Exchange Rate Pass-Through and Market Structure in Multi-Country World*

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Abstract

Micro-estimates of exchange rate pass-through yield elasticities well outside the range of values predicted by theory. We provide a multi-country quadratic utility model that allows us to examine how export prices are affected by movements in own-currency and cross-currency exchange rates. Own-currency appreciations move firms along the demand curve while cross-currency appreciations shift the position of the demand curve. Both affect the firm's elasticity of demand and therefore the degree to which exchange rate movements affect prices. When own- and cross-currency exchange rates are correlated, as when the euro rises in value against both the dollar and the yen, this yields exchange rate pass-through elasticities that match facts. The model also yields testable predictions for how firms respond to cross-currency exchange rate shocks even when there is no movement in the own exchange rate.

JEL Classifications: F31; F41

Key words: Exchange rate pass-through; Pricing to market; Exchange rate shocks

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1 Introduction

When a currency appreciates, exporters must choose between raising export prices in the foreign market or absorbing the exchange rate shock in the form of lower (seller's currency) export prices. The extent to which firms absorb the shock through changes in seller's currency prices is known as the degree of exchange rate pass through (ERPT). Conceptually, movements in the exchange rate are analogous to cost or tariff shocks, so that optimal price setting for a firm depends on factors such as market structure and the shapes of demand and cost curves. (Krugman, 1987; Dornbusch, 1987; Feenstra, 1989; Atkeson and Burstein, 2008). The degree of ERPT will therefore vary across industries, but the elasticity should lie between 0 and -1. At these extremes the firm either holds prices constant in seller currency (0) or in the buyer currency (-1).

Curiously, a large number of prominent studies have provided empirical estimates of the ERPT elasticity that lie outside these bounds, with estimates varying from -2.26 to 2.55 (Feenstra, 1989; Froot and Klemperer, 1989; Knetter, 1993; Feenstra, Gagnon and Knetter, 1996; Goldberg and Knetter, 1997; Campa and Goldberg, 2005). In this paper we provide a theoretical explanation for why previous studies have found values outside the predicted range, and demonstrate how to estimate the ERPT elasticity in a consistent way.

The key idea in our paper is that the existing literature takes the position of the demand curve facing the firm as given and examines how exchange rate shocks move the firm along the demand curve. This is appropriate if the exporting firm is a monopolist in the foreign market or only faces competition from firms in the buyer's market whose costs are unaffected by the exchange rate shock. However, if the exchange rate shock affects exporters with costs denominated in a third currency, it can also shift the demand curve facing an individual firm. Depending on the nature of the shock and where a firm's competitors are located it is then possible to generate ERPT elasticities that are outside the 0 to -1 range.

In our model firms are monopolistically competitive and representative consumers have quadratic preferences over differentiated products as in Ottaviano, Tabuchi and Thisse (2002). Quadratic preferences provide two key advantages. One, they yield quasi-linear demand curves with a variable price elasticity of demand. Two, they enable us to examine the effect of competitors' pricing behavior on the position of the demand curve facing a firm. The literature contains many examples of papers in which a monopolist faces a variable elasticity demand curve, or in which constant-elasticity-of-substitution (CES) preferences and monopolistic competition allow pricing of rival firms to affect the position of the demand curve, but not its elasticity. Quadratic preferences allow us to do both, and to aggregate the correlated shocks to the demand.

Feenstra et al. (1996) and Atkeson and Burstein (2008) do generate variable markups with nested CES preferences by assuming a small number of competitors or small competitors so that a firm internalizes the effect of own-price changes on the aggregate price index. Our model generates variable markups with a large number of firms and so is more broadly applicable. In addition, firms' prices are affected by both own-currency and cross-currency shocks. For the nested CES model, in contrast, cross-exchange rate movements can shift the position of the demand curve and quantity of sales a firm can achieve, but does not affect the elasticity of demand facing the firm.

Providing a theoretically grounded aggregation of correlated shocks is especially important because a single bilateral exchange rate does not move around in isolation. All else equal, a dollar depreciation against the euro would move a US exporter to Europe down along the demand curve. But if other currencies are also depreciating against the euro, then the position of the demand curve shifts as well. The net effect on the elasticity of demand facing the firm depends on appropriately aggregating the shocks hitting the import market. Given this setup, we can decompose the ERPT elasticity into two components. The first component is driven by the variable price elasticity of demand as in the existing literature. Our major contribution is in the second component, which is driven by shocks to the bilateral exchange rates between the importing country and other competing countries. These cross exchange rate shocks influence the residual demand for exports from competing countries, thus they act as demand shocks. For this reason, currency depreciation in the competing countries shifts the residual demand curve inward and reduces the ERPT elasticity. On the other hand, currency appreciation in the competing countries shifts the residual demand curve outward and raises the ERPT elasticity.

