

PRICING-TO-MARKET: PRICE DISCRIMINATION OR PRODUCT DIFFERENTIATION?

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We employ a vertical differentiation model to examine the potential bias in pricing-to-market results when using export unit values aggregating differentiated products. Our results show that: (i) false evidence of pricing-to-market is always found when using unit values, whether the law of one price holds or not; and (ii) the size of the bias increases with the level of product differentiation. Our simulation results support those conceptual findings. Thus, some of the positive pricing-to-market results in the literature could be an artifact of the product heterogeneity embodied in unit values rather than evidence of imperfect competition.

Key words: price discrimination, pricing-to-market, quality upgrading, unit values, vertical differentiation.

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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 Dunn (1970) and Mann (1986) and later was termed "pricing-to-market" (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. This approach has been particularly popular in the study of food and agricultural

exports (e.g., Pick and Park 1991; Pick and Carter 1994; Griffith and Mullen 2001; Carew and Florkowski 2003; and Glauben and Loy 2003), automobile exports (e.g., Knetter 1989, 1993; Marston 1990; Gagnon and Knetter 1995), and in a wide range of other industries.¹

Most PTM studies, such as those listed above, use export unit values as the price variable.² 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 unit values is that they often aggregate data on products employed for very different uses.³ Thus, findings of PTM that are attributed to price discrimination might alternatively indicate product differentiation when unit values are used (Sexton and Lavoie 2001). It is important to understand the effect of unit value data on PTM testing because evidence, or lack of evidence, of PTM can be used for policy purposes (e.g., Carter 1993; Gil-Pareja 2003). Moreover, PTM can have important effects on the international transmission of monetary and fiscal policy, and

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¹ We count over 100 studies under a search "pricing-to-market" by default fields in EconLit, not counting working paper duplicates.

² Exceptions include Goldberg and Verboven (2001), Griffith and Mullen (2001), and Gil-Pareja (2003), who use product level data.

³ Gehlhar and Pick (2002) found that forty percent of U.S. food exports are characterized by nonprice competition, such as product differentiation. For those products, they argue that unit values are a poor measure of prices in international trade.

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 potential bias in pricing-to-market results when using unit values aggregating differentiated products.

Product differentiation has been explicitly modeled in studies evaluating the extent of exchange rate pass-through (e.g., Dornbush 1987; Feenstra, Gagnon, and Knetter 1996; Yang 1997; Bodnar, Dumas, and Marston 2002).⁴ In these studies, 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 the home country and sold to the home and a foreign market. Second, we specifically examine how product differentiation affects the test of PTM.

The disadvantages of unit values are acknowledged in many PTM studies using Knetter's model. Common criticisms of unit values are that they do not account for different qualities shipped to different markets and for changes in product quality over time (Gil Pareja 2002).⁵ However, authors, like Knetter (1989), typically argue that systematic differences in product quality, such as shipping different qualities to different markets, can be captured by country dummies. Similarly, changes in the quality of the product that is common across countries can be captured by time effects. Thus, the impact of product differentiation on the evaluation of PTM is typically argued to be minimal.⁶

While prior authors acknowledge the problems associated with unit values when they reflect different qualities shipped to different countries or across time, we address an issue that to our knowledge has not been studied before in the PTM literature. Namely, we examine *destination-specific* changes in the product-quality mix and the false PTM findings

that may result when unit values aggregate differentiated products. False PTM findings occur because fluctuations in exchange rates cause a change in the product-quality mix exported, which in turn affect the unit values. We demonstrate that this relationship between exchange rate and unit values can be mistakenly interpreted as PTM in empirical work. We also show that the magnitude of the bias in PTM results depends on the level of product differentiation.⁷

To examine the incidence of spurious PTM results, we introduce a conceptual model where a monopolist sells vertically differentiated products to a domestic and a foreign market. Two polar scenarios are analyzed. In the first one, there is perfect and costless consumer arbitrage, and the law of one price (LOP) holds for individual products (i.e., before aggregation). In the second scenario, consumer arbitrage is not feasible and markets are segmented. In both scenarios, we find "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 "real PTM" as well because markets are segmented, and we show that the extent of pseudo PTM increases with the level of product differentiation.⁸ To evaluate the implication of these findings for empirical work, we employ Monte Carlo simulations analyzing the relationship between PTM and the level of product differentiation. The results indicate the presence of pseudo PTM for a sufficiently high level of product differentiation when the LOP holds. In both scenarios, a higher level of product

⁴ Exchange rate pass-through refers to the extent to which the price to a given importing country adjusts to changes in the exchange rate.

⁵ See also Alston, Carter, and Whitney (1992), and Goldberg and Knetter (1997) for discussions on the use of unit values in the evaluation of PTM. Abbott, Patterson, and Reca (1993) and Larue (2004) provide overviews of issues surrounding the specification of the PTM model in agri-food trade.

