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## Pricing-to-market or hysteresis? An empirical investigation of German exports

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# WIRTSCHAFTSTHEORETISCHE DISKUSSIONSBEITRÄGE

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**PRICING-TO-MARKET OR  
HYSTERESIS?:  
AN EMPIRICAL INVESTIGATION  
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Emilia Penkova

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## DISCUSSION PAPERS IN ECONOMICS



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**PRICING-TO-MARKET OR HYSTERESIS ? :  
AN EMPIRICAL INVESTIGATION OF GERMAN EXPORTS<sup>1</sup>**

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**Abstract**

The paper initiates a new area of research: both concepts of hysteresis and of pricing-to-market are simultaneously investigated in relation to German exports into Belgium, France, Italy, UK, Spain and Sweden over the period 1975 to 1994 at 4-digit ISIC level. There is abundant empirical evidence that German exporters price-to-market. Part of this observed limited exchange rate pass-through, however, might be due to hysteresis as well. A dynamic panel estimation is undertaken, a new concept “pricing-to-market due to hysteresis in quantities” is introduced, and a method for capturing it is proposed. A test for measuring hysteresis in prices is also suggested. There is evidence that hysteresis and pricing-to-market deserve a better empirical modelling.

JEL classification: C23, F14.

Keywords: international trade, panel data.

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## 1. Introduction

The aim of this paper is to investigate the concepts of pricing-to-market (PTM) and of hysteresis, and more particularly, to search for ways to distinguish between them empirically in relation to German exports into Belgium, France, Italy, UK, Spain and Sweden. No previous research attempts to model the similarities and differences between the two phenomena, which explains the confusion in the literature. Giovannetti and Samiei (1995), for example, adopt a terminology where hysteresis, due to limited exchange rate pass-through, is PTM. Gagnon and Knetter (1995) claim that price differentials across destination markets for car exports (USA, Germany and Japan) are often related to exchange rate changes and that these differentials can persist for many years. Kikuchi and Sumner (2002), however, argue that the only long-run effect of exchange rate changes on export prices operate through costs, not through strategic variations in profit margins.

These and other examples raise many questions which seem to be unanswered or inadequately addressed in the literature, such as: Is PTM a long-run phenomenon? Can geographic or industry price discrimination persist in the long run? Is PTM in the long run hysteresis in prices, and if it is, how to distinguish between the two concepts in the short and the long run? By definition, hysteresis is a phenomenon associated with permanent changes which suggests that it could persist in the long run. This will however mean that the law of one price does not hold in the long run. Is this a valid claim? And finally, can PTM and hysteresis co-exist?

Although the current paper will not be able to provide answers to all these challenging questions, this first attempt will hopefully provide a basis for better modelling of both concepts. Throughout the paper we will be seeking to address the following issues. First, we will be searching for an appropriate dynamic specification of prices and exchange rates which will shed some light on the short- and long-run issues in relation to both concepts. Second, we will introduce a new term “PTM due to hysteresis

in quantities” and propose a method to capture it, and finally we will suggest a simple test for measuring hysteresis in prices.

The empirical investigation is undertaken using panel data of German exports (4-digit ISIC level) to six destination markets, these being Belgium, France, Italy, UK, Spain and Sweden over the period 1975 to 1994. German exports are modelled as there is abundant empirical evidence that German exporters price-to-market. It could however be argued that part of this observed limited exchange rate pass-through might be due to hysteresis as well. Compared to other studies, the data set is not highly disaggregated. In an attempt to improve the accuracy of the unit values (the value of exports divided by the quantity) we include quality factors, proxied by relative patents which is another innovative approach of the current paper.

The rest of the paper is organised as follows. First, the two concepts are briefly introduced by looking back at the events which initiated their empirical investigation. Second, some stylised facts about PTM in German exports are briefly presented. Third, a description of the data is provided. Fourth, we will be searching for an appropriate dynamic specification of prices which could reveal some of the differences between the two phenomena. Fifth, a new term “PTM due to hysteresis in quantities” is introduced and a method for capturing it is proposed. Sixth, a simple way to model hysteresis in prices is suggested, and finally some conclusions and outline of areas for further research are provided.

## **2. Pricing-to-Market versus Hysteresis**

As there is no previous research on which the current analysis can be based, we look back at the events which initiated the research on the two concepts to search for key features which could reveal some important insights into the two phenomena. PTM became evident in the 1980-1984 period when there was a marked appreciation of the US dollar and a failure of some foreign exporters to pass-through exchange rate changes into dollar import prices. Hysteresis in trade prices and flows, however, became evident after 1984, when the dollar depreciated and imports were not reduced as anticipated. A

significant exchange rate change just in one direction is therefore enough for PTM to be captured empirically. If, for example, there is a temporary depreciation of the US currency, foreign exporters may increase their dollar prices by less. This is because the depreciation is temporary and there is expectation of a future appreciation. Foreign firms will, therefore, find investments in market share more attractive and will prefer instead to let their profit margins decrease. The reasons behind PTM might be an expected reversed change but the PTM itself can be captured empirically when there is *only* appreciation or depreciation. On the other hand, for hysteresis to become evident, a temporary depreciation/appreciation, just in one direction is not enough, we need a depreciation/appreciation followed by appreciation/depreciation. A depreciation of the exporter's currency may for example lead to entry of new exporting firms into foreign markets which, due to high sunk costs, will not necessarily exit when there is a reversed unfavourable exchange rate change; this is when hysteresis becomes evident. Furthermore, hysteresis in quantities and PTM can occur together. For example, in the presence of hysteresis in quantity adjustment through entry or exit, there could be PTM as a firm with a longer planning horizon tends to give more emphasis to market share than on short-term profitability with price adjustment, or this is what we call "pricing-to-market due to hysteresis in quantities".

