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The Pass-Through of Exchange Rate Changes to Import Prices

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Abstract

In this paper, we analyze the empirical relevance of exchange rate pass-through for Finland, Sweden and Denmark during the period 1980–1994. Further, we attemp to determine if there has been a structural change in the pass-through relationship in 1990s. We find that about half the changes in exchange rates and world prices are passed through to import prices within one year, and three-quarters of such changes are passed through to import prices in two years when a long-run pass-through of one is imposed. Moreover, there are no major differences among countries. Parameter constancy tests indicate the possibility of a structural change where the pass-through has slowed in recent years. Possible explanations of this are that the exchange rate regime has changed and competition has increased.

Key words: exchange rate pass-through, import prices, structural change

Tiivistelmä

Tutkimuksessa analysoidaan empiirisesti valuuttakurssin läpimenovaikutusta Suomen, Ruotsin ja Tanskan osalta vuosina 1980–1994. Lisäksi tutkitaan onko valuuttakurssin läpimenovaikutus muuttunut 1990-luvulla.Tutkimuksen mukaan puolet valuuttakurssien ja maailmanmarkkinahintojen muutoksista välittyy tuontihintoihin vuoden ja kolme neljäsosaa noin kahden vuoden kuluessa, kun pitkän ajan läpimenokerroin pakotettiin ykköseksi. Tutkimuksessa käytettyjen maiden välillä ei ole suuria eroja valuuttakurssin läpimenovaikutuksessa. Parametrien stabiilisuustestit osoittavat että 1990-luvulla on mahdollisesti tapahtunut rakenteellinen muutos, missä valuuttakurssin läpimenon vaikutus on hidastunut. Mahdollisia selityksiä tälle rakennemuutokselle ovat valuuttakurssiregiimin muutos ja kilpailun kiristyminen.

Asiasanat: valuuttakurssin läpimenovaikutus, tuontihinnat, rakenteellinen muutos

Contents

1 Introduction

The breakdown of the Bretton Woods system gave way to large exchange rate fluctuations with an enormous impact on trade flows. The pricing strategies and the costs of production (depending on the imported inputs) of international companies changed dramatically. This period also saw the emergence of a certain asynchronism between observed exchange rate and price movements. The large swings of the dollar in the 1980s, for example, did not have the theoretically expected effect on US import prices, domestic inflation, trade balance, or current account. One might expect that a nominal appreciation of the importing country's currency should also lead to an equivalent decrease in import prices denominated in the importing country's currency, and that the depreciation of the exchange rate should give way to an equivalent fall in import prices denominated in the importing country's currency. In fact, US import prices do not well reflect the appreciation of the dollar prior to 1985. After 1985, however, US export prices more closely follow dollar depreciation. These fluctuations cannot be explained simply as differences in productivity growth across countries.[1]

This unexplained asymmetry added exchange rate pass-through, i.e. the extent to which exchange rate movements are transferred to the import prices, to the discussion. It also made people ask whether the pricing strategies of exporting companies were relevant and how extensively they were pricing to market (PTM), as Krugman (1986) dubbed the phenomenon.

In this paper we analyze the extent to which the import prices of manufactured goods (SITC classes 5, 6, 7, 8 and 9) of three Nordic countries (Sweden, Finland and Denmark) were affected by exchange rate pass-through and PTM from 1980Q1 to 1994Q3. Further, we concentrate on the link between the exchange rate and import prices, rather than the link between import prices and domestic prices. Kuismanen (1995) has determined that the long-run exchange rate pass-through is about 0.7 for Finland; Naug and Nymoen (1996) have found that the long-run exchange rate pass-through is about 0.63 for Norway. This study extends the analysis by examining the performance of these three relatively similar countries simultaneously using a Seemingly Unrelated Regression (SUR) estimation. This estimation enables us to study all three countries together rather than estimating them separately. Further, we test whether there is a structural change in the pass-through relationship in the 1990s.

The remainder of this paper is organized as follows: section 2 discusses theoretical issues, reviews some earlier studies, and presents the model to be used in this paper. Section 3 presents the data and its sources, as well as some preliminary analysis of the data. Section 4 contains the analysis of the data by means of SUR estimation, and section 5 concludes.

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[1] Ghosh and Wolf (1994) quote the 1987 Economic Report of the US President, commenting on the slow response of the US trade balance to the dollar depreciation after 1985, as follows: "This phenomenon results from the choice of foreign producers to boost profit margins as their currencies depreciate against the dollar and to allow these margins to narrow so as to maintain market share as their currencies appreciate against the dollar. [...]".

2 Theoretical issues

2.1 The Classical versus the Keynesian view

Exchange rate pass-through refers to the relationship between the nominal exchange rate and import prices, denominated in local currency. The standard literature on price adjustment in open economies ranges between two extremes: the classical "Law of One Price" and the Keynesian model of open economies in the tradition of Meade and Mundell.[2]

The "Law of One Price" postulates an equalization of prices (adjusted for tariffs and transportation costs) in different locations by means of geographical arbitrage. The underlying assumptions such as perfect competition, full information, and homogeneity of goods indicate that this model serves as a polar case. It is related to the idea of purchasing power parity (PPP), implying a long-run identity of domestic prices of certain goods and corresponding prices abroad, converted to local currency using the exchange rate, such that

$$P_i = EP_i^* ,$$

where P_i and P_i^* are the prices of good i at home and abroad, respectively, and E is the exchange rate. As Dornbusch (1987) points out, a key notion here is that relative national price levels in a common currency are independent of the exchange rate, so the exchange rate moves only in response to divergent national price trends. The literature on exchange rate pass-through does not support this view. According to the vast majority of empirical work on this subject, the national price level is, via import prices, also influenced by the exchange rate. This effect, of course, depends, among other factors, on the size of the importing country. For example, the import market in the USA is relatively small, compared to the domestic market in the USA. On the other hand, many other countries, serving as export markets for US firms, are more dependant on international trade. In these countries national prices are expected to be more sensitive to the exchange rate movements. This might be one way to explain the above-mentioned asymmetry concerning the reaction of the US import and export prices on the large swings in the value of the dollar in the 1980s.

The opposing Keynesian view rejects the idea of full homogeneity of goods. Instead, national prices are given, based on a constant markup of prices over unit labour costs (with wages assumed to be sticky). Any change in a nominal exchange rate will then be fully reflected in the relative price of domestic and foreign goods such that

$$\lambda = P/EP^* ,$$

where P and P^* are the national GDP deflators, respectively. According to this idea, every movement of the exchange rate will have immediate real consequences. A nominal (E) and a real exchange rate ($1/\lambda$) will move perfectly in line. The

[2] See Dornbusch (1987) for a more thorough presentation of these two theories.

assumption of constant markups is of particular relevance to the following discussion, since this would imply the absence of any strategic pricing behaviour of firms.

While the "Law of One Price" implies an absence of exchange rate pass-through, the Keynesian idea postulates a one-to-one relationship between exchange rate and import prices.

2.2 Exchange rate pass-through and pricing to market (PTM)

When we speak of the "pass-through" of exchange rate changes, we have to consider the sensitivity of both producer costs and markups to changes in the exchange rate.[3]

The cost structure may vary with the exchange rate. This variation arises when the imported inputs are priced in a foreign currency, or the export demand significantly affects marginal cost. The first factor is more important when the producer and his country depend heavily on foreign inputs. The second factor is influenced by the size of the destination markets. Consider a Finnish producer who both exports into the US and buys inputs from there. An appreciation of the Finnish markka against the US dollar then has an effect of lowering his costs, and should so have a tendency to lower his export price, denominated in markka. Furthermore, assuming increasing (decreasing) returns to scale, a large enough depreciation of the markka to increase US demand for Finnish products significantly, could reduce (increase) marginal cost of the producer. This, again, should push down his export price.

On the other hand, reacting to exchange rate movements the Finnish exporter may vary his mark-up of price over cost in order to maximize profits. Assuming imperfect competition, he may be in the position to follow a strategy of price discrimination among the various destinations of his exports. In this case we face the phenomenon of pricing to market (PTM). Many studies following an industrial organization approach assume some degree of monopoly power, stemming from product differentiation, an oligopolistic market structure or similar circumstances.

Zietz (1993) lists several reasons a firm might exhibit such pricing behavior. First, the firm's willingness to adjust its profit margin (instead of its export prices) in response to changes in the exchange rate might be greater in cases where the change of the currency's value is considered to be temporary. In fact, certain empirical works on PTM and exchange rate pass-through[4] have specifically tried to separate the effects of anticipated and unanticipated changes in exchange rates. Second, large exchange rate movements may change the number of firms operating in the home market, affecting the demand elasticities faced by each of them and thus influencing their choice of a mark-up (and profit margins). Third, foreign firms might be

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[3] Technically speaking, pass-through is defined as the "elasticity of the local currency price of a foreign-produced good with respect to a change in the exchange rate between the local currency and the currency of the exporter" (Knetter (1992)). Athukorala and Menon (1994) explicitly take account of the described two-fold nature of the import price's changes for *given cost*, and their "total pass-through coefficient" combines the PTM coefficient with the effect of exchange rate changes on cost of intermediate inputs.