We analytically show that the first component of the ERPT elasticity ranges between

-1 and -0.5. We rely on a simulation to demonstrate the impacts of cross-currency shocks, and investigate the sensitivity of measured ERPT to the correlation in own-currency and cross-currency exchange rates, and the market share of the importer in the buyer's market.

There are three main findings from the simulation. First, we can generate simulated ERPT values ranging well outside the 0 to -1 range predicted by previous theories. Second, the simulated values depend on how own-currency and cross-currency exchange rates co-move. Negative co-movements exaggerate the own-currency effect, leading to ERPT values less than -1. Positive co-movements counter-act the own-currency effect, and can even lead to ERPT values greater than 0. That is, a US exporter could respond to an depreciation of the euro by raising rather than lowering dollar prices of exports. This finding suggests that de facto exchange rate regimes could have large effects on pass through. Third, cross-currency exchange rate shocks become more important when an exporter is small relative to the rest of the world. Intuitively, the residual demand curve facing the firm is shifted to a greater degree by cost-shocks felt elsewhere when that firm has only a small share of the import market. This suggests that measured pass through will be systematically different for large and small exporters, with smaller exporters more likely to have ERPT elasticities outside the 0 to -1 range.

Our reexamination of ERPT provides insights into international pricing at the firm level, but also has macro implications. At the aggregate level, the extent of ERPT determines the degree to which exchange rate shocks affect the domestic prices of imported goods and the consumer price index (CPI). This in turn has important implications for monetary policy in open economies (Devereux and Engel, 2002; 2003). The macro literature has focused on cross country differences in the ERPT elasticity, linking it to the volatility and persistence of exchange rate depreciation, the level of CPI inflation, monetary stability, and the industry composition of trade (Baldwin 1988; Froot and Klemperer, 1989; Taylor, 2000; Devereux, Engel and Storgaard, 2004; Campa and Goldberg, 2005, Devereux, Engel and Storgaard (2004) and Bacchetta and van Wincoop (2005)). As in the micro literature, these macro models predict the ERPT to be in the range 0 and -1 because they ignore the multi-country aspects of trade and so neglect the correlated shocks we examine.

In contrast, we highlight the point that we cannot understand ERPT and dynamics of CPI inflation unless we take into account pricing decisions of all exporters. We provide a clear implication for the role of exchange rate regimes in the determination of ERPT. Specifically, we show that the typical estimating equation in the ERPT literature gives a biased estimate of ERPT elasticity, and the bias is increasing in the correlation between own exchange rate and competing exporters' exchange rates. For this reason, we propose that the estimating equation must include competing exporters' exchange rates to correct the bias. The coefficient of this additional term measures the cross-price effect, which has important implications for trade but has never been estimated in the trade literature.

Our work also has implications for long-run instability of ERPT estimates found in Taylor (2000) and Campa and Goldberg (2005). Taylor (2000) argues that ERPT is increasing in the CPI inflation, hence structural changes in inflation can explain instability of ERPT estimates. However, our theory suggests that instability of ERPT can arise from changes in the number of competitors faced in a given market and the co-movements between own- and cross-currency exchange rates. These are testable hypotheses from our model.

We discuss the model in the next Section. Section 3 presents the simulation results and Section 4 concludes our study.

2 Model

We construct a static or one-period partial equilibrium model, in which exchange rate fluctuations are exogenous. We assume that a monopolistically competitive exporter costlessly adjusts the seller's currency price after observing exchange rate movements. We abstract from uncertainty for this reason. Technically, it does not matter whether the exporter sets price in seller's or buyer's currency given the flexible price assumption. We assume that prices are set in the seller's currency for the sake of exposition since we are interested in the degree of ERPT to seller's currency price.

The assumptions concerning goods trade are the following. First, the world economy consists of a large number of countries producing a large number of differentiated products for exporting and domestic consumption. Second, products are differentiated by location of production. Hence, the trade pattern is given and exchange rate movements influence only equilibrium price and quantity without changing composition of trade. Since a monopolist exporter takes the demand curve as given when setting price, we discuss the consumers' problem before the firms' problem in the next subsection.