### **3. Stylised Facts about PTM in German Exports**

There are some recent empirical studies on PTM in German exports. Two major studies by Knetter (1992, 1993) investigate PTM for German exports among other countries. These two papers have established several interesting facts about the pattern of PTM behaviour. First, the evidence clearly indicates that PTM is a strategy widely adopted by German exporters. Second, PTM is only modest in consumer goods industries and relatively high in steel and chemicals. Knetter (1993) points out that this contrasts sharply with Krugman's (1987) finding, using more aggregate data, that PTM is confined to machinery and transport equipment and is absent in chemicals and basic manufactures. Furthermore, Knetter (1993) finds surprisingly little evidence of PTM in German exports of large

cars, whereas the data indicate its presence in price adjustment of exports of small cars<sup>2</sup>. He explains this puzzling result by arguing that it is possible that PTM does not exist within export markets, but does exist between export markets as a whole and the domestic market. This might also be due to the fact that German carmakers have more market power in large cars and as a consequence are better able to pass on exchange rate changes to buyers more easily than they can in small cars, where they may presumably face greater competition. Third, substantial doubt has been cast on the importance of destination market in determining the extent of local currency price stability. It also appears that industry is the critical dimension upon which future research should focus in explaining PTM behaviour. By contrast, a recent paper by Falk et al. (1997) finds that PTM varies greatly for German exporters across destination countries. It is more important in export markets such as the United States, Japan, Spain and Italy. PTM is not observable for small destination countries. However, they also confirm that PTM prevails more often in exports of relatively homogenous products, such as chemical products and fertilisers, than in machines or vehicles.

#### **4. Data**

The annual values and quantities of German exports to the selected destination countries: Belgium, France, Italy, UK, Spain and Sweden over the period 1975 to 1994, have been supplied by the OECD on an SITC rev2 basis, and then converted to ISIC to obtain data at the 4-digit (ISIC) industry level<sup>3</sup>. The values are net of transportation, insurance and tariffs which makes them a good basis for investigation of PTM.

The choice of the data set and the annual frequency are determined by availability. The data are not at finely disaggregate level such as 7 or 8– digit but patents are also included in the estimation, which will account for the effect of quality changes on export unit values. The original patent data were from

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<sup>2</sup> Krugman's (1987) original work on PTM was motivated in part by common currency price differentials in European luxury cars in the mid 1980's.

<sup>3</sup> Refer to Table 6 for description of the manufacturing industries at 4-digit level.

the US Patent and Trademark Office then converted from the US patent classification system to the ISIC system, and they are at 3-digit level.

The exchange rate series used as an independent variable is expressed in units of the buyer's currency per unit of the exporter's and is based on the annual average nominal exchange rate published in International Financial Statistics. The nominal rate is adjusted by dividing by the Wholesale Price Index in the destination market. The reason for this adjustment is that the optimal export price should be neutral with respect to inflation in the destination market. The Wholesale Price Indices are annual averages taken from International Financial Statistics.

### **5. Dynamic Modelling of Pricing-to-Market**

In this section we shall be searching for the appropriate dynamic specification of export prices which will help us to improve the empirical modelling of the two phenomena. We shall estimate equilibrium-correction models of PTM by following Gagnon and Knetter (1995), who consider the possibilities that PTM exists in both the short and the long run. The innovative element of our empirical approach is the inclusion of quality factors proxied by relative patents, and estimation of long-run PTM coefficients not only across destination markets but also at industry level.

In searching for the appropriate dynamic specification of export prices we first estimate equation (1) in levels for each industry at 4-digit level for all selected destination markets (Belgium, France, Italy, UK, Spain and Sweden):

$$\ln p_{it} = \alpha_i + \delta_i D_t + \beta_i \ln e_{it} + \mu_i \ln RPAT_{it} + u_{it} \quad (1)$$



where  $u_{it}$  is the residual error term in equation  $i$  ( $i=1..6$ ) during period  $t$  ( $t=1975-1994$ ),  $D_t$  is a time dummy variable which replaces the unobservable marginal cost, and  $RPAT$  is defined as German patents relative to country  $i$ 's patents<sup>4</sup>.

An intercept term,  $\alpha_i$  is also included to control for factors that are constant over time but differ by country<sup>5</sup>. This term also captures differences in the average mark-ups to different markets that do not vary with exchange rate changes. Since we use annual data, price adjustment lags (which are usually found to be high frequency phenomena) are ignored.