[4] See, e.g., Feenstra (1988), Hooper and Mann (1989), or Marston (1990).

concerned about maintaining their market share in the home market when deciding on their mark-up. Finally, existing or expected trade barriers may affect the pricing strategy of these companies. For example, Marston (1990) and Gagnon and Knetter (1990)[5] consider whether imposing voluntary export restraints (VERs) on Japanese cars exported into the US in 1981 had any effect on the PTM elasticities, i.e. whether they caused a structural change in the revealed relationships. The increased coverage of Japanese car exports into the US by the non-tariff barriers kept US import prices from falling as the dollar appreciated between 1981 and 1985. Japanese exporters also preferred to reduce their profit margins instead of raising prices any further after 1985, when the dollar weakened.

It should be emphasized here that the scope for PTM is limited by the opportunities for arbitrage between the importing countries. It is also likely that an industry characterized by relatively small companies with limited abilities to reduce their profit margins temporarily should show a smaller degree of PTM than a sector with large units. On the other side, Krugman (1986) pointed out that complete pass-through is unlikely (which is certainly true for the short run). This makes sound theoretical sense, and empirical work supports this view. Moreover, it is important to note that full pass-through does not mean a lack of PTM. In theory, a unity elasticity of the import price with respect to the exchange rate would mean complete pass-through, but we would not be able to conclude that PTM was totally absent in this case: the cost effects outlined above and the pricing behaviors of the company *both* define the linkage between the currency's value and import prices. Accordingly, zero elasticity could not be interpreted as the total absence of pass-through. For these reasons, any interpretation of pass-through coefficients is going to be somewhat vague. Thus, it may be useful to apply an approach such as the one chosen by Athukorala and Menon (1994), which defines a "PTM coefficient" that describes the direct effect of exchange rate changes on domestic-currency export prices *for given cost* as well as a "total pass-through coefficient" which additionally takes into account exchange rate effects on marginal cost.

2.3 The need for embedding dynamics

Working within a static framework would require a special effort to ignore firm expectations as to whether a movement of the exchange rate (or other influencing factors) is temporary or permanent. The assessment of factors determining their pricing behaviour would also be incomplete as a firm should be concerned about its future profits. As mentioned, there have been attempts to disentangle expected and unexpected changes in exchange rates. As Marston (1990) points out, we do not have to take care of this effect as long as firms set export prices in domestic currency, or they set export prices in foreign currency without lags in price-setting. When they preset their export prices in foreign prices, however, they only account for observed changes in factors influencing their price setting. Thus, the currency-denomination of contracts plays an important role.

Further, the firm's expectations on transitory or permanent nature of a movement in the exchange rate may be tempered in the presence of adjustment

[5] See Branson's (1989) comment on the paper by Hooper and Mann (1989).

costs[6], such that transitory changes are passed through to a lesser extent than permanent ones. Froot and Klemperer (1988) emphasize the aspect of market shares: in the case of transitory changes of exchange rate firms are willing to absorb these changes by changing their profit margins in order to maintain their current market shares (and future sales). However, if the changes are permanent, then competitive pressures will eventually force the firm towards more complete pass-through.

Further scope for dynamic modeling is provided by the phenomenon of hysteresis in import prices[7], which may occur when there are substantial differences in the pass-through behavior in response to either large or small exchange rate movements, depending on the size of fixed costs to market entry. A small appreciation of the importing country's currency would not change the number of foreign firms supplying to this market. Pass-through may then be low or even absent and could be reversed later in the case of depreciation. A large appreciation, however, might increase the number of firms on the home market. Import prices would be pushed down as a result of greater competition and the degree of pass-through would be higher. The changed market structure results in a larger pass-through coefficient in the case of smaller exchange rate movements happening later, compared with the coefficient before the market structure was changed. Further, in the case where large appreciation is reversed, all firms try to stay in the market. They are reluctant to increase import prices to the extent compared with the less competitive market structure before, resulting in a smaller degree of pass-through. Hysteresis in import prices means that asymmetry occurs: a large appreciation of the home currency which is reversed later, results in permanently lower import prices compared to the situation without exchange rate movements.

2.4 The underlying model

Many studies, like Athukorala and Menon (1994), Hooper and Mann (1989), Kuismanen (1995) or Naug and Nymoen (1996) make use of a mark-up model. It is usually assumed that a foreign firm sets the price of its exports PX^* in its own currency at a mark-up $\theta > 1$ over its marginal cost of production C^*:

$$PX^* = \theta * C^*.$$

The import price PM is then calculated using the exchange rate E:

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[6]The "menu cost" approach used, for example, by Ghosh and Wolf (1994), follows a similar idea. These costs are typically believed to consist of informational and administrative components. Informational costs capture the inconvenience imposed on customers as prices are changed. Administrative costs arise when determining and implementing new prices. Here, we ignore this more microeconomic direction, and we make no efforts to explicitly deal with transport, marketing, distribution costs, or trade barriers. However, it should be noted that all these factors may partially explain the existence of PTM.

[7] See, e.g. Hooper and Marquez (1993).

$$PM = E * PX^* = E * \theta * C^*.$$

The mark-up can be chosen by the foreign firm due to the conditions it faces on a single market. It is assumed to be determined by competitive pressure on the domestic market (proxied by the relationship between the competitors' prices P on the domestic markets and the marginal cost to the foreign firm, expressed in domestic currency) and by demand pressure (proxied by the foreign firm's rate of capacity utilization CU^*) with the elasticities a and b, respectively:

$$\theta = \left(\frac{P}{C^* * E} \right)^a * (CU^*)^b.$$

This leads to a model which describes import prices PM as a function of exchange rate, competitor prices on the domestic market, and the cost situation and a capacity utilization rate faced by the foreign firm. Both CU^* and C^* capture influences on the firm's export pricing strategy which arise in the firm's home country. Here, these and other factors which occur abroad are aggregated to a variable "world export price" PW^*, constructed as a weighted average of the export prices of the Nordic countries' main trading partners. Except for exchange rate E, the remaining variables describe the domestic situation: a variable for competitive pressure (competitor prices P), and a variable for demand pressure Y:

$$PM = f(PW^*, E, P, Y).$$

Hooper and Marquez (1993) observe that many empirical studies on exchange rate pass-through assume that prices can be determined independent of demand. This view may arise from the notion that foreign firms are perfectly competitive with constant returns to scale, thus yielding a fully elastic export supply curve. The mark-up idea at least recognizes the existence of imperfect competition, and that there is some scope for demand influence on import prices.

Of course, this is only a partial-equilibrium approach, treating variables exogenously which are not predetermined in reality. For example, as argued above, the costs to a foreign firm, hidden in PW^*, are influenced by exchange rate changes. Second, the model outlined so far is a static one, giving no room to the dynamic elements mentioned. Thus we incorporate dynamic elements when implementing the model econometrically.

3 Data

The data are gathered quarterly over the period 1980Q1–1994Q3 for three Nordic countries: Finland, Sweden, and Denmark[8]. The variables are import prices, exchange rates, world export prices, producer price indices and gross domestic product.

Due to varying statistical categorizations, acquiring comparable import price data for the different countries was difficult. The import price indices for Sweden and Denmark were taken from an OECD databank (1991=100). Missing observations in the Swedish data for the period 1993Q1–1994Q3 were then proxied by the unit value of imports taken from International Financial Statistics (November 1995, IMF). For Finland, the import price index calculated by Statistics Finland was used. Indices are defined on a customs basis and denominated in local currency. The data cover SITC classes 5, 6, 7, 8 and 9, i.e. all manufactured goods. It should be noted that the choice of sector considered for PTM study is crucial[9]. Different commodity groups yield different degrees of PTM, and an analysis of imports as a whole covers very heterogeneous goods.

The world export price of manufactures has been provided by the National Institute of Economic and Social Research (NIESR) in London and is applied within the Institute's NIGEM economic model. The time series, which is denominated in US dollars (1987 = 100) and uses a trade-weighted average of all major industrial countries,[10] is applied to the import price equations of three Nordic countries. Naturally, it would be more accurate to take into account country-specific differences, i.e. the varying degree of importance of a trading partner for Denmark, Finland and Sweden. Moreover, the use of constant weights neglects change in the trade structure over time. The world export price of manufactures is used as a proxy here for the combined effect of all domestic factors of the exporting countries on the Nordic countries' import prices such as capacity utilization, costs of production including wages and the demand situation at home.

