

Findings of Pricing-to-Market: Market Segmentation or Product Differentiation?*

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Abstract

Pricing to market (PTM) has been examined extensively in the recent trade literature using Knetter's (1989) model. The technique is typically applied using export unit values that aggregate differentiated products. We examine the potential bias in PTM results when using export unit values using a vertical differentiation model. We find that: i) false evidence of PTM ("pseudo PTM") is always found due to aggregation when calculating export unit values, whether the law of one price (LOP) holds or not; ii) when markets are segmented, the fraction of pseudo PTM increases with the level of product differentiation. Correspondingly, our simulation results suggest that: i) it is possible to get a statistically significant estimate of the exchange rate coefficient, even when there is no real PTM; ii) the significance of the estimate increases with product differentiation.

JEL Classification: D42, F10, L12.

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1 Introduction

Movements in exchange rates can have an important influence on an imperfectly competitive exporter's pricing behavior. Exchange rates create a wedge between the price set by the exporter and the price paid by the importer and can be used as an instrument of price discrimination. The idea that an exporter can adjust destination-specific markups to accommodate changes in exchange rates was first documented in Mann (1986) and later was termed "pricing-to-market" (henceforth PTM) by Krugman (1987). Knetter (1989) developed an empirical model to analyze the presence of PTM. Knetter's model has since been used extensively, due to its simplicity and data availability, to determine the presence of price discrimination in international trade. Examples of studies include: Knetter (1989, 1993), Marston (1990), Gagnon and Knetter (1995) in the auto industry; Pick and Carter (1994), Carew (2000), Griffith and Mullen (2001), Rakotoarisoa and Shapouri (2001), Carew and Florkowski (2003), Glauben and Loy (2003) in the food and agriculture industry; Kan (2001) in the textile industry; Takeda and Matsuura (2003) in the DRAM industry; Bodnar, Dumas and Marston (2002) in industries including construction machinery and copies etc., and Mahdavi (2002) in 13 manufacturing industries.

Most PTM studies, such as those listed above, use export unit values as the price variable.¹ Export unit values are calculated as the ratio of value to volume of exports for a specific product category and destination country. Market- or customer-specific price information is typically confidential, making export unit values the next best alternative. The disadvantage of export unit values is that they often aggregate data on products employed for very different uses. In fact, Gehlhar and Pick (2002) found that 40 percent of U.S. food exports are characterized by non-price competition, such as product differentiation. For those products, they argue that unit values are poor measures of prices in international trade. Thus, observation of PTM could be an indication of product differentiation (Sexton and Lavoie, 2001). It is important to understand the effect of the use of unit values on PTM testing because evidence, or lack of evidence, of PTM can be used for policy purposes, e.g., Carter (1993). Moreover, PTM can have important effects on the international transmission of monetary and fiscal policy, and can increase exchange rate volatility, relative to a situation where markets are integrated (Betts and Devereux, 2000). The objective of our study is to examine the impact of the use of unit values characterized by vertical product differentiation on the evaluation of pricing-to-market.

¹Few exceptions include Gron and Swenson (2000), Goldberg and Verboven (2001) and Stefano (2003), which use product level data.

Product differentiation has been explicitly modelled in studies evaluating the extent of exchange rate pass-through (e.g., Dornbusch (1987), Feenstra, Gagnon, and Knetter (1996), Yang (1997), Bodnar, Dumas and Marston (2002)).² Gron and Swenson (2000) also considered input substitutability in their study of cost pass-through in the U.S. automobile market. In the studies listed above, substitution occurs between a good produced by the home firm and a good produced by the foreign firm. Our analysis of product differentiation differs from the above studies in two respects. First, substitution occurs between a set of vertically differentiated goods produced in one country and sold domestically and to a foreign market. Second, we address the issue of product differentiation in the context of the use of unit export values as price data to detect the presence of PTM.

The issue of product differentiation in the use of unit values is acknowledged in many PTM studies using Knetter's model. Common criticisms of the use of unit values are that "they do not account for quality differences across shipments to different countries or quality changes over time in the product under consideration" (Gil-Pareja, 2002, p.301).³ Authors, such as Knetter (1989), typically argue that systematic differences in product quality, such as when different qualities are shipped to different markets, can be captured by country dummies. Moreover, changes in the quality of the product that is common across countries can be captured by time effects.⁴ Thus, the impact of product differentiation on the evaluation of PTM is typically argued to be minimal.

While prior authors acknowledge the problems associated with unit values when they reflect different qualities shipped to different countries, we address an issue that to our knowledge has not been addressed before. Namely, that movements in the exchange rates can alter the mix of qualities imported by countries, and as a result cause false detection of PTM.⁵ Our paper represents a first step into the impact of using export unit values on the evaluation of PTM.

We introduce a conceptual model where a monopolist sells vertically differentiated products to a domestic and a foreign market. Two scenarios are of interest. In the first one, there is perfect and costless consumer arbitrage, and the law of one price (LOP) holds for individual

²Exchange rate pass-through refers to the extent to which the price to a given importing country adjusts to changes in the exchange rate.

³See also Alston, Carter, and Whitney (1992), and Goldberg and Knetter (1997) for discussions on the use of unit values in the evaluation of PTM.

