):

$$v - g\tau - p_j \leq v - g\left[\frac{1}{(n+n^*)} - \tau\right] - p_i, \tag{3.7}$$

where equality indicates indifference. Maximizing profits on part of representative foreign and domestic firms taking competitor's prices as given yields solutions for prices charged. Their elasticities with respect to the exchange rate are of the following form if unit costs are assumed initially equal:[19]

$$\alpha = -\frac{dp_j}{de}\cdot\frac{e}{p_j} = \frac{\dfrac{2}{1+\dfrac{g}{(n+n^*)c}}}{3} \equiv 2\frac{\psi}{3} \tag{3.8}$$

$$\hat{\alpha} = -\frac{dp_i}{de}\cdot\frac{e}{p_i} = \frac{\psi}{3} \tag{3.9}$$

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[19] Foreign firm j's profits are given by $(p_j - c^*/e)2L\tau$, since $2L\tau$ is the total number of units sold as L represents the total number of consumers and the firms serves both sides of its location. Assuming constant unit factor costs, taking prices of other brands as given, and solving τ from (3.7) allows us to write out foreign profits: $(p_j - c^*/e)2L(p_i + g/(n+n^*) - p_j)/2g$ to be maximized. The reaction functions of the representative foreign and domestic firms become: $p_j = (p_i + g/(n+n^*) + c^*/e)/2$ and $p_i = (p_j + g/(n+n^*) + c)/2$. Rearranging and differentiating with respect to e yields (3.8) and (3.9). (Dornbusch 1987, p.101)

Note that e.g. in case of a domestic appreciation the competitive pressure results in a decline in the price of domestic varieties as (3.9) demonstrates. However, there is a fall in the relative price of the imported brands which equals $\psi/3$. As the above equations show, the tighter the competition (greater number of firms), the higher the substitutability (smaller g) the larger EPT results. Note that in this setting EPT is always incomplete, even when the utility cost equals zero. For example, in case of a domestic appreciation consumers trade-off the reduction in the prices of foreign varieties for a larger distance from their optimum location on the circle. A larger g and a smaller number of firms, (longer distance between brands on the circle), make consumeres more reluctant to switch between brands, and thus, allow foreign firms to raise their profit margins by not "passing-through" completely.[20] (Dornbusch 1987)

3.3 Monopolistic price discrimination

The most commonly given explanation for PTM phenomenon and persisting dumping in international trade is monopolistic price discrimination. In addition to hindered arbitrage, monopoly power or barriers to free trade can facilitate price discrimination. The central idea behind international price discrimination is naturally exploiting different demand elasticities in various markets so that the price will be higher in the market whose demand is less elastic. Optimal pricing rules for a foreign monopolistic firm active in both foreign and domestic markets are given by the first-order conditions of profit maximization (3.3):

$$p_j^* = \frac{\phi_j'(x_j)c^*\varepsilon^*}{(\varepsilon^*-1)} \tag{3.10}$$

$$p_j = \frac{\phi_j'(x_j)(c^*/e)\varepsilon}{(\varepsilon-1)}, \tag{3.11}$$

where p_j^*, p_j, ε^* and ε are output prices and elasticities of demand in foreign and domestic markets respectively. The price charged in foreign market is invariant to e, and the two pricing decisions are independent. According to (3.11), in order to yield incomplete EPT, i.e. PTM behaviour on part of the foreign price discriminating monopolist, the demand elasticity must decrease as the price falls, (Brander and Spencer 1984, p. 233–235 consider analogously a tariff absorption). A linear demand curve satisfies this condition, and then e.g. a domestic appreciation leads to a less than proportionate fall in the import price. But with constant elasticity there will be no PTM. Hence, the result depends again crucially on the perceived shape of the domestic demand curve. (Krugman 1986, Knetter 1989)

[20] Note that the effect of the relative number of foreign firms is in line with Fisher's (1989) reasoning. As it rises the probability of foreign firms competing against each other raises which compels them to cut their prices more than in case of having domestic firms as competitors who do not experience a cost reduction when the domestic currency appreciates.

Marston (1990, p. 218–222) deals with this problem more formally by presenting a model of price discrimination, where PTM depends on elasticities of domestic and foreign mark-ups with respect to prices charged in domestic and foreign markets, δ and τ respectively. He defines PTM elasticity μ as an elasticity of the relative price in the two markets, $q_j = (p_j^*/e)/p_j$ with respect to the exchange rate, which in terms of the EPT-elasticities equals $1+\alpha-\alpha^*$. α and α^* are in turn functions of δ and τ in addition to marginal costs and revenues. In this framework PTM can take place only when mark-ups vary with prices in a way that $\delta, \tau < 0$, i.e. when domestic and foreign demand curves are less convex than the constant elasticity curve, (e.g. linear).[21] Marston shows that then, regardless of whether marginal costs are constant or increasing, μ is a positive fraction.

The most apparent shortcoming of the static model of price discrimination is that it relies so heavily on the shape of the demand curves, and does not give fundamental causes of changes in perceived demand elasticities like an increase in competitive pressure in the domestic market (Baldwin 1988b).

3.4 Summary and shortcomings of the static monopolistic competition models

To summarize, in a monopolistic competitive industry incomplete EPT is a "natural" outcome, whose magnitude depends mainly on the monopoly power of foreign firms, especially relative to other foreign firms active in the domestic market. Monopoly power results from consumers' inflexibility of moving between brands, or shows as a more inelastic demand curve in the SDS-model. Decreasing demand elasticity ε_j can be regarded as describing increasing buyers' preferences for the particular brand over the other ones (Chamberlin 1956, p. 93). Monopoly power gives freedom in price setting and mark-up manipulation, and hence generates lower EPT elasticity. EPT is shown, however, to depend on the industry specific demand and cost schedules as well as on the specification of consumers' preferences. Therefore, observations of highly variable EPT coefficients in different industries with varying competitive structures present evidence in support of the models just described.

The static models neglect, however, the strategic interaction of firms as a part of the pass-through effect, and do not separate short- and long-run behaviour from each other. The influence of the duration of the exchange rate movement is neither investigated, and also the effects on the industry structure are neglected. Further, the exchange rate expectations, that clearly matter for equilibrium prices (see e.g. Fisher 1989), are not considered explicitly, but rather it is assumed that firms' anticipation about the probability distribution of the exchange rate is correct with respect to its expected value. Thus, e in the analysis of this section equals E(s), where s is the relevant spot rate.

These dynamic issues are adressed in the following chapter.

[21] E.g. δ can be written in terms of the demand elasticity: $\delta = -[(d\varepsilon/dp_j)p_j] / [\varepsilon(\varepsilon-1)P]$, where P is the industry price for the particular commodity. Thus, δ depends on the curvature of the domestic demand through $d\varepsilon/dp_j$. (Marston 1990, p. 221)

4 Hysteresis in import prices and dynamic analyses of exchange rate pass-through

4.1 Hysteresis and trade inertia

Ample definition of *hysteresis* is: *"the failure of an effect to reverse itself as the underlying cause is reversed"* which means that a temporary shock leaves behind a permanent effect (Dixit 1989a, p. 622). In this context, hysteresis refers to permanent effects of large exchange rate changes on market structures and import prices, which imply a path-dependent EPT-relationship. In preceding models in international economics, hysteresis has been ruled out, i.e. it has been assumed that temporary real exchange rate shocks can only have temporary real effects without any impact on the structure of the economy. For instance, in the Dornbusch's overshooting model, these shocks are neutral in the long-run (Dornbusch 1976, p. 1173).

Models that give a rationale for the hysteretic effects, explore in depth the behaviour of foreign suppliers or domestic consumers and their implications on trade prices and quantities. These models that are accomplishments of recent research and have dynamic nature, can be grouped to belong either in the supply- or demand-side, depending on what is the core of their explanation. The supply-side models or, as frequently referred, *sunk-cost models* provide an economic explanation of why it can be an optimal decision for a foreign firm not to "pass-through" an exchange rate change to its home-currency export prices, or to keep supplying the domestic market in spite of an unfavourable exchange rate movement. In general, these models yield a sluggish adjustment of both trade prices and quantities referred as *trade inertia* which is in accordance with recent observations. The term sunk-cost model refers to the fact that the existence of sunk costs, which must be incurred to be able to supply the domestic market, has been found crucial in order to yield the hysteretic results. Cutting profit margins in face of a domestic depreciation, which is often given as an explanation for the incomplete EPT, is rather an implication of rising costs and constant prices than an explanation of foreign firms' behaviour (Baldwin 1988a).

One of the main implications of these models is that they establish that it can be optimal for a firm to adopt a *"wait and see" strategy*, i.e. to remain in the current position. The rationale behind the optimality is that if the investment opportunity does not disappear, time brings more information about its future prospects, and a later decision can be a better one (Dixit 1992). In terms of the sunk-cost models, this means that while the exchange rate fluctuates within a certain range of values, the number of foreign firms in the domestic market remains constant as the "wait and see" strategy is employed. But when the exchange rate leaves this *zone of inaction* entry or exit of foreign firms occurs, which leads to a change in the industry supply. This change is permanent (hysteretic), because the return of the exchange rate to its original level does not restore the original supply conditions, since the *trigger-values* of the exchange rate are separate for entry and exit decisions (Baldwin & Krugman 1989). These trigger values are defined by means of the optimality of entry and exit decisions: on the upper limit entry, and on the lower limit exit, become just optimal. Dixit (1989a) has shown that the zone of inaction becomes substantially widened as the exchange rate uncertainty is taken into account, and further, it gets larger as the exchange rate volatility increases.

Baldwin and Krugman (1989) have shown that by aggregating single firms and industries the zone of inaction does not get smoothed away to a considerable degree. Thus, trade inertia applies also at the aggregate level. Krugman (1989 ch.2) stresses also the circularity between volatility of the exchange rates and inertia of the trade flows. The more volatile the exchange rate is the more reluctant firms are to respond to small exchange rate changes, (even more so when they are perceived to be temporary). Hence, the real economy becomes "delinked" from the exchange rate, and the echange rate, as Krugman (1989) argues, is free to become even more volatile. These effects have very important implications on the exchange rate and balance of payments theories, which shall be discussed briefly in chapter five. A certain exchange rate change, for instance, will have less effective and predictable effects on balance of payments adjustment than is proposed by the elasticity approach.

In dynamic demand-side models hysteresis is a result from a certain behaviour of consumers. For example, if consumers are incurred substantial costs when they switch between brands, consumers have a degree of brand loyalty, and firms' future demands depend on their current market-shares. Hence, firms become reluctant to abandon their market share investments in face of exchange rate changes, which are perceived to be temporary. The reasoning is quite similar to the sunk-cost models, where the inertia arises from sunk investments in the sales infrastructure. (Froot & Klemperer 1989)

4.2 Nature and causes of supply-side hysteresis

4.2.1 Existing sunk-cost models of hysteresis

Baldwin's *beachhead model* (Baldwin 1988b), *Baldwin and Krugman's model* (1989) and *Dixit's model* (1989a and 1989b) are the three recently developed supply-side models of hysteresis providing microeconomic foundations for trade dynamics. They make different assumptions about the market structure and exchange rate determination, but the core of the analysis in each model is the examination of foreign firm's entry and exit decisions when sunk market-entry and exit costs need to be incurred. Dixit's model assumes perfect competition, and the exchange rate uncertainty is most profoundly taken into account by adhering to random walk as a characterization of the exchange rate behaviour. The beachhead model and Baldwin and Krugman's model assume imperfect competition, and perfect foresight and i.i.d.-distributed exchange rates respectively. All three models employ a partial equilibrium approach by specifying the exchange rate process exogenously, and their analysis is at the firm and industry level, (though, an aggregation is proposed by Baldwin and Krugman (1989)). Price hysteresis results in each model as a consequence of a lasting change in the domestic market structure generated by a large-enough exchange rate shock which is followed by foreign entry or exit.

The theoretical foundations for hysteresis, and its relevance and magnitude are first assessed by following the lines of Dixit (1989a, 1989b and 1992). The effect of the exchange rate uncertainty when explicitly modelled becomes the dominant feature in the analysis. Hysteresis in imperfectly competitive markets is examined as a dynamization of the static monopolistic competition model in the next section. The culmination of each analysis is to appraise the effects on the EPT relationship.

4.2.2 The plain effect of sunk market-entry costs

The sunk market-entry costs are rather investments in firm- and market-specific assets that foreign firms are required to make in order to sell in the domestic market. A partial list includes costs associated with setting up a distribution and sales network, product launching, training, product adjusting in line with new requirements and financing. In reality some of these costs could be recouped in case of exit, and the re-entry costs could be below the entry costs. This notion is however irrelevant, since as long as at least a part of the costs are sunk, the results of the sunk-cost models hold. In all three models the impact of sunk costs is captured by assuming a lump-sum investment k which is denominated in the domestic currency and must be reincurred to be able to re-enter.

A simple model of a single discrete investment project (Dixit 1989a) discloses the significance of the sunk investment costs. Let w be the avoidable operating cost per unit of time, and ρ the applied interest rate assumed constant over time. If the output flow is defined to equal unity, the revenue is given by the output price P which is exogeneous to the firm in perfect competition. The firm is assumed to have static (naive) expectations about the output price, i.e. its future value is anticipated to equal the current market price. Following decision rules can then be constructed:

i) if $P > w + \rho k = P_H$, make the investment
ii) if $P < w = P_L$, abandon the project

where P_H represents the full cost of making and operating the investment project.[22] This simple model can be interpreted also as a description of entry and exit decisions of a foreign firm. Convert all terms into the foreign currency, then P_H acts as the entry trigger, and P_L as the exit trigger. In this context, w can be given the meaning of a fixed maintenace cost per unit of time, which accounts for all costs that must be paid in order to remain in the domestic market. P_H and P_L, and the gap between them are labelled by Dixit (1989a, p. 623) as *Marshallian trigger prices* and *range of inaction* respectively in order to stress the association with the Marshallian theory of investment. I.e. entry occurs when long run average costs are covered, and exit when variable costs exceed revenues. An explanation for hysteresis can be found even in this simplest setting. If the price rises from range $P_L < P < P_H$ above P_H entry is induced, but abandonment does not take place if P falls back into the original range. (Dixit 1992)

[22] This type of reasoning was introduced by Oi (1962, p. 539) in the context of labour economics. He argued that labour is a "quasi-fixed" factor, since in addition to the variable labour costs firms must incur some fixed investments in "human agent", e.g. acquisition and training costs, which are sunk in nature. Hence, there will be short-run fixities in demand for labour with respect to changes in firm's output price.

Clearly the assumption of static expectations is unrealistic, but further analysis shows that the plain sunk-cost hysteresis implied by the simple model is independent of the exchange rate evolution.

4.2.3 The impact of exchange rate uncertainty on hysteresis

The simple model of the previous section is capable of explaining why trade patterns can be insensitive to small exchange rate fluctuations. But, it is not powerful enough to illustrate why trade flows and pricing seem to ignore the recent large swings which generate considerable changes in relative production costs. Further, there is an observable reduction in the degree of sensitiveness (Krugman 1989, p. 46). If firms assume, instead of having static expectations, that the exchange rate fluctuates around its long-term value, they find it profitable to hold to their current position longer than the simple model suggests. Uncertainty in this form is referred as a *risk of mean reversion*, and it leads to a larger range of inaction than the Marshallian one. Suppose that the perceived long-term value P^* is in the range $[P_L,P_H]$, then a higher entry trigger than P_H is required, since greater short-run revenue is needed to compensate for later lower revenues when P reverts back to its mean. Similar reasoning applies also to the exit trigger P_L (Baldwin & Krugman 1989).

Another concept, employed by Dixit's model, is *ongoing uncertainty* which emerges when the exchange rate follows random walk, i.e. it has equal probabilities of rising or falling during the next period. Random walk characterization is the most realistic one in terms of empirical support (see e.g. Frankel & Meese 1987), and its formal application allows option pricing theories to be used in concluding firms' optimal strategies. The foreign firm can be considered as having options to enter, exit or remain in its current position, depending whether it is active in the domestic market or not. For example, an option to enter the domestic market entitles the exporter to some expected profit stream. The exercise price of such an option is, in this setting, the lump-sum entry cost.

The option pricing theory states that it is not optimal to exercise the option when it is just in-the-money, because of the volatility. When the output price in foreign currency equals P_H the expected value of the entry investment, which is never reversed, is zero due to the random walk assumption, and the entry option is just in-the-money. If the domestic currency appreciates during the first period, the expected value of the entry-investment becomes positive. This is the value of the "wait and see" strategy referred earlier, which Baldwin & Lyons (1989) call an *"incumbency premium"*. Hence, the entry trigger price in foreign currency will be higher than P_H, and similarly exit trigger price lower than P_L. Dixit's model gives a formal treatment to the option-feature by using dynamic programming. It solves explicitly, under ongoing exchange rate uncertainty, the gap between entry and exit trigger values, which is shown to be much wider than the Marshallian gap. Greater exchange rate uncertainty increases the value of the entry and exit options, and makes them less readily exercised. Hence, uncertainty becomes a strong source of hysteresis. (Dixit 1989a, 1989b)

4.2.4 Entry and exit decisions of a single firm

The purpose of this section is to derive exact expressions for the trigger-levels of the exchange rate in order to verify and assess the magnitude of the hysteretic effects of large exchange rate movements. The analysis presented here follows Dixit's (1989a and 1991) reasoning where the market price follows a random walk. Here the exchange rate is considered as a source of uncertainty to be able to explore the entry and exit decisions of a foreign exporting firm.