National producer price indices (1990 = 100) are used to represent competitive pressure on Nordic markets. For Finland and Denmark the producer price index for consumer goods is used; in Sweden's case an index for manufactured goods has been applied. There are, however, missing observations in the Swedish data in the period 1980Q1–1981Q4. Therefore, the implicit price level of the GDP is used as a proxy for these observations. The data source is the OECD's Main Economic Indicators (MEI).

The nominal exchange rates, denominated in local currency/US dollar, are taken from the same source. Finally, national GDP has been included as a variable to represent economic growth. It is denominated in local currency, and used with constant prices (prices from 1980 for Sweden and Denmark, from 1990 for Finland). These series have also been taken from the OECD (MEI).

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[8] Our model does not fit Norway very well, so it is excluded.

[9] See e.g. Krugman 1986, p. 9. Krugman found PTM only in machinery and transportation equipment sector.

[10] The index covers Canada, France, the UK, the US, Italy, Spain, Japan, the Netherlands, Germany, Belgium, the EFTA countries, and the rest of the EC. These countries accounted for about 90–92% of imports to Finland, Sweden and Denmark.

All data are quarterly, spanning the period from 1980Q1 to 1994Q3. Thus, the data covers a period of significant exchange rate fluctuations, including the devaluation period of the Danish krone in the mid-1980s and the strong movements of the Swedish krona and the Finnish markka during recent years.

Figures 1 to 3 compares the development of import prices, world export prices and the national currency's value versus the dollar. In Finland's case, import prices in the mid-1980s increased due to a falling markka relative to the dollar. During this period world prices were quite stable, as can be observed for the other countries as well. From 1985 to early 1990s, world export prices show an upward trend, accompanied by very modest increases in import prices. At one extreme is Denmark, which has enjoyed relatively stable import prices since 1985. The depreciation of the dollar since 1985 is not reflected by falling import prices. It is apparent that the upward trend of the world prices is compensated to some extent by the appreciation of the Nordic currencies against the dollar. All in all, it seems that export prices and exchange rates together can to a great extent explain import price movements.

Figure 1. **Finland: Import Prices, Exchange Rate and World Export Prices**, 1987 = 100

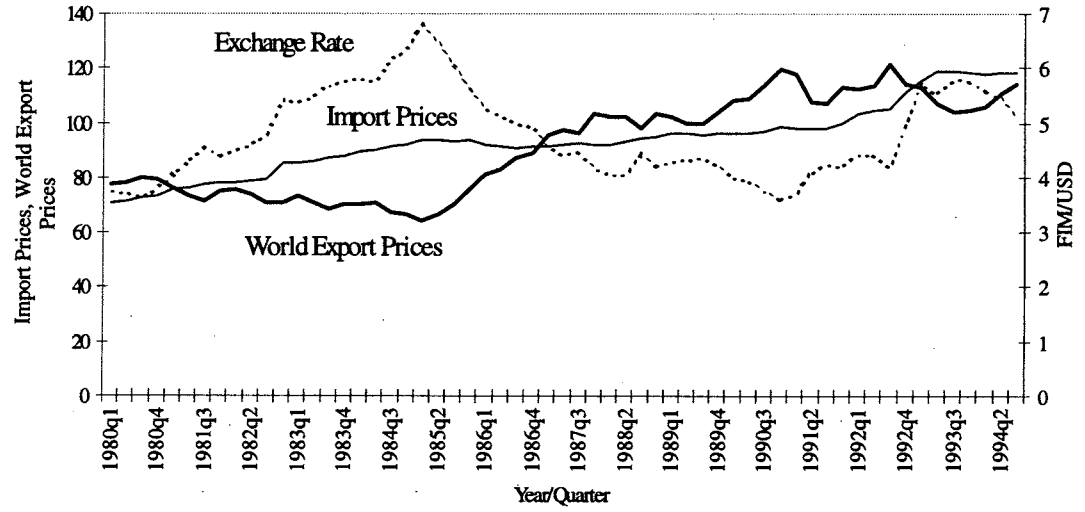


Figure 2. **Sweden: Import Prices, Exchange Rate and World Export Prices**, 1987 = 100

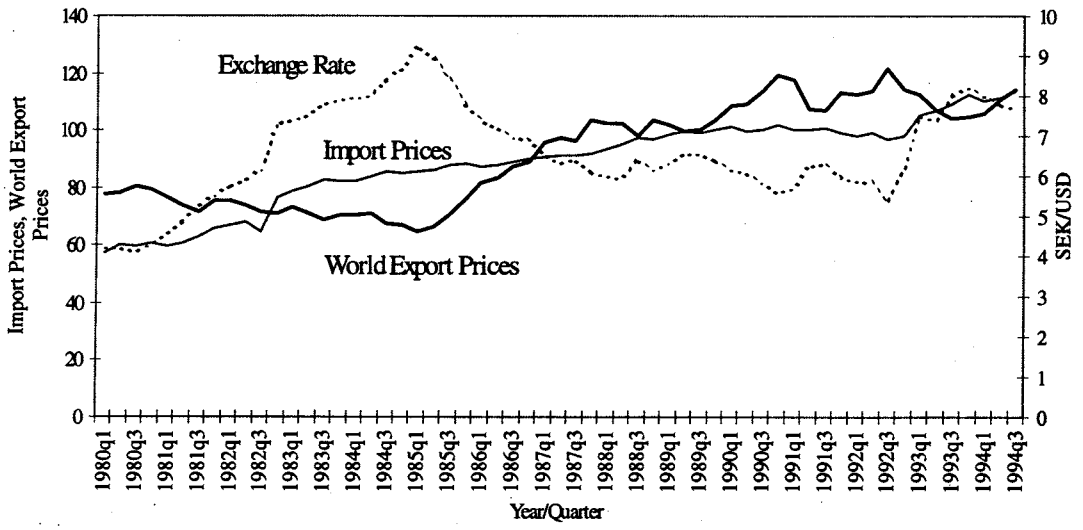
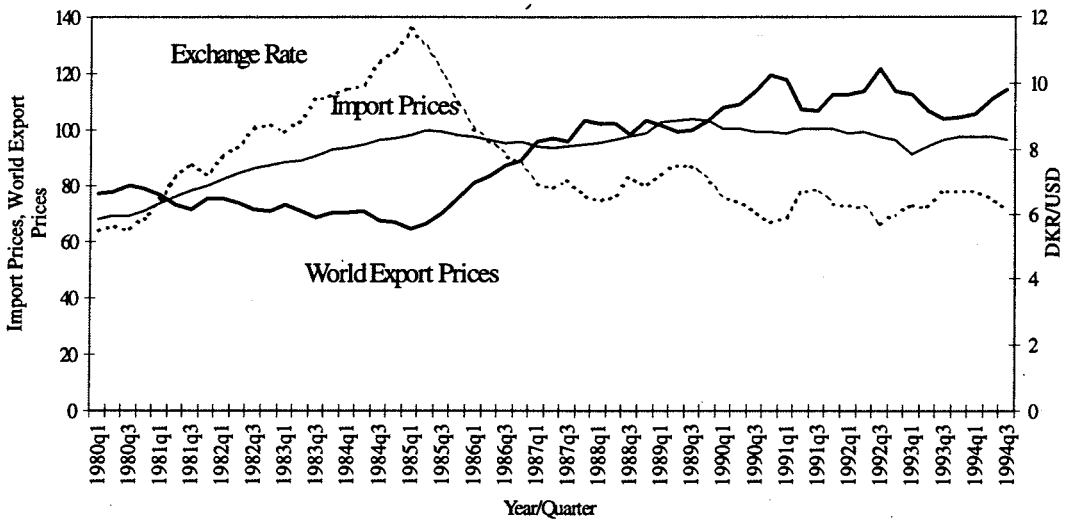


Figure 3. **Denmark: Import Prices, Exchange Rate and World Export Prices**, 1987 = 100



If there is complete pass-through of exchange rate and world export prices, then world export prices in local currency should perfectly match import prices, i.e. serve as a perfect predictor for them. Movements of any of these explanatory variables should, at least on the long run, be fully transmitted to import prices. But, as already noted, this would not mean the complete absence of PTM. Figures 4, 5 and 6 depict import prices and transformed world export prices (i.e. world export price*exchange rate / mean exchange rate in 1980Q1–1984Q3). In the Finnish case, we see that import prices closely follow the world export price level denominated in markka. We therefore would expect that the deviation of import prices in Finland since 1992, when the markka started losing value, to be only temporary in nature. Thus, Finnish importers could have chosen to wait and see whether the Finnish economy (and currency) would stabilize again or the changes were more fundamental. The same reasoning applies to Sweden as well. In Denmark's case, import prices seem to be consistently higher than world export prices in Danish krones, though deviations are small.