⁴Gil-Pareja contends that estimating a PTM regression in first differences also alleviates the problems associated with the use of unit values.

⁵Gil-Pareja pointed out that using unit values can be problematic when there are destination-specific changes in the quality levels of shipments.

products (i.e., before aggregation). In the second scenario, consumer arbitrage is not feasible and markets are segmented. We derive the equilibrium prices and quantities and use them to calculate unit values. In both scenarios, we find the presence of “pseudo PTM”, i.e., PTM that is purely the result of data aggregation and product differentiation rather than price discrimination across markets. In the first scenario, there is pseudo PTM only. In the second scenario, there is pseudo and “real PTM,” i.e., PTM due to market segmentation. We show that the fraction of pseudo PTM increases with the level of product differentiation.⁶ Next we employ a Monte Carlo simulation to analyze the relationship between PTM and the level of product differentiation. More specifically, we quantify the threshold level of product differentiation necessary to generate statistically significant evidence of PTM. The simulation and regression results indicate a higher statistical significance of the coefficient indicating PTM when there is real and pseudo PTM. Moreover, in both cases, a higher level of product differentiation is more likely to lead to a statistically significant evidence of PTM.

The rest of the paper is organized as follows. The conceptual model is presented in section 2 and the two scenarios are analyzed in section 3. Section 4 provides a simulation study and we summarize the results in section 5. Proofs of propositions can be found in the appendix.

2 The model

Consider two countries: country 1 and 2. A monopolist in country 1 produces two vertically differentiated products with exogenous qualities q_l and q_h ($0 < q_l < q_h$). The two goods are sold domestically and exported to country 2.⁷ The marginal cost is $\frac{1}{2}q_j^2$ for the product of quality q_j ($j = l, h$).⁸

We model the vertical differentiation à la Mussa and Rosen (1978). Consumers are heterogeneous in their preferences for quality. A consumer with preference parameter θ will enjoy a utility of $\theta q - p$ if she buys one unit of the product of quality q at price p , and zero if she buys

⁶This is in the same spirit as in Bodnar, Dumas and Marston (2002), who find that the impact of higher product substitutability (higher ρ) is to moderate the exchange rate pass-through, using a model where an exporting firm and a foreign import-competing firm produce products of various substitutability.

⁷We use “market” and “country” interchangeably in this paper.

⁸Marginal cost is assumed constant with respect to quantity for simplicity. The choice of a quadratic functional form with respect to quality derives from the uninteresting outcome that results from choosing a linear functional form such as $c_j = q_j$. Namely, the monopolist does not sell the low-quality product. In general, whenever $c_h/c_l = q_h/q_l$ or $c_j = 0$, the monopolist sets $p_l = p_h \frac{q_l}{q_h}$. As a result, the price quality ratio for each good is the same, and consumers are indifferent between the high-quality and the low-quality product.

nothing. There is a continuum of consumers in each country, i.e. $\theta \in U[0, \theta_i]$ with density $1/\theta_i$ in country i ($i = 1, 2$).

Let θ_{il} ($i = 1, 2$) denote the consumer in market i who is indifferent between buying the low- quality product or buying nothing, that is, θ_{il} is the value of θ that solves $\theta q_l - p_l = 0$.⁹ Similarly θ_{ih} is the consumer in market i who is indifferent between buying the low- or high-quality product, i.e., θ_{ih} is the value of θ that solves $\theta q_h - p_h = \theta q_l - p_l$. Thus consumers with $\theta \in [0, \theta_{il})$ will not buy, those with $\theta \in [\theta_{il}, \theta_{ih}]$ will buy low quality product and the others ($\theta \in (\theta_{ih}, \theta_i]$) will buy the high-quality product.

Accordingly, the demands for the low- and high-quality products in country i are:

$$d_{il}(p_h, p_l) = \frac{\theta_{ih} - \theta_{il}}{\theta_i} = \frac{p_h q_l - p_l q_h}{\theta_i (q_h - q_l) q_l}$$

$$d_{ih}(p_h, p_l) = \frac{\theta_i - \theta_{ih}}{\theta_i} = 1 - \frac{p_h - p_l}{\theta_i (q_h - q_l)}$$

Krugman (1987) described the evidence of PTM as that the import price (relative to exporter's domestic price) fails to change (fall or rise) proportionately to the exchange rate change (appreciation or depreciation).

Following the same logic, Marston (1990) describes the presence of PTM by the “export-domestic price margin.” It is calculated as the ratio of country 2's price to country 1's price ($\frac{P_2}{P_1}$), where P_i is the price in country i , expressed in country 1's currency. This ratio equals one when there is no PTM, i.e., the prices expressed in the same currency are equal.

In this paper, we use $X = \frac{P_1}{P_2/e}$ ¹⁰ to analyze the presence of PTM, where P_1 and P_2 are all in local currencies and e is the exchange rate expressed in units of country 2's currency per unit of country 1's currency. There is no PTM if $X = 1$. The PTM effect can be measured as the effect of a change in the exchange rate on X . Thus, when there is PTM, a change in the exchange rate will have a non-zero impact on the ratio X . Said differently, there is pricing to market when the exporter responds to a change in the exchange rate by varying the price to one or both markets not proportionally.