The exchange rate is assumed to follow *a Brownian motion in continuous time*:

$$\frac{de}{e} = \mu dt + \sigma dz, \tag{4.1}$$

where dz is an increment of the *standard Wiener process,*[23] and dt an infinitely small time interval. Brownian motion is a function of the standard Wiener process with a drift-parameter μ and volatility σ. Thus, μ represents the trend rate of growth of e. (Shimko 1991, p. 2–7). The fact that actual exchange rate data resemble a random walk makes it convenient to use Brownian motion formulation as a foundation of the model (Frankel & Meese 1987). Further, it is a central concept in option pricing theories (see e.g. Merton 1973, section 6) which enables their rather straightforward application.

In addition to the simple model's assumptions, the foreign firm is assumed to be risk neutral, and to have rational exchange rate expectations, i.e. the actual and anticipated probability distributions of the exchange rate coincide (Lucas & Prescott 1971, p. 660). Further, a lump-sum exit cost equals l which is, as k, denominated in the domestic currency, while w in the foreign currency. This assumption, although the most reasonable one, can be altered without difficulty by adapting the mathematics.

The firm must in each point of time weigh the two alternatives of acting now and waiting for another period against each other. Thus, a value must be assigned to the benefits of either being in or out of the domestic market. The decision problem can be presented as having two state variables, the current exchange rate and a discrete variable that indicates whether the firm is active (1) or not (0). The exchange rate captures all uncertainty, all other variables are nonstochastic. Therefore, the exchange rate is the variable on which the firm bases its decisions:[24] in state (e,1) continue being active or exit, and in state (e,0) remain idle or enter. The values attached to these states depend on e and on the value of

[23] z(t+dt)=z(t)+ε(t+dt), where ε~i.i.d. N(0,dt), specifies the standard Wiener process. Define dz(t)≡z(t+dt)−z(t), which is referred to as white noice. The distribution of the error term ensures that dz:s are uncorrelated through time.

[24] This is a reasonable assumption as far as a major part of uncertainty stems from the exchange rate. Also the exchange rate is usually far more difficult to forecast than other variables affecting demand and supply conditions in the domestic market when domestic and foreign currencies float against each other. (Giovannini 1988)

the option to reverse actions later. Thus, let $V_1(e)$ be *the Bellman value function*[25] for the active state which by definition equals the expected net present value achieved by following optimal policies with e as a "starting" value of the exchange rate. $V_0(e)$ is defined similarly for the idle state.

Formal solution of the model requires establishing the value functions and the rule of moving between states (1) and (0). Option pricing theories can be adopted by analogy to yield the solutions for the value functions. $V_0(e)$ is interpreted as a sum of values (or prices) of the two interlinked options to enter and to revert to the original state. The latter option is obtained through exercising the former, but their prices need to be determined simultaneously, since the excercise of the latter option is endogenous. Similar reasoning applies to $V_1(e)$, too. (Brennan and Schwartz[26] 1985, p. 137–138, Dixit 1989b, p. 210)

The second order differential equations (4.2) that determine $V_1(e)$ and $V_0(e)$ follow from equating operating profits and expected capital gains over time, (resulting from $V_1(e)$ and $V_0(e)$ varying with e), with a normal return on the assets (option values) $V_1(e)$ and $V_0(e)$. The general solutions of $V_1(e)$ and $V_0(e)$ are given by (4.3). (see Vesala 1992, Appendix 1 for the derivation of (4.2) by applying Itô's lemma, and for their solution.)

$$\frac{1}{2}\sigma^2 e^2 V_0''(e) + \mu e V_0'(e) - \rho V_0(e) = 0$$
$$\frac{1}{2}\sigma^2 e^2 V_1''(e) + \mu e V_1'(e) - \rho V_1(e) = w - eP \tag{4.2}$$

$$V_0(e) = Be^{\beta}$$
$$V_1(e) = Ae^{-\alpha} + \frac{eP}{\rho - \mu} - \frac{w}{\rho} \tag{4.3}$$

where $-\alpha$ and β are the characteristic roots, and A and B nonnegative constants that must be determined in order to yield the definite solutions. The term $[eP/(\rho-\mu)]-(w/\rho)$ equals the expected present value of the operating profit from export supply when the abandonment never takes place, since e rises at a trend rate of μ (see e.g. Brealey & Myers (1988) for a reference to a simple stock valuation model). Hence, the rest of the solution of $V_1(e)$ gives the value of the option to shut down optimally, i.e. the value of waiting, when the firm starts from the active state. The entire solution of $V_0(e)$ shows the value of the option to start exporting

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[25] *The Bellman's Principle of Optimality* underlies the option pricing theories that are adopted here. It takes the optimization task that spreads over time as a succession of static problems, whose value functions can be established. Whatever the decision at t, the subsequent decisions are made optimally for the subproblem starting at t+1. This method is then applied to all periods starting from t=0 untill the optimization horizon T. (Dixit 1990, ch. 11)

[26] Brennan and Schwartz (1985) consider optimal timing and abandonment of a natural resource investment (mine opening), when the output price follows a random walk. The decision to engage in mining resembles closely entry and exit decisions when uncertainty is associated with the market price. Hence, the core Brennan and Schwartz's and Dixit's (1989a) models are similar.

at an optimal time for the idle firm, (since in the idle state there is no operating profit).

A way to link the two states together is to establish the conditions of the optimal exercise of the entry- and exit-options. The entry trigger e_H must satisfy the following two conditions of optimal exercise:

$$V_0(e_H) = V_1(e_H) - e_H k \tag{4.4}$$

$$V_0'(e_H) = V_1'(e_H) - k \tag{4.5}$$

The value-matching condition (4.4) must hold, since by paying $e_H k$ to exercise the entry option the firm obtains an asset of value $V_1(e_H)$. At e_H the expected value in both states must be identical. At e_H the function $V_0(e)$ must be just a tangent to $V_1(e) - ek$, lying above it entirely. This requirement, *the smooth pasting condition,*[27] is given by (4.5). Similar conditions establish also the exit-trigger e_L. Inserting the general solutions (4.3) into (4.4) and (4.5) enables us to write out four equations that yield definite values for A, B, e_H and e_L.

To probe the effect of the exchange rate uncertainty on the zone of inaction firstly define: $G(e) \equiv V_1(e) - V_0(e)$. For the G-function the value-matching and smooth pasting conditions at e_H and e_L are: $G(e_H) = e_H k$, $G(e_L) = -e_L l$, $G'(e_H) = k$ and $G'(e_L) = -l$. Thus, e_H is given by the tangency between G(e) and a ray ek through the origin, while e_L appears at tangency between G(e) and -el. The general shape of G(e) is as depicted in *figure 4.1.* Optimality of e_H and e_L requires G(e) to be concave at e_H ($G''(e) < 0$) and convex at e_L ($G''(e) > 0$). Evaluating the differential equation for G(e) at e_H, obtained by using the equations for $V_1(e)$ and $V_0(e)$ (4.2), and holding to the above value-matching and smooth pasting conditions in terms of G(e) gives:

$$w - e_H P = \tfrac{1}{2}\sigma^2 e_H^2 G''(e_H) + \mu e_H G'(e_H) - \rho G(e_H) < -(\rho - \mu) e_H k \tag{4.6}$$

The impact of uncertainty on the zone of inaction is exposed through rearranging (4.6), and similarly evaluating the equation for G(e) at e_L:

$$e_H P > w + (\rho - \mu) e_H k \equiv m_H P \tag{4.7}$$

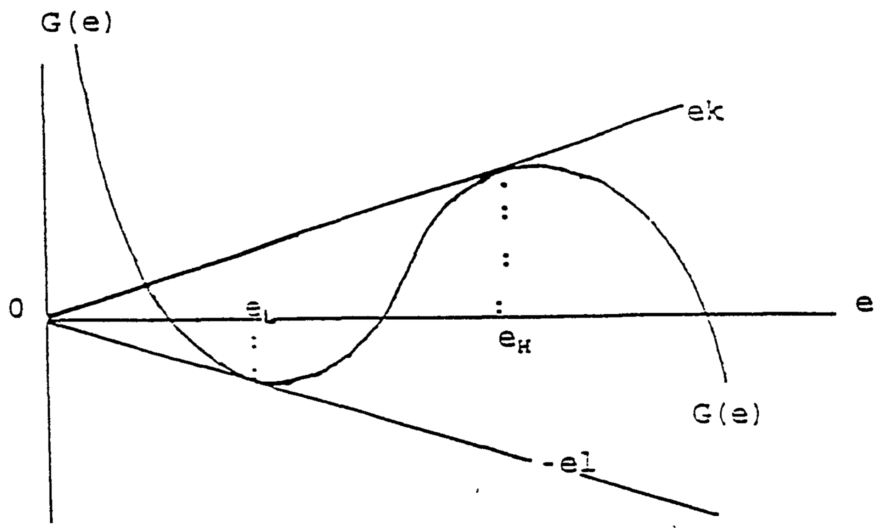
$$e_L P < w - (\rho - \mu) e_L l \equiv m_L P, \tag{4.8}$$

where m_H and m_L denote the Marshallian trigger-values of the exchange rate. The gap between them, as in the simple model, represents the plain effect of the sunk

[27] To establish this condition suppose that $V_1(e_H - \delta) - (e_H - \delta)k$ and $V_1(e_H + \delta) - (e_H + \delta)k$ were *greater than* $V_0(e_H - \delta)$ and $V_0(e_H + \delta)$, where δ is the amount, of which e has an equal probability of falling or rising in a time period. Then it would not be optimal to enter at e_H, since greater value could be received either by hurrying or delaying the entry decision. By making the time period arbitarily short we obtain (4.5) (Krugman 1989, p. 71–73).

entry costs. The first inequality states that at the optimal entry point the revenue in foreign currency (e_HP) exceeds the full cost (variable cost plus interest on the entry capital). Similarly, at the exit point operating loss is greater than the interest on the abandonment cost. In other words, options to enter or exit are not exercised when they are just in-the-money. Sunk costs are essential for hysteresis as e_HP and e_LP tend to the common limit w when k and l tend to zero. (4.6) demonstrates that in the absence of uncertainty, (σ=0), the zone of inaction coincides with the Marshallian one, and the sunk-cost hysteresis remains.

Figure 4.1 **Determination of entry- and exit-triggering exchange rates. (Modified presentation of Dixit 1989a, p. 629).**



Hysteretic effects emerge very rapidly even when sunk costs are insignificant, provided that some exchange rate uncertainty exists.[28] A rise in w raises both e_H and e_L, but a rise in k strenghtens hysteresis by increasing e_H and reducing e_L. Dixit (1989a) has shown with a help of numerical simulations[29] that the ongoing uncertainty generates much more distinct hysteresis than sunk costs alone. Thus, the major part of the gap between e_H and e_L arises from the option values. Assuming a mean reverting process instead of a pure random walk widens the zone of inaction, while adhering to risk-aversion shifts it upwards. Thus, the general results just derived hold, by and large, when the key assumptions are altered. (See Dixit 1989a for the exact proofs.)

[28] As $k \to 0$, $de_H/dk \to \infty$ and $de_L/dk \to -\infty$.

[29] With following central values w=1, k=4, ρ=2.5%, l=0 and σ=0.1 implying 10% standard deviation over one and 20% over four years, ($\sigma=\sqrt{(\sigma^2 t)}$ Simko 1991, p. 5), and μ=0, e_HP is 33% above the full costs m_HP and e_LP 24% below the variable cost m_LP. Thus, the hysteretic gap caused by uncertainty is 7 times larger than the one generated by sunk costs alone. With k=0.4 the above percentages are +15% and –13%, and with σ =0.025 +10% and –11%. Hence, hysteresis is strong even with small sunk costs, and even a little uncertainty is significant. (Dixit 1989a, p. 630–634)

4.2.5 Hysteresis in a competitive industry

Dixit (198b) establishes the industry equilibrium when foreign entry and exit occurs, and shows by using again option pricing methods that hysteresis remains at the industry level. By adhering to the same assumptions and denotations made in the single firm model the key elements of the industry analysis are presented here. (For a closer elaboration, see Vesala 1992).

P=P(X) represents the downward-sloping import demand in inverse form, where X denotes the total import volume. The domestic social surplus equals the area under the P-function, hence, an increasing and concave utility function U(X) can be defined to satisfy P(X)=U'(X). The number of potential foreign suppliers equals N whose import supply is set to equal one unit per time period which permits us to replace X by n, the number of active foreign firms. w_n denotes the variable cost associated with the output unit of the n^{th} firm. Foreign firms are assumed to differ only in their variable costs,[30] and they are put in order so that w_n is increasing. The prevailing market price with n active foreign firms, P_n, equals the n^{th} firm's marginal contribution to utility. Thus, $U_n = \Sigma_{j=1}^{n} P_j$ given the specification of U(X).

Lucas and Prescott (1971) have proven that a competitive equilibrium development in an industry with stochastic demand and rational expectations can be defined *as if* a certain consumer surplus expression were maximized.[31] Further, the associated maximization problem can be solved by applying dynamic programmming. Hence, in terms of the model under consideration, the equilibrium evolves through maximizing the expected present value of the overall surplus of the industry measured in the foreign currency.[32] The outcome of the maximization problem is a single Bellman value function $\Phi_n(e)$ of the exchange rate.

The group of active n firms can be regarded as an asset earning a current flow of net surplus and capital gains stemming from changes in the expected present value due to variations in the exchange rate. Further, there exists an option to move at an optimal exchange rate value to (n+1) and (n−1) active firms with exercise prices of ek and el respectively in foreign currency. The assets $\Phi_{n+1}(e)$ and $\Phi_{n-1}(e)$ aquired through exercising these options are, as in the single firm

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[30] Dissimilar sunk costs would distort the relative order of entry and exit, and complicate the analysis severely as the number of possible states and value functions would rise upto 2^N as a firm-by-firm characterization of the industry would become necessary.

[31] Lucas and Prescott's (1971) model concerns an industry, in which product demand shifts randomly in each period but the factor costs remain stable. The equilibrium time paths of investment rates, output and price are then assessed. Thus, the analogy with Dixit's model, (stochastic revenue and constant variable costs), is straightforward.

[32] $S = E\left\{\int_0^\infty (e_t U_{n_t} - W_{n_t})\exp(-\rho t)dt - \sum_i e_i[k(\Delta n_i)_+ + l(\Delta n_i)_-]\exp(-\rho i)\right\}$ represents the maximad, where the second part of the expression describes the negative impact of of sunk costs on the industry surplus at instants t=i when the number of active firms increase or decrease. W_n gives the sum of the variable costs of first n firms (Dixit 1989b, p. 209).

model, endogeneous to the model. Thus, $\Phi_n(e)$ satisfies a familiar differential equation:

$$\tfrac{1}{2}\sigma^2 e^2 \Phi''_n(e) + \mu e \Phi'_n(e) - \rho\Phi_n(e) = W_n - eU_n \tag{4.9}$$

whose general solution is of the following form:

$$\Phi_n(e) = A_n e^{-\alpha} + B_n e^{\beta} + \frac{eU_n}{\rho - \mu} - \frac{W_n}{\rho} \tag{4.10}$$

As in the single firm model, the last two terms represent the expected present value of the surplus when exactly n firms remain active infinitely. Hence, the first term gives the option value to decrease, and the second to increase the number of firms.

Dixit (1989b) shows that the general solution of $\Phi_n(e)$, the value with n active firms, can be expressed as a sum of the single firm value functions of all active and idle firms, $V_1(e)$ and $V_0(e)$:

$$\Phi_n(e) = \sum_{j=1}^{n} \left\{ A_j e^{-\alpha} + \frac{eP_j}{\rho - \mu} - \frac{w_j}{\rho} \right\} + \sum_{j=n+1}^{N} B_j e^{\beta}$$
$$\Rightarrow \Phi_n(e) = \sum_{j=1}^{n} V_{1_j}(e) + \sum_{j=n+1}^{N} V_{0_j}(e) \tag{4.11}$$

Therefore, the generalization of the single firm model is straightforward, and the value-matching and smooth pasting conditions are exactly the firm-by-firm conditions of optimal entry and exit at e_H^n and e_L^n respectively. Hence, the exchange rate uncertainty makes again the revenue in the foreign currency exceed the full flow cost, and therefore strenghtens hysteresis. The only new feature, compared with the single firm model, is that the price-reducing effect of a possible upward movement in the exchange rate as new foreign firms enter is taken into account in the determination of the optimal entry point e_H^n for the n^{th} firm as e_H^n, e_L^n, w_n and P_n depend now on the number of active firms in the industry.