⁶ More generally, Davis and Hewitt (1996) illustrate the problem of using unit values in trade analysis when quality is important. They provide two definitions of aggregate quality and implement the procedure of Aw and Roberts (1986) in that context. The procedure decomposes changes in unit values into a change in price and a change in average quality.

⁷ Price stickiness and currency invoicing have also been indicated as potential reasons for bias in PTM findings (e.g., Goldberg and Knetter 1997; Glauben and Loy 2003; Gervais and Larue 2004). Other authors have raised the possibility of PTM findings due to quality differentiation without analyzing the problem *per se*. Gagnon and Knetter (1995) suggest that correlation between destination-specific quality and exchange rate changes may result in false detection of PTM. Hummels and Skiba (2004) examine empirically the Alchian–Allen conjecture—a per unit cost lowers the price of the high-quality good relative to that of the low-quality good thus raising the demand for the high-quality good (Borcherding and Silberberg 1978)—using unit values. In doing so they examine the alternative hypothesis that different prices to different markets could be due to imperfect competition and PTM rather than different qualities shipped to different markets under perfect competition. Their results are consistent with the Alchian–Allen conjecture and suggest that PTM alone cannot explain their findings, thus lending support to our theoretical work.

⁸ This is in the same spirit as in Bodnar, Dumas, and Marston (2002), who find that higher product substitutability moderates exchange rate pass-through, using a model where an exporting firm and a foreign import-competing firm produce products of various substitutability.

differentiation is more likely to lead to a statistically significant evidence of PTM.

The rest of the article is organized as follows. First, we present the conceptual model and the analysis of the two scenarios. This is followed by a simulation study and the conclusion.

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. The marginal cost is $\frac{1}{2}q_j^2$ for the product of quality q_j ($j = l, h$).⁹

We model vertical differentiation *à la* Mussa and Rosen (1978). Consumers are heterogeneous in their valuation of quality. The conditional indirect utility of a consumer with a marginal willingness to pay for quality of θ and income y is given by $y + \theta q - p$ if she buys one unit of the product of quality q at price p , and y if she does not buy the differentiated product. There is a continuum of consumers with total mass of one distributed uniformly in each country. In other words, $\theta \in U[0, \theta_i]$ 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 not buying the differentiated product. In other words, that consumer obtains the same level of indirect utility from either option. Thus, θ_{il} is the value of θ that solves $y + \theta q_l - \lambda_i \cdot p_{il} = y$, where $\lambda_1 = 1$ and $\lambda_2 = e$, and e is the exchange rate expressed in units of country 2's currency per unit of country 1's currency.¹⁰ 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 $y + \theta q_h - \lambda_i \cdot p_{ih} = y + \theta q_l - \lambda_i \cdot p_{il}$ with $\lambda_1 = 1$ and $\lambda_2 = e$. Thus, consumers with $\theta \in [0, \theta_{il})$ will not buy the differentiated product, those with $\theta \in [\theta_{il}, \theta_{ih}]$ will buy the low-quality product and the others ($\theta \in (\theta_{ih}, \theta_i]$) will buy the high-quality product.¹¹ Accordingly, the demand for each quality is the length of the consumer interval buying the given quality multiplied by the density of

consumers along that interval ($1/\theta_i$) times the total number of consumers, $N = 1$. The demands for the low- and high-quality products in country $i = 1, 2$ are

$$(1) \quad d_{il}(p_{ih}, p_{il}) = \frac{\theta_{ih} - \theta_{il}}{\theta_i} \\ = \frac{\lambda_i(p_{ih}q_l - p_{il}q_h)}{\theta_i(q_h - q_l)q_l},$$

$$(2) \quad d_{ih}(p_{ih}, p_{il}) = \frac{\theta_i - \theta_{ih}}{\theta_i} \\ = 1 - \frac{\lambda_i(p_h - p_l)}{\theta_i(q_h - q_l)}.$$

When there is pricing-to-market, a firm with market power will set different prices (in the same currency) in different markets based on their respective market conditions. Accordingly, Marston (1990) examines PTM by forming the ratio of the export to the home price set by a domestic monopolist and evaluating how it varies with the exchange rate. Similarly, we use the domestic–export price ratio

$$(3) \quad X = \frac{P_1}{P_2},$$

where P_i is the price in country i , expressed in country 1's currency.¹² The PTM effect can be measured as the effect of a change in the exchange rate on X . When there is PTM, a change in the exchange rate will have a non-zero impact on the ratio X . In other words, there is PTM when a movement in the exchange rate leads to disproportionate price changes in the two markets. In our theoretical setting there is product differentiation, but it cannot be observed and product aggregates are taken to be homogeneous. Thus, in this setting, there is no PTM when $X \equiv 1$. We use this latter definition in this article.^{13, 14}

¹² Other studies using this measure include Bergin and Feenstra (2001) and Gervais and Larue (2004).