We consider two scenarios. In the first scenario, consumers can resell their products across countries without incurring any cost. In this scenario, LOP holds for each individual product, and the prices of each product in the two markets are the same after being converted into the

⁹Throughout the paper, prices are all in local currencies.

¹⁰This ratio will prove to be more straightforward to interpret than Marston's ratio in what follows.

same currency. In the other scenario, markets are segmented and arbitrage between consumers across countries is not feasible. Consequently, the two markets are independent and each product is sold by the monopolist at a different price in each country.

3 Analysis

In this section, we solve for the equilibrium price and quantities in both scenarios. The monopolist's objective is to maximize its profit by choosing prices. Using equilibrium prices and quantities, we calculate unit values of sales to each country, expressed in country's 1 currency. Recall that unit values are used as prices in empirical applications. We use the unit values to calculate the domestic-export price margin (X). "Evidence" of PTM occurs when this ratio is not equal to one, or when a change in the exchange rate has a non-zero impact on X .

We begin with the first scenario where the LOP holds for each individual product.

Scenario 1. LOP holds

The non-discriminatory monopolist chooses the prices p_l and p_h (in country 1's currency) to maximize profits to the two markets according to:

$$\max_{p_l, p_h} (p_l - \frac{1}{2}q_l^2)(d_{1l} + d_{2l}) + (p_h - \frac{1}{2}q_h^2)(d_{1h} + d_{2h})$$

where $d_{il}(p_l, p_h)$ and $d_{ih}(p_l, p_h)$ are the demand functions for the low- and high-quality product in country i ($i = 1, 2$) as derived in section 2. Note however that the prices p_l and p_h are in country 1's currency, whereas consumers' demand in market 2 is a function of the price in the local currency, i.e., $p_l \cdot e$ and $p_h \cdot e$, where e is the exchange rate. We assume that in equilibrium the monopolist produces both products and sells to both countries.¹¹

From the first-order conditions, we obtain the equilibrium prices p_l^* and p_h^* and the equilibrium quantities d_{il}^* and d_{ih}^* for market i ($i = 1, 2$). The unit value P_i is computed as the weighted average price for sales to market i , or:

$$P_i = \frac{p_l^* d_{il}^* + p_h^* d_{ih}^*}{d_{il}^* + d_{ih}^*}$$

The presence of PTM is determined by computing $X = \frac{P_1}{P_2/e}$ and evaluating whether it is equal to one or varies with the exchange rate.

¹¹It can be easily shown that the monopolist is better off supplying both products than supplying either product in both scenarios, under the parameters we assign.

Our results are summarized in the next proposition.

Proposition 1 *When the LOP holds for individual products, there is pseudo PTM due to aggregation.*

Proof. See appendix. ■

The intuition of why aggregation leads to pseudo PTM is as follows. Note that the domestic-export price ratio is¹²

$$\begin{aligned} X &= \frac{(p_l d_{1l} + p_h d_{1h}) / (d_{1l} + d_{1h})}{(p_l d_{2l} + p_h d_{2h}) / (d_{2l} + d_{2h})} \\ &= \frac{p_l \frac{d_{1l}}{d_{1l} + d_{1h}} + p_h \frac{d_{1h}}{d_{1l} + d_{1h}}}{p_l \frac{d_{2l}}{d_{2l} + d_{2h}} + p_h \frac{d_{2h}}{d_{2l} + d_{2h}}} \\ &= \frac{p_l \sigma_1 + p_h (1 - \sigma_1)}{p_l \sigma_2 + p_h (1 - \sigma_2)} \end{aligned}$$

where $\sigma_i = \frac{d_{il}}{d_{il} + d_{ih}}$, $i = 1, 2$, is the fraction of low-quality product in country i .

Note that a change in exchange rate will change all the equilibrium prices and quantities. For this ratio to remain at 1, it must be that $\sigma_1 = \sigma_2$. However, it can be shown that (see Appendix)

$$\sigma_1 = \frac{\frac{p_h - p_l}{q_h - q_l} - \frac{p_l}{q_l}}{\theta_1 - \frac{p_l}{q_l}} \text{ and } \sigma_2 = \frac{e \frac{p_h - p_l}{q_h - q_l} - e \frac{p_l}{q_l}}{\theta_2 - e \frac{p_l}{q_l}}$$

We need $\theta_2 = e\theta_1$ to have $\sigma_1 = \sigma_2$. But θ_2 is a fixed parameter, which can not vary with the exchange rate. Therefore, $\sigma_1 = \sigma_2$ can not hold when e varies, and there is always pseudo PTM.

Numerical example

To get a sense of the pseudo PTM, we give a numerical example. Suppose that $q_l = .3$, $q_h = .7$, $\theta_1 = 1$ and $\theta_2 = 2$. Applying the results in the appendix, the equilibrium prices are

¹²To ease the burden on notations, we remove the asterisk sign from the equilibrium prices. Similarly in scenario 2.

$p_h^* = \frac{7}{400} \frac{7e+94}{e+2}$, $p_l^* = \frac{3}{400} \frac{86+3e}{e+2}$.¹³ The ratio of the unit prices, as the following, is clearly a function of exchange rate e , instead of a constant.

$$X = \frac{(2956e - 1364 + 219e^2)(3e^2 + 6e - 160)}{(37e - 6)(804e^2 + 244e + 61e^3 - 15040)}$$

Next, we analyze the second scenario, where markets are segmented and consumer arbitrage is not feasible.