The stationarity of variables was tested with an augmented Dickey-Fuller -test[11]. Acknowledging the sample size is small and that the ADF test results may be somewhat inaccurate, we can still state the test results indicate that for most variables the null hypothesis (i.e. variables are non-stationary and integrated to order one[12]) cannot be rejected.

[11] 5% critical values are used. The results do not change very much when the trend component is included in the ADF-test.

[12] Integrated to order one means that the difference of a variable is stationary.

Figure 4. **Finland: Import Prices and World Export Prices in Domestic Currency**, 1987 = 100

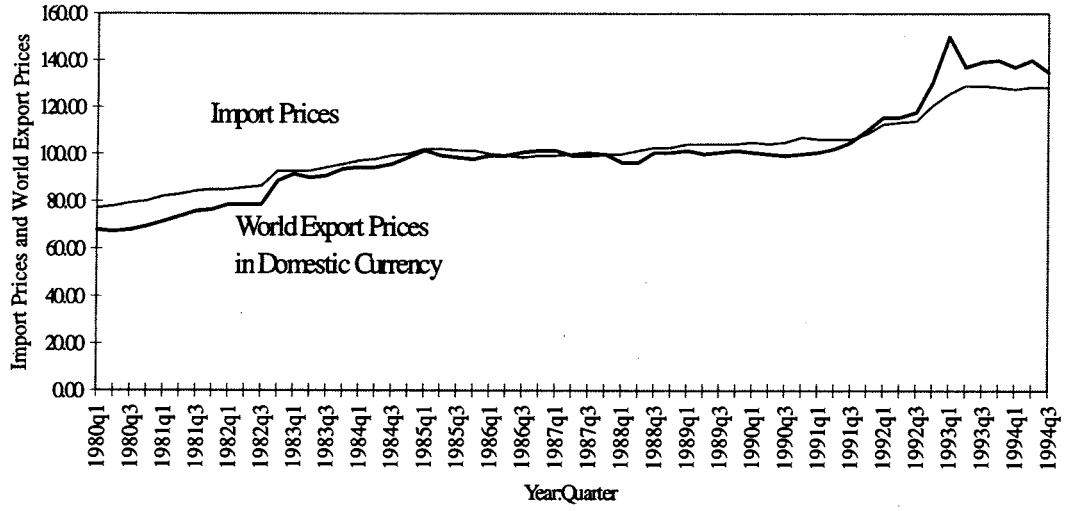


Figure 5. **Sweden: Import Prices and World Export Prices in Domestic Currency**, 1987 = 100

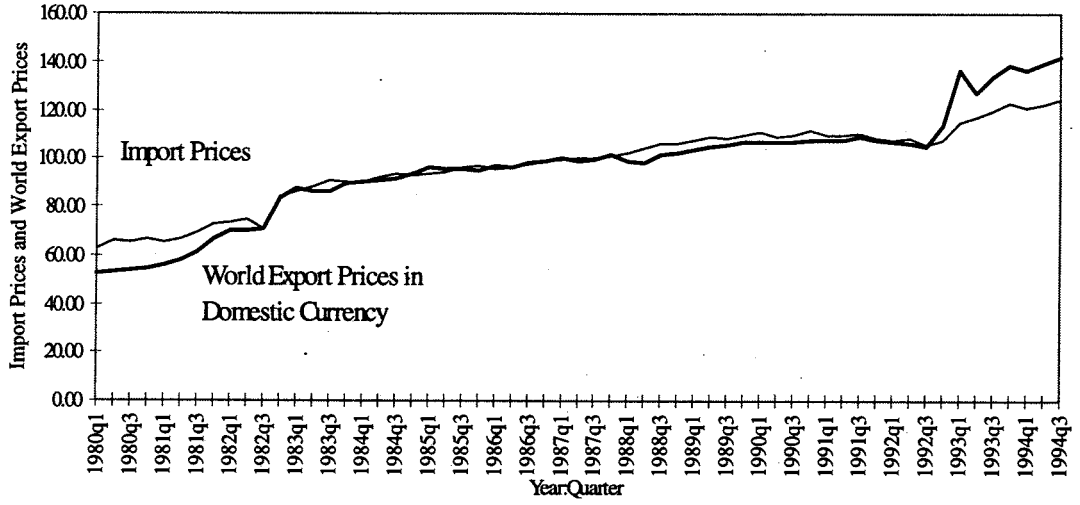
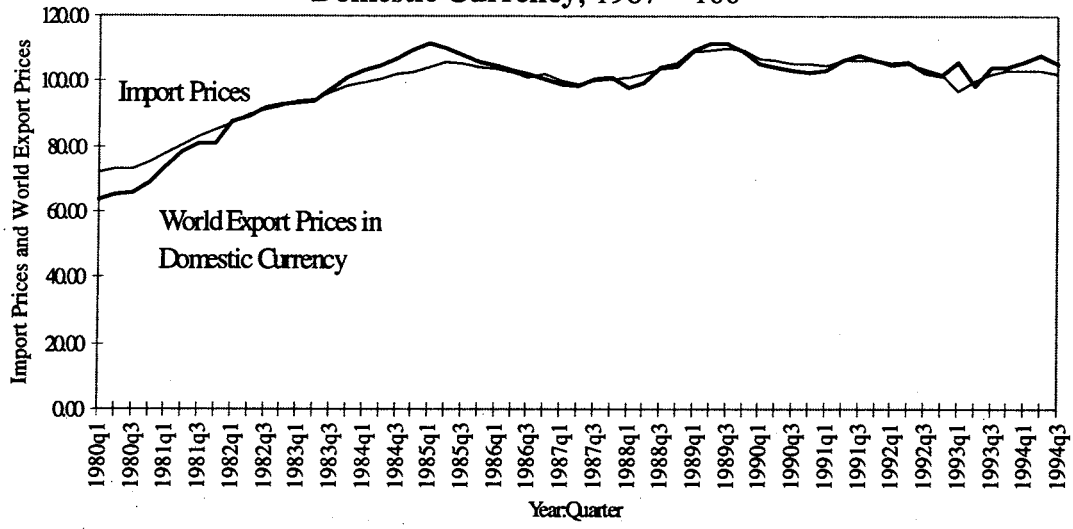


Figure 6. **Denmark: Import Prices and World Export Prices in Domestic Currency**, 1987 = 100



4 Empirical Results

4.1 Seemingly Unrelated Regression (SUR) analysis[13]

About the bias in estimators

In Monte Carlo studies, Nerlove (1971) showed that when $N \to \infty$ (the number of individuals approaches infinity) and T is small (the number of time periods) then there are small asymptotic biases in the parameter estimates of the first order autoregressive models estimated by the Ordinary Least Squares using panel data and including individual fixed effects. Maximum likelihood estimates are also biased. Nickell (1981) has shown analytically the size of this bias for an OLS estimate. Further, Arellano and Bond (1991) suggest the use of the Generalized Method of Moments estimator when such bias exists. The data analyzed here consist of only three countries (N = 3) in the estimation period 1980Q1–1994Q3 (T = 59). Therefore, the Monte Carlo evidence presented by Nerlove does not apply well as the number of individuals is so low. Further, the biases of the Least Squares Dummy Variable and Maximum Likelihood parameter estimates are approximated using Nickell's analytical estimate of bias, which is fairly small in our case. Basically, our results contain some, but not too severe, bias.

The empirical model

The theoretical model, presented in Chapter 2, is estimated in the following form:

$$\Delta pm_t = \alpha_0 + \sum_{i=1}^{4} \alpha_i \Delta pm_{t-i} + \sum_{j=0}^{4} \beta_j \Delta pw^*_{t-j} + \sum_{k=0}^{4} \gamma_k \Delta e_{t-k} + \delta_1 \Delta_4 p_t +$$
$$\delta_2 \Delta_4 y_t + \delta_3 (pm_{t-1} - pw^*_{t-1} - e_{t-1}) + \delta_4 e_{t-1} + \delta_5 pw^*_{t-1} + \delta_6 trend + \epsilon_t \ ,$$

where pm, pw*, e, p and y are natural logarithms of the import prices, world prices, exchange rates, Producer Price Index and Gross Domestic Product respectively. The quarterly change in a variable is defined as $\Delta x_t = x_t - x_{t-1}$ .The yearly change is defined as $\Delta_4 x_t = x_t - x_{t-4}$. The term in a parenthesis ($pm_{t-1} - pw_{t-1}^* - e_{t-1}$) is a relative import price. Trend refers to a time trend. Since quarterly data is employed, four lags are included to encounter for the possible seasonal effects.