¹³ A reviewer correctly points out that it is the change in the price ratio X in response to a change in the exchange rate, holding quality composition constant (if this could be done or observed), that provides evidence of PTM. We do not use this more general definition because our objective is to show that not taking into account product differentiation may lead to false PTM results. The implicit assumption that product differentiation cannot be observed is consistent with the use of unit values in the empirical PTM literature.

¹⁴ Our results also hold using the more general definition of PTM, i.e., changes in exchange rates have a nonzero impact on the ratio X . Some results in this case can only be demonstrated numerically, which is not as appealing. Furthermore, we can also show that our results hold in the presence of transaction costs. However, we assume that transaction costs are zero for simplicity.

⁹ When marginal cost is linear in quality, it can be shown that only the high-quality product will be sold.

¹⁰ Throughout this article, prices are expressed in country 1's currency.

¹¹ This demand structure requires that $0 \leq \theta_{il} \leq \theta_{ih} \leq \theta_i$, which holds in equilibrium.

We consider two scenarios. In the first one, the LOP holds for each individual product, and the prices of each product in the two markets are equal in the same currency. In the other scenario, markets are segmented and arbitrage between consumers across countries is not feasible. Consequently, each product is sold by the monopolist at different prices in each country.

Analysis

In this section, we solve for the equilibrium prices and quantities in each scenario. The monopolist’s objective is to maximize profit by choosing prices. Using equilibrium prices and quantities, we calculate the unit values of sales to each country, expressed in country 1’s currency. Unit values then enter the domestic-export price ratio (X), which is used to determine the presence of PTM. We begin with the first scenario where the law of one price (LOP) holds for each product.

Scenario 1. LOP Holds The monopolist cannot price discriminate between markets 1 and 2 in this scenario. Thus $p_{il} = p_l$ and $p_{ih} = p_h (i = 1, 2)$, and profit is maximized according to:

$$(4) \quad \max_{p_l, p_h} \left(p_l - \frac{1}{2} q_l^2 \right) (d_{1l} + d_{2l}) + \left(p_h - \frac{1}{2} q_h^2 \right) (d_{1h} + d_{2h})$$

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 the previous section. Note that the prices p_l and p_h are set by the monopolist 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.¹⁵

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 $i (i = 1, 2)$.¹⁶ The unit value P_i is computed as the weighted average price in market i , i.e.,

$$(5) \quad P_i = \frac{p_l^* d_{il}^* + p_h^* d_{ih}^*}{d_{il}^* + d_{ih}^*}$$

The presence of PTM is determined by computing $X = \frac{P_1}{P_2}$ and evaluating whether it is identically equal to one or varies with the exchange rate. Our results are summarized in the next proposition.

PROPOSITION 1. *When the LOP holds for individual products, there is pseudo PTM when using unit values.*

Proof: We begin with the premise that there is no PTM when $X = \frac{P_1}{P_2} \equiv 1$. Substituting equation (5) into equation (3), the domestic-export price ratio can be expressed as

$$(6) \quad X = \frac{p_l^* \sigma_1 + p_h^* (1 - \sigma_1)}{p_l^* \sigma_2 + p_h^* (1 - \sigma_2)}$$

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

For $X = 1$, it must be that $\sigma_1 = \sigma_2$. Substituting the equilibrium quantities (see Lavoie and Liu 2006), we have

$$(7) \quad \sigma_1 = \frac{q_h (\theta_2 + e \theta_1)}{4e \theta_1^2 - q_l (\theta_2 + e \theta_1)}$$

and

$$(8) \quad \sigma_2 = \frac{q_h e (\theta_2 + e \theta_1)}{4 \theta_2^2 - e q_l (\theta_2 + e \theta_1)}$$

It follows that $\theta_2 = e \theta_1$ is required for $\sigma_1 = \sigma_2$. Given that θ_1 and θ_2 are fixed parameters, $\sigma_1 = \sigma_2$ cannot hold when e varies. Thus, $X \equiv 1$ does not hold, indicating PTM. We find false evidence of PTM (pseudo PTM) using unit values.

Pseudo PTM is found because the exchange rate affects the ratio of unit values through a change in the product-quality mix. An appreciation of the foreign currency (decrease in e) results in an increase in imports of the high-quality variety in country 2 relative to the total quantity of imports. The reverse is true for a depreciation of the foreign currency.