Scenario 2. Market segmentation

In this scenario, the monopolist charges p_{ij} (all in local currencies) to country i ($i = 1, 2$) for product of quality q_j ($j = l, h$). The monopolist is able to charge different prices in different markets, and each market can be treated independently because of the assumption of constant marginal cost with respect to quantity.

Define X_l as the domestic-export price margin for the low-quality product and X_h , as that for the high-quality product. A ratio different from one or varying with changes in exchange rate indicates that the monopolist price discriminates. Thus, X_l or X_h different from zero indicates real PTM. The next proposition summarizes the results in this scenario.

Proposition 2 *When markets are segmented,*

i) There is real PTM for both individual products due to market segmentation, because

$$X_l = \frac{p_{1l}}{p_{2l}/e} = \frac{(2\theta_1 + q_l)e}{2\theta_2 + eq_l} \neq 1$$

$$X_h = \frac{p_{1h}}{p_{2h}/e} = \frac{(2\theta_1 + q_h)e}{2\theta_2 + eq_h} \neq 1$$

ii) There is also pseudo PTM due to aggregation.

Proof. See appendix. ■

Because only the equilibrium quantities in market 2 are affected by movements in the exchange rate, the domestic-export price ratio ($X = \frac{P_1}{P_2/e}$) corresponds to,

¹³The equilibrium prices are positive. Equilibrium quantities are positive when $e \in (\frac{2}{3}, \sqrt{17} - 1)$.

$$\begin{aligned}
X &= \frac{P_1}{\frac{p_{2l}d_{2l}+p_{2h}d_{2h}}{d_{2l}+d_{2h}}/e} \\
&= \frac{P_1}{\frac{p_{1l}\sigma_2}{X_l} + \frac{p_{1h}(1-\sigma_2)}{X_h}}
\end{aligned}$$

where σ_2 is the fraction of low-quality product in market 2.

This ratio shows the presence of real PTM through X_l and X_h , which was missing in the first scenario. There is also pseudo PTM through σ_2 due to aggregation, same as in the previous scenario.

Now we know that pseudo PTM is due to the aggregation of differentiated products, it is interesting to analyze the relationship between the fraction of pseudo PTM and the level of product differentiation. We obtain various levels of product differentiation by fixing q_l and varying q_h . A higher q_h would imply a higher level of product differentiation. The next corollary summarizes our results.

Corollary 3 *When markets are segmented, the fraction of pseudo PTM increases with the level of product differentiation.*

Proof. To get a sense of how X, X_l and X_h vary with the level of product differentiation (q_h), we assign some parameter values, and plot these three measures against q_h . We set $q_l = \frac{3}{10}$, $\theta_1 = 1$, $\theta_2 = 2$, $e = 3$.¹⁴ The results are provided in Figure 1.

While these are numerical results, some observations are worth notifying. First, there is always pseudo PTM, since in the graph X is always higher than $\max\{X_l, X_h\}$. Second, pseudo PTM increases with the level of product differentiation. This is because while X_l and X_h are either stable or decreasing with the level of product differentiation, X increases with q_h .¹⁵ This implies that, as products become more differentiated, the real PTM for each product stays stable or decreases, and the aggregate PTM increases. Therefore, the fraction of pseudo PTM increases with the level of product differentiation.

¹⁴All quantities and prices are positive under these parameter values.

¹⁵The observation that X_h decreases with q_h might seem counterintuitive initially. One explanation is that, we assume $\theta_1 = 1$ and $\theta_2 = 2$, i.e. there are relatively more consumers who care more about quality in the second market. As a result, when q_h increases and prices of high quality product increase in both markets, price increase in the second market may be relatively more as the monopolist is able to get relatively more out of the second market.

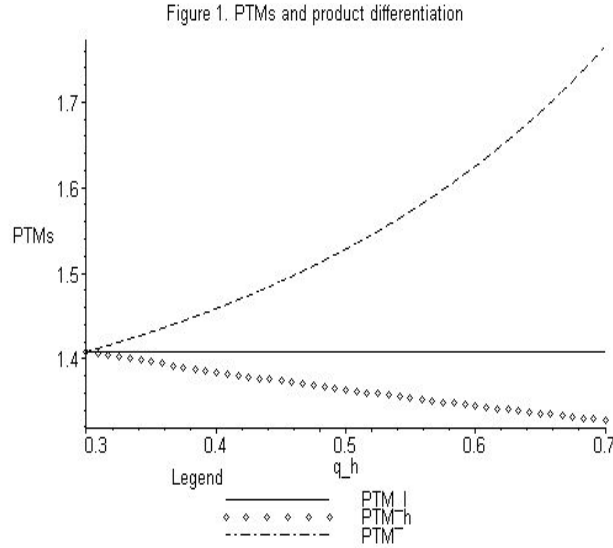


Figure 1: PTMs and product differentiation

An alternative way to see this is to calculate an approximate fraction of pseudo PTM in the whole PTM, and analyze its relationship with the level of product differentiation. Since the real PTM originates from the real PTM in both individual products, we assume that the fraction of real PTM using unit prices is the average of the real PTMs for both individual products, i.e., $\frac{1}{2}(X_l + X_h)$. Then the fraction of pseudo PTM is

$$fraction = 1 - \frac{(X_l + X_h)/2}{X} = -\frac{(10q_h - 3)(76577 + 44700q_h^2 + 111410q_h)}{1519(3q_h + 4)(100q_h^2 + 30q_h - 409)}$$

This fraction is plotted against q_h in Figure 2. One can see clearly that the fraction of pseudo PTM increases with q_h - the level of product differentiation.