4.2.6 Supply-side hysteresis and exchange rate pass-through

Clearly, in a market characterized by hysteresis, EPT depends on the phase of the industry evolution. The three phases characterized by different EPT elasticities are one where the exchange rate appreciates and foreign firms enter, another where the exchange rate fluctuates within the range between trigger-values, and the third where exchange rate depreciates enough to induce foreign exit. If domestic firms are assumed to be indifferent of exchange rate movements, the above industry model implies that the domestic market price stays constant over the second phase irrespective of the exchange rate fluctuations producing zero EPT. (Dixit 1989b)

Nonzero EPT results during the first phase as the domestic market price falls and during the third phase as the price rises due to foreign entry and exit respectively. By running various numerical simulations with plausible parameter values, Dixit (1989b) arrives at EPT elasticities between 0.63 and 0.80. Dixit found that an increase in import penetration raises EPT. This is the same conclusion that results from the static oligopoly model discussed in chapter three. Dixit (1989b) shows also that varying employed parameter values over a wide range does not alter the basic conclusions. However, Dixit does not consider the supply response of the firms that do not enter or exit. Thus, his simulations tend to underestimate EPT.

The industry model implies that an increase in the exchange rate uncertainty reduces EPT as the range of inaction becomes wider. It predicts also apparent shifts in EPT, since at the outset there is no distinct price response as the "wait and see"-strategy is employed over some time interval, and a significant EPT response occurs only after the exchange rate has reached the trigger-levels. Thus, also when applied to firms that have price-setting power, an increase in the exchange rate uncertainty can be used in part to explain many observations of clear PTM in exports to the USA in various industries during the dollar appreciation[33] and the following depreciation in the 1980's, as the drastic appreciation of the dollar meant also a sharp increase in the volatility.[34] Krugman (1986) concluded that the amount of PTM depends negatively on both how long the appreciation or depreciation has lasted and how persistent it is expected to be. The increase in the exchange rate uncertainty shortens the time interval, over which exchange rate movements are expected to last, and thus enhances PTM behaviour following Krugman's deductions.

4.3 Dynamization of the static monopolistic competition model

The shortcomings of the static models of monopolistic competition, (discussed in section 3.4), can be overcome by examining firms' intertemporal decision making, and the effect of exchange rate shocks on the underlying structure of the industry, which affects industry's prices and volumes. Baldwin (1988b) presents a dynamization of the static SDS-model and develops a sunk-cost model of hysteresis – the Beachhead model. The formulation of the exchange rate evolution and its anticipation is not crucial to produce sunk-cost hysteresis as the Beachhead model demonstrates by assuming perfect foresight. However, the nature of expectations affects crucially the adjustment paths of prices and quantities.

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[33] See e.g. Baldwin and Krugman 1987a, Giovannini 1988, Ohno 1988, Feenstra 1989 and Marston 1990.

[34] Distinct PTM occurs also during the inertia phase in case of domestic depreciation, and foreign firms absorb most of the depreciation into their profit margins without any strategic predatory motive. Thus, the price in foreign currency could fall below unit production costs plus delivery costs, which is the definition of dumping in the trade law of the USA and many other countries. Note that there is no indication of international price discrimination, and even small firms can practice dumping in this sense in competitive markets (Dixit 1989a and 1992, Ethier 1982).

If active in the domestic market representative foreign and domestic firms choose their sales x_j and x_i respectively to maximize their discounted profits (Baldwin 1988b, p. 775):

$$\max_{x_{j_t}} \pi_j = \sum_{t=0}^{\infty} R^t \{p_j(\omega_t, x_{j_t}) x_{j_t} - \phi(x_{j_t}) \frac{c_t^*}{e_t} - h\} - k \tag{4.12}$$

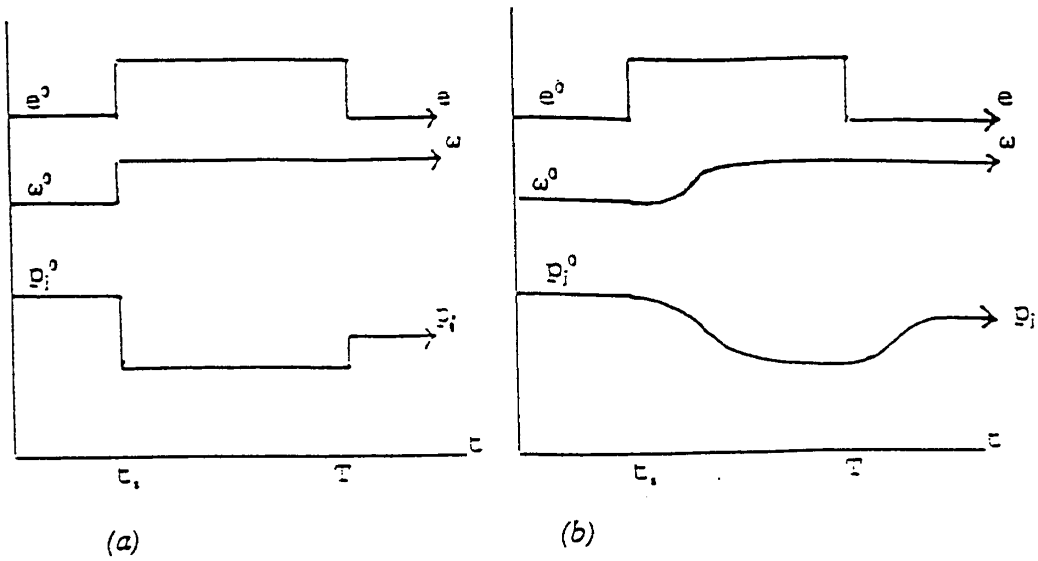
$$\max_{x_{i_t}} \pi_i = \sum_{t=0}^{\infty} R^t \left\{p_i(\omega_t, x_{i_t}) x_{i_t} - \phi(x_{i_t}) c_t - h\right\} - k \tag{4.13}$$

where R is a constant discount factor, h (<k) a fixed maintenance cost per time period, and perfect foresight is assumed. Firms contemplating entry or exit calculate their profits resulting from an optimal choice of sales based on a period-by-period Cournot-Nash equilibrium. Entry will take place in period τ if the discounted operating profits of typical foreign and domestic firms excluding k, $O\Pi_\tau^*$ and $O\Pi_\tau$ respectively exceed the sunk entry costs k. Respectively exit occurs if variable costs are not covered, i.e. $O\Pi_\tau^* < 0$ or $O\Pi_\tau < 0$. Thus, there is again a gap between entry and exit conditions, which implies that hysteresis is present also in monopolistic markets. A large enough domestic appreciation induces foreign entry which is not reversed by a corresponding depreciation. A persistent increase in the number of firms, and consequently in the number of offered brands, ω, increases the demand elasticity of different brands, and thus leads to a persistent decrease in profit margins as the equation (3.3) demonstrates (Dixit & Stiglitz 1977). (Baldwin 1988b)

A large exchange rate shock is now defined to be such that alters the size and the domestic/foreign composition of ω due to its large absolute size or long duration. Small shocks have no effect on the market structure. Under perfect foresight ω jumps up instantly at the announcement of a large domestic appreciation at t_s, since foreign firms revise their expectations instantly which leads to a rise of $O\Pi_\tau^*$ above k causing foreign entry. The import price falls as a consequence of the marginal cost reduction and the market structure change as more competition reduces profit margins. The shock reverses itself at T, but ω remains higher than before the shock as exit is not induced. Hence, the post-shock price is permanently lower than the pre-shock price.

In the perfect foresight case changes in profit margins are once-off as depicted in *figure 4.2.(a)*. When the exchange rate expectations are based on the random walk profit margins shift over time, and the import price follows a S-shaped time path as illustrated in *figure 4.2.(b)* Note that the import price adjusts only gradually also after the shock is removed at T. The Beachhead model implies that EPT elasticity changes over time due to the real effects of large exchange rate movements, which show up as *structural breaks in empirical trade equations.* However it does not establish what affects the exact magnitude of EPT. (Baldwin 1988a)

Figure 4.2 **A large domestic appreciation and the time paths of ω and p_j when the exchange rate expectations are based on (a) perfect foresight and (b) random walk. (Baldwin 1988a and 1988b)**



4.4 Firms' planning horizons and lags in exchange rate pass-through

Ohno (1989) shows that the *planning horizons* of domestic and foreign firms are crucial in determining the actual size of EPT in a particular industry in addition to the relative market shares and mark-ups when the market exhibits hysteresis. If foreign exporters are long term maximizers relative to domestic firms (use lower discount rates), EPT will be lower and the export penetration higher than otherwise. This appears as PTM strategies of foreign firms whereby market shares are preserved at sacrifice of short term profits. Long term maximizers prefer more stable output under fluctuating exchange rates, since in a hysteretic environment winning new customers or old ones back requires large promotional efforts. (Ohno 1989)[35]

Additionally, the size of the exchange rate deviation from the value, on which current output decisions were based, has an impact on EPT. Ohno (1989) argues that in every case the development of EPT, and industry output is in four phases as the deviation becomes magnified. Neither foreign or domestic firms respond to insignificant variations due to promotional costs, but as the variation gets larger at first only foreign firms, and then also domestic firms adjust their output. The

[35] Ohno presents a model of Cournot competition, which resembles closely the Beachhead model, but does not consider entry and exit explicitly as causes of changes in the market structure. Rather, he assumes a constant promotional cost for each additional unit sold over the previous period, which is not recouped when a firm reduces its sales volume. The promotional cost operates similarly as the sunk market-entry cost. Thus, hysteresis in prices and quantities is present in this formulation too. (Ohno 1989)

adjustment on part of home firms is a competitive response to exporters' actions. Finally, as the deviation becomes extreme, some foreign firms enter or exit which leads to an increase or decrease in EPT respectively as the static Cournot model (3.1) demonstrates. Planning horizons of domestic and foreign firms affect the critical points at which these output adjustments take place.

Differences in planning horizons provide a plausible explanation for the observed asymmetries in the pricing behaviour of exporters from different countries. E.g. several empirical studies confirm (revert to section 2.3.3) that PTM is much more common in Japanese and German than American exports.[36]

Import prices can also be subject to implicit commitments or be a part of the marketing strategy, under which price variations will be more moderate. For example, firms often have to cultivate a *reputation* over time for being in a certain price range especially in relatively expensive manufactures (Krugman 1986). Therefore, unexpected rises or falls in marginal costs due to exchange rate fluctuations will not be "passed-through" completely in order not to loose reputation if the long-run costs of this loss exceed the benefits of exploiting short-run market power. This in turn depends again on the planning horizon.

Whether the costs of adjusting output arise from the supply-side as capacity and distribution adjustment costs or from the demand-side as promotional costs, import prices will fall only gradually as the infrastructure is put in place or domestic demand is allured when the domestic currency appreciates. Therefore, regardless of the formulation of expectations, *figure 4.2.(b)* gives a more reasonable picture of the price ajustment when there are constraints on distribution capacity and demand (Krugman 1986, Kim 1990).There are many other possible explanations for the lagged response of import prices than output adjustment costs whose plausibility depends on the characteristics of the particular industry. As well as the rationale for lags also their lenght and structure varies across different industries. In general, the exchange rate uncertainty enhances stability in import prices by making "wait and see"-strategies optimal as discussed previously. However, the most commonly viewed reasons for lags are *long term customer relationships* and *explicit* or *implicit trade contracts*. Revision of these commitments is time-consuming, and produces stickyness in import prices. Commitments to particular suppliers are conventionally seen also as an explanation for the sluggish response of the trade balance to exchange rate changes (the J-curve) (Krugman and Baldwin 1987, Moffett 1989).

The simplest, and the most frequently used formulation of the lags in empirical studies are *the delivery lags* which emerge because it is impossible or very costly to alter rapidly physical trade flows. Then, the short-run supply curve becomes more inelastic, and produces slow adjustment of prices and volumes to exchange rate changes. Thus, even time-consuming delivery without a need to

[36] Traditional explanations like dollar's dominant role as an international invoice currency, substantial market power of American firms and their lower export dependency can not account for the whole discrepancy, which Ohno (1988, p. 16) observes across all industries at SIC 4-digit level. Further, since contract currencies can be revised and Japanese and German firms have considerable market power in many industries and a large domestic market too, it can be concluded that American firms have greater preference of short-term profits than Japanese and German firms. Ohno (1989) stresses the role of the US stock market in promoting such behaviour: most stocks are owned by individuals and institutional investors who are mainly interested in capital gains rather than the long term viability of the firms. (Knetter 1989, Ohno 1989)

accommodate distribution capacity can provide a microeconomic rationale for the observed lags in EPT. (Krugman and Baldwin 1987, p. 27–31)

Hysteresis in import prices and volumes has been found to result from foreign entry and exit, but hysteretic effects can emerge also when firms face a distribution capacity constraint (marketing bottleneck) in the short-run. With an extreme version of the capacity constraint the marginal cost function becomes a step-function where the discontinuity appears at the prevailing capacity. Exchange rate movements shift vertically the marginal cost curve whose kink absorbs small variations without causing changes in the import price or volume. Hysteresis in import prices and volumes results from a large exchange rate movement that induces capacity changes, since even a larger reverse movement is required to restore the original capacity. On the industry or national level marketing bottlenecks predict reduced rather than zero pass-through when exchange rate changes are absorbed, since diffrent firms are usually constrained at dissimilar capacity levels, and the firms without binding constraints should alter their prices when exchange rate movements take place. (Baldwin 1988a)

4.5 Dynamic demand-side considerations

On the demand-side emerges another independent cause of hysteresis, namely *brand loyalty*. If a degree of brand loyalty exists buyers do not necessarily choose different brands each time they repurchase the good. This may be due to unawareness of other brands or uncertainty about their quality (Ohno 1989). Consumers may face also significant *switching costs* when moving between brands. Klemperer (1987, 375–377) concludes that the costs that arise are transaction, search, learning, cotractual costs (e.g. penalties) or artificial costs (e.g. repeat-purchase discounts). The more substantial the switching costs are, the greater consumers' brand loyalty is. The reason why brand loyalty can generate hysteresis is that firms' future demands depend now on their current market shares. To accentuate this conclusion, Froot and Klemperer (1989) stress also the role of *network externalities*, i.e. consumers' incentives to purchase goods that others have purchased previously.

The existence of switching costs does not require definitely differentiated goods, since *ex ante* undifferentiated products can turn *ex post* differentiated if producers are able to impose these costs (Klemperer 1987). But these costs are more likely to be substantial in case of "genuinely" differentiated products. Further, many authors consider investments in market share to take place by means of current prices (e.g. Froot & Klemperer 1989, Krugman 1986). When prices are used in this strategic way, all changes in firms' investment decisions are reflected directly to the EPT relationship producing somewhat different conclusions than those of the supply-side approach.

Following this type of reasoning, Froot and Klemperer present a two-period *market-share model* in which the future development of the exchange rate affects the value of the current market share, and thus has a direct effect on current pricing strategies. Lowering the current price charged raises firm's first-period market share, and thus increases second-period profits. Froot and Klemperer show that under these conditions foreign firm's first-period price in domestic currency

p_1 has a reduced form,[37] $p_1=p_1(c_1,c_2,\lambda)$, where c_1 and c_2 are the first- and second-period marginal costs in domestic currency γ/e_1 and γ/e_2 respectively as constant marginal costs γ are assumed. Domestic and foreign interest rates, λ_d and λ_f respectively, are related to the expected future depreciation (e_2/e_1) by uncovered interest parity: $\lambda_d=\lambda_f(e_2/e_1)=\lambda$, where λ_f is assumed constant. Note that all arguments in the reduced form depend directly on the exchange rates e_1 and e_2.

The effect of a proportional change in e_t, (measured in logarithms), on the current price p_1 is therefore chanelled through its impact on foreign costs and the applied discount rate. By applying the chain rule of differentiation on the reduced form, the effect of a temporary first-period appreciation and an expected second-period appreciation of the domestic currency are given by (4.14) and (4.15) respectively (Froot and Klemperer 1989, p.641):[38]

$$\frac{dp_1}{de_1} = -c_1\left(\frac{\partial p_1}{\partial c_1}\right) - \lambda\left(\frac{\partial p_1}{\partial \lambda}\right) \tag{4.14}$$

$$\frac{dp_1}{de_2} = -c_2\left(\frac{\partial p_1}{\partial c_2}\right) + \lambda\left(\frac{\partial p_1}{\partial \lambda}\right) \tag{4.15}$$

Using these formulations Froot and Klemperer (1989) are able to distinguish separate *cost effects* (the first terms on the right hand side), and *real interest rate effects* (the second terms) in the foreign price response. Froot and Klemperer's reasoning can be seen as a straightforward dynamization of the static framework, where only the first-period cost effects matter in the determination of EPT. If the current market share matters the intertemporal considerations of the model are valid, and the real interest rate terms are nonzero. As (4.14) and (4.15) display, the cost and real interest rate effects work in opposite directions. In general, EPT response to a temporary appreciation is ambiguous, depending on the relative size of the cost and real interest rate effects. Note that the greater the impact of the current price on the current market share, and the effect of the current market share on future profits (significance of the demand-side stickynesses), the larger real interest rate effect results.