The shift in the product-quality mix occurs because fluctuations in the exchange rate affect the relative demand for the high-quality variety in market 2. To illustrate, note that

$$(9) \quad \frac{d_{2h}}{d_{2l}} = \frac{q_l [\theta_2 (q_h - q_l) - e (p_h - p_l)]}{e (p_h q_l - p_l q_h)}$$

¹⁵ For both scenarios, it can be easily shown that the monopolist is better off supplying both products than supplying either product.
¹⁶ See Lavoie and Liu (2006) for the derivations of the equilibrium prices and quantities.

and the derivative with respect to the exchange rate is

$$(10) \quad \frac{\partial(d_{2h}/d_{2l})}{\partial e} = -\frac{q_l \theta_2 (q_h - q_l)}{e^2 (p_h q_l - p_l q_h)}.$$

When $\frac{p_h}{q_h} > \frac{p_l}{q_l}$ — a necessary condition that is always satisfied in equilibrium for the demand of both goods to be positive—this derivative is negative. In other words, even though both goods face the same change in the exchange rate, a decrease in exchange rate decreases the relative price of the high-quality good, which results in a shift in product-quality mix toward the higher quality product, i.e., quality upgrading.¹⁷ For consumers, a currency appreciation translates into an increase in income. With more income, quality upgrading implies that consumption of the two varieties does not increase proportionally, i.e., preferences are non-homothetic. Any other ad valorem costs (e.g., tariffs and taxes) would have the same effect in the context of nonhomothetic preferences (Das and Donnenfeld 1987; Donnenfeld 1988; Wall 1992; and Krishna 1992). There is substantial support for preferences of this type in the empirical literature. For example, Deaton and Muellbauer (1983) have shown that food accounts for a much larger budget share of low-income households. While the quantity of food consumed does not generally increase when income increases, the quality of food purchased often does. For example, more expensive cuts of steak, and brand name as opposed to generic products are bought. The same could be said of cars, i.e., with more income people generally tend to buy more expensive cars, not more cars. We argue that it is this mechanism that operates when false PTM results are obtained. Note that all consumers are assumed to have nonhomothetic preferences in this model. However, in practice, having only some consumers with nonhomothetic preferences is sufficient to obtain some quality upgrading and therefore, the observation of pseudo PTM.

The empirical trade literature provides more support for the assumption of nonhomotheticity of preferences. Hunter and Markusen (1988) reject the homotheticity of preferences using a linear expenditure system for 11

commodities in 34 countries. Using the same approach, Hunter (1991) estimates that non-homothetic preferences may account for more than one quarter of interindustry trade flows. There is also empirical evidence of quality upgrading or downgrading following movements in ad valorem costs. Conley and Peterson (1995) find evidence for a decrease in quality of U.S. export of beef products to Japan following a depreciation of yen in the 1980s. Hummels and Skiba (2004) show that lower ad valorem tariffs and higher transportation cost result in quality upgrading using export data for more than 5,000 product categories. Goolsbee (2004), in an empirical study of the effect of ad valorem tax subsidies, finds that all of the increase in investment comes from an upgrade in the quality of the capital purchased. The empirical evidence listed here suggests that quality upgrading/downgrading is an important concern for PTM studies using commodity aggregates.

The quality upgrading/downgrading reasoning applies to many consumer products and also applies to intermediate goods, such as some agricultural products. The extent to which the substitution occurs for intermediate goods depends on the production process. There are at least two situations where the quality upgrading/downgrading argument holds for intermediate goods. First, higher quality inputs may lead to higher quality output that can be sold at higher prices. For example, a decrease in the price of organic soybeans relative to the price of conventional soybeans could result in a shift in production towards more organic soybean products that can be sold at a premium. Second, higher quality inputs may lead to a decrease in processing costs. For example, cleaner wheat results in lower flour processing costs without changing the quality of the end product. Processing costs can also be reduced by altering the blend of inputs. For example, wheat is blended for protein according to the type of bread flour desired. Many wheat importing countries tend to blend their own wheat, which is usually low in protein, with imported wheat of higher protein content. A favorable movement in the exchange rate would result in substitution towards higher protein wheat because not as much imported wheat is necessary to bring up the flour protein level to the right level.

When these conditions hold, or when the substitution happens after a certain threshold change in exchange rate, false PTM results occur for intermediate goods. Note also that if the

¹⁷ This result is akin to the Alchian–Allen theorem (see footnote 7), which has motivated the literature on trade restraints and quality upgrading (e.g., Falvey 1979; Aw and Robert 1986; Feenstra 1988). Feenstra (1995) notes that quality upgrading “can refer to either a shift in demand towards higher priced import varieties (i.e., a change in product mix), or to the addition of improved characteristics on each variety” (p. 1572).

substitution does not occur for certain firms, in practice it may be present at the country level. Thus, while there are some limitations to our model in the context of intermediate goods, our results still draw attention to the fact that false PTM results are a concern when data for commodity aggregates are used.

Remark Under perfect competition, where export prices are equal to marginal cost, we also find pseudo PTM using unit values.