Given the short sample (the time period consists of twenty years), we cannot determine with confidence the time-series properties of the variables we estimate. In searching for the appropriate dynamic specification of the model we calculate the mean, the standard deviation, the maximum and the minimum value of export unit values by sector and destination country<sup>6</sup>. The results reveal high volatility in German export unit values. The evidence suggests that all series could be non-stationary, quite possibly integrated processes of order one<sup>7</sup>.

When dealing with non-stationary variables it is important to consider the time-series properties of the residuals in the estimated equation. There are two possibilities. First, the residuals are transitory (or stationary) and arise from adjustment lags, measurement error, or temporary shifts in the composition of exports. Second, the residuals are permanent (or non-stationary) and arise from lasting changes in consumer tastes, market structures, or the composition of exports. Given the low power of tests for unit roots we cannot be certain if the residuals are stationary or non-stationary. Hence, we proceed by estimating equations (1) both in levels and in first differences. The levels regressions are equivalent to

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<sup>4</sup> The sign of the estimated coefficient  $\mu_i$  could be either negative or positive.

<sup>5</sup> This term was included for five destinations or it had to be dropped from one equation due to the inclusion of complete set of time dummies.

<sup>6</sup> All of the results are available from the author upon request.

<sup>7</sup> Previous studies by Knetter (1993), Gagnon and Knetter (1995) and Gil-Pareja (2000) also maintain the hypothesis that the time series of export unit values and exchange rates are processes integrated of order one.

estimating a long-run co-integrating relationship between export unit values, the time dummy variables, exchange rates and relative patents. On average the Durbin-Watson statistics provided substantial evidence of dynamic behaviour in the levels regression but not for the regression in first differences. The evidence of dynamic behaviour in the levels regressions suggests that we should proceed by estimating equilibrium-correction models of PTM and we employ the Engle-Yoo three-stage procedure. This is an estimation technique which deals with non-stationary series and allows to obtain more efficient estimates and asymptotically normal standard errors on the long-run PTM coefficients. This procedure is also recommended in this particular case because the inclusion of time dummy variables in every period precludes simultaneous estimation of the co-integrating vector (equation 1) and the error-correction model (equation 2 below). The third stage of the Engle-Yoo three stage procedure provides a solution to this problem (equation 3 below).

After careful examination of the diagnostic tests from the first-stage regression we proceeded to the second stage which includes estimating an equilibrium-correction model only for the industries for which the R-squared revealed a good fit of the estimation, and the Durbin-Watson statistics showed that dynamic adjustment is important but not that low to invalidate the assumption that equations (1) express a co-integrating relationship<sup>8</sup>:

$$\Delta \ln p_{it} = \gamma_{i0} + \gamma_{i1} \Delta \ln p_{it-1} + \gamma_{i2} \Delta \ln e_{it} + \gamma_{i3} \ln RPAT_{it} + (1 - \gamma_{i2} - \gamma_{i3})(\hat{\delta}_i - \hat{\delta}_{i,t-1}) - \gamma_{i4} \hat{u}_{it-1} + \varepsilon_{it} \quad (2)$$

The equation is estimated using  $\delta$  and  $u$  from the first-stage estimates of equations (1), where  $\hat{\delta}$  is the estimated coefficient vector,  $\delta$ , converted into time series. In most cases,  $\gamma_{i0}$  and  $\gamma_{i1}$  are small and not significantly different from zero, so they are constrained to zero for every source and destination and in this way conserve degrees of freedom.

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<sup>8</sup> Equation (2) was estimated for fifty out of seventy seven industries.

The third stage regresses the residuals from equation (2) on the lagged values of the independent variables in equations (1):

$$\hat{\varepsilon}_{it} = \lambda_i + \varphi_i D_{i-t} + \eta_i \ln e_{i-t} + \zeta_i \ln RPAT_{it} + \nu_{it}, \quad t=2 \dots T, i=1 \dots 6 \quad (3)$$

The final estimates of long-run PTM are given by:

$$\tilde{\beta}_i = \hat{\beta}_i + \hat{\gamma}_i \hat{\eta}_i$$

where the standard error on  $\tilde{\beta}$  is the estimated standard error on  $\eta$  from the third stage regression. In this way we estimate the long-run PTM coefficients for each 4-digit industry and each destination market<sup>9</sup>. By employing Wald-tests, based on the covariance matrix of the third-stage coefficient, we test if these coefficients diverge across destinations. The interesting result is the marked similarity of the estimated values of the long-run coefficients of PTM across destinations ( $\tilde{\beta}$ ). For almost all industries the Wald-test, based on the covariance matrix of the third-stage coefficient estimates, cannot reject that  $\tilde{\beta}$  is identical across all destinations (only six out of fifty industries). Table 1 provides information on the exceptions<sup>10</sup>.

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<sup>9</sup> Insignificant dummy variables are dropped from the estimated equations to conserve degrees of freedom.

<sup>10</sup> The results for all of the industries are available from the author upon request.