Estimation with exchange rate levels and world prices

The above model was first estimated with Seemingly Unrelated Regression (iterations are allowed to converge, i.e. the estimator is the Maximum Likelihood Estimator). Second, following a general-to-specific modeling strategy, the parsimonious (lag) structure was selected by the likelihood ratio tests. The lag

[13] The model is also estimated with the least squares dummy variable estimator (Panel data estimation). However, since the results are not very different from the one presented here we show only SUR estimation results.

structure is kept the same across the countries for later comparison of SUR and panel estimation results. Third, we tested to determine if the levels of exchange rates and world prices could be restricted to zero in above model, i.e. the long-run effect would arise solely from the relative import price term.

The results indicate that the levels of the exchange rates and world prices cannot be restricted to zero when they are included in estimation. As mentioned above, the levels of exchange rates and world prices were found to be non-stationary. This non-stationarity might cause spurious regression, i.e. in a non-stationary series, spurious correlations may persist in large samples even in the absence of any connection between the underlying series (Banerjee et al, 1993). As a result, traditional t-values are no longer valid and instead much higher critical values must be used. In addition, when using the levels of exchange rates and world prices, it is possible to obtain the long-run pass-through to be significantly lower than one. However, the data covers only fourteen years and estimating the long-run coefficients from such a short period may be somewhat inaccurate. Hence, as the interpretation of the level terms is difficult in the model above, these are dropped off from further analysis. By abolishing the levels of the exchange rates and world prices from the above model, we inherently assume that the long-run pass-through effect arises solely from the relative import price term. Further, the relative import price term is assumed to be stationary and to work as an error correction mechanism in the above equation. The pass-through from the exchange rates and world prices into the import prices is assumed to be one in the long-run. Finally, the Nordic countries may be viewed as small open economies that face perfect elasticity of supply, i.e. foreigners will not adjust the foreign currency price of the import due to exchange rate changes and hence the pass-through will be one.[14]

Estimation without exchange rate levels and world prices

The model is estimated again on the condition that the level terms of the exchange rate and world prices are zero. Thus, the long-run effects of world prices and exchange rates are captured solely by the relative import price term ($pm_{t-1} - pw_{t-1}^{*} - e_{t-1}$), which imposes a pass-through of one in the long-run. The appropriate lag structure is chosen by the likelihood ratio tests. As above, the lag structure is kept the same across countries to permit later comparison of SUR estimation and panel estimation results. The results of the preferred model are presented in Table 1.

Below we list some immediate observations of the estimation results. First, the diagnostic tests applied to residuals are Normality, serial correlation (Ljung-Box) and Autoregressive Conditional Heteroscedasticity tests. Nearly all diagnostic tests were passed – only the residual of the Danish equation for which the null hypothesis of normality was rejected. The rejection of normality of the residuals of Danish equations arises mainly from high kurtosis (which may be a result of outliers). Second, it is noted that the coefficient of the yearly changes of the gross domestic product could be restricted to zero, i.e. no pressure arises from domestic demand. Third, many coefficients have insignificant t-values, e.g. the coefficient of the trend is insignificant (using the conventional 5% significance level) in the Finnish equation, but is significant in the Swedish and Danish equations. However, when we tested whether the coefficient of the trend could be restricted to be zero in all

[14] See, e.g. Dwyer and Lam, 1995.

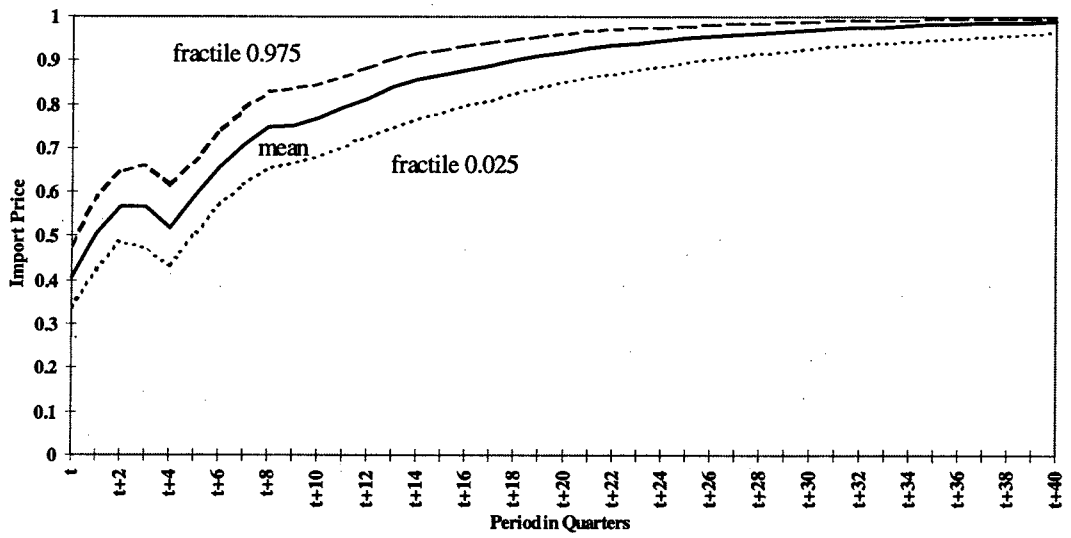
equations, this hypothesis was clearly rejected. Fourth, the model includes four lags of the dependent variable, only one lag and the contemporaneous change of world prices in period t as well as two lags and the contemporaneous change of the exchange rate in the period t. Hence, it seems that when dynamics are introduced through lags of the dependent variable, less higher order lags of other variables are needed. Finally, the coefficient of the levels of the relative import prices is highly significant and negatively signed for all countries. When the restriction is imposed that coefficients of the levels of exchange rate and world prices do not enter the model, then the coefficient of the relative import price has a higher t-value than without this restriction.

Table 1. **Results of SUR estimation**

	Finland		**Sweden**		**Denmark**	
	Parameter	t-value	Parameter	t-value	Parameter	t-value
Constant	-0.32	-5.07	-0.41	-4.57	-0.28	-2.09
Δpm_{t-1}	-0.17	-1.67	-0.33	-3.82	-0.17	-1.33
Δpm_{t-2}	-0.18	-1.86	-0.18	-2.17	-0.25	-2.05
Δpm_{t-3}	-0.15	-1.65	-0.17	-2.28	-0.18	-1.74
Δpm_{t-4}	-0.28	-3.24	-0.23	-3.60	0.06	0.65
Δpw^*_t	0.31	5.84	0.55	6.94	0.31	2.87
Δpw^*_{t-1}	0.08	1.43	0.16	1.71	0.27	2.56
Δe_t	0.40	10.75	0.54	10.37	0.36	4.51
Δe_{t-1}	0.05	1.00	0.11	1.41	0.18	2.30
Δe_{t-2}	0.05	1.90	0.04	0.74	0.16	4.61
$\Delta_4 p_t$	0.29	4.25	0.32	4.21	0.06	0.78
$pm_{t-1}-pw^*_{t-1}-e_{t-1}$	-0.21	-5.04	-0.22	-4.41	-0.15	-2.18
trend	-0.00001	-0.08	-0.0005	-2.22	-0.0003	-2.14
		Sign.lev.		Sign.lev.		Sign.lev.
LogL	519.06		519.06		519.06	
Adj. R^2	0.59		0.60		0.45	
Model test	7.38		7.54		4.58	
AR(1)	-0.0007		0.057		0.0131	
σ	0.0083		0.0161		0.0109	
skewness	0.46		-0.41		-1.19	
excess kurtosis	0.43		0.16		4.52	
Normality	2.64	0.27	1.86	0.4	17.72	0.0001
Q(1)	0.00042	0.95	0.15	0.7	0.0003	0.96
Q(5)	0.91	0.97	2.18	0.82	1.33	0.93
ARCH(1)	0.93	0.33	2.41	0.12	0.37	0.54

Above estimates are used to analyze the dynamic characteristics of the model. The level of import prices is solved to be an infinite sum of the lags of the levels of the exchange rate.[15] The cumulative lag weights are presented in Figs. 7–9. The solid line refers to a mean response while broken lines refer to 97.5% (upper) and 2.5% (lower) fractiles; i.e. 95% of the draws fall between the boundaries[16]. All charts show that in the long-run the mean exchange rate pass-through indeed converges to one as our model imposes. The upper and lower fractiles of Finland and Sweden also converge towards one in the long-run. For Denmark, the upper and lower fractiles remain stable in the long run. The long-run constraint of unity pass-through is well achieved for all countries in 40 periods, i.e. within ten years after the initial shock. There is also a visible drop in the response of import prices 3–4 quarters after the initial shock. We interpret this drop as a peculiar byproduct of our model. Alternatively, this could indicate a change in the pricing behavior within one year after the shock. Short-term responses differ somewhat across countries (see Table 2). According to the model, the mean response to a 1% rise in the foreign exchange rate (i.e. the markka depreciates by 1%) increases import prices by 0.75% in Finland in two years time. In addition, 95% of the draws fall between 0.65% – 0.83% in Finland in two years time.