The intuition for this remark is the same as presented for proposition 1. This result is particularly important given that PTM results are typically interpreted as evidence of imperfect competition (Goldberg and Knetter 1997).

Scenario 2. Market Segmentation In this scenario, the monopolist price discriminates between markets. Each market can be treated independently because of the assumption of constant marginal cost with respect to quantity. The monopolist maximizes profit by setting the price p_{ij} to country i ($i = 1, 2$) for product of quality q_j ($j = l, h$) according to:

$$(11) \quad \max_{p_{il}, p_{ih}} \left(p_{il} - \frac{1}{2}q_l^2 \right) d_{il} + \left(p_{ih} - \frac{1}{2}q_h^2 \right) d_{ih}$$

for market i ($i = 1, 2$), 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 as derived earlier.

Define X_l as the domestic-export price ratio for the low-quality product (i.e., p_{1l}^*/p_{2l}^*) and X_h , as that for the high-quality product (i.e., p_{1h}^*/p_{2h}^*). A ratio different from one or varying with exchange rates indicates that the monopolist price discriminates. Thus, there is real PTM when $X_l \equiv 1$ or $X_h \equiv 1$ does not hold. The next proposition summarizes our findings for this scenario.

PROPOSITION 2. *When markets are segmented, (i) There is real PTM for each individual product. (ii) There are both real and pseudo PTM when using unit values.*

Proof: (i) Substituting the expressions for the equilibrium prices (see scenario 2 in Lavoie and Liu [2006]), the domestic-export price ratios can be expressed as

$$(12) \quad X_l = \frac{(2\theta_1 + q_l)e}{2\theta_2 + eq_l}$$

and

$$(13) \quad X_h = \frac{(2\theta_1 + q_h)e}{2\theta_2 + eq_h}$$

For $X_l = X_h = 1$, it must be that $\theta_2 = e\theta_1$. Given that θ_1 and θ_2 are fixed parameters, $\theta_2 = e\theta_1$ cannot hold when e varies. Thus, $X_l \equiv 1$ and $X_h \equiv 1$ do not hold, indicating PTM. We label this result “real PTM” given that the non-aggregated prices used in this calculation are set by a discriminatory monopolist.

(ii) Because the two markets are independent, fluctuations in the exchange rates affect only the equilibrium prices and quantities in market 2. Thus, a change in the exchange rate would affect the domestic-export price ratio ($X = \frac{P_1}{P_2}$) only through P_2 , which can be expressed as $P_2 = \frac{p_{1l}^*\sigma_2}{X_l} + \frac{p_{1h}^*(1-\sigma_2)}{X_h}$.

It follows that

$$(14) \quad \frac{\partial P_2}{\partial e} = \frac{\partial \sigma_2}{\partial e} \left(\frac{p_{1l}^*}{X_l} - \frac{p_{1h}^*}{X_h} \right) - \frac{\partial X_l}{\partial e} \frac{p_{1l}^*}{X_l^2} \sigma_2 - \frac{\partial X_h}{\partial e} \frac{p_{1h}^*}{X_h^2} (1 - \sigma_2) < 0.$$

A change in the exchange rate affects P_2 through (1) a change in the composition of imports (σ_2) generating the pseudo PTM effect, and (2) a change in X_l and X_h , which reflect real PTM. The negative sign of the derivative follows from: $\frac{\partial \sigma_2}{\partial e} = \frac{2q_h\theta_2}{(2\theta_2 - eq_l)^2} > 0$, $\left(\frac{p_{1l}^*}{X_l} - \frac{p_{1h}^*}{X_h} \right) = p_{2l}^* - p_{2h}^* < 0$, $\frac{\partial X_l}{\partial e} = \frac{2\theta_2(2\theta_1 + q_l)}{(2\theta_2 + eq_l)^2} > 0$, $\frac{\partial X_h}{\partial e} = \frac{2\theta_2(2\theta_1 + q_h)}{(2\theta_2 + eq_h)^2} > 0$, and $(1 - \sigma_2) > 0$. Thus, $\frac{\partial X}{\partial e} > 0$ (because $\frac{\partial P_1}{\partial e} = 0$, $\frac{\partial P_2}{\partial e} < 0$) due to both real and pseudo PTM.

As with scenario 1, a change in the exchange rate affects the composition of imports. This effect does not matter when examining PTM using individual product prices. However, because unit values constitute a weighted average of the price of high- and low-quality good in each market, a change in the exchange rate not only affects the landed prices in country 2, but also the weights associated to those prices through a change in the product-quality mix imported. Thus, PTM findings are the result of two effects: (1) a true PTM effect, because the monopolist does price discriminate in this scenario, and (2) a pseudo PTM due to the use of unit values, which average the price of good h and l , and the resulting change in the

composition of imports following fluctuations in the exchange rate.