Table 1: Industries for which the Wald Test Rejects the Null Hypothesis of Similar Long-Run PTM Coefficients across Destinations

Industry Code	3122	3213	3214	3312	3319	3511
Destination						
Belgium	-0.41* (0.06)	-0.58* (0.14)	-	-	-	-0.45* (0.23)
France	-0.33* (0.16)	-0.48 (0.51)	-0.40 (0.33)	-0.50 (0.32)	-0.42 (0.22)	-0.47* (0.13)
Italy	-0.41* (0.09)	-0.58* (0.07)	-0.44* (0.11)	-0.59* (0.12)	-0.39* (0.08)	-0.47* (0.05)
UK	-0.37* (0.06)	-0.57 (0.43)	-0.19 (0.51)	-	-0.48 (0.61)	-0.47* (0.09)
Spain	-0.35* (0.12)	-0.59* (0.21)	-0.45 (0.24)	-0.61 (0.34)	-0.40* (0.17)	-0.45* (0.16)
Sweden	-0.15 (0.31)	-0.57* (0.17)	-0.51* (0.25)	-	-	-0.45* (0.13)
Wald Test						
[P-value]	[.002]	[.009]	[.029]	[.001]	[.020]	[.018]

Note: Standard errors are in parentheses  
\* significant at 5% level.

There is a strong price discrimination across destinations in industry 3213 (fabrics and articles). The estimated average coefficient is - 0.57, with the highest coefficient for Spain (-0.59). The implications are that for example a 10 per cent appreciation of the Deutsche mark (DM), all else constant, would elicit a 5.9 per cent reduction in the price charged to Spanish buyers, or the peso price would rise by only 4.1 percent. There is also a marked price discrimination for industry 3511 (basic industrial chemicals) where all of the coefficients are correctly signed and significant.

As in most cases the estimates cannot reject that  $\tilde{\beta}$  is identical across all destinations, we continue the estimation and impose the same coefficients across destinations (except for the industries for which there is PTM across destinations), which enables us to test if PTM can persist in the long run as an industry phenomenon. The results, which are summarised in Table 2, show convincing evidence for PTM in the industries below. The coefficients vary significantly in magnitude: the most pervasive long-run PTM coefficient is for industry 3111- meat products (-3.02), followed by 3540 - petroleum and coal (-1.29), 3212 - textile goods (-1.01), and then 3842- railway and tramway locomotives (-0.87). The smallest ones are for 3710-iron and steels, 3720-non-ferrous metals and 3813-structural metal products (-0.24 on average).

Table 2 : Industries for which the Long-Run PTM Coefficients are Significant at 5 % level

Industry	Long-run PTM	Industry	Long-run PTM	Industry	Long-run PTM	Industry	Long-run PTM
3111	-3.02 (0.24)	3215	-0.83 (0.12)	3540	-1.29 (0.16)	3821	-0.65 (0.07)
3112	-0.48 (0.11)	3219	-0.80 (0.06)	3551	-0.55 (0.05)	3823	-0.68 (0.05)
3113	-0.54 (0.08)	3232	-0.75 (0.17)	3610	-0.64 (0.07)	3825	-0.78 (0.04)
3115	-0.33 (0.08)	3320	-0.75 (0.04)	3691	-0.49 (0.07)	3829	-0.65 (0.07)
3116	-0.80 (0.07)	3411	-0.38 (0.05)	3692	-0.38 (0.07)	3831	-0.63 (0.03)
3117	-0.32 (0.05)	3419	0.32 (0.15)	3699	0.46 (0.04)	3842	-0.87 (0.13)
3119	-0.46 (0.05)	3420	-0.47 (0.05)	3710	-0.26 (0.04)	3843	-0.56 (0.05)
3131	-0.66 (0.14)	3512	-0.68 (0.16)	3720	-0.22 (0.05)	3852	-0.81 (0.09)
3133	-0.30 (0.12)	3513	-0.34 (0.03)	3811	-0.66 (0.06)	3901	-0.85 (0.13)
3211	-0.59 (0.04)	3523	-0.59 (0.03)	3812	-0.61 (0.04)	3903	-0.42 (0.05)
3212	-1.01 (0.05)	3530	-0.86 (0.12)	3813	-0.23 (0.05)		

Note: Standard errors are in parentheses  
\* significant at 5% level

It is interesting to note that there is only one positive and significant PTM coefficient for industry 3419– pulp and paper articles (0.32). This implies that the mark-up adjustment associated with exchange rate changes amplifies movements in foreign currency prices. In particular, the estimate of  $\tilde{\beta}$  implies that all else being equal, a 10 per cent depreciation of foreign currency leads to a 3.2 percent increase in DM price charged to foreign buyers. Thus, the foreign price rises by 13.2 percent. This “perverse” PTM can be due to measurement error which might bias  $\tilde{\beta}$  upward. If market share matters and much of the movement in exchange rates is temporary then in the context of Froot and Klemperer (1989) model interest rate effects dominate cost effects and we may observe positive  $\tilde{\beta}$ ’s. It may also be due to heterogeneity either within the sector or within the market of consumers. For example, when an exchange rate movement causes an exporter to raise prices, he may lose sales to his

most price-elastic consumers first, or, he may lose sales of products that face the highest price elasticity of demand<sup>11</sup>.