When the exchange rate change is perceived permanent, i.e. $de_1=de_2$, the price effect is the sum of (4.14) and (4.15), and the real interest rate effects cancel out as the relative values of current and future profits do not change. Thus, a

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[37] The reduced form $p_1=p_1(c_1,c_2,\lambda)$ follows from the first order conditions of profit maximization. Only now the current market share σ_1 enters into the expression for second-period profits. Firms balance the marginal cost of the market share investment, (through lower current price), $(\partial\pi_1/\partial p_1)$ against the discounted marginal return on this investment, (through higher second-period profits), $(\lambda(\partial\pi_2/\partial\sigma_1))$. Since c_1 and c_2 affect π_1 and π_2 respectively they are arguments of p_1. Note that the industry equilibrium is noncooperative, and no conjectural variation is perceived. (Froot and Klemperer 1989, p. 639–641)

[38] (4.14) and (4.15) are obtained by using following notations: $e_1(dc_1/de_1)=e_1(-\gamma/e_1^2)=-c_1$, and similarly results $-c_2$, $e_1(d\lambda/de_1)=e_1(-\lambda_{fe_2}/e_1^2)=-\lambda$, and $e_2(d\lambda/de_2)=e_2(\lambda_f/e_1)=\lambda$.

permanent appreciation leads to a larger EPT than a temporary one, since both cost effects reduce current prices. Similar reasoning applies also to depreciations, e.g. an expected depreciation of the domestic currency leads to an increase in p_1.

Froot and Klemperer's (1989) results are general when demand-side stickynesses apply, since they do not depend on the exact form of the domestic demand. Further, Froot and Klemperer show that the nature of competition and the number of periods considered are not critical. Lower exchange rate pass-through than predicted by static models can now occur if the exchange rate movement is perceived temporary. Also it is theoretically feasible to observe negative (perverse) pass-throughs resulting from real interest effects that outweigh the cost effects.

5 Some theoretical extensions

5.1 The dependence on the exchange rate regime

All analysis sofar concerns directly the regime of floating exchange rates. In case of fixed exchange rates, when occasional devaluations and revaluations take place, the general conclusions about the impact of market organisation and demand and cost characteristics on EPT remain valid. When the exchange rate is completely fixed or is allowed to float within a certain band of index values, the change in exchange rate expectations can be described as a shift in the mean value of the density function characterizing the exchange rate process by the readjustment percentage (Fisher 1989). Then, devaluations and revaluations should cause a more dramatic revision of the expectations than market fluctuations in case of flexible exchange rates which should lead to a more swift adjustment of import prices and quantities, as well as distribution capacities and the number of foreign firms.

Also the uncertainty concerning the new level of the exchange rate is generally smaller than with floating exchange rates, which should similarly speed up the adjustment process. Hence, the time paths of the above variables should resemble more closely a step function (*figure 4.2.*). This need not, however, apply in every particular case.

5.2 Choice of the currency denomination of export prices

The presumption behind all analyses in this chapter is that the foreign firm automatically sets its output price in domestic (importer's) currency. This assumption is justified when considering Finnish exports, since in 1990 17.5% of total exports, and only 2.6% of the exports of paper products were invoiced in Finnish Marks (The Board of Custom's Foreign Trade Monthly Bulletin, December 1990). Giovannini (1988) is one of the only authors that examines the problem of the currency denomination of export prices explicitly. He concludes that theoretically this question is not trivial, since provided that there is uncertainty associated with the exchange rate, the currency denomination should be regarded as a choice variable that affects the value of the foreign exporting firm.[39]

Giovannini (1988) investigates also how effects of an increase in the exchange rate uncertainty are affected by the currency denomination. When the exporter is risk neutral, and prices are set in domestic currency, a rise in volatility leaves

[39] By considering a model, where a foreign risk neutral firm is able to price discriminate between the domestic and foreign market, and prices need to be set before the exchange rate is realized, Giovannini (1988) concludes that quoting export prices in domestic (importer's) currency leads to higher expected profits if profits are a concave function of the exchange rate. When the profit function is convex, foreign currency should be chosen. Further, a condition of a concave profit function reduces to concavity of the domestic demand if marginal costs are constant. Exact proofs are given in Giovannini 1988, p. 47–52.

export prices unaffected, but this is not the case when foreign currency is chosen.[40] Further, Giovannini separates *"the expectations effect"* and *"the price discrimination effect"* in the response of prices to exchange rate movements. These effects represent causes of departures from complete EPT, and thus, from the "law of one-price". The currency denomination is crucial, since when foreign exporter's prices are quoted in the same currency as its home market prices (in foreign currency), deviations from the "law of one price" must imply *ex ante* price discrimination as the "expectations effect" becomes zero. But instead, when prices are denominated in domestic currency these deviations are the sum of exchange rate surprises and *ex ante* price discrimination. The main implication of Giovannini's work is that the currency denomination problem is not trivial, and its choice should be properly modelled when assessing the determinants of EPT, and detecting price discrimination.

5.3 Macroeconomic implications of hysteresis

Baldwin and Krugman (1989, p. 642–647) demonstrate that the conclusions concerning hysteresis in a single industry do not become considerably softened when many industries with different characteristics are aggregated (see Vesala 1992). Thus, a sluggish adjustment of export and import prices to exchange rate movements as predicted by the dynamic models leads to a sluggish adjustment of trade imbalances. Moreover, the hysteretic effects that cause persistent changes in prices and volumes even at the aggregate level weaken the power of the exchange rate in correcting disturbances. Models presented in chapter four provide microeconomic foundations for trade dynamics that differ significantly from the traditional views, such as the J-curve. The general conclusion is that the timing and the magnitude of the balance of payments response to an exchange rate movement is not clear at the aggregate level, unless specific factors affecting price and volume responses in various export and import sectors are examined. The fact that entry and exit triggering levels of the exchange rate differ leads Bladwin and Krugman (1989) to conclude that a period of an overvaluation of the domestic currency leads to a permanent reduction in the equilibrium exchange rate that is required to restore the trade balance.

The behaviour of the US trade deficit constitutes evidence in favour of the models described in chapters three and four. The fall of the dollar after the 1985 peak led only to a slight increase in real import prices implying low pass-through, and import volumes remained at a high level (even continued to rise slightly). Thus, the US trade deficit did not improve (Baldwin and Krugman 1987a, Baldwin 1988a).

Implications of hysteresis on the exchange rate determination have not yet been thoroughly researched. As only authors, Baldwin and Krugman (1989, p. 647–652) and Baldwin and Lyons (1989) examine the feedback of entry and exit

[40] When prices are set in domestic currency the first order conditions for profit maximization are linear functions of the exchange rate. Then a mean preserving change in the exchange rate distribution, a rise or a fall in the volatility, has no effect on the first order conditions, and thus on export prices when the firm is risk neutral. When prices are set in foreign currency the effects are ambiguous as the exchange rate now enters the domestic demand function. (Giovannini 1988)

decisions of foreign firms to the exchange rate. Baldwin and Krugman present a model where both capital inflow and market structure are arguments of the exchange rate. In their model exchange rate has a static relationship with the capital inflow when the number of foreign firms in the market remains constant. However, when a large capital inflow produces a large enough appreciation to provoke entry on part of foreign firms, a return of the capital inflow to its previous level will not shift the exchange rate back to its original level. Instead, the exchange rate will fall more in the long run, since a lower level is now required to balance the trade deficit as the change in the market structure caused by the appreciation is permanent. All lost markets will not, however, be regained. Thus, Baldwin and Krugman conclude that a large temporary movement in capital inflow or outflow yielding an exchange rate movement in one direction will cause the mean of the exchange rate process (equilibrium exchange rate) to shift into opposite direction in the long run. Baldwin and Krugman's treatment is a strict abstraction from reality, but it demonstrates that the feedback to the exchange rate is a relevant issue, and should not be ignored.

Baldwin and Lyons' (1989) model is based on similar reasoning, but they concentrate on the effects of large monetary policy misalignments on the equilibrium exchange rate. Hysteresis in the market structure and in the steady state exchange rate follows in the same fashion as in the Baldwin and Krugman's framework. Baldwin and Lyons examine also the implications on other macro variables by applying Dornbusch's (1976) sticky price monetary model. These effects are, however, beyond the scope of this paper.

The dynamic models dealing with hysteresis are partial equilibrium models, where exchange rate development is defined exogeneously. Thus, Dixit (1989b) concludes that building a general equilibrium model that explains both real exchange rate fluctuations and the behaviour of aggregate import prices is the main task of future research. Not until this is accomplished, a straightforward application of the industry level results at the aggregate level is not properly grounded.

6 Empirical study of export pricing of Finnish paper manufactures

The purpose of the empirical study is to examine the export pricing behaviour in the Finnish paper manufacturing industry. Paper industry was chosen, because it is the only Finnish industry that can be considered having market power in international markets. The study aims at assessing the magnitude of EPT elasticity in the European market (excluding the Soviet Union and other former COMECON countries) and in the US market by estimating export price equations based on standard mark-up pricing. The second goal is to investigate whether any hysteretic effects as implied by the theory have occured in Finnish paper exports. Especially dollar evolution in the 1980's is regarded as a shock that could have evoked hysteretic shifts in EPT and market structure. Necessary conditions for accepting the hysteresis hypothesis are tested by means of general stability tests, and the specific shifts in parameter values are examined by introducing dummy variables to evaluate more detailed predictions of the theory.

The study is organised as follows. At first some basic facts about Finnish paper exports are reviewed, and methods of data construction explained. Then follows the formulation of the empirical model, and estimation results of the export price equations. Results of the stability tests and dummy estimations are then reported, and finally evaluated against the predictions of the theory. At every phase quarterly data is used. The estimation period is uniform for all equations: 1975:1–1991:4.

6.1 Exports and production costs of the Finnish paper industry

6.1.1 Some background facts

Exports of the Finnish forest industry made up 37.6% of total Finnish exports in 1990. The share of pulp, paper and paperboard products in the total exports was 30.5%. The most important market for these products was EC, comprising 66.4% of total exports, (73.4% when Sovjet Union and other former COMECON countries are excluded). Exports to the USA amounted to 4.7%, (5.3%). *Table 6.1.* shows more in detail the distribution of the exports by countries and country groups. For comparison, figures for 1980 are also presented.

Export volumes grew quite steadily at an average rate of 5% between 1983 and 1988. A downturn begun in 1989; since then export volumes have been falling around 1% per year. To meet increasing demand from home and abroad production capacity rose simultaneously. Production of paper products rose by 57% from 1980 to 1990, (4% increase compared to 1989), and the production of pulp by 23%, (3% decrease vs. 1989). (Central Association of Finnish Forest Industries (Metsäteollisuuden Keskusliitto), Yearbook 91)

Table 6.1 **Exports of the Finnish forest industry, and total Finnish exports in 1990 and 1980 by destination (per cent)**

	Pulp		Paper board	& paper-	Total exports of the forest industry		Total exports	
Destination	1990	1980	1990	1980	1990	1980	1990	1980
EFTA	5.4	7.3	8.3	7.5	8.8	8.5	20.3	23.5
EC	72.7	57.7	65.5	47.7	67.7	55.2	46.5	38.6
Germany	26.4	18.0	15.7	11.8	17.7	13.6	12.4	10.6
UK	18.5	14.3	18.0	18.8	18.2	18.3	10.4	11.3
France	9.9	8.7	9.1	6.5	9.2	7.7	6.2	4.5
OECD EUROPE	78.5	67.8	74.1	57.8	76.8	66.6	67.2	63.7
USA & Kanada	0.6	0.8	5.3	2.3	4.1	1.8	5.4	3.6
SUM	79.1	68.6	79.5	60.4	80.9	68.1	72.6	67.3
USSR & EASTERN EUROPE	13.0	17.5	9.1	22.4	8.2	15.6	14.1	20.1
TOTAL	3804	3462	27066	11841	38142	22396	101345	52793
MFIM	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Central Association of Finnish Forest Industries, Yearbooks 1981,–91

Printing paper had the greatest market share in 1989, among Finnish exports of paper products in European and North American markets. As measured by the share in world's consumption its market share was 6.6%, and in regard to the consumption in the Western Europe 14%. Finnish exports made up 19.8% of North American imports of printing paper. For newsprint, (other important export grade), and for pulp these figures were somewhat lower as presented in *table 6.2*. The evolution of the figures is also given.

Table 6.2 **Percentage shares of Finnish exports in World's and Western Europe's consumption, and North-American imports, 1975–1989**

	World			Western Europe			North-America		
	Pulp	News print	Printing paper	Pulp	News Print	Printing paper	Pulp	News Print	Printing paper
-75	1.0	3.8	4.3	3.0	14.7	7.6	0.2	0	19.2
-76	1.0	3.9	4.2	3.4	14.5	7.7	0.3	0	12.0
-77	1.1	3.7	4.5	3.7	13.7	8.4	0.3	0	19.5
-78	1.3	4.6	4.4	4.7	15.7	7.6	0.6	0	20.6
-79	1.6	5.7	4.1	5.3	18.2	7.0	0.6	0.9	19.0
-80	1.6	5.6	4.3	5.5	18.4	7.5	0.5	0.2	14.1
-81	1.4	5.9	4.2	5.0	17.4	7.7	0.4	0.1	10.5
-82	1.3	5.3	4.6	4.3	19.1	8.4	0.1	0.5	9.8
-83	1.3	5.6	4.7	4.4	19.3	9.4	0.5	1.8	11.7
-84	1.2	6.0	5.2	4.1	20.1	10.4	0.7	1.9	14.1
-85	1.2	5.8	5.5	4.1	20.4	11.8	0.3	1.7	12.9
-86	1.1	5.0	5.3	3.8	17.2	12.0	0.3	2.1	12.8
-87	1.2	4.6	5.8	4.0	15.9	13.3	0.4	2.4	14.0
-88	1.2	3.7	6.4	4.1	14.5	13.9	0.8	0.4	15.5
-89	1.1	3.2	6.6	4.1	12.0	14.0	0.3	0.4	19.8

Source: Central Association of Finnish Forest Industries, Research Department

6.1.2 Data construction

Estimations are performed for five different export price series. Aggregate export prices of paper products, paperboard products and pulp, (industries 344, 343 and 341 according to the Finnish industry classification). These series are labelled WPAPER, WBOARD and WPULP respectively. The level of aggregation is all Finnish exports except exports to the Sovjet Union and other former COMECON countries. Thus, the major part of these series, 93.3% according to *table 6.1.*, consists of exports to Western Europe, (88.3% to the EC market). Finnish exports to the USA are taken as a special case to investigate more closely effects of large changes in the dollar value as a shock that could cause hysteretic effects. Prices of total exports of paper products, (SITC 64) constitute the serie SITCUS, and export prices of printing paper (CCCN 48.01.012 / HS 48.01. 00.00) the serie CCCNUS. Printing paper was selected, because it makes up a considerable share of American imports, and hence it can be considered as having more market power than other exported paper grades. All series are given as unit value indices (1980=100) derived from f.o.b. prices denominated in FIM.

To measure exchange rate development correctly for the arggregate exports, an index is constructed using relative shares of different currencies in export price denomination as weights. These weights are presented in *table A1.1.* in *Appendix 1*. This information is available only starting from 1979. Therefore, the weights of 1979 are used also for years 1975-78. Note that the share of USD is drastically larger than the share of the USA in total exports. The most dominant invoice currencies have been USD, GBP and DEM so that the relative share of USD has decreased while that of GBP and DEM increased over the observation period. *Figure A1.1.* in *Appendix 1* plots the evolution of FIM-rates of USD, GBP and DEM between 1975:1 and 1991:12 (average monthly offer rates). Monthly observations are transformed into quarterly ones by taking arithmetic averages.

The development of the currency index is presented in *figure A1.2.*, as well as the prices of aggregate exports. In turn, prices of exports to the USA are depicted in *figure A1.3.* against monthly FIM/USD rates. During the 1980's pulp prices have fluctuated heavily, while paper and paperboard prices have risen quite steadily. Plots of FIM prices of exports to the USA imply stronger correlation with the exchange rate than plots of the aggregate exports. Thus, a graphical examination suggests lower EPT in terms of importers' currencies in the US than in the European market.