■

4 Simulations

Previous theoretical results indicate that when sales to a given market involve differentiated products and unit values are used to evaluate the prices of PTM, there is always pseudo PTM due to aggregation. Pseudo PTM arises as a result of a change in the mix of qualities purchased due to a change in the exchange rate. Thus, it is possible, as in scenario 1, that

Figure 2. The fraction of pseudo PTM and product differentiation

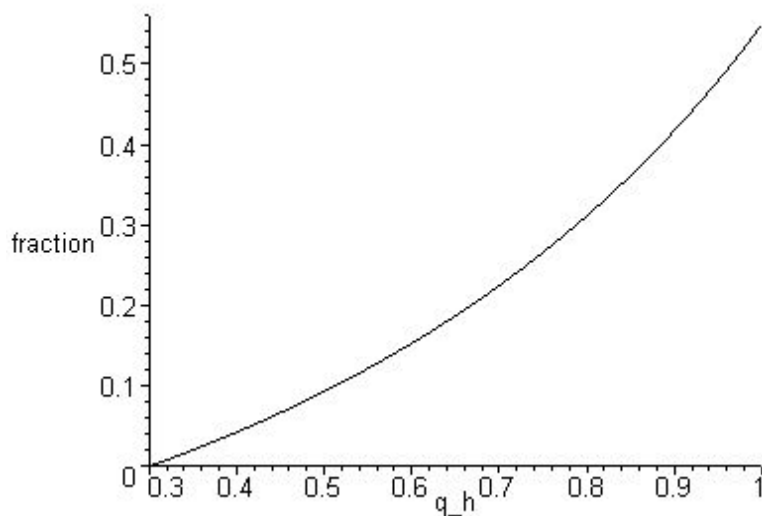


Figure 2: The fraction of pseudo PTM and product differentiation

the law of one price holds, but PTM is observed falsely because of the aggregation of different quality products in the calculation of unit values. Moreover, we show that the contribution of pseudo PTM to total PTM increases with the level product differentiation. This implies that in regression analysis following Knetter (1989), the exchange rate coefficient may pick up the effects of pseudo PTM. Next we conduct a Monte Carlo simulation to answer the following two questions:

i) Is it possible to get statistically significant coefficient of exchange rate when there is actually no real PTM?

ii) Does the significance level increase with the level product differentiation, whether there is real PTM or not?

The model we estimate is the following,

$$\log X_t = \beta_0 + \beta_1 \log e_t + U_t \quad (1)$$

where $e_t \sim U[a, b]$ is the exchange rate, X_t is the domestic-export price ratio, generated as $\frac{P_1(e_t) + \epsilon_1}{P_2(e_t) + \epsilon_2}$. $P_i(e_t)$, $i = 1, 2$ are the unit values computed as described in each scenario of section 3, $\epsilon_i \sim N(0, \sigma^2)$ and $E(\epsilon_1 \epsilon_2) = 0$.

If there is no PTM, the domestic-export price ratio (and its log) should be independent

of the exchange rate and β_1 should be statistically insignificant. By analyzing the estimate of β_1 under different levels of product differentiation, we can evaluate the effect of product differentiation on pseudo PTM.

We estimate the above model under the two scenarios examined in section 3. Parameters are chosen to ensure that all quantities and prices are positive. For both scenarios, we set $a = 1.5$, $b = 2.5$ and $\sigma = 1/15$. The parameters of the theoretical model are the same as in section 4, i.e. $\theta_1 = 1$, $\theta_2 = 2$, and $q_l = .3$. The number of draws is 100 for the first scenario and 75 for the second scenario.¹⁶ We conduct three trials for each level of product differentiation (q_h). The results are provided in the tables 1 and 2.

Table 1: β_1 under the LOP scenario

q_h	Trial 1		Trial 2		Trial 3	
	estimate	$Pr > t $	estimate	$Pr > t $	estimate	$Pr > t $
0.4	0.15398	0.2945	0.05886	0.6909	-0.01016	0.9515
0.5	0.32780	0.0025	0.27939	0.0169	0.54944	< .0001
0.6	0.39157	0.0003	0.86776	< .0001	0.59411	< .0001
0.7	0.92054	< .0001	0.91363	< .0001	0.89571	< .0001

Table 2: β_1 under the market segmentation scenario

q_h	Trial 1		Trial 2		Trial 3	
	estimate	$Pr > t $	estimate	$Pr > t $	estimate	$Pr > t $
0.4	0.27907	0.5368	1.31023	0.0048	1.98118	< .0001
0.5	0.84896	0.0022	0.73828	0.0504	0.81466	0.0081
0.6	0.85509	< .0001	1.02160	0.0001	1.08151	< .0001
0.7	1.03067	< .0001	1.48639	< .0001	1.56314	< .0001