The results for short-run PTM are quite disappointing. There is only one industry (3829-machinery and equipment) for which the short-run coefficient  $-0.59^*$  (0.12) is significant at 5% level. A possible explanation could be related to the invoicing issues. If the invoicing is in the exporter's currency, infrequent price adjustment leads to a bias against finding PTM in the short run. Further support for this speculation is provided by Page (1981), who claims that German exporters have used the DM for over 82 per cent of all exports. Most of the estimated equilibrium correction coefficients ( $\gamma_{i4}$ ) are correctly signed and significant and they lend support to the maintained hypothesis of a stable long-run co-integrating relationship in the estimated equations 1- 3. Finally, the inclusion of the relative patents as a quality proxy in the estimation is quite promising. In most cases the estimated coefficients are highly significant which is shown in Table 3 below.

Table 3 : Industries for which the RPAT Coefficients are Significant at 5 % level

Industry	RPAT	Industry	RPAT	Industry	RPAT	Industry	RPAT
3113	-0.08 (0.04)	3231	-0.22 (0.10)	3521	-0.75 (0.19)	3813	-0.69 (0.32)
3119	-0.15 (0.05)	3233	-0.52 (0.13)	3522	-0.66 (0.27)	3819	-0.41 (0.13)
3121	-0.19 (0.08)	3240	-0.56 (0.13)	3523	-0.28 (0.08)	3822	-0.40 (0.14)
3133	-0.24 (0.08)	3311	-0.38 (0.11)	3530	-0.50 (0.11)	3823	-0.46 (0.17)
3140	-0.40 (0.13)	3312	-0.61 (0.17)	3540	-0.26 (0.13)	3824	-0.22 (0.14)
3211	-0.24 (0.05)	3319	-0.56 (0.16)	3551	-0.88 (0.34)	3831	-0.52 (0.13)
3212	-0.35 (0.10)	3320	-0.41 (0.13)	3559	-0.72 (0.21)	3842	0.18 (0.06)
3213	-0.23 (0.10)	3411	-0.45 (0.13)	3560	-1.75 (0.49)	3843	0.22 (0.07)
3214	-0.38 (0.10)	3419	1.05 (0.38)	3620	0.27 (0.13)	3903	-0.47 (0.16)
3219	-0.43 (0.09)	3511	-0.47 (0.09)	3710	0.11 (0.06)	3909	-0.67 (0.34)
3220	-0.63 (0.29)	3512	-1.44 (0.36)	3811	-0.45 (0.19)		

Note: Standard errors are in parentheses

<sup>11</sup> In the case of "normal" PTM the price elasticity of demand increases with the price charged.

In ninety one percent of the cases the significant coefficients of relative patents are negative which suggests that the better relative quality of the German produced goods leads to a lower export price in German currency in the long run<sup>12</sup>.

## **6. Pricing-to-Market due to Hysteresis in Quantities**

In this section we will introduce a new term “pricing-to-market due to hysteresis in quantities” which may account for part of the observed limited exchange pass-through in the long run detected in the previous section.

To capture PTM due to hysteresis in quantities, we consider two main different scenarios and estimate equation (4) below. In the first scenario we model PTM due to hysteresis caused by “continuous“ or long enough depreciation (defined as at least two years of continuing depreciation) of the exporter’s currency followed by a period of appreciation of the exporter’s currency when the observed phenomenon becomes evident. Similarly, in the second one we model PTM due to hysteresis caused by “continuous“ or long enough appreciation (at least two years of continuing appreciation) of the exporter’s currency followed by a period of depreciation. The intuition behind this is that PTM due to hysteresis in volumes is associated with permanent changes in quantities and to capture it we need the estimation to be focused on a period which includes first a “continuous” or a long enough change in one direction and then a reversed change in the exchange rate – this is when the hysteresis should become evident. The decision to define “continuous” (or long enough) change as a change which is in the same direction for at least two consecutive years, is based on careful examination of the exchange rate changes over the period of investigation. Two main facts are taken into account: first, there is mainly real depreciation of the German DM, and second, the minimum period of consecutive real appreciation is two years.

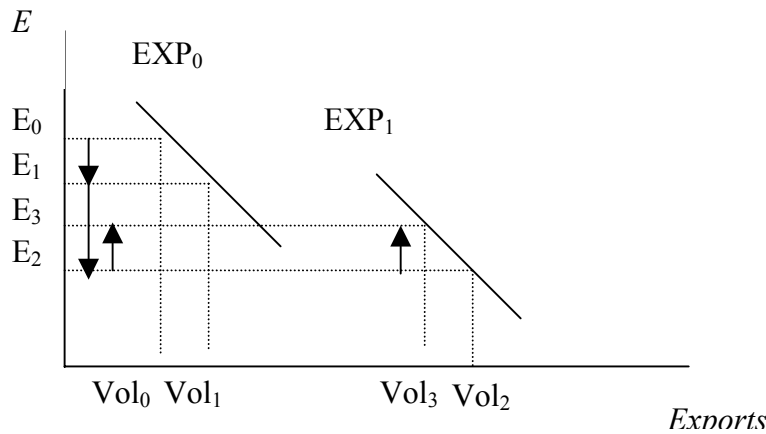
Figure 1 shows the relationship between the exchange rate, defined in exporter’s currency and the volume of exports. This is useful, as it illustrates the main idea behind the modelling we propose. First, assume that there is a depreciation of the German currency for two consecutive years - from  $E_0$