Average hourly compensation for labour, prices of raw materials (average of the delivery prices of pine log and spruce pulpwood) and a composition of fuel, water, heat and electricity prices labelled as energy prices are used to represent production costs of the Finnish paper industry. Hourly compensation is based on average quarterly income of manufacturing workers. (The share of salaried employees in the total wage bill varied between 28% and 31.6%). Wood prices are available only semiannually. Thus, prices of raw-materials obtain the same value for two successive quarters. Time series of these three cost components are plotted in *figure A1.4* all converted into indices 1980=100. Apparently, there is considerable seasonal fluctuation in the average hourly compensation due to seasonal production alterations, and the timing of negotiated wage increases.

As a cyclical variable to measure demand pressure in particular markets, seasonally adjusted GNP volume indices of the OECD Europe and the USA are applied. Relative shares of the export volumes and values, and a minor share of Finland in the index, justify the use of OECD Europes GNP-volumes. These series are shown in *figure A1.5.* All data sources are reported in *Appendix 1.*

6.2 Empirical implementation

6.2.1 Formulation of the export-price equation

As in (2.1) the EPT coefficient is defined to be the elasticity of f.o.b price in importers' currency with respect to the nominal exchange rate. Actually the term importers' currency refers to a basket of currencies weighed by relative shares in price denomination when aggregate exports are concerned, and to the US dollar in case of exports to the USA. Export price indices are expressed in Finnish Marks. Hence, in actual estimations one minus the EPT coefficient will be obtained which is expected to fall between 0 and 1.

Finnish paper exporters are supposed to follow a mark-up pricing strategy over production costs. In terms of the SDS (Spence-Dixit-Stiglitz) model, the mark-up over costs depends upon the perceived demand elasticity faced by the firm, which in turn is a function of the demand pressure, competitors' prices and market structure (the number of firms in the industry) (Hooper and Mann 1989, Baldwin 1988a). This general formulation does not impose any prior competitive restrictions on the empirical model, and allows us to examine persistent effects of exchange rate shock induced market structure changes on export prices. Thus, the desired export price p_{dt} depends on the mark-up, exchange rate and unit production cost, and the pricing strategy in terms of rates of change expressed in logarithms becomes:

$$\mathring{p}_{d_t} = \beta_0 + \alpha^* \mathring{e}_t + \theta \mathring{c}_t, \tag{6.1}$$

where β_0 is a constant term that captures all factors affecting the mark-up. α^* and θ are the long- run elasticities of p_d with respect to the nominal exchange rate (FIM prices of foreign currencies) and unit production costs respectively. To reveal both short-run dynamics of the exchange rate pass-through and long-run elasticities a general model of lagged response with an incorporated Error Correction Mechanism (ECM) is specified as e.g. in Mills (1990, p. 273). ECM ensures that the deviations from the desired relationship (6.1) are corrected over time:[41]

$$\mathring{p}_t = \gamma(p_{t-1} - p_{d_{t-1}}) + \mathring{p}_{d_t} + \varepsilon_t, \tag{6.2}$$

where γ measures the speed of error correction, and is expected to be negative. Thus, the general representation for the export price equation can be written:

$$\beta(B)\Delta p_t = \beta_0 + \alpha^*(B)\Delta e_t + \theta(B)\Delta c_t + \gamma(p_{t-1} - p_{d_{t-1}}) + \eta(B)\varepsilon_t, \tag{6.3}$$

where B is a general lag operator, and instantaneous changes are approximated by first differences. This strategy is the same as Kim (1990) employed with the exception that here long-run elasticities are allowed to be nonunitary. This assumption is justified in terms of models including imperfect competition, when product substitutability is high, and the market shares of Finnish firms are relatively low in markets under observation. As stated in chapter four, there are strong theoretical reasons to expect lags in the pass-through response, e.g. due to adjustment costs, uncertainty and long-term contracts. The general ECM-model has the desired feature of accounting for these lags, and both unconstrained and constrained lag structures can be handled within this framework (see e.g. Hooper and Mann 1989). Further advantage of this spesification is the difference approach, which avoids serial correlation in the error terms and disturbing spurious correlations in the time series.

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[41] The ECM-model has desirable features for dynamic analyses as it preserves the long-run relationship as specified in (6.1) and accounts for short-run dynamics in price adjustment. Thus, it is a flexible way to formulate an empirically feasible equation (see e.g. Ohno 1988 and Kim 1990). Further, systems of co-intergated time series have an error-correction representation (Engle & Granger 1987) which gives theoretical support to the application of the ECM.

Equation (6.3) is estimated in the following form:

$$\Delta p_t = (1-\gamma)\beta_0 + \sum_{i=1}^{T_p}\beta_i \Delta p_{t-i} + \sum_{i=0}^{T_e}\alpha_i^* \Delta e_{t-i} + \sum_{i=0}^{T_c}\theta_i \Delta c_{t-i} + \gamma(p_{t-1} - \bar{\alpha}^* e_{t-1} - \bar{\theta} c_{t-1}) + \delta \Delta y_t + \varepsilon_t, \tag{6.4}$$

where y_t is a appropriate cyclical variable, which is added to control for changes in the demand pressure (Ohno 1988). Thus, the constant term captures the effect of competitors' prices and market structure on the mark-up. α^*_0 and θ_0 represent the short-run elasticities, i.e. impact effects, while the long-run elasticities are given by the sum of coefficients of lagged variables. Note that in (6.4) the lag distribution is unconstrained (DL), and the number of lags is allowed to vary across different explanatory variables. The method of model selection, instead of using a prior estimate for the lags, is to establish their appropriate number by testing their significance with F-tests, since t-values are not reliable due to multicollinearity among lagged regressors.

Since export unit value indices are used in estimations to measure unobservable contract prices, the lags in (6.4) can be also interpreted as describing order-delivery lags and the relation of unit value indices to actual contract prices (Kim 1990). The ratio of the coefficient β_i to $\sum\beta_i$ represents then the fraction of traded goods with order-delivery lag of i periods when the maximum order-delivery lag is T_p periods.

Two different approaches to measure the production costs are employed. Firstly, a proxy for unit costs is calculated as a weighed average of the indices describing average hourly conpensation, raw-materials prices and energy (electricity, fuel, heat and water) costs. Thus, the equation (6.4) remains unaltered when this approach is applied. The weights, 17.1% for wages, 69.8% for materials and 13.1% for energy, are based on the means of their relative shares in the production costs, since they are relatively stable throughout the estimation period. The costs shares are presented in *Table A1.2* of *Appendix 1.*

Secondly, a two-input cost function characterized by constant returns to scale is estimated simultaneously with the export price equation. Firms are supposed to minimize the unit cost of production by choosing the best combination of labour and materials (84.2% raw-materials and 15.8% energy, see *table A1.2*). Materials represent tradable inputs, whose prices can be affected by exchange rate movements. The applied cost function in translog form is (Ohno 1988, p. 9):

$$c_t = \theta_0 + \theta_1 w_t + \theta_2 q_t + \tfrac{1}{2}\eta_{11} w_t^2 + \tfrac{1}{2}\eta_{22} q_t^2 + \eta_{12} w_t q_t - \phi t, \tag{6.5}$$

where c stands for unit costs, w wages, q materials prices and ϕ the rate of technical change. This specification is consistent with various degrees of input substitutability, and reduces to a Cobb-Douglas cost function with unitary elasticity of substitution when η_{ij}s are zero. Further, $\eta_{12}=-\eta_{11}=-\eta_{22}$ due to the linear homogenity in input prices. Hence, the rate of change in unit cost approximated by first differences becomes:

$$\Delta c_t = \theta_1 \Delta w_t + \theta_2 \Delta q_t - \eta(w_t - q_t)(\Delta w_t - \Delta q_t) - \phi \tag{6.6}$$

Since the right hand side of the both equations (6.4) and (6.6) consist of exogeneous variables to the model, they can be estimated simultaneously with OLS by incorporating the cost function into the export price equation (6.4):

$$\begin{aligned}\Delta p_t = (1-\gamma)\beta_0 + \sum_{i=1}^{T_p}\beta_i \Delta p_{t-i} + \sum_{i=0}^{T_e}\alpha_i^* \Delta e_{t-i} + \sum_{i=0}^{T_c}\theta_{1i}\Delta w_{t-i} + \\ \sum_{i=0}^{T_c}\theta_{2i}\Delta q_{t-i} - \sum_{i=0}^{T_c}\eta_i (w_{t-i} - q_{t-i})(\Delta w_{t-i} - \Delta q_{t-i}) + \\ \gamma(p_{t-1} - \bar{\alpha}^* e_{t-1} - \bar{\theta}_1 w_{t-1} - \bar{\theta}_2 q_{t-1} + \frac{1}{2}\eta(w_{t-1} - q_{t-1})^2 + \phi(t-1)) + \delta \Delta y_t + \varepsilon_t\end{aligned} \tag{6.7}$$

6.2.2 Estimation results

Table 6.3. reports the OLS regression results of the best variants of (6.4) on the export unit value series CCCNUS, SITCUS, WPAPER and WBOARD with the weighed cost approach. All other coefficients are significant except those of cyclical variables.[42] They are included, however, to purify the constant terms from changes in the demand pressure. All coefficients are signed as expected: pass-through coefficients are positive while those of error correction terms negative. The OLS regression fits the data reasonably well, as measured by the adjusted R^2, given that the equation explains changes in the export prices. The fit reduces from a considerably high value for printing paper exports to the USA as the level of aggregation rises. None of the equations suffers from serial correlation as displayed by Ljung-Box statistics (see e.g. Knif 1989, p. 34). According to White-test procedure (White 1980, p. 825) there is indication of a heteroscedasticity problem only in the equation for aggregate paperboard exports. Therefore a correction method, using a heteroscedasticity consistent parameter covariance matrix, is applied in estimating the fourth equation. For aggregate pulp exports only the coefficients of twice lagged dependent variables are significant, also when FIM/USD rates are used. The presentation of these results is omitted here (refer to Vesala 1992, Appendix 4), as well as the further examination of the WPULP equation is dropped.

Table 6.4. shows the estimation results of the EPT coefficients when the cost function approach is utilized. The EPT coefficients seem insensitive to the cost specification in aggregate equations, but the estimates concerning exports to the USA are to some extent higher than with weighted costs. Note, that the equations for CCCNUS and SITCUS suffer from a significant loss of degrees of freedom. Thus, caution should be exercised when interpreting these results. In the following stability tests only the weighed cost approach will be used due to this problem.

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[42] This may be due to poor specification of the demand pressure. A more direct measure than changes in GNPs might prove to be more plausible. Hooper and Mann (1989) suggest the use of capacity utilization.

Table 6.3 **Equation (6.4) with ECM and weighted costs for Finnish paper exports (Q:75:1–91:4).**

Coeff.	CCCNUS 76:2-91:4	SITCUS 76:2-91:4	WPAPER 75:2-91:4	WBOARD 75:2-91:4
β_0	–1.129	–0.673	–0.293	–0.175
	(–3.872)**	(–2.506)**	(–2.248)*	(–1.654)
T_p	0	5	0	0
$\sum\beta_i$		0.488		
F-tests		F(5,44)		
		(3.465)*		
T_e	4	4	0	0
α^*_0	0.843	0.702	0.306	0.339
	(6.080)**	(4.505)**	(3.234)**	(4.348)**
$\sum\alpha^*_i$	0.703	0.306		
F-tests	F(5,50)	F(5,44)		
	(10.637)**	(8.075)**		
T_c	2	2	0	0
θ_0	0.425	0.543	0.310	0.440
	(1.707)	(1.797)	(3.147)**	(2.700)**
$\sum\theta_i$	1.297	1.292		
F-tests	F(3,50)	F(3,44)		
	(4.181)*	(3.264)*		
γ	-0.424	-0.468	-0.0995	-0.227
	(-4.422)**	(-3.095)**	(-1.486)	(-3.934)**
$\bar{\alpha}^*$	-1,114	-0.669	-1.032	-0.350
	(-4.422)**	(-2.899)**	(-2.706)**	(-2.610)*
$\bar{\theta}$	-0.700	-0.769	-0.680	-0.848
	(-3.890)**	(-2.826)**	(-1.327)	(-4.035)**
F-tests	F(3,50)	F(3,44)	F(3,60)	F(3,60)
	(7.125)**	(3.604)*	(2.757)*	(4.465)**
δ	0.199	0.549	-0.186	-0.482
	(0.305)	(0.694)	(-0.522)	(-1.051)
Adj. R^2	0.606	0.530	0.266	0.264
Ljung-Box Q^*	$\chi^2(21)$	$\chi^2(21)$	$\chi^2(24)$	$\chi^2(24)$
	(0.531)	(0.954)	(0.134)	(0.327)
White	$\chi^2(28)$	$\chi^2(36)$	$\chi^2(28)$	$\chi^2(28)$
	(0.125)	(0.381)	(0.326)	(0.0819)
SEE	0.0410	0.0457	0.0173	0.0209

Notes: i) * implies significant parameters at 95%, and ** at 99% level.
ii) t- and F-test values for joint significance of a group of parameters are given in parentheses.
iii) Ljung-Box Q^* is a general test for serial correlation with H_0 of no serial correlation. White-statistic tests H_0 of homoscedastic error terms. Significance levels are in parentheses.
iv) SEE is the standard error of the estimate.

Table 6.4 **Exchange rate pass-through coefficients following the cost function approach (6.7) (Q:75:1–91:4)**

Coeff.	CCCNUS 76:2–91:4	SITCUS 76:2–91:4	WPAPER 75:2–91:4	WBOARD 75:2–91:4
T_e	4	4	0	0
α^*_0	1.062	0.921	0.287	0.343
	(6.805)**	(5.002)**	(3.296)**	(2.955)**
$\sum\alpha^*_i$	0.863	0.733		
F-tests	F(5,42)	F(5,35)		
	(11.608)**	(7.014)**		
Adj.R^2	0.655	0.632	0.397	0.267
Ljung-Box Q^*	$\chi^2(21)$	$\chi^2(21)$	$\chi^2(24)$	$\chi^2(24)$
	(0.403)	(0.355)	(0.0512)	(0.169)

6.2.3 Testing for hysteresis in export prices

Dynamic models presented in chapter four imply that a favourable exchange rate shock should increase the number of firms active in the particular market as well as the export volumes. These shocks have been shown to be able to cause persistent changes in the market structure, the demand elasticity faced by the firms and the prices of exported products. Thus, these models predict hysteretic shifts also in pass-through coefficients, since they are shown to be among others functions of these factors.

There is no reason to expect a once-off shift in the relationships, since more likely the shifts should occur gradually e.g. due to inertia, adjustment costs, information lags and contracts. But a failure to find evidence of a structural break would cast doubt on hysteresis in export prices of Finnish paper manufactures. Especially, shifts are expected in prices of exports to the USA, since a sharp rise in the dollar value during the first half of the 1980's, by over 80% against the FIM, constitutes clearly a shock that could induce hysteretic effects. Further, irrespective of the used model of the perceived exchange rate determination, shifts in the market structure should occur sometimes during the dollar upswing, and persist, at least to some extent, during the following dollar downswing.

Its is also expected that α^* decreases relative to θ, when the exchange rate volatility increases, since the response of firms to exchange rate movements reduces as shown by Dixit's model (Dixit 1989a). Similarly γ should fall with an increase in the volatility as firms have less incentive to correct deviations from long term pricing (desired prices) quickly. A drastic appreciation of the dollar during the first half of the 1980's meant also a sharp increase in the volatility. The volatilities of USD, DEM, GBP and the constructed index measured by standard errors of their monthly FIM-rates over different subperiods are presented in *table 6.5.*

Devaluations of FIM in February 1978 by 8,5%, October 82 by 8%, and November 91 by 14%, as well as a revaluation in March 1989 by 4%, represent also shocks that could cause persistent changes in the pass-through relationships, and in export activities of Finnish firms that show up as movements in the constant term. These shifts in the currency index target zone are usually expected to be irreversible over a fairly long period of time. Therefore, the reaction to the devaluations should be more stronger and quicklier than to other movements as they contain less uncertainty. Above all effects of the devaluations are expected in aggregate export price equations, since due to the composition of the former Finnish currency index, DEM, GBP, FRF and SEK have been otherwise more stable against FIM than USD. (Edin and Vredin 1991)

Table 6.5 **Standard errors of average monthly FIM- offer rates of USD, DEM, GBP and the Index**

	75:1–91:12	75–79	80–84	85–89	90–91
USD	21.54	5.10	23.72	21.82	6.34
DEM	13.51	12.65	5.32	5.91	3.50
GBP	8.04	7.66	4.39	4.74	3.11
Index	7.69	4.99	7.72	5.59	3.09

6.2.3.1 General stability tests

As a first step to detect structural breaks in the pass-through relationships, a succession of Chow-tests are performed (as in Thomas 1985, p. 116–117) for a variety of break points using the equations reported in *table 6.3.* to probe the general stability of the coefficients. The test covers as many periods as possible in order not to restrict the timing of the shifts. The test range includes the dollar cycle and the 1982 devaluation. The results of the Chow-tests, reported in *table 6.6.*, indicate that there is in general a significant structural break among parameters in equations for CCCNUS and SITCUS between periods 1982:1 and 1984:1. There is indication of a break also at a beginning of the 1980's in the aggregate equations, especially in paperboard exports.