Figure 7. **Cumulative response to exchange rate shock, Finland**



[15] See e.g. Greene, 1993.

[16] Distributions are simulated by Monte Carlo with 1000 draws.

Figure 8. **Cumulative response to exchange rate shock, Sweden**

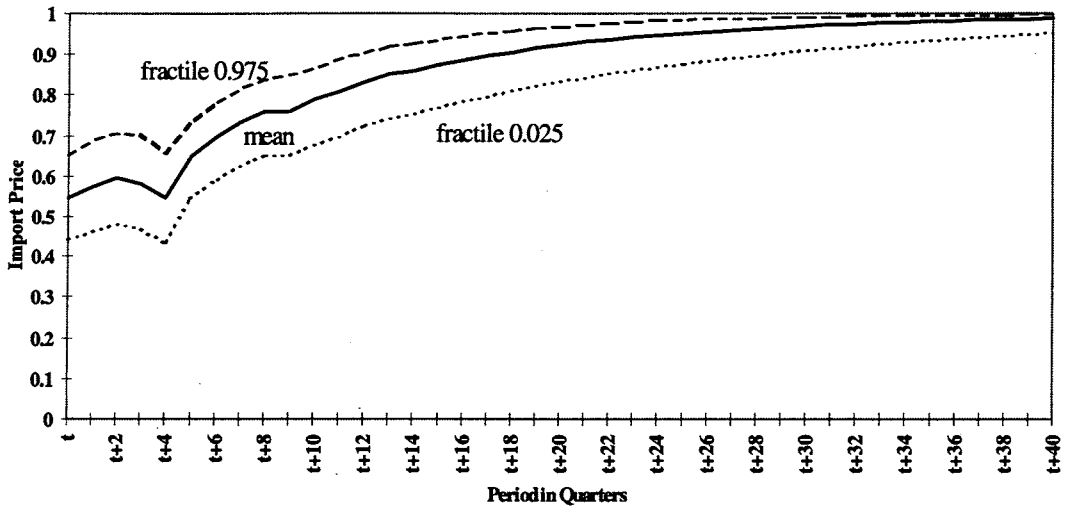


Figure 9. **Cumulative response to exchange rate shock, Denmark**

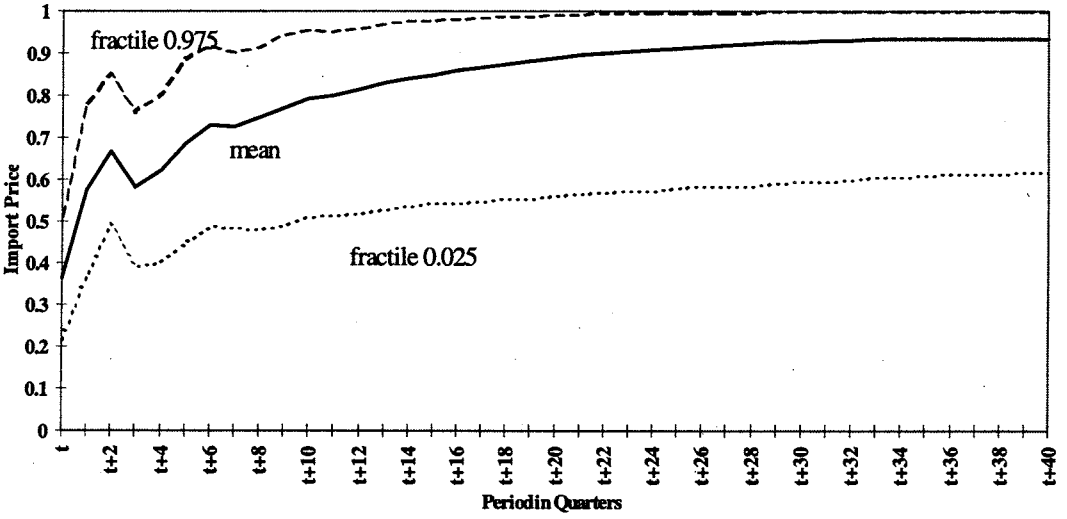


Table 2. **Adjusment of import prices to exchange rate shock in period t**

Adjustment time	Finland			Sweden			Denmark		
	mean	2.5% fractile	97.5% fractile	mean	2.5% fractile	97.5% fractile	mean	2.5% fractile	97.5% fractile
same quarter	0.41	0.34	0.48	0.55	0.44	0.65	0.36	0.21	0.51
after one quarter	0.50	0.42	0.59	0.57	0.46	0.69	0.57	0.36	0.78
after two quarters	0.57	0.49	0.65	0.60	0.48	0.71	0.67	0.49	0.85
after one year	0.52	0.43	0.61	0.54	0.44	0.66	0.62	0.40	0.80
after two years	0.75	0.65	0.83	0.76	0.65	0.84	0.75	0.48	0.91
after five years	0.92	0.85	0.96	0.92	0.83	0.97	0.89	0.56	0.99
after ten years	0.99	0.97	1.00	0.99	0.95	1.00	0.93	0.62	1.00

The effect of a world export price shock on import prices is analyzed in the same manner as the exchange rate shock. The cumulative lag weights are presented in Figures 10–12. These figures indicate that the effects of the world export price shock on import prices resemble the effect of exchange rate shock. All charts show that, in the long run, the mean world price pass-through indeed converges to one as our model imposes. Nevertheless, there are slight differences in the short term, e.g. the mean response of import prices on world export prices shock is 0.31 (in the same quarter) while it is 0.41 on exchange rate shock in the Finnish case. The mean adjustment of import prices together with the 2.5% and 97.5% fractiles on the world export price shock are presented for certain periods in Table 3. According to the model, the mean response to 1% increase in the world export price raises import prices by 0.72% in Finland in two years time. The 2.5% and 97.5% fractiles are 0.61 and 0.81 respectively for two years time.