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<sup>12</sup> By export price we mean price in exporter’s currency.

to  $E_1$  and from  $E_1$  to  $E_2$ . According to the diagram, during year two, when there is a depreciation from  $E_1$  to  $E_2$ , new German exporters may start exporting or the existing firms may increase the volume of exports as they may find it more profitable. This may however lead to a structural break in the volume of exports. If this “continuous” depreciation is followed by an appreciation of the exporter’s currency this will cause a decrease in the volume of exports. In the presence of hysteresis in quantities, however, the volume of exports will be persistently higher than before the reversed change of the exchange rate (or  $Vol_3 > Vol_1$ ), or by adjusting the mark-up over marginal costs in response to exchange rate changes, the exporting firms will be able to stay in the market despite the unfavourable exchange rate changes. In other words, if the DM depreciates new German firms will start exporting, and if, for example, they incur high sunk costs, even if there is an appreciation of the currency, rather than exit the market, these firms will stay and absorb the reversed exchange rate changes in their profit margin (in this particular case there will be a decrease of the profit margin); or this is pricing-to-market due to hysteresis in quantities.

Fig. 1 Relationship between Exchange Rate and Volume of Exports



In accordance with the discussion above we estimate the following equation:

$$\Delta \ln p_{it} = \theta + \beta^a \Delta \ln e_{it}^a \times D^a + \beta^d \Delta \ln e_{it}^d \times D^d + \gamma \ln RPAT_{it} + u_{it} \quad (4)$$



Where  $D^a$  ( $D^d$ ) is a dummy variable which helps us to capture only this appreciation (depreciation) of the exporter's currency which follows at least two years of depreciation (appreciation) and the volume of exports is persistently greater (lower) than the one before the reversed exchange rate change. This allows us to assume that  $\beta_i^a$  ( $\beta_i^d$ ) may capture PTM due to hysteresis in quantities which becomes evident over a period of appreciation (depreciation) of the exporter's currency.  $D^a$  is therefore 1 if there is an appreciation which follows at least two years of consecutive depreciation and the appreciation is accompanied by an increase rather than decrease in the volume of exports, compared with the period before the reversed change<sup>13</sup>, otherwise  $D^a = 0$ . Similarly,  $D^d$  is 1 if there is a depreciation of the exporter's currency which follows at least two years of appreciation and the volume of exports decreases, rather than increases, otherwise  $D^d = 0$ .

In Table 4 below we present the results only for the industries for which either  $\beta^a$  or/and  $\beta^d$  are significant<sup>14</sup>.

Table 4 : Significant Coefficients of PTM due to Hysteresis in Quantities at 5% level

Industry Code	$\beta^a$	$\beta^d$
3119	0.59* (0.27)	-0.90 (0.54)
3215	-0.52* (0.21)	-0.31 (0.23)
3419	0.77 (0.44)	0.90* (0.25)
3610	0.79 (0.60)	-0.83* (0.35)
3813	0.93* (0.33)	-0.11 (0.56)
3821	0.86* (0.35)	-0.15 (0.45)
3823	0.86* (0.38)	-0.72* (0.32)

Note: Standard errors are in parentheses; \* significant at 5% level.

The first striking feature is that there was only one significant short-run coefficient, estimated in the previous section, and here, we receive much more evidence of PTM due to hysteresis than just for PTM in the short run. This is puzzling, however, and casts some serious doubts about the validity and

<sup>13</sup> Again, the decision is made after careful examination of the data.

<sup>14</sup> The results for all of the industries are available from the author upon request.

robustness of the method we propose. All of these industries however exhibit significant pricing-to-market in the long run. This may suggest that the observed limited exchange rate pass-through for these industries in the long run could be due to hysteresis in quantities which here is captured in short run. The second striking feature is that some of the significant coefficients are positive. In searching for explanation we should point out that most of the short-run coefficients estimated in the previous section were positive which was justified with the invoicing currency.

In summary, the results in this section suggest that “pricing-to-market due to hysteresis” and “pricing-to-market” in the short run are two separate phenomena and further research should attempt to model in the long run.