Graphical examination of cumulative sums (CUSUM) of recursive residuals, and cumulative sums of squared recursive residuals (CUSUMSQ) is employed as a second method to detect departures from papameter constancy over time (Brown, Durbin and Evans 1975). Time paths of CUSUM and CUSUMSQ statistics are plotted in *figures 6.1.–6.8.* against lines representing *5%* (.....) and 10% (____) levels of significance. Instability is indicated whenever the CUSUM or CUSUMSQ graphs cross the critical lines. Pikkarainen (1984) stated on the basis of simulation experiments that especially CUSUM, but also CUSUMSQ tests, are conservative in discovering jumps in coefficients of exogeneous variables, which is the case here. (On the contrary, they are sensitive to instabilities in coefficients of lagged endogeneous variables.) Pikkarainen concluded, however, that the graphical analysis of CUSUM and CUSUMSQ plots is useful in revealing the exact timing of parameter shifts. *Appendix 2* gives more information about the cumulative sums procedures and their application.

CUSUM plots do not indicate significant instabilities in any of the export price equations. This seems to be due to low power of the CUSUM tests, since CUSUMSQ plots point out significant shifts. CUSUM suggests a clear parameter shift in in the CCCNUS equation in 1982:4 (observation 32) which CUSUMSQ verifies significant at 5% level. Similarly for SITCUS in 82:4 (32), 83:1 (33) at 5%, and in 81:4 (28) at 10% level. Knif (1989, p. 42) states that the longer the path of the CUSUMSQ will stay over the critical line the later the instability occurs, or if the parameters are increasing or decreasing slowly. Hence, a gradual shift in parameter values could explain the persistent stay of CUSUMSQ plots in the critical region in case of CCCNUS, and especially SITCUS. However, CUSUM paths suggest a shift also later during the dollar fall, 86:3 (48), in both equations. *Figures 6.5–6.8.* indicate a shift in parameter values of WPAPER and WBOARD equations more early, 81:4 (28) and 80:2 (22) respectively, both at 10% level.

Note that here Chow-tests and Cumulative sums -tests measure genuine parameter variation, since movements in error variances are ruled out by White-tests. Further, the fact that both procedures point out breaks in the same periods, (except for the WPAPER equation), reinforces the rejection of the parameter stability hypothesis over the observation period.

Table 6.6 **Chow-tests to detect structural breaks in the export price equations, (Q:1975:1–1991:4)**

Break point	CCCNUS 76:2–91:4	SITCUS 76:2–91:4	WPAPER 75:2–91:4	WBOARD 75:2–91:4
79:4		n.a.	*	*
80:1		n.a.		
80:2		n.a.		*
80:3	*	n.a.		*
80:4		n.a.		*
81:1				*
81:2				
81:3				
81:4				
82:1		**		
82:2	*	**		
82:3	**	**		
82:4	**	**		
83:1	**	*		
83:2	*	*		
83:3	*	*		
83:4	*	*		
84:1	**	*		
84:2				
84:3				
84:4				
85:1–87:3				
87:4–88:3		n.a.		

Note: * indicates significant structural break at 95% level and ** at 99% level. n.a. marks an unperformed test

Figure 6.1

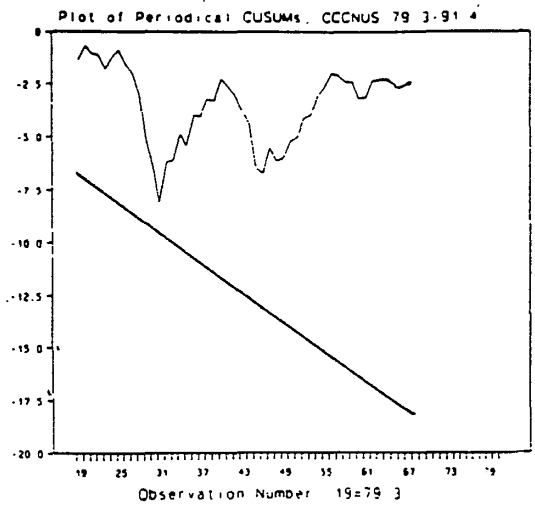


Figure 6.2

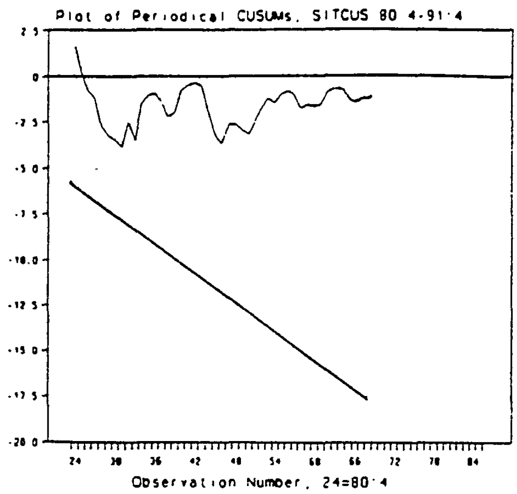


Figure 6.3

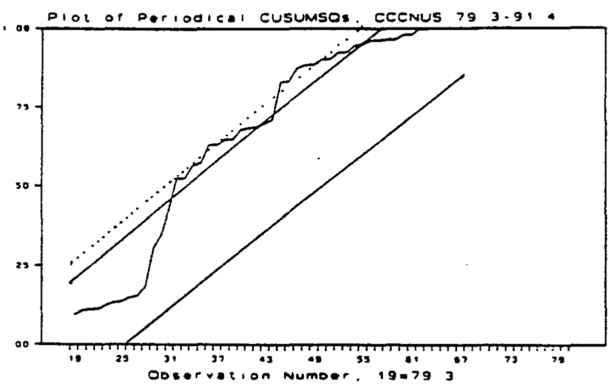


Figure 6.4

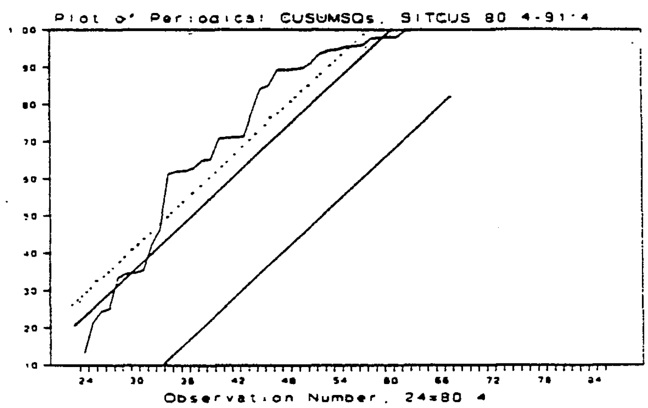


Figure 6.5

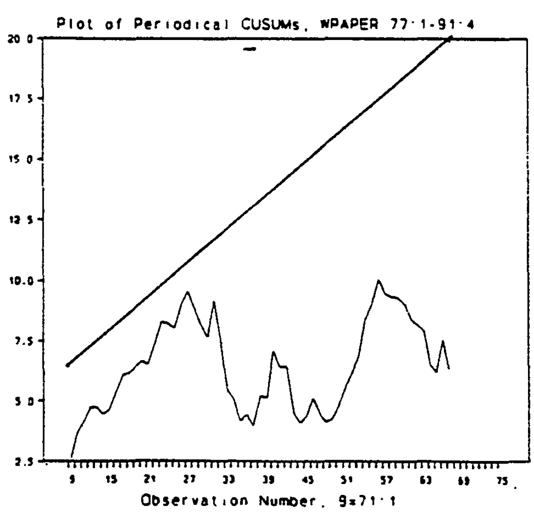


Figure 6.6

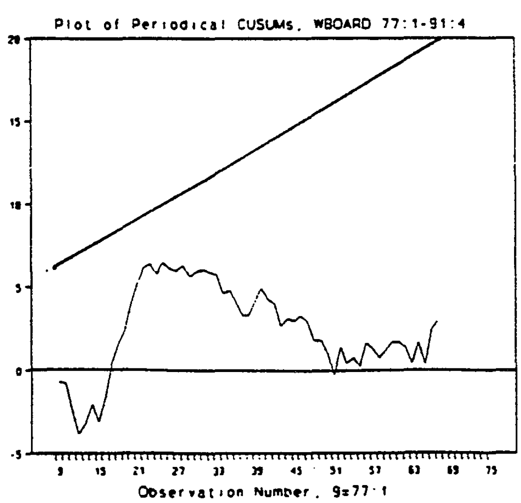


Figure 6.7

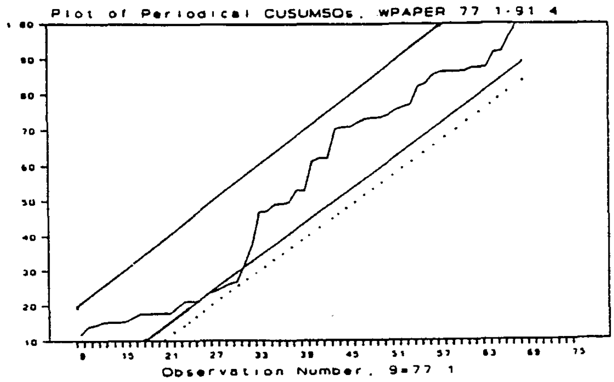
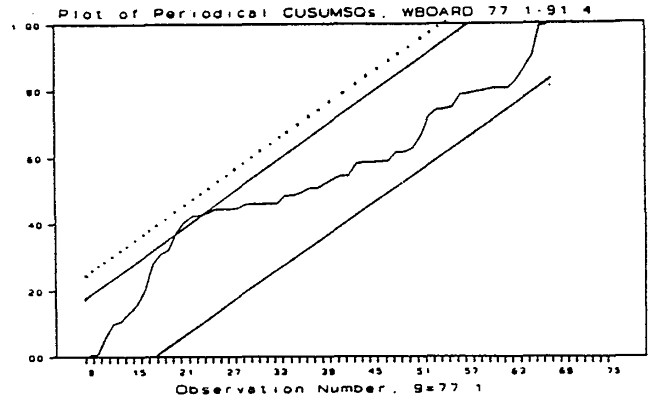


Figure 6.8



6.2.3.2 Tracing variable parameters

In order to distinguish, which parameters actually shift over time, an intercept dummy and additional interaction terms (dummy times regressor) are introduced beginning at a variety of periods indicated by Chow-and cumulative sums tests between 80:1 and 85:4. Breaks are traced in values of the constant term, exchange rate and cost pass-through coefficients, and the ECM-coefficient γ. A simultaneous inclusion of all dummies would increase the number of regressors up to 23 and 28 in equations for CCCNUS and SITCUS respectively, which would lead to an excessive loss of degrees of freedom. Therefore, lags are excluded from the model version applied here, and only changes in the impact effects are examined. Thus, the equation (6.4) with dummies incorporated takes the following form:

$$\Delta p_t = (1-\gamma)\beta_0 + D_{\beta_0} BI_t + \alpha_0^* \Delta e_t + D_e \Delta e_t BI_t + \theta_0 \Delta c_t + D_c \Delta c_t BI_t + \gamma(p_{t-1} - \bar{\alpha}^* e_{t-1} - \bar{\theta} c_{t-1}) + D_\gamma p_{t-1} BI_{t-1} + \delta \Delta y_t + \varepsilon_t, \qquad (6.8)$$

where BI_t is an indicator variable that equals 1 when t is greater or equal than that at the particular break point, and 0 otherwise. *Tables 6.7 and 6.8* report estimates of the equation (6.8) for CCCNUS and SITCUS. Note that each row represents a separate regression. Dummy estimates are added to corresponding parameters to show the coefficient values for particular subperiods. Estimation results of (6.8) for CCCNUS and SITCUS when parameter shifts are not allowed by dummy variables are also presented in *tables 6.7* and *6.8*. Significant intercept dummies and interaction terms concerning exchange rate and error correction variables were found in both equations of exports to the USA indicating lasting changes in these coefficients. In both equations dummies detecting shifts in the cost pass-through coefficients are not significant.

Table 6.7 **Equation (6.8) for CCCNUS, (Q:1976:2–1991:4)**

Excluding dummies			**Including dummies**			
Coeff.			$\beta_0 + D_{\beta 0}$	$\alpha^*_0 + D_e$	$\theta_0 + D_c$	$\gamma + D_\gamma$
β_0	−1.053	81:1	−1.404	1.056	0.771	−0.333
	(−3.76)**		(−0.59)	(2.86)**	(2.11)*	(−3.47)**
		81:2	−1.698	1.058	0.827	−0.383
			(−3.13)**	(1.96)	(1.63)	(−2.02)*
α^*_0	0.884	81:3	−1.788	1.033	0.730	−0.399
	(6.90)**		(−2.33)*	(2.58)*	(1.51)	(−2.84)**
		81:4	−1.893	1.060	0.734	−0.403
			(−4.90)**	(2.88)**	(1.62)	(−1.82)
θ_0	0.597	82:1	−1.513	1.025	0.590	−0.350
	(2.58)*		(−1.42)	(1.59)	(0.93)	(−1.56)
		82:2	−1.572	1.025	0.559	−0.347
			(−1.81)	(1.66)	(1.01)	(−2.84)**
γ	−0.420	82:3	−1.492	1.015	0.557	−0.341
	(−4.42)**		(−3.26)**	(1.73)	(0.77)	(0.20)
		82:4	−1.339	1.042	0.542	−0.336
			(−2.98)**	(2.00)*	(0.20)	(1.22)
$\bar{\alpha}^*$	−1.075	83:1	−1.338	1.023	0.599	−0.348
	(−4.28)**		(−3.06)**	(2.27)*	(0.24)	(2.24)*
		83:2	−1.158	1.057	0.622	−0.339
			(−4.02)**	(1.86)	(0.32)	(6.07)**
$\bar{\theta}$	−0.699	83:3	−0.841	1.068	0.608	−0.334
	(−3.82)**		(−0.65)	(1.29)	(0.09)	(1.57)
		83:4	−1.037	1.091	0.579	−0.412
			(−3.01)**	(1.27)	(−0.23)	(5.90)**
		84:1	−0.433	1.084	0.364	−0.267
δ	−0.325		(4.51)**	(1.04)	(−0.49)	(−3.39)**
	(−0.53)	84:2	−0.894	1.075	0.399	−0.370
			(1.19)	(1.35)	(−0.95)	(−0.10)
		84:3	−0.847	1.023	0.350	−0.352
			(2.46)*	(1.34)	(−0.98)	(−2.19)*
		84:4	−0.948	1.073	0.333	−0.324
			(−0.64)	(1.25)	(−1.06)	(1.77)
Adj.R^2	0.586	85:1	−0.821	0.914	0.209	−0.336
Ljung-Box	$\chi^2(21)$		(2.60)*	(0.56)	(−1.33)	(−2.81)**
Q*	(0.248)	85:2	−0.868	0.931	0.171	−0.318
White	$\chi^2(28)$		(1.19)	(0.49)	(−1.50)	(−1.98)
	(0.347)	85:3	−0.875	0.940	0.195	−0.321
SEE	0.0421		(1.00)	(0.74)	(−1.41)	(−2.16)*
		85:4	−0.908	0.935	0.180	−0.300
			(−1.80)	(0.82)	(−1.45)	(1.48)

Note: t-values are given in parentheses. In the right hand part of the table, t-values are those of the dummy variables.