Figure 10. **Cumulative response to world export price shock, Finland**

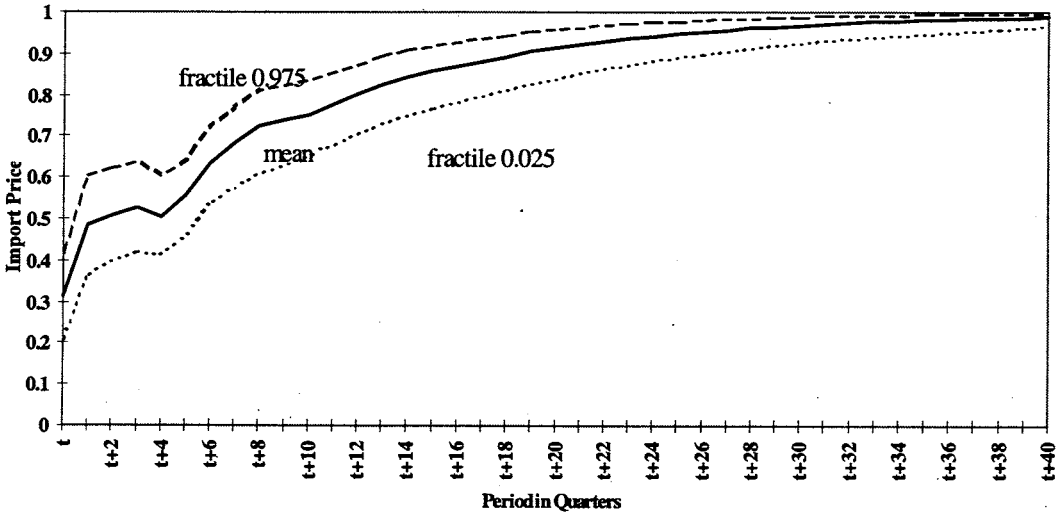


Figure 11. **Cumulative response to world export price shock, Sweden**

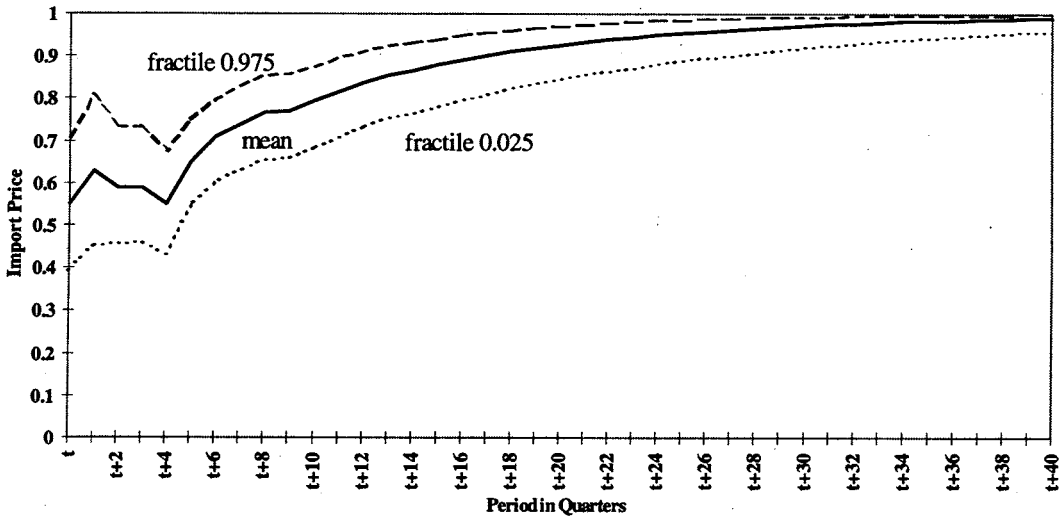


Figure 12. **Cumulative response to world export price shock, Denmark**

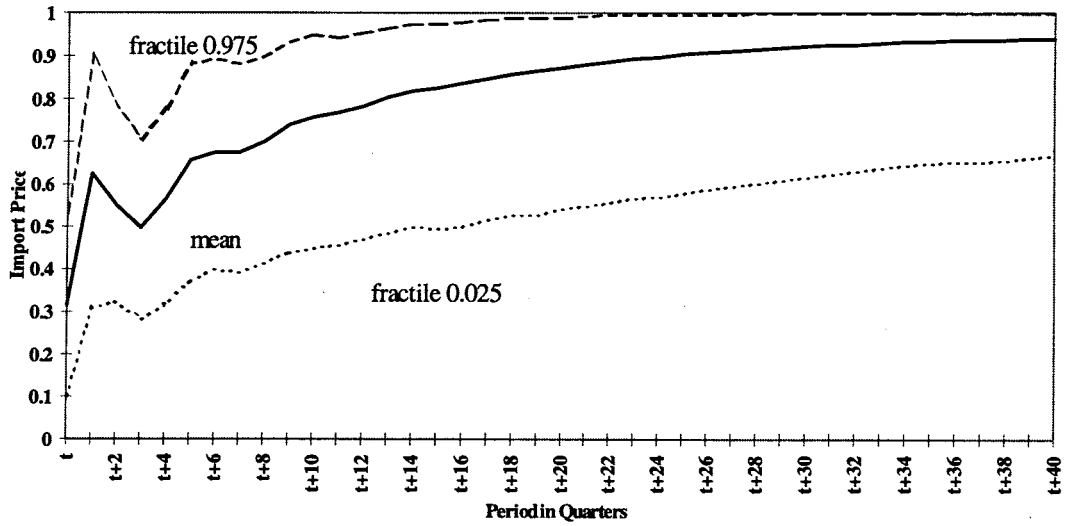


Table 3. **Adjustment of import prices to world export price shock in period t**

Adjustment time	Finland			Sweden			Denmark		
	mean	2.5% fractile	97.5% fractile	mean	2.5% fractile	97.5% fractile	mean	2.5% fractile	97.5% fractile
same quarter	0.31	0.21	0.42	0.55	0.39	0.71	0.55	0.39	0.71
after one quarter	0.48	0.36	0.60	0.63	0.46	0.80	0.63	0.46	0.80
after two quarters	0.51	0.40	0.62	0.59	0.46	0.73	0.59	0.46	0.73
after one year	0.51	0.41	0.60	0.55	0.43	0.67	0.55	0.43	0.67
after two years	0.72	0.61	0.81	0.77	0.66	0.85	0.77	0.66	0.85
after five years	0.91	0.84	0.96	0.93	0.85	0.97	0.93	0.85	0.97
after ten years	0.99	0.97	1.00	0.99	0.96	1.00	0.99	0.96	1.00

Estimation without the levels of the exchange rate and world prices and constraining equal parameters

Next, the SUR estimation, in which the coefficients of the same variables are constrained to be equal across countries (country specific constants are allowed in estimation), is analyzed. As the country specific constants are also very close each other, we estimate the dynamic characteristics of the model by using the Finnish equation. The significance of this constraint was tested by the likelihood ratio test. The null hypothesis that the coefficients of the variables are equal across countries could be rejected only marginally at the 5% risk level. The dynamic adjustment paths of the import prices to the exchange rate and world export price shocks are presented in figures 13 and 14. As before, the long-run pass-through converges to one as our model imposes. In the short term there is a clear jump in import prices in the first period after the initial shock. Thereafter, the adjustment stabilizes quite quickly and after around one year starts smoothly to approach one.

Figure 13. **Cumulative response to exchange rate shock, all countries, free constant**

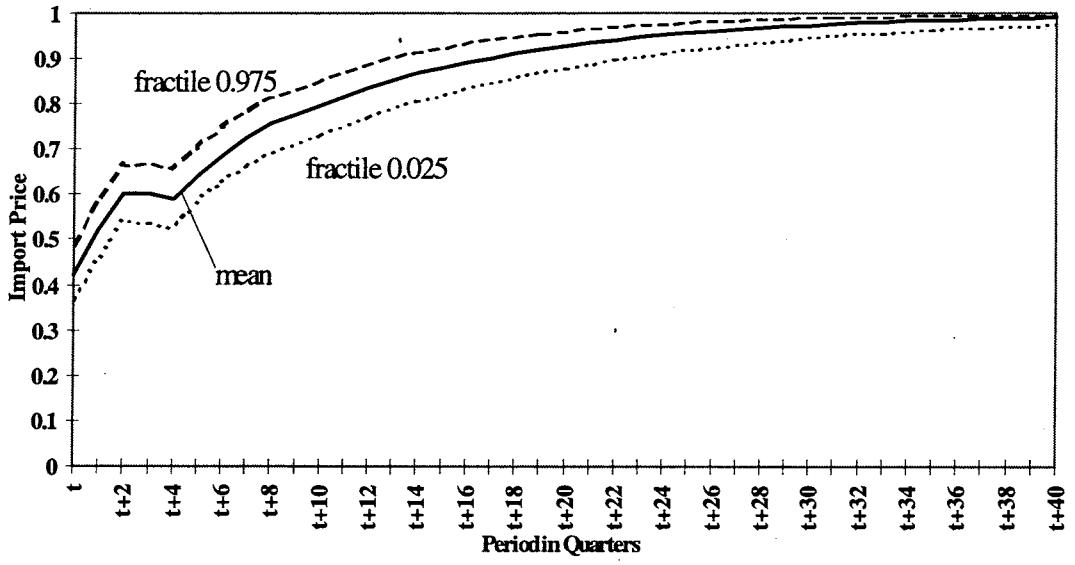
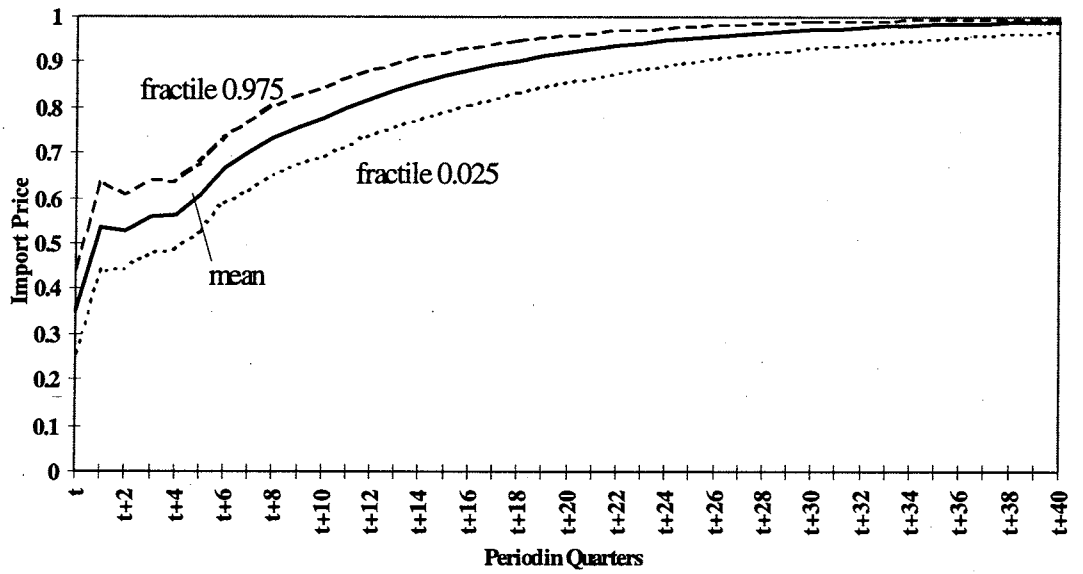


Figure 14. **Cumulative response to world export price shock, all countries, free constant**



Stability of parameter estimates with respect to change in the exchange rate regime

The exchange rate regime of Finland and Sweden changed from the fixed to floating arrangement in fall 1992. Did this change in the regime somehow change the pass-through effect after that period? To find out, we performed OLS regressions for each country using the same variable and lag structure as above in the SUR estimation. However, the model was estimated so that it produced forecasts for the period 1992Q3–1994Q3.