## 7. Hysteresis in Prices

We adopt a quite similar approach to that in the previous subsection, and apply it to investigate if we could find any evidence of hysteresis in German export prices. We estimate equation (6) below in which we include two dummy variables as before. The dummy variable  $d^a$  (and respectively  $d^d$ ) captures hysteresis during a period of appreciation (depreciation), which follows at least two years of depreciation (appreciation); the intuition behind the estimation is the same as in the previous case when we model PTM due to hysteresis in quantities, and again the decision on the value of the dummy variables is made after very careful examination of the export price data. The main difference is that rather than including time dummy variables ( $\theta_t$ ) which keep the marginal cost constant across destinations and of course allow it to vary over time, we have an intercept in the equation and also *TIME* to account for factors that are not included in the estimation, e.g income in the destination markets. The response of mark-up over marginal costs to exchange rate changes does not need to be isolated any more. Rather, we need to search for permanent changes in export price due to temporary exchange rate changes which could operate through both marginal cost and mark up over marginal cost.

$$\Delta \ln p_{it} = \alpha_{0i} + \beta_i^a d^a \Delta \ln e_{t^a} + \beta_i^d d^d \Delta \ln e_{t^d} + \gamma_i \ln RPAT_{it} + \lambda_i TIME + u_{it} \quad (6)$$

Table 5 below presents only those industries for which the coefficients ( $\beta^a$  and  $\beta^d$ ) are significant which, according to the approach we adopt, means that there is evidence of hysteresis in prices<sup>15</sup>. A negative and significant  $\beta^d$ , for example, means that during a period of appreciation we would expect the export price to increase, however, in the presence of hysteresis the change is in the reverse direction, or it is negative; the dummy variable  $d^d$  helps us to take into account only this appreciation of the exporter's currency which follows at least two years of depreciation, that is we focus the estimation only on the period of a reverse exchange rate change, and if then the change of the export price is in the opposite direction to the one we would expect, we claim that there is evidence of hysteresis in prices. One might raise two questions here. First, this "persistence" in export prices over a period of a reverse exchange rate change could be due to adjustment lags rather than hysteresis. This is of course possible, although we do not think that it is quite likely as the data are annual. Second, hysteresis in prices might be better captured at a bilateral level, or it might be better to estimate the equation for each pair of industry and destination market separately. However, we have already received some convincing empirical evidence that German exporters' pricing behaviour in the long run is quite similar across destinations and that is why we impose the same coefficients across destination markets. This could, however, be a promising area for some further research.

Table 5: Significant Coefficients of Hysteresis in Prices at 5% level

Industry Code	$\beta^a$	$\beta^d$
3131	-0.80 (0.96)	-0.91* (0.46)
3211	0.70 (0.48)	0.27* (0.13)
3312	-0.94* (0.27)	0.39 (0.80)
3320	0.78 (0.95)	-0.27* (0.13)
3551	0.84* (0.36)	0.16 (0.13)
3691	-0.11 (0.92)	0.34* (0.16)
3812	0.72* (0.35)	-0.19 (0.21)
3825	-0.98 (0.64)	-0.57* (0.24)
3852	-0.75 (1.00)	0.89* (0.40)

*Note: Standard errors are in parentheses; \* significant at 5% level.*

Table 5 shows that the nine industries for which we find evidence of hysteresis in prices are among the ones which show significant limited exchange rate pass through in the long run.

Another interesting point is that none of these industries had significant short-run coefficients for pricing-to-market estimated in the previous sections by using Engle-Yoo three stage procedure. Furthermore, these industries did not have significant coefficients for PTM due to hysteresis in quantities either; or the limited exchange rate pass through in these cases is obviously due to the effects the exchange rate changes have on costs.

Here the significant positive coefficients capturing hysteresis could be problematic. Still, we should bear in mind that the estimation is in the short run. An interesting area for further research is therefore modelling hysteresis in prices in the long run.

With this section, again, we lend support to the argument that although the two concepts of pricing-to-market and hysteresis in prices become evident as a limited exchange rate pass-through, they are two different concepts and deserve separate modelling.

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<sup>15</sup> All of the results are available from the author upon request.

## 8. Conclusions

The lack of both a conventional theoretical framework and previous research explains the approach adopted in the current paper. Here we analyse German exports at 4-digit ISIC level from several different aspects, or throughout the whole paper the same data set is used to investigate different concepts, namely: PTM in the short and the long run, PTM due to hysteresis in quantities and hysteresis in prices. This allows us to compare the empirical results which reveal some of the similarities and differences in the two main investigated concepts: PTM and hysteresis. We recognise that the data are not that highly disaggregate and there might be some measurement errors, and relying on the empirical results entirely and deriving conclusions from them might be misleading at times. Still, this is a valuable method for approaching this new area of research, and an interesting first step.

The current paper has established several new and interesting facts. First, PTM and hysteresis are two different phenomena and they deserve a better modelling, which will clarify the existing confusion in the literature. Second, PTM for German exports (4-digit level) is pervasive in the long run in relation to industries but not across destinations. Third, the inclusion of quality proxied by relative patents when the exchange rate pass through is estimated for not that finely disaggregated data can considerably improve the estimation. Fourth, PTM might not be clearly revealed in the short run due to invoicing issues. If exporters tend to invoice in domestic currency there could be a bias against finding PTM in the short run. Fifth, in the current paper we introduced a new term, “PTM due to hysteresis in quantities”, proposed a method for capturing it and receive some good results. Sixth, a test for measuring hysteresis in prices has been constructed and some support to hysteresis in prices in German exports has been received. Seventh, regarding the results we receive for German exports we confirm the major findings by Knetter (1992,1993) that PTM is similar across destinations and differ across industries.