Table 6.8 **Equation (6.8) for SITCUS, (Q:1976:2–1991:4)**

Excluding dummies			**Including dummies**			
Coeff.			$\beta_0 + D_{\beta 0}$	$\alpha^*_0 + D_e$	$\theta_0 + D_c$	$\gamma + D_\gamma$
β_0	−0.470	81:1	−0.994	0.874	0.541	−0.406
	(−2.09)*		(0.83)	(0.54)	(0.53)	(−3.98)**
		81:2	−1.086	0.899	0.568	−0.399
			(−2.29)*	(0.05)	(0.27)	(0.25)
α^*_0	0.787	81:3	−0.906	0.854	0.401	−0.411
	(4.96)**		(−0.27)	(0.59)	(0.04)	(−2.16)*
		81:4	−1.501	0.994	0.439	−0.456
			(0.93)	(1.69)	(0.51)	(−7.82)**
θ_0	0.489	82:1	−1.776	1.030	0.408	−0.471
	(1.84)		(−5.06)**	(2.31)*	(0.53)	(−1.34)
		82:2	−1.651	1.020	0.360	−0.474
			(−5.30)**	(2.55)*	(0.60)	(1.20)
γ	−0.385	82:3	−1.190	0.945	0.405	−0.429
	(−4.66)**		(−1.18)	(2.08)*	(0.16)	(−1.28)
		82:4	−1.135	1.069	0.387	−0.412
			(−3.83)**	(2.23)*	(−0.06)	(2.67)**
$\bar{\alpha}^*$	−0.653	83:1	−1.071	1.047	0.507	−0.402
	(−3.14)**		(−3.58)**	(2.64)*	(0.07)	(4.68)**
		83:2	−0.483	1.033	0.486	−0.340
			(−0.55)	(1.70)	(0.23)	(3.20)**
$\bar{\theta}$	−0.708	83:3	−0.496	1.073	0.447	−0.358
	(−4.17)**		(−1.72)	(1.84)	(0.07)	(4.25)**
		83:4	−0.499	1.101	0.424	−0.314
			(−2.11)*	(1.83)	(−0.16)	(−2.72)**
δ	0.004	84:1	−0.188	1.064	0.256	−0.370
	(0.01)		(3.19)**	(1.73)	(−0.42)	(3.82)**
		84:2	−0.496	1.090	0.307	−0.333
			(−1.32)	(1.97)	(−0.77)	(−3.01)**
		84:3	−0.286	0.994	0.228	−0.362
			(2.83)**	(1.73)	(−0.81)	(−2.60)*
		84:4	−0.434	0.941	0.250	−0.349
			(1.54)	(1.22)	(−0.91)	(−1.68)
Adj.R^2	0.408	85:1	−0.474	0.873	0.179	−0.349
Ljung-	$\chi^2(21)$		(0.56)	(1.02)	(−0.95)	(0.02)
Box Q*	(0.003)	85:2	−0.477	0.861	0.133	−0.356
White	$\chi^2(28)$		(0.38)	(0.93)	(−1.16)	(1.27)
	(0.983)	85:3	−0.499	0.859	0.134	−0.346
SEE	0.053		(−0.74)	(1.05)	(−1.20)	(0.02)
		85:4	−0.515	0.846	0.135	0.357
			(−1.56)	(0.85)	(−1.42)	(1.28)

Notes:

i) t-values are given in parentheses. In the right hand part of the table, t-values are those of dummy variables

ii) due to serial correlation, this equation was estimated with help of a general correction method, (which does not require the type of serial correlation to be known), where serial correlation is allowed up to a moving average of correlated lags.

Dummies are not able to display significant shifts in parameter values of the WPAPER equation, and for WBOARD there is clear sign of variation only in the cost pass-through coefficient during periods 82:3-83:4. Therefore, the results of running the regression (6.8) on WPAPER and WBOARD series are omitted here (refer to Vesala 1992). Considering all stability testing performed, there is no clear evidence of parameter shifts in equations concerning aggregate exports, while they are obvious in case of exports to the USA. The dummy estimates are elaborated in the next section more closely to examine hysteresis more closely.

6.3 Summary and interpretation of estimation results

6.3.1 The exchange rate and cost pass-through results

Exchange rate and cost pass-through elasticities are given by $\alpha=1-\alpha^*$ and θ in terms of f.o.b prices in importers' currencies recalling the structure and definitions of the empirical model.[43] *Table 6.9* summarizes the estimated pass-through elasticities directly from *table 6.3.*

Table 6.9 **Summary of estimated exchange rate and cost pass-through elasticities.**

	CCCNUS	SITCUS	WPAPER	WBOARD
Exchange rate pass-through				
Short term				
α_0	0.16	0.30	0.69	0.66
Long term				
$\sum\alpha_i$	0.30	0.69	----	----
Cost pass-through				
Short term				
θ_0	0.43	0.54	0.31	0.44
Long term				
$\sum\theta_i$	1.30	1.29	----	----

As noted the major part of the aggregate exports (USSR and Eastern Europe excluded), consist of exports to Western Europe. Hence, by and lagre, pass-through elasticities derived from WPAPER and WBOARD series reflect conditions in the West European market, particularly in the EC market. Incomplete EPTs in both US and European markets are obvious, since both markets are far from the "small

[43] Pass-through elasticity of Finnish production costs is the same with respect to export price in importers' currencies or in FIM. $\theta = (dp^f/p^f)/(dc/c) = (dp^fe/p^fe)/(dc/c)$, where p^f is the price in importers' currencies. In the latter formulation, which applies here as costs and export prices are given in FIM, e is regarded as constant and cancels away.

country" case where nation(s) are price takers in world markets. Lower EPT in the US market is a natural outcome in light of imperfect competition models discussed in chapter four, since in case of homogeneous goods EPT is positively related to the market share of exporting firms relative to domestic firms (see equation 3.1). The USA has far more larger domestic component in its paper markets than the Western Europe. Comparing the shares of Finnish exports in world's and Western Europe's consumption (*table 6.2*) confirms also this interpretation.

A degree of product differentiation can be considered especially in case of paper exports. In regard to monopolistic competition models, above results are not too problematic. Market share of Finnish exporters relative to export market's domestic firms and the tightness of competition increases again EPT, while monopoly power, e.g. through lower product substitutability, decreases it (see section 3.2). Printing paper exports to the USA (CCCNUS) face lower EPT than total exports to the USA, although markets shares predict the inverse. However, higher level of differentiation could explain this result. Note that EPT depends on unobservable market specific demand conditions, thus dissimilar EPTs in the two markets and for different products is natural also from this point of view. The general conclusion is that the stronger PTM in case of exports to the USA results from relative market conditions rather than from active price discrimination on part of Finnish exporters.

The stability testing shows that stability of the pass-through coefficients of aggregate export price equations can not be clearly rejected, while there are clear shifts in equations concerning exports to the USA. However, introduced dummies indicated a further decrease in the US elasticities, thus the above general conclusions need not be altered. To base forecasts on the estimation results is justified in case of aggregate exports as the historical relationship seems stable even over the devaluations. (CUSUM plot of WBOARD has a peak at 78 devaluation and WPAPER at 89 revaluation, but these peaks are far from significant.) Thus, the prediction concerning the November 1991 devaluation by 14% is that aggregate export prices of Finnish paper and paperboard products decrease by 9.7% and 9.2% in importers' currencies respectively, and rise by 4.3 % and 4.8% in FIM, leading to higher revenue irrespective of the volume response, (as long as demand is not upward sloping).

Failure to find significant lags in aggregate equations is somewhat disturbing, since they are strongly proposed by the theory. In equations of exports to the USA the estimated lag structure implies that adjustment costs, inertia, delivery, and / or contracts make the increase of the exchange rate pass-through to its long term value last a year. The volatility of the dollar has been much greater than that of the constructed currency index (see *table 6.5*), and according to Dixit (1989a) increased exchange rate uncertainty strengtens inertia. The share of the "floating component", the dollar, in the index has also decreased. Hence, higher level of associated uncertainty can explain, together with longer delivery lags, why firms respond to exchange rate movements more sluggishly in case of exports to the USA. However, significant and negative error correction terms γ in all equations display a tendency to correct export prices towards desired levels. In the general general error correction model (6.3) on which the empirical model (6.4) is based, short-run dynamics of export prices is accounted for by both the ECM and lagged variables. Higher absolute estimates of γs indicate a greater tendency toward long-run relationship in exports to the USA than to the European market. Thus, the conclusion of slower price adjustment in the US market is somewhat ambiguous.

Cost pass-through estimates show that in the short run rises in Finnish production costs, keeping the exchange rate constant, are only partially reflected to export prices. Higher cost pass-through, and long term value over unity, in the U.S. equations is surprising, since cost pass-through should depend positively on the market power of Finnish firms.

6.3.2 Evidence of hysteresis in export prices

Hysteresis should show up in the estimated equations as *persistent* shifts in the constant term and in the EPT coefficient indicating lasting changes in market conditions and export prices. Thus, detecting shifts in parameter values is a necessary condition for accepting the hysteresis hypothesis. Chow-tests show a lasting change in parameters in both US equations during the dollar rise which is well predicted by the theory. Also CUSUM and CUSUMSQ plots point in the same direction implying parameter jumps at the same time, (also at the 82 devaluation). Note also that Chow-tests do not indicate a shift during the dollar fall, and CUSUM peaks in 1986:3 are far from significant. Thus, shifts that occured during the appreciation seem to have persisted over the following period of dollar depreciation.

In case of aggregate exports evidence of parameter shifts is weak. This is not surprising, since the constructed index has been quite stable against FIM over the observation period without huge swings as in the dollar evolution (see *figures A1.1* and *A1.2*).

All in all, the results of the stability tests suggest that the dollar rise induced hysteresis in prices of Finnish exports to the USA which is reinforced by the fact that no clear shifts are observed during the dollar fall. However, the exact nature of the parameter variation needs to be examined by introducing dummies to appraise more spesific predictions of the theory. Significant intercept dummies in both equations concerning exports to the USA indicate that there has been persistent changes in the US market for paper products during the dollar rise, especially in 1982 and 1983. Following the interpretation of the constant term, either the market structure (competitive pressure), or competing firms' pricing policies have changed permanently. Note that a market structure change must imply now a rise in the number of offered varieties and / or in the trade volumes, because the price-announcement currency USD appreciates. Significant decrease in the value of the constant term in both equations *suggests* a permanent fall in profit margins (mark-ups over marginal costs), since according to the static SDS model an increase in the number of offered varieties raises the demand elasticity faced by Finnish exporters, which leads to a fall in the mark-up (see equation 3.3).

Significant and positive dummies for the EPT coefficients in CCCNUS and SITCUS equations imply a reduction in the short run pass-through in dollar terms close to zero during the first half of the dollar rise. Dixit's model (1989a) predicts pass-through close to zero when inertia applies, i.e. when the number of active firms, and output volumes do not change. Dummies beginning at later periods, (although not significant), show a slight rise in the EPT, which indicates an increase in the market power of Finnish firms caused by an expansion that was induced by a favourable exchange rate movement. (Also other than Finnish firms faced the favourable exchange rate shock and expanded). A sharp increase in the volatility of the FIM/USD rate during the dollar rise, (see *table 6.5*), can explain why Finnish exportes' pricing in dollar terms become less sensitive to exchange rate movements. It is apparent from *tables 6.7* and *6.8* that the change in the short term EPT was hysteretic, it shifted permanently to a lower level.

A rise in the volatility is predicted to cause a reduction in the speed of the error correction, (a decrease in the absolute value of γ). This is clear in case of CCCNUS, but contradictory in case of SITCUS.

Dummies are not able to display significant shifts in parameter values of the WPAPER equation. The EPT coefficient seems to have decreased (EPT increased) after the October 1982 devaluation, but the dummies indicating this shift are not significant. Similarly, but more slightly, in case of the WBOARD equation. A decrease in the cost pass-through in aggregate paperboard exports could represent an increase in competition faced by Finnish exporters. Hence, there is no evidence of hysteretic effects of exchange rate changes on the aggregate exports of paper and paperboard products.

6.4 Export volumes and direct investments

A direct method to examine effects of exchange rate changes is to compare export volumes and direct investments of the Finnish paper industry against the exchange rate development. A favourable exchange rate shock should induce direct investments to the particular market, and raise export volumes. Export volumes should remain permanently at a higher level if hysteresis applies. *Table 6.10* reports the evolution of volume indices, and *table 6.11* gives information about the yearly turnover of foreign subsidiaries of Finnish forest industry firms. The growth of the turnover serves as a proxy for foreign investments

Table 6.10 **Export volume indices of aggregate paper and paperboard exports (excluding USSR and Eastern Europe), and of total paper and printing paper exports to the USA**

Volume Indices (1980=100)	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**
WPAPER	100	100	101	114	136	142	145	159	171
WBOARD	100	107	106	118	125	125	139	155	177
SITCUS	100	72	87	180	286	262	291	370	354
CCCNUS	100	72	78	93	188	157	146	207	246

Table 6.11 **Yearly turnover of foreign subsidiaries of Finnish forest industry firms**

	1981	1982	1983	1984	1985	1986	1987	1988
Yearly turnover (milj.FIM)	4 220	5 114	5 549	6 534	7 351	7 883	9 285	10 363
Turnover growth %		21%	9%	18%	12%	7%	18%	12%
Distribution by market areas								
EFTA	1%	1%	0%	1%	1%	2%	2%	5%
EC	83%	78%	73%	72%	82%	85%	88%	84%
North-America	16%	21%	26%	27%	17%	13%	10%	10%

Source: Kinnunen (1990, p. 72–74). These figures represent for the most part the production of paper manufactures abroad.

The appreciation of the dollar led to a sharp expansion of export volumes to the USA, and induced direct investments to the North-American market as indicated by an increase in its relative share in the turnover abroad. These figures verify the conclusions made concerning hysteresis in the previous section on grounds of the estimation results. Export volumes did not react much to the downswing of the dollar, and increased further during 1987 and 1988. Thus, there is an indication of hysteresis also in export volumes. In the second half of the 1980's North America's relative share in investments decreased as Finnish firms concentrated on the EC area due to intensified integration and common market plans (Kinnunen 1990).

Volume growth in aggregate exports was far more moderate, and continued at the approximately same pace after the constructed exchange rate index started depreciating in 1985:1. Aggregate investments abroad were highest in 1984 when the exchange rates were most favourable. However, the evolution of the foreign investments has been relatively stable between 1981 and 88. Hence, the appreciation of the index from 1982:1 to 1984:4 seems not to have caused any hysteretic jumps in export volumes or foreign activities.

6.5 Concluding remarks

6.5.1 Comments on the data

Considering the data series used, the most apparent shortcoming is the unavailability of quarterly data on wood prices. Using averages of two successive semiannual observations instead of previous values as quarterly observations, could improve the performance of the model. Improvement could also be achieved by introducing seasonal dummies to account for seasonal fluctuation in wage (hourly compensation) data. These alterations would not probably change the estimation results significantly, or increase model performance, since serial correlation problem is not present in estimated equations as displayed by general Ljung-Box Q^* -tests.

In estimating EPT for aggregate exports or imports there is always the problem of constructing a plausible exchange rate index. The most commonly used weighting scheme is based on bilateral export shares.[44] This study applies, however, the shares of different currencies in export price denomination. The main reason for this strategy is the far more larger share of the dollar in price announcement than the share of the USA in Finnish paper exports. (Dollar was the most dominant invoice currency until 1984, while exports to the USA constituted less than 5% of total exports. See *tables 6.1* and *A1.1.*)

6.5.2 Remarks on the applied empirical models

Detecting instabilities in the estimated export price equatios concerning exports to the USA implies that the standard OLS model that assumes parameter stability is not an appropriate model formulation. Estimating EPT in an environment characterized by hysteresis would require a Varying Parameter Model (VPM) that allows for structural breaks in parameter values. Thus, the model applied here is able to reveal hysteresis in the US equations, but at the same time this detection implies that the original model should be replaced by VPM in order to measure EPT properly. Thus, VPM is consistent with and implied directly by the theory of hysteresis as illustrated by *figure 4.2.*

Further, VPM would be more powerful than embodied dummies in discovering parameter shifts that occur gradually throughr time due to the lagged behaviour of firms' response to exchange rate movements. Dummy variables may not even be able to locate significant shifts in parameter values that spread over a long time interval. Kim (1990, p. 310–312) estimates a VPM model for aggregate US imports, where the parameter vector is allowed to follow a random walk. He finds that a VPM outperforms a fixed parameter OLS model in all estimations as measured by RMSEs (Root Mean Squared Forecasting Errors). Thus, specifying a VPM for export prices of Finnish paper products would be an useful extension of this study.

Applying a different model version (excluding lags) in the dummy estimations for exports to the USA than in the general stability tests weakens the comparison of the results of these two procedures. To investigate whether the change in the model formulation affects the conclusions, (6.8) was estimated for CCCNUS and SITCUS with lags as in *table 6.3*, but dummies were introduced only to measure shifts in the short-run coefficients. Thus, the core of the model remained the same as in the stability tests. These estimations showed significant shifts in the constant and the error correction term in the same periods and with the same signs as in *tables 6.7 and 6.8.*

However, is was noted that if lags are allowed for the EPT coefficient they need to be allowed also for the attached dummy to detect significant shifts in the EPT. Therefore, additional estimations were carried out using the lagged model (as in *table 6.3*) with all dummies introduced, but lags only in the EPT coefficient.

[44] Aggregate EPT using trade weights are studied e.g. by Baldwin and Krugman (1987), Ohno (1988), Hooper and Mann (1989), Moffet (1989) and Kim (1990).