Table 1 is consistent with our theoretical results which indicate that when products are sufficiently differentiated ($q_h \geq .5$ in our setup), statistically significant result suggesting PTM can be obtained, although there is no real PTM. Table 2 reflects scenario 2 where there is

¹⁶In the second scenario with real PTM, when the number of draws is set to 100, statistically significant estimate of β_1 are always obtained, even when the level of product differentiation is small. When we set the number of draws to 50, the regression results are fairly unstable. Thus we pick 75 draws to avoid these problems.

both real and pseudo PTM. It is interesting to note in this case, that even though there is real PTM, the coefficient on the exchange rate is not statistically significant until there is sufficient product differentiation, i.e., $q_h \geq .5$. Second, as product differentiation (i.e. q_h) increases, the level of significance increases. This is consistent with the corollary to proposition 2. Finally, in many instances, the significance level ($1 - p$ -value) is higher in the second scenario. This is intuitive, given that there is pseudo as well as real PTM in this case.¹⁷

5 Concluding remarks

The pricing-to-market (PTM) model of Knetter (1989) has been used widely in the recent empirical trade literature to determine the presence of price discrimination across international markets. The technique has been used extensively due to its simplicity and data availability. Most PTM studies use export unit values as the price variable. Export unit values typically aggregate products that are differentiated. In this study, we examine the extent to which false result of PTM (pseudo PTM) arises from the use of unit value data.

For that purpose, we develop a vertical differentiation model to derive demands for two products of different qualities produced by a monopolist. These products are sold domestically and exported to a foreign market. There is evidence of PTM when the ratio of the domestic price to the export price (expressed in domestic currency's unit) is different from one or is affected by a change in the exchange rate.

To determine whether the use of unit values result in false detection of PTM we examine two scenarios. In the first scenario, we assume that arbitrage between the two markets prevails and the monopolist is forced to charge the same price to both markets, i.e., the law of one price (LOP) holds. When using unit values, regardless of the values of the parameter chosen, we find that there is always pseudo PTM even though markets are truly integrated. In the second scenario, arbitrage is not possible and the same product is sold at different prices in different markets. In this case, we find evidence of both real and pseudo PTM when using unit values.

Unit values consist of an average price of products sold to a market. Pseudo PTM occurs when the LOP holds because a movement in the exchange rate causes a change in the mix of qualities purchased, thus affects the ratio of unit values. In the second scenario where markets are segmented, the change in the exchange rate affects the ratio of unit values through two

¹⁷Note also that the estimate of the coefficient increases with q_h . This can be verified using our theoretical results by calculating $\frac{\partial \ln X}{\partial \ln e}$, and seeing that it increases with q_h .

channels: 1) a true PTM effect, 2) a change in the composition of the qualities purchased within each country.

In the second scenario, we also determine that the contribution of pseudo PTM to the finding of PTM increases with product differentiation, thus increasing the likelihood of false detection of PTM in empirical work. To test the hypothesis that product differentiation increases statistical finding of PTM, we conduct a Monte Carlo simulation. For both scenarios, we determine the threshold value of product differentiation necessary to obtain a statistically significant evidence of PTM. We find such threshold for scenario 1 even though there is no real PTM. The results also show that the statistical significance of the exchange rate coefficient (indicating the presence of PTM) increases with product differentiation. In addition to finding similar results for scenario 2, we also observe that the statistical significance of this coefficient is greater in scenario 2 where there is both real and pseudo PTM.

These findings imply that when unit values characterize sufficiently differentiated products, false evidence of PTM is found. Our results should serve to caution users of the approach to evaluate the level of differentiation present in the product category chosen and to interpret the results accordingly. Alternatively, more confidence can be placed on results obtained using disaggregated data. Such caution is especially important when results are used for policy purposes.

APPENDIX: Proofs of propositions

Proof of proposition 1

First, we derive the equilibrium price and quantity of each product in each market. In country 1, the consumer indifferent between buying the low-quality product or buying nothing is defined by the value of θ solving $\theta q_l - p_l = 0$, i.e., $\theta_{1l} = \frac{p_l}{q_l}$. Similarly, the consumer indifferent between the low- and high-quality products is defined by the value of θ solving equation $\theta q_h - p_h = \theta q_l - p_l$, i.e. $\theta_{1h} = \frac{p_h - p_l}{q_h - q_l}$.

Thus the low-quality product is purchased by consumers with $\theta \in [\theta_{1l}, \theta_{1h}]$ and the demand for the low-quality product is,

$$d_{1l} = \frac{\theta_{1h} - \theta_{1l}}{\theta_1} = \frac{q_l p_h - p_l q_h}{(q_h - q_l) q_l \theta_1}$$

The high-quality product is purchased by consumers with $\theta \in (\theta_{1h}, \theta_1]$ and the demand for the high-quality product is,

$$d_{1h} = \frac{\theta_1 - \theta_{1h}}{\theta_1} = 1 - \frac{p_h - p_l}{(q_h - q_l) \theta_1}$$

The demands for the low- and high-quality products in country 2 can be obtained in a similar manner. Note however that the demands of consumers in country 2 depend on the price of the product expressed in local currency, i.e., $p_l \cdot e$ and $p_h \cdot e$, where e is the exchange rate expressed in units of country 2's currency per unit of country 1's currency.