This result indicates that one would conclude correctly that there is PTM using unit values as prices. However, there is also pseudo PTM. The extent to which X departs from one is affected by the aggregation of differentiated products, i.e., the importance of pseudo PTM. In what follows, we examine the relationship between the level of product differentiation and the extent of pseudo PTM for both scenarios. Increasing levels of product differentiation is modeled by fixing q_l and increasing q_h . The next two corollaries summarize our results.¹⁸

COROLLARY 3. *Under the LOP, the extent of pseudo PTM increases with the level of product differentiation.*

Proof: Under the LOP, PTM findings using unit values represent solely pseudo PTM. Thus, let $|X - 1|$ measure the extent of pseudo PTM. The extent of pseudo PTM increases with product differentiation if $|X - 1|$ increases with q_h . To show that, we need to show that if $X - 1 > 0$, then $\frac{\partial X}{\partial q_h} > 0$, and if $X - 1 < 0$, then $\frac{\partial X}{\partial q_h} < 0$. In Lavoie and Liu (2006) we show that when $\theta_2 < e\theta_1$, $X - 1 > 0$, and $\frac{\partial X}{\partial q_h} > 0$. When $\theta_2 > e\theta_1$, $X - 1 < 0$, and $\frac{\partial X}{\partial q_h} < 0$.

COROLLARY 4. *Under market segmentation, the extent of pseudo PTM increases with the level of product differentiation.*

Proof: Recall that $X_l = \frac{p_{1l}^*}{p_{2l}^*}$, $X_h = \frac{p_{1h}^*}{p_{2h}^*}$ and $X = \frac{p_{1l}^*\sigma_1 + p_{1h}^*(1-\sigma_1)}{p_{2l}^*\sigma_2 + p_{2h}^*(1-\sigma_2)}$. Under market segmentation (scenario 2), findings of PTM using unit values represent both real and pseudo PTM. Let $|X - X_h|$ and $|X - X_l|$ together measure the extent of pseudo PTM in this scenario. The extent of pseudo PTM increases with product differentiation if $|X - X_j|$ ($j = h, l$) increases

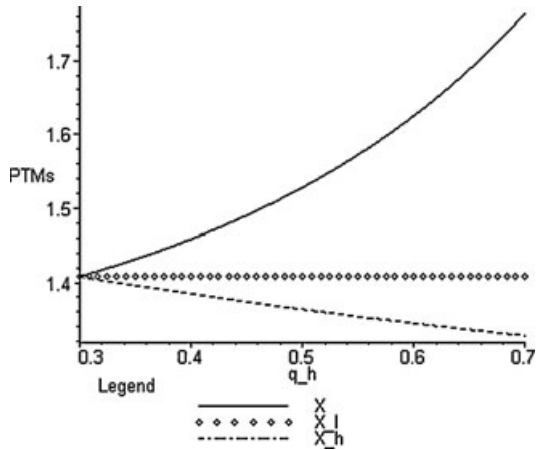


Figure 1. Domestic-export price ratios and product differentiation

with q_h . To show that, we need to show that if $X - X_j > 0$ then $\frac{\partial(X-X_j)}{\partial q_h} > 0$, and if $X - X_j < 0$ then $\frac{\partial(X-X_j)}{\partial q_h} < 0$. We divide this proof into two cases.

Case 1. $\theta_2 < e\theta_1$. Note that when $q_h = q_l$, $X_l = X_h = X > 1$. Moreover, $\frac{\partial X_l}{\partial q_h} = 0$, $\frac{\partial X_h}{\partial q_h} < 0$, $\lim_{q_h \rightarrow \infty} X_h = 1$, and $\frac{\partial X}{\partial q_h} > 0$.¹⁹ This implies that when $q_h > q_l$, $X - X_j > 0$ and $\frac{\partial(X-X_j)}{\partial q_h} > 0$ ($j = h, l$). See Lavoie and Liu (2006) for the derivations.

Case 2. $\theta_2 > e\theta_1$. When $q_h = q_l$, $X_l = X_h = X < 1$. Moreover, $\frac{\partial X_l}{\partial q_h} = 0$, $\frac{\partial X_h}{\partial q_h} > 0$, $\lim_{q_h \rightarrow \infty} X_h = 1$, and $\frac{\partial X}{\partial q_h} < 0$.²⁰ This implies that when $q_h > q_l$, $X - X_j < 0$ and $\frac{\partial(X-X_j)}{\partial q_h} < 0$ ($j = h, l$). See Lavoie and Liu (2006) for the derivations.

To get a sense of how X , X_l , and X_h vary with the level of product differentiation (q_h), we take scenario 2's model, assign parameter values, and plot these three measures against q_h . We set $q_l = 0.3$, $\theta_1 = 1$, $\theta_2 = 2$, $e = 3$ ($\theta_2 < e\theta_1$). The results are provided in Fig. 1.