The 1-step parameter constancy can be tested formally with the following statistics:[17]

$$\eta=(nH)^{-1}\sum_{i=1}^{H} e_{T+i}^{'}\tilde{\Psi}_{T+i}^{-1}e_{T+i} \underset{app}{\sim} F(nH,T-k),$$

where n is the number of dependent variables, T time period, k the number of independent variables (including lagged dependent variables), H the number of forecast periods, e the vector of residuals, and Ψ a transformation of the coefficient matrix. This test statistic is appropriate for small samples, under parameter uncertainty; it does not take into account correlation between forecast errors. The results of this test are presented below.

Parameter constancy forecast test, 1-step(ex post) forecast analysis from 1992Q3 to 1994Q3:

All countries F(27,32) = 3.03[0.0015]**

According to the statistics above, the null hypothesis of parameter constancy is rejected at 1% significance level for all countries.

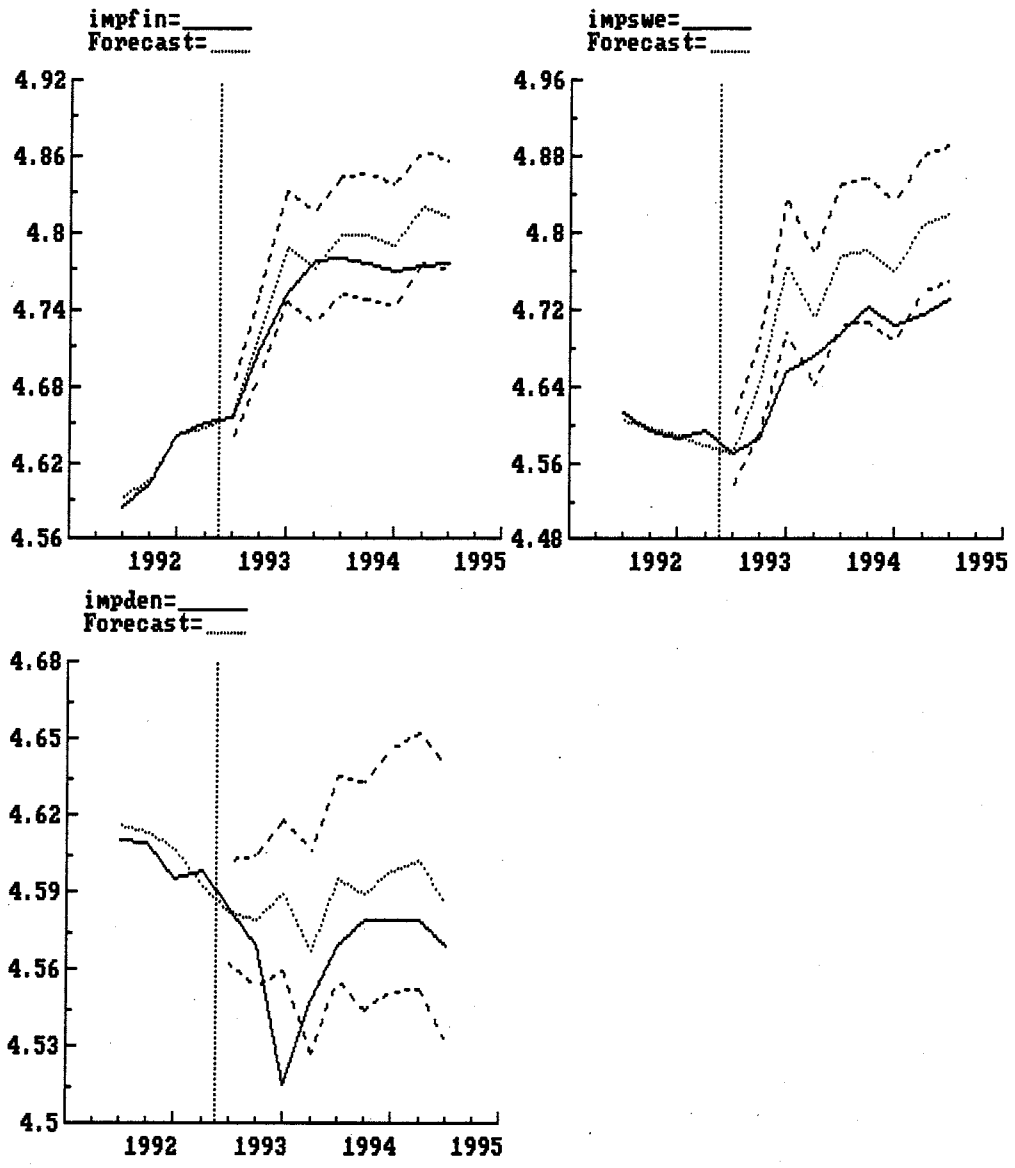
The above analysis uses 1-step forecasts. These are *ex post* forecasts for which any lagged information is based on observed values. However, the dynamic forecasts for the whole forecast period might be more appropriate in this case. These are *ex ante* forecasts and will reuse forecasts from previous periods as required. The estimated dynamic forecasts of import prices produced by the model together with the 95% confidence level and the realized values of the levels of import prices are presented in Fig. 15. The estimation is done under parameter uncertainty. In Fig. 15, impfin, impswe and impden refer to the realized levels of import prices in Finland, Sweden and Denmark. The broken lines refer to the upper and lower boundaries of the 95% confidence interval of the dynamic forecast.

Interestingly, the realized levels of the import prices are lower than the mean forecast levels for Finland, Sweden and Denmark. However, for Denmark only one observation is below the 95% confidence level. This observation may well be an outlier, although it otherwise fits well with the turmoil in the financial markets in the end of 1992. For Sweden, the realized levels fall below the 95% confidence level for five out nine cases. The dynamic forecasts for Finland are well within the 95% confidence level, except in one case.

The results show that the parameter constancy of our model is rejected when using 1-step forecasts jointly for all countries. The dynamic forecasts show that for Sweden there is a clear fall in the rate of pass-through in comparison to our model. This fall is also visible for Finland and Denmark, although the forecasts lay most of the time within the 95% confidence level.

[17] See Doornik and Hendry, 1994.

Figure 15. **Dynamic forecasts of the model and realized level of import prices**



5 Conclusions

This paper considered the extent to which import prices for the three Nordic countries: Sweden, Finland and Denmark were affected by exchange rate pass-through and pricing to market during the period 1980Q1–1994Q3. The mark-up model is employed as a point of departure. This theoretical model is estimated in a difference form. Further, we included lagged dependent variables to induce dynamics in the model. The model was analyzed with both SUR and Panel data estimation. After estimating the model, the parsimonious structure was selected using a general-to-specific modeling strategy. Our preferred model imposes a long-run pass-through of one.

The results indicate that approximately half the changes in exchange rates and world prices are passed through to import prices within one year and three-quarters of changes in exchange rates and world prices are passed through to import prices in two years. Moreover, there are no major differences among the countries. Only minor differences arise across countries through the short-term adjustment of the import prices to the exchange rate and world export price shocks e.g. the adjustment is somewhat less in Finland than in Sweden and Denmark for the first year.

The structural change in the pass-through relationship in 1990s was tested using 1-step forecasts jointly for all countries as well as dynamic forecasts for each country separately. The joint test rejects the parameter constancy of our model. The dynamic forecasts show that for Sweden there is a clear fall in the rate of pass-through in comparison to our model. This fall is also visible for Finland and Denmark although the forecasts lay most of the time within the 95% confidence level.

A possible explanation of this slowdown in the pass-through of exchange rate and world price changes to import prices could be the change in the exchange rate regime in the fall 1992. This could partly reflect the fact that while the depreciation after the change in the regime has been quite substantial for both Finland and Sweden, this depreciation may have been excessive, and therefore somewhat temporary. Another explanation for this slowdown in the pass-through may be increased competition. Further, increased competition or the threat of possible competition may have affected the pricing behavior so that the importers cut their mark-ups.

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