The demands in country 2 can be represented as,

$$d_{2l} = \frac{\theta_{2h} - \theta_{2l}}{\theta_2} = e \frac{q_l p_h - p_l q_h}{(q_h - q_l) q_l \theta_2}$$

and

$$d_{2h} = \frac{\theta_2 - \theta_{2h}}{\theta_2} = 1 - e \frac{p_h - p_l}{(q_h - q_l) \theta_2}$$

The firm's profit is

$$\pi = (p_l - \frac{1}{2} q_l^2) \frac{q_l p_h - p_l q_h}{(q_h - q_l) q_l} \left(\frac{1}{\theta_1} + \frac{e}{\theta_2} \right) + (p_h - \frac{1}{2} q_h^2) \left[2 - \frac{p_h - p_l}{(q_h - q_l)} \left(\frac{1}{\theta_1} + \frac{e}{\theta_2} \right) \right]$$

The first-order conditions are:

$$\frac{\partial \pi}{\partial p_l} = \frac{1}{2} \frac{(\theta_2 + e\theta_1)(4q_l p_h - 4p_l q_h + q_l^2 q_h - q_l q_h^2)}{(q_h - q_l)q_l \theta_1 \theta_2} = 0$$

$$\frac{\partial \pi}{\partial p_h} = \frac{1}{2} \frac{-4\theta_2 p_l - 4e\theta_1 p_l + q_l^2 \theta_2 + q_l^2 e\theta_1 - 4\theta_1 \theta_2 q_h + 4\theta_1 \theta_2 q_l + 4\theta_2 p_h + 4e\theta_1 p_h - q_h^2 \theta_2 - q_h^2 e\theta_1}{(-q_h + q_l)q_l \theta_1 \theta_2} = 0$$

Solving these two equations simultaneously for p_l , p_h , we obtain the equilibrium prices,

$$p_h^* = \frac{1}{4} \frac{(4\theta_1 \theta_2 + q_h \theta_2 + q_h e\theta_1)q_h}{\theta_2 + e\theta_1}, \quad p_l^* = \frac{1}{4} \frac{q_l(4\theta_1 \theta_2 + q_l \theta_2 + q_l e\theta_1)}{\theta_2 + e\theta_1}$$

The equilibrium quantities are

$$d_{1l}^* = \frac{q_h}{4\theta_1}, \quad d_{1h}^* = \frac{q_h \theta_2 + q_h e\theta_1 - 4e\theta_1^2 + \theta_2 q_l + q_l e\theta_1}{-4\theta_1(\theta_2 + e\theta_1)}$$

$$d_{2l}^* = \frac{q_h e}{4\theta_2}, \quad d_{2h}^* = \frac{q_h e\theta_2 + q_h e^2 \theta_1 - 4\theta_2^2 + q_l e\theta_2 + q_l e^2 \theta_1}{-4\theta_2(\theta_2 + e\theta_1)}$$

The unit value of sales to each country corresponds to:

$$P_1 = \frac{p_l^* d_{1l}^* + p_h^* d_{1h}^*}{d_{1l}^* + d_{1h}^*} \quad \text{and} \quad P_2 = e \frac{p_l^* d_{2l}^* + p_h^* d_{2h}^*}{d_{2l}^* + d_{2h}^*}$$

Converting P_2 into the exporter's currency, the domestic-export price ratio is

$$X = \frac{P_1}{P_2/e} = \frac{AB}{CD}$$

where

$$A = -(\theta_2^2 q_l^2 + 2\theta_2 q_l^2 e\theta_1 + q_l^2 e^2 \theta_1^2 - 2\theta_2 q_l q_h e\theta_1 - \theta_2^2 q_l q_h - q_l e^2 \theta_1^2 q_h - 4\theta_1 \theta_2^2 q_h + 16\theta_1^3 \theta_2 e + 4q_h e^2 \theta_1^3 - 2\theta_2 q_h^2 e\theta_1 - \theta_2^2 q_h^2 - e^2 \theta_1^2 q_h^2)$$

$$B = (\theta_2 q_l e + e^2 q_l \theta_1 - 4\theta_2^2)$$

$$C = (-\theta_2 q_l - q_l e\theta_1 + 4e\theta_1^2)$$

$$D = (q_l^2 e\theta_2^2 + 2q_l^2 e^2 \theta_2 \theta_1 + q_l^2 e^3 \theta_1^2 - 2q_l e^2 \theta_2 q_h \theta_1 - \theta_2^2 e q_l q_h - q_l e^3 \theta_1^2 q_h + 4\theta_2^3 q_h + 16\theta_1 \theta_2^3 - 4e^2 \theta_1^2 \theta_2 q_h - 2e^2 \theta_2 q_h^2 \theta_1 - \theta_2^2 q_h^2 e - e^3 \theta_1^2 q_h^2)$$

It can be shown that no combination of parameter choices $(q_l, q_h, \theta_1, \theta_2)$ can lead to a constant $X = 1$, with e being a variable. Based on our previous explanation, there is PTM. However, in this scenario markets are not segmented and the LOP holds, i.e., the monopolist is unable to treat the two markets differently. As there is no real PTM, we call this **pseudo PTM**.