As indicated in the second case of corollary 4, when $q_h = q_l$, $X_l = X_h = X > 1$, indicating PTM but no pseudo PTM. With differentiated products ($q_h > q_l$), there is pseudo PTM because X is different from X_h and X_l . Moreover,

¹⁸ Our setting assumes that quality is exogenous. Alternatively, quality can be endogenous and the monopolist chooses qualities followed by prices. The qualitative results do not change, i.e., there is always pseudo PTM. If a change in the exchange rate does not induce a change in the qualities (e.g., the change is perceived to be temporary and quality adjustments are costly, as in the short run), qualities are fixed once chosen. Because our findings of pseudo PTM holds for any $q_h > q_l > 0$, endogenous qualities do not improve the model. If qualities adjust automatically with a change in the exchange rate (say in the long run), we also find pseudo PTM. One important disadvantage of the endogenous quality model will become obvious with corollaries 3 and 4—it does not allow us to determine how product differentiation affects the extent of pseudo PTM. This outcome of our model is important because in the construction of unit values, aggregation is performed over products that are more differentiated in some industries than in others.

¹⁹ As product differentiation increases, X_h decreases but never actually reaches a value of 1 because negative quantities of either variety are not allowed. Thus, $X_h > 1$ and $X > X_l > X_h > 1$.

²⁰ As product differentiation increases, X_h increases but never actually reaches a value of 1 because negative quantities of either variety are not allowed. Thus, $X_h < 1$ and $X < X_l < X_h < 1$.

the graph clearly shows the increasing importance of pseudo PTM with greater levels of product differentiation because X moves away from both X_l and X_h when q_h increases.²¹

Simulations

Our theoretical results indicate that when sales to a given market involve differentiated products and unit values are used as prices to evaluate PTM, there is always pseudo PTM. This result applies with or without price discrimination and even under perfect competition. This implies that in regression analyses following Knetter (1989), the exchange rate coefficient may pick up the effects of pseudo PTM. Next we conduct a Monte Carlo simulation to investigate: (1) how prevalent are false statistical findings of PTM, and (2) quantify how the level of product differentiation impacts statistical findings of PTM.

We estimate the following model,

$$(15) \quad \ln X_t = \beta_0 + \beta_1 \ln e_t + u_t, t = 1, \dots, T$$

where T is the number of draws, $e_t \sim U[a, b]$ is the exchange rate for draw t , and u_t is the error term. X_t is the domestic–export price ratio generated as $\frac{P_1 + \epsilon_{1t}}{P_2 + \epsilon_{2t}}$, where P_i is the unit value for market i ($i = 1, 2$) computed as described in each scenario of the previous section, and $\epsilon_{it} \sim N(0, \delta^2)$ and are identically and independently distributed across i and t .

If there is no PTM, the domestic–export price ratio should be independent of the exchange rate and β_1 should be zero. 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 the previous section. For both scenarios, we set $a = 1.5$, $b = 2.5$, $\delta = 1/15$, $T = 100$ (the number of draws), $\theta_1 = 1$, $\theta_2 = 2$, and $q_l = 0.3$.²² We conduct 1,000 trials for each level of product differentiation (q_h) to obtain $\hat{\beta}_1$ and its p-value.

²¹ In the process of proving corollary 4, we also showed that when there is both real and pseudo PTM, product differentiation exaggerates the real level of price dispersion, i.e., the extent to which the prices to the two markets differ. The more X , X_h , and X_l diverge from 1 (in a positive or negative fashion), the greater the price dispersion. When $\theta_2 < e\theta_1$ and $q_h > q_l$, $X > X_l > X_h > 1$, and X shows a greater price dispersion than is demonstrated by either X_h or X_l . When $\theta_2 > e\theta_1$ and $q_h > q_l$, $X < X_l < X_h < 1$, and X again shows a greater price dispersion than is demonstrated by either X_h or X_l .

²² The parameters are chosen to ensure that all equilibrium prices and demands are nonnegative. Moreover, $P_i + \epsilon_{it}$ must be positive to calculate $\ln X_t$, and δ is chosen accordingly.

Table 1. $\hat{\beta}_1$ under the LOP Scenario

q_h	Number of Trials	Mean of $\hat{\beta}_1$	Percentage of Trials with p -value < 10%
0.4	1,000	0.1717	12.5%
0.5	1,000	0.3975	42.8%
0.6	1,000	0.6218	85.6%
0.7	1,000	0.8841	99.6%

Table 2. $\hat{\beta}_1$ under the Market Segmentation Scenario

q_h	Number of Trials	Mean of $\hat{\beta}_1$	Percentage of Trials with p -value < 10%
0.4	1,000	1.0328	90.6%
0.5	1,000	1.0702	99.3%
0.6	1,000	1.1361	100%
0.7	1,000	1.2267	100%

The means of $\hat{\beta}_1$ and the percentages of trials with p-value less than 10% are provided in tables 1 and 2.