The empirical approach adopted in this paper needs to be extended in future research. Furthermore, the robustness of the methods we introduce should be further tested by analysing more countries at a more disaggregate level (7 or 8 digit level). Non-parametric methods could also be employed to address non-linearities between exchange rate and price changes. Further work should also focus on modelling PTM mainly as an asymmetric process which leads to hysteresis. By employing threshold cointegration tests, for example, asymmetric adjustment towards a long-run equilibrium relationship can be modelled. In this way a major shortcoming of previous studies on asymmetric PTM can be overcome, that is the failure to take into account the possibility of the presence of an equilibrium relationship between prices and exchange rate changes.

Table 6: Description of the Manufacturing Industries at 4-digit level

Code	Activity/Description
3111	Slaughtering, preparing and preserving meat
3112	Manufacture of dairy products
3113	Canning and preserving of fruits and vegetables
3114	Canning, preserving and processing of fish, crustacea and similar foods
3115	Manufacture of vegetable and animal oils and fats
3116	Grain mill products
3117	Manufacture of bakery products
3118	Sugar factories and refineries
3119	Manufacture of cocoa, chocolate and sugar confectionery
3121	Manufacture of food products n.e.c.
3122	Manufacture of prepared animal feeds
3131	Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials
3132	Manufacture of wines
3133	Manufacture of malt liquors and malt
3134	Manufacture of soft drinks; production of mineral waters
3140	Manufacture of tobacco products
3211	Spinning, weaving and finishing textiles
3212	Manufacture of made-up textile goods except wearing apparel
3213	Manufacture of knitted and crocheted fabrics and articles
3214	Manufacture of carpets and rugs
3219	Manufacture of textiles n.e.c.
3220	Manufacture of wearing apparel, except footwear
3231	Tanning and dressing of leather
3232	Fur dressing and dyeing industries
3233	Manufacture of products of leather and leather substitutes, except footwear and wearing apparel
3240	Manufacture of footwear, except vulcanised or moulded rubber or plastic footwear
3311	Manufacture of veneers, sheets, plywood, laminated wood, particle board
3312	Manufacture of wooden and cane containers and small cane ware
3319	Manufacture of wood and cork products n.e.c.
3320	Manufacture of furniture and fixtures, except primarily of metal
3411	Manufacture of pulp, paper and paperboard
3412	Manufacture of containers and boxes of paper and paperboard
3419	Manufacture of pulp, paper and paperboard articles n.e.c.
3420	Printing, publishing and allied industries
3511	Manufacture of basic industrial chemicals except fertilisers
3512	Manufacture of fertilisers and pesticides
3513	Manufacture of synthetic resins, plastics materials and man-made fibres except glass
3521	Manufacture of paints, vanishes and lacquers
3522	Manufacture of drugs and medicines
3523	Manufacture of soap and cleaning preparations, perfumes, cosmetics and other toilet preparations
3529	Manufacture of chemical products n.e.c
3530	Petroleum refineries
3540	Manufacture of miscellaneous products of petroleum and coal
3551	Manufacture of rubber tyres and tube industries
3559	Manufacture of rubber products n.e.c.
3560	Manufacture of plastic products n.e.c.
3610	Manufacture of non-structural and non-refractory ceramic ware (pottery, china, and earthenware)
3620	Manufacture of glass and glass products

3691	Manufacture of structural clay products
3692	Manufacture of cement, lime and plaster
3699	Manufacture of non-metallic mineral products n.e.c.
3710	Iron and steels basic industries
3720	Non-ferrous metal basic industries
3811	Manufacture of cutlery, hand tools and general hardware
3812	Manufacture of furniture and fixtures primarily of metal
3813	Manufacture of structural metal products
3819	Manufacture of fabricated metal products except machinery and equipment n.e.c.
3821	Manufacture of engines and turbines
3823	Manufacture of metal and woodworking machinery
3824	Manufacture of special industrial machinery and equipment except metal and woodworking machinery
3825	Manufacture of office, computing and accounting machinery
3829	Machinery and equipment except electrical n.e.c.
3831	Manufacture of electrical industrial machinery and apparatus
3832	Manufacture of radio, television and communication equipment and apparatus
3839	Manufacture of electrical apparatus and supplies n.e.c.
3841	Ship building and repairing
3842	Manufacture of railway and tramway locomotives and rolling stock
3843	Manufacture of motor vehicles
3844	Manufacture of motorcycles and bicycles
3845	Manufacture of aircraft
3849	Manufacture of transport equipment n.e.c.
3851	Manufacture of professional and scientific, and measuring and controlling equipment n.e.c.
3852	Manufacture of photographic and optical goods
3853	Manufacture of watches and clocks
3901	Manufacture of jewellery and related articles
3902	
3903	Manufacture of sporting and athletic goods
3909	Manufacture of carbon paper, small metal articles n.e.c.



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