Proof of proposition 2

The monopolist treats each market independently due to market segmentation and constant marginal cost. The firm's problem in country 1 is,

$$\max_{p_{1l}, p_{1h}} (p_{1l} - \frac{1}{2}q_l^2)d_{1l} + (p_{1h} - \frac{1}{2}q_h^2)d_{1h}$$

Similarly, the firm's problem in country 2 is,

$$\max_{p_{2l}, p_{2h}} (\frac{p_{2l}}{e} - \frac{1}{2}q_l^2)d_{2l} + (\frac{p_{2h}}{e} - \frac{1}{2}q_h^2)d_{2h}$$

We solve the firm's problem in the market 1 first. The marginal consumers are,

$$\theta_{1l} = \frac{p_{1l}}{q_l}, \quad \theta_{1h} = \frac{p_{1h} - p_{1l}}{q_h - q_l}$$

and thus the demands can be represented by,

$$d_{1l} = \frac{\theta_{1h} - \theta_{1l}}{\theta_1} = \frac{q_l p_{1h} - p_{1l} q_h}{(q_h - q_l) q_l \theta_1}, \quad d_{1h} = \frac{\theta_1 - \theta_{1h}}{\theta_1} = 1 - \frac{p_{1h} - p_{1l}}{(q_h - q_l) \theta_1}$$

Firm's profit is,

$$\begin{aligned} \pi_1 &= (p_{1l} - \frac{1}{2}q_l^2)d_{1l} + (p_{1h} - \frac{1}{2}q_h^2)d_{1h} \\ &= (p_{1l} - \frac{1}{2}q_l^2) \frac{q_l p_{1h} - p_{1l} q_h}{(q_h - q_l) q_l \theta_1} + (p_{1h} - \frac{1}{2}q_h^2) (1 - \frac{p_{1h} - p_{1l}}{(q_h - q_l) \theta_1}) \end{aligned}$$

The first order conditions are,

$$\frac{\partial \pi_1}{\partial p_{1l}} = \frac{4q_l p_{1h} - 4p_{1l} q_h + q_l^2 q_h - q_l q_h^2}{2(q_h - q_l) q_l \theta_1}$$

$$\frac{\partial \pi_1}{\partial p_{1h}} = \frac{-4p_{1l} + q_l^2 - 2\theta_1 q_h + 2\theta_1 q_l + 4p_{1h} - q_h^2}{2(-q_h + q_l)\theta_1}$$

Solving these two equations simultaneously for p_{1l} and p_{1h} , we have,

$$p_{1h}^* = \frac{1}{4}q_h(2\theta_1 + q_h), \quad p_{1l}^* = \frac{1}{4}q_l(2\theta_1 + q_l) \quad (2)$$

Thus the equilibrium quantities are,

$$d_{1l}^* = \frac{q_h}{4\theta_1}, \quad d_{1h}^* = \frac{2\theta_1 - q_l - q_h}{4\theta_1} \quad (3)$$

Similarly, by solving the maximization problem of the monopolist in country 2, we can obtain the following equilibrium prices and quantities,

$$p_{2h}^* = \frac{1}{4}q_h(2\theta_2 + eq_h), \quad p_{2l}^* = \frac{1}{4}q_l(2\theta_2 + eq_l) \quad (4)$$

$$d_{2l}^* = \frac{eq_h}{4\theta_2}, \quad d_{2h}^* = \frac{2\theta_2 - e(q_l + q_h)}{4\theta_2} \quad (5)$$

Because markets are segmented and treated independently by the monopolist, the equilibrium prices and quantities in market 1 are not affected by movements in the exchange rates whereas the exchange rate affects the equilibrium prices and quantities in market 2. Thus, there is (real) pricing-to-market for both individual products, because

$$X_l = \frac{p_{1l}^*}{p_{2l}^*/e} = \frac{(2\theta_1 + q_l)e}{2\theta_2 + eq_l} \neq 1$$

$$X_h = \frac{p_{1h}^*}{p_{2h}^*/e} = \frac{(2\theta_1 + q_h)e}{2\theta_2 + eq_h} \neq 1$$

By substituting the expressions for the equilibrium prices and quantities of the low- and high-quality products in each market (equations (2) – (5)), we can obtain, after some simplifications, the domestic-export price ratio as the following expression:

$$X = \frac{P_1}{P_2/e} = -\frac{(q_h^2 + q_l q_h - q_l^2 - 4\theta_1^2)(-2\theta_2 + q_l e)e}{(-q_l + 2\theta_1)(e^2 q_h^2 + e^2 q_l q_h - 4\theta_2^2 - q_l^2 e^2)}$$

A change in the exchange rate has a non-zero impact on this ratio indicating the presence of PTM. However, we have shown above that in this case, there is real and pseudo PTM. Real

PTM is attributable to the monopolist charging different prices to different markets for the same quality product. Pseudo PTM is attributable to the use of unit values, which average the price for different quality products. A change in the exchange rate causes a change in the mix of quality imported causing a non-zero impact on the unit value to market 2.

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