Table 1 is consistent with our theoretical results and indicates that when products are sufficiently differentiated, statistically significant results suggesting PTM may be obtained, although there is no real PTM. We obtain false evidence of PTM with over 42% of our trials when $q_h = 0.5$ and almost 100% of the trials when $q_h = 0.7$. Table 2 reflects scenario 2 where there is both real and pseudo PTM. For all levels of product differentiation, the significance level ($1 - p$ -value) is higher than in the first scenario. This is intuitive given that there is pseudo as well as real PTM in this case. Both tables indicate that the PTM elasticity ($\hat{\beta}_1$) increases with product differentiation, and so does the proportion of statistical PTM findings—a result consistent with corollaries 3 and 4.²³

Conclusion

In this study, we examine the extent to which a false detection of pricing-to-market (pseudo PTM) may arise from the use of unit value data. To do so, we analyze two scenarios. Both scenarios involve a monopolist located

²³ We can verify numerically using our theoretical results that $\frac{\partial \ln X}{\partial \ln e}$ increases with q_h .

in the home country producing a low- and high-quality variety of a good. In the first scenario, arbitrage prevails and the monopolist sets the same price to both markets for a given variety. In the second scenario, arbitrage is not possible and the monopolist price discriminates between the two markets. Pseudo PTM is found in both scenarios. Findings of PTM when the law of one price (LOP) holds are purely spurious, whereas they represent a combination of real and pseudo PTM when markets are segmented. Moreover, pseudo PTM is found even under perfect competition. Pseudo PTM occurs because movements in the exchange rate alter the product-quality mix sold to each market thus affecting the unit values, even when the prices to the two markets are identical by variety.

For both scenarios, we demonstrate that product differentiation increases the extent to which results are biased by pseudo PTM, thus increasing the likelihood of false detection of PTM in empirical work. Our simulation results show that for sufficiently differentiated products, a statistical finding of PTM occurs when the LOP holds. Moreover, the PTM elasticity increases with product differentiation in both scenarios.

Our study is limited by the occurrence of changes in the product-quality mix following fluctuations in exchange rates. This argument relies on the nonhomotheticity of consumer preferences embodied in the Mussa and Rosen (1978) model of vertical differentiation. There is ample support for the assumption of nonhomothetic preferences in the literature and our results do not rest on this assumption holding true for all consumers. In practice, having some consumers with nonhomothetic preferences is sufficient to generate pseudo PTM result. Moreover, our model describes demand for consumer goods, which encompasses numerous goods examined in previous PTM studies, notably automobiles. The applicability of our model to intermediate goods, such as several agricultural commodities, also relies on the extent to which quality upgrading/downgrading occurs. We presented two conditions under which quality substitution occurs for inputs. Those conditions can be argued to hold for many agricultural inputs, at least at the country demand level and for threshold levels of exchange rate change. Even with these limitations, our study draws attention to and formalizes the link between pseudo PTM and the use of unit value when products are differentiated, and more importantly explains how the

level of product differentiation is related to the magnitude of the pseudo PTM problem.

While other potential reasons have been raised for bias in PTM findings (e.g., currency invoicing and menu costs), our results suggest that the prevalence of PTM findings in the literature could also be attributed to the use of unit values aggregating differentiated products. PTM findings have been interpreted as evidence of price discrimination and market power, without explaining the source of market segmentation or market power (see Goldberg and Knetter [1997] for a discussion). Sexton and Lavoie (2001) also observe the general lack of justification for the examination of imperfect competition and price discrimination among PTM studies focusing on food and agricultural products. Thus, while we do not dismiss the possibility of strategic pricing, our research emphasizes the need for future PTM studies to (1) investigate the plausibility of market power in international trade of the product of interest, (2) evaluate the level of differentiation present in the export unit value data for the product category chosen, and (3) interpret the results accordingly. More confidence can be placed on results obtained using disaggregated data for which there are good reasons to believe exporters have market power in the international market (i.e., they produce a differentiated product relative to other countries' products, exports are conducted by a large entity, such as a state-trading firm, the exporter has a large world market share, etc.).²⁴ Such caution is especially important when results are used for policy purposes. Alternatively, other approaches may be more suitable to test for imperfect competition and price discrimination when differentiated products are exported. Examples of such methods include Verboven (1996), Goldberg and Knetter (1999), and Lavoie (2005).

Future research includes finding ways to mitigate pseudo PTM (e.g., by controlling for quality changes), providing empirical evidence of false PTM by comparing results obtained using data at different levels of product aggregation, and exploring further the link between unit values and pseudo PTM in the context of intermediate goods.

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²⁴ See for example Gil-Pareja (2002), and Glauben and Loy (2003) where such care is taken.

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