Significant decrease in the short-run EPT elasticity close to zero was discovered in periods 81:2, 81:3, 81:4 in CCCNUS equation, and 81:2, 81:3, 81:4, 82:2 and 82:3 in SITCUS equation. CCCNUS equation involves 21 and SITCUS equation 26 regressors, while there are 63 usable observations. Thus, caution should be exercised in interpreting these results. The model version excluding lags is preferred in dummy estimations (reported in *tables 6.7 and 6.8*), since a complete dynamization of the equation (6.8) in case of exports to the USA would consume exessively degrees of freedom. In addition, the fact that a partial dynamization leads to similar conclusions concerning parameter shifts as reported *tables 6.7* and *6.8* supports this model selection, and reinforces the conclusions of hysteretic shifts in the US equations during the dollar appreciation.

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Appendix 1: Data sources

i) Export prices

The series WPULP, WBOARD and WPAPER are retrieved from ETLA's database for years 1975-1990, and represent quarterly export unit value indices (1908=100) for industries 341 (production of pulp), 343 (cardboard), and 344 (paper products) after the Finnish industry classification. Indices are based on f.o.b. prices in FIM, derived by using Laspeyres' formula, and published by The Board of Customs of Finland (Tullihallitus). Index values for 1991 are obtained from *The Board of Custom's Foreign Trade Monthly Bulletin*, December 1991. Unit value indices for exports to the USA, i.e. SITCUS (SITC 64, paper, paperboard and articles thereof), and CCCNUS (CCCN 48.01.00.00 / HS 48.01.00.00, uncoated printing paper, mechanical pulp over 10%), are calculated from quarterly export values and volumes listed in *The Board of Custom's yearly and monthly datafiles K11–2 and K1* respectively.

ii) Exchange rates

Nominal exchange rate series, monthly averages of spot offer rates (FIM prices of USD, GBP, SEK, DEM, NOK, DKK, NLG, BEC and FRF), are supplied by *The Bank of Finland*, and are obtained from ETLA's database. The relative share of various invoice currencies are calculated from *The Board of Custom's Foreign Trade Monthly Bulletins*, 1979–1991.

Table A1.1 **Percentage shares of various currencies in Finnish paper exports, SUR excluded, 1979–1991**

	USD	GBP	SEK	DEM	NOK	DKK	NLG	BEC	FRF
-79	52.59	14.73	6.21	11.97	1.38	2.76	3.22	1.61	5.52
-80	41.22	20.87	8.98	15.72	2.38	2.64	3.04	1.45	3.70
-81	41.98	20.18	8.02	14.16	2.38	2.76	2.76	1.25	6.52
-82	35.61	23.19	8.62	14.83	2.92	3.04	3.30	1.52	6.97
-83	36.63	22.22	8.06	13.92	2.69	3.30	3.66	1.83	7.69
-84	38.89	21.87	7.21	13.12	2.48	3.07	3.90	2.01	7.45
-85	23.13	27.35	7.95	17.83	2.65	3.25	5.42	2.65	9.76
-86	19.43	26.30	8.53	20.02	2.84	3.44	6.28	2.96	10.19
-87	20.02	26.96	8.19	19.80	2.50	3.30	5.46	2.96	10.81
-88	19.15	27.77	9.07	19.37	2.13	2.80	5.71	3.02	10.97
-89	18.05	25.16	12.14	19.91	1.86	2.74	5.69	3.17	11.27
-90	16.40	24.20	10.10	22.60	2.20	3.10	6.30	3.30	11.80
-91	17.50	22.66	10.10	23.15	2.46	3.08	6.40	3.45	11.20

iii) Production costs

The serie of average hourly compensations in paper industry is obtained from yearly publications *Wages in Manufacturing Industries,* (1989–1991), and *PA,* (1975–1988), of the *Statistics Finland* (Tilastokeskus). These figures represent average income of male and female manufacturing workers per a worked hour including overtime pays, but excluding all social security compensations. Semiannual delivery prices of pine log and spruce pulpwood (FIM / m^3) are retrieved from ETLA's database for years 1981–1991. Data concerning years 1975–1980 are acquired from the *Yearbooks of Forest Statistics,* (1979, p. 131–136, 1981, p. 148–149, and 1989, p. 175), published by *The Finnish Forest Research Institute* (Metsäntutkimuslaitos). Quarterly basic price index (1980=100) of electricity, gas, heat and water for domestic supply comprises prices of "energy" entering the Finnish market, (ex works for domestically produced, and c.i.f. plus taxes for imported "energy"). The index serie is obtained from the publications *Producer Price Indices,* (1989–1991), and *TH,* (1975–1988) of the *Statistics Finland.*

The relative shares of the three production cost components (*Table A1.2.*) are calculated from input aquisition expenditures of the paper industry (code 15 / 341). This data are got from the *Industrial Statistics Volumes I* (Teollisuustilasto), *1975–1990,* of the *Statistics Finland,* as well as the shares of officials in the total wage bill. Data for 1991 is not available. Now the wage data contains wages paid to all workers in order not to give too a low weight for the labour costs.

iv) GNP data

GNP volumes for the USA and OECD Europe are retrieved from the OECD database: *Main Economic Indicators, USAMEI89/91* and *EURMEI89/91.* Quarterly data composes seasonally adjusted GNP volume indices (1980=100).

Figures A1.1–A1.5 provide a graphical description of the data.

Table A1.2. **Relative production costs (percent) of the Finnish paper industry, 1975–1990**

	Wages	Wood	Energy	Wood & Energy	Sum	Relat. shares of Wood & Energy	
-75	17.5	70.7	11.8	82.5	100	85.7	14.3
-76	18.1	69.8	12.1	81.9	100	85.2	14.8
-77	18.4	69.5	12.1	81.6	100	85.2	14.8
-78	18.3	68.9	12.8	81.7	100	84.3	15.7
-79	16.9	70.6	12.5	83.1	100	85.0	15.0
-80	17.0	68.6	14.4	83.0	100	82.7	17.3
-81	16.4	68.1	15.5	83.6	100	81.5	18.5
-82	16.8	66.5	16.7	83.2	100	79.9	20.1
-83	16.4	68.3	15.3	83.6	100	81.7	18.3
-84	15.5	69.9	14.6	84.5	100	82.7	17.3
-85	16.1	67.9	16.0	83.9	100	80.9	19.1
-86	16.2	71.6	12.2	83.8	100	85.4	14.6
-87	16.6	73.0	10.4	83.4	100	87.5	12.5
-88	19.5	70.1	10.4	80.5	100	87.1	12.9
-89	16.5	72.9	10.6	83.5	100	87.3	12.7
-90	17.9	70.3	11.8	82.1	100	85.6	14.4
Means	17.1	69.8	13.1	82.9	100	84.2	15.8

Figure A1.1.

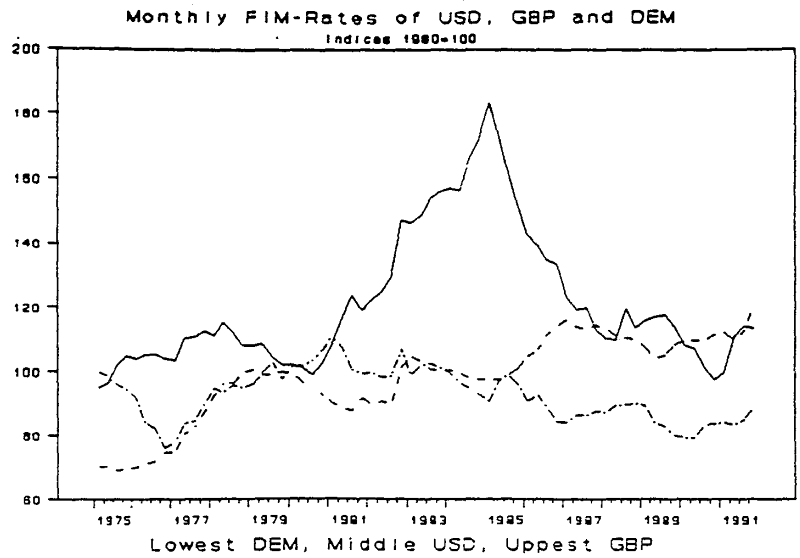


Figure A1.2.

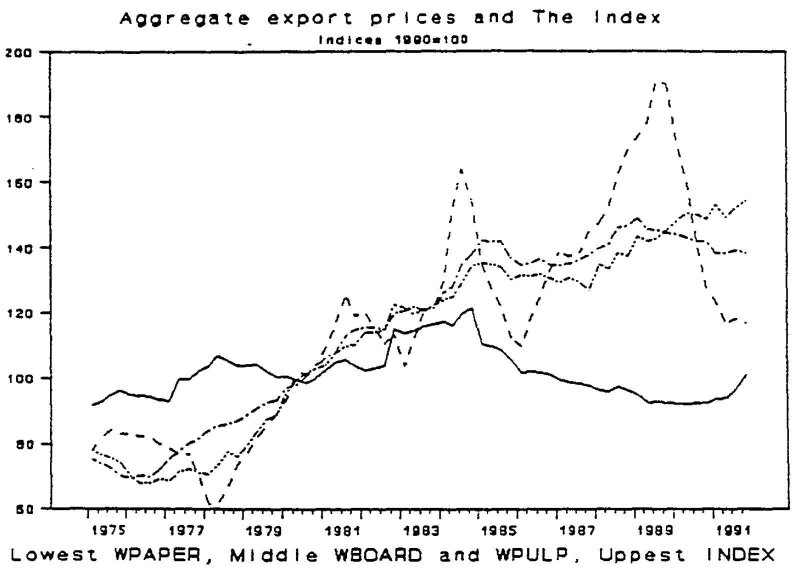


Figure A1.3.

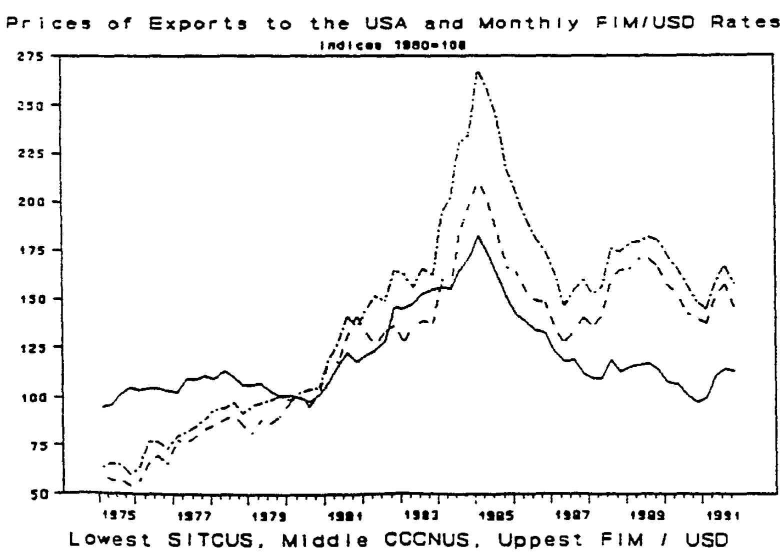


Figure A1.4.

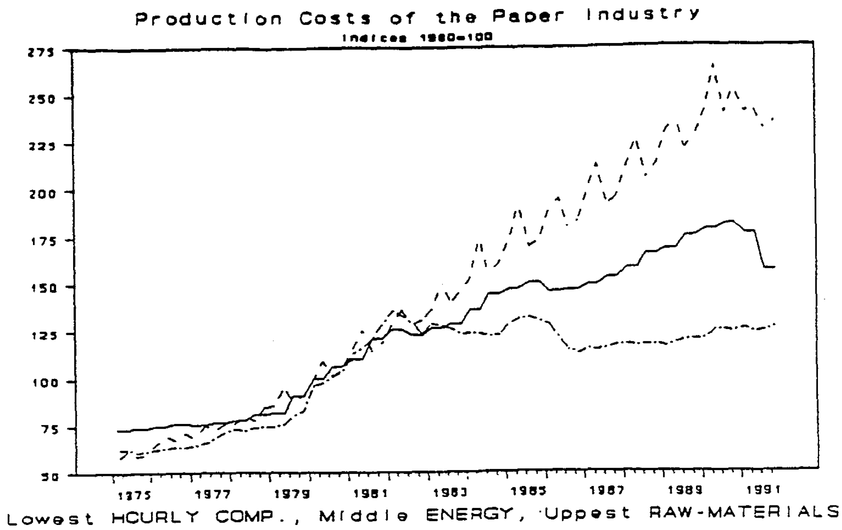
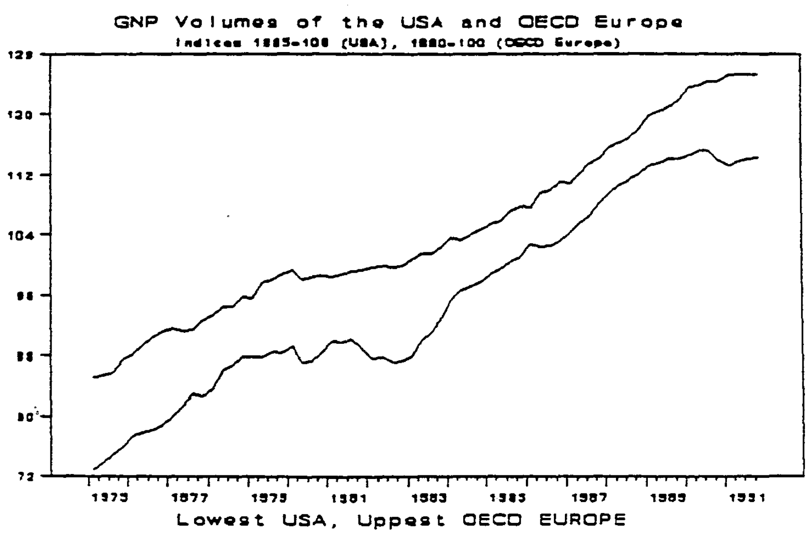


Figure A1.5.



Appendix 2:

CUSUM and CUSUMSQ-test procedures

CUSUM and CUSUMSQ tests are based on recursive residuals, which are standardized one-step ahead prediction errors of the empirical model. The rationale behind using recursive residuals is to judge the prediction performance of the model in forecasting each observation when parameter estimates are based on preceding observations. Recursive residuals w_r are given by (Brown, Durbin and Evans 1975, p. 151):

$$w_r = \frac{y_r - x'_r\hat{\beta}_{r-1}}{\sqrt{1 + x_r'(X'_{r-1}X_{r-1})^{-1}x_r}}, \quad r=k+1,...,T, \tag{A2.1}$$

where $X'_{r-1} = [x_1, ..., x_{r-1}]$, and the update estimate $\hat{\beta}_r$ is obtained from Kalman filter (Knief 1989, p. 32):

$$\hat{\beta}_r = \hat{\beta}_{r-1} + \Sigma_r X_r' r^{-1}(y_r - x_r'\hat{\beta}_{r-1}), \tag{A2.2}$$

where $\sum$ is the covariance matrix of the parameters.

Under H_0 of parameter stability, i.e. $\hat{\beta}_1 = ... = \hat{\beta}_T$ and $\sigma^2_1 = ... = \sigma^2_T$, $w_r \sim N(0,\sigma^2)$ for all r. The CUSUM quantity W_r is given by the following cumulative sum (Brown, Durbin and Evans 1975, p. 153):

$$W_r = \left(\frac{1}{\sqrt{s^2}}\right) \sum_{t=k+1}^{r} w_t, \quad r=k+1,...,T, \tag{A2.3}$$

where s^2 is the unbiased estimator for σ^2 calculated from the total sample.

Significance of the breaks is tested against a pair of straight lines through the points $\{k, \pm a\sqrt{(T-k)}\}$, $\{T, \pm 3a\sqrt{(T-k)}\}$, where a is a parameter indicating the desired level of significance, e.g. a=1.143, 0.984 and 0.850 for the 1%, 5% and 10% level of significance respectively. The hypothesis of stability is rejected if W_r crosses one of the two critical lines. The equation for the pair of critical lines is $\pm a\sqrt{(T-k)} \pm 2a(r-k)/\sqrt{(T-k)}$ (Knif 1989, p. 35). (Brown, Durbin and Evans 1975, p. 153)

The CUSUMSQ test statistics S_r uses the squares of the recursive residuals (Brown, Durbin and Evans 1975, p. 154):

$$S_r = \frac{\left(\sum_{t=k+1}^{r} w_t^2\right)}{\left(\sum_{t=k+1}^{T} w_t^2\right)}, \quad r=k+1,...T \tag{A2.4}$$

S_r increases monotonically to S_T=1. The critical lines for S_r are $\pm c_0+(r-k)/(T-k)$, where c_0 is obtained from Durbin 1969, table 1, p. 4. Note that n in Durbin's table corresponds ½(T–k)–1. For this study relevant values of c_0 are reprinted in *table A2.1*.

Table A2.1 **Critical values of c_0 for n=22, 24 and 29**

Signif. level	**n=22** k=18, T=63	**n=24** k=13, T=63	**n=29** k=7, T=67
1%	0.283	0.273	0.252
5%	0.224	0.216	0.200
10%	0.193	0.187	0.173

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