2.1 Consumers

For simplicity we assume the Cobb-Douglas demand over a finite number of goods in the consumption basket. Hence, the representative consumer in country d takes the expenditure for each good as given when choosing quantity of imports from country i, where $i = 1, 2, ..., M$ and $d \neq i$. Hence, i indicates both distinct firms and distinct varieties.

Let q_{id} be demand for import from each exporter to the destination country d, and q_{0d} be demand for the homogeneous numeraire non-traded good in country d. Traded goods are differentiated by location of production and aggregated into final consumption by the following quadratic utility as in Ottaviano, Tabuchi and Thisse (2002).

$$u(q_{0d}; q_{id}) = q_{0d} + \alpha \sum_i q_{id} - \frac{\beta}{2} \sum_i (q_{id})^2 - \gamma \sum_{j \neq i} \sum_i q_{id} q_{jd},$$

where $\alpha > 0$ and $\beta > \gamma > 0$. γ measures the degree of substitutability across varieties. The key advantage of this utility function is that it features a variable price elasticity of demand and demand can be tractably aggregated over distinct varieties. Although the nested CES preferences, as in Feenstra, Gagnon and Knetter (1996) and Atkeson and Burstein (2008), can also generate variable price elasticity of demand, the nested CES preference requires that a small number of firms engage in strategic interactions.

Let p_{id}^d denote the price charged by exporter i for the product shipped to country d in country d's currency. The subscript denotes the pair of source and destination countries, and the superscript denotes the currency of denomination. The representative consumer faces the following budget constraint:

$$\sum_i p_{id}^d q_{id} + q_{od} = w_d l_d + y_d,$$

where w_d, l_d, and y_d are wage, labor supply and endowment of the numeraire in Country d, respectively.

The consumers maximize the utility taking as given the number of varieties, wage and labor demand. The first order condition is the following.

$$\alpha - \beta q_{id} - \gamma \sum_{j \neq i} q_{jd} = p_{id}^d, \tag{1}$$

Define Q_d as the industry demand, $Q_d = \sum_i q_{id}$. Thus,

$$\alpha - (\beta - \gamma) q_{id} - \gamma Q_d = p_{id}^d. \tag{2}$$

Equation (2) implies the following relationship between any pair of imports. For all $j \neq i$,

$$q_{id} - q_{jd} = \frac{1}{\beta - \gamma} [p_{jd}^d - p_{id}^d]. \tag{3}$$

Substituting (3) into (1) gives the variety demand function:

$$q_{id} = \frac{\alpha(\beta - \gamma) + \gamma \sum_{j \neq i} p_{jd}^d}{(\beta - \gamma)(\beta + \gamma(N-1))} - \frac{\beta - \gamma + \gamma(N-1)}{(\beta - \gamma)(\beta + \gamma(N-1))} p_{id}^d \tag{4}$$

To address the role of market structure, next we assume that there are N_i symmetric exporting firms in each source country i. Let N be the total number of firms, $N =$

$\sum_{i=1}^{M} N_i$. The residual demand for each country variety becomes:

$$q_{id} = \frac{\alpha(\beta - \gamma) + \gamma \sum_{j \neq i} N_j p_{jd}^d}{(\beta - \gamma)(\beta + \gamma(N-1))} - \frac{\beta + \gamma(N - N_i - 1)}{(\beta - \gamma)(\beta + \gamma(N-1))} p_{id}^d \tag{5}$$

According to the residual demand in (5), a rise in own price implies a downward move along the demand curve. The own-price elasticity of demand is:

$$\theta_{id} = -\frac{\partial q_{id}}{\partial p_{id}^d} \frac{p_{id}^d}{q_{id}} = \left[\frac{\beta + \gamma(N - N_i - 1)}{(\beta - \gamma)(\beta + \gamma(N-1))} \right] \frac{p_{id}^d}{q_{id}}. \tag{6}$$

In the limit case in which Country i is the only exporter to Market d, $N - N_i = 0$ and $N = 1$, thus the own price elasticity reduces to $p_i^d/(\beta q_{id})$. In contrast, when Country i has a very small number of exporters, $N - N_i$ is approximately equal to N, thus the own price elasticity becomes $p_i^d/((\beta - \gamma)q_{id})$.

The own-price elasticity of demand is high when the number of exporters from country i is small relative to the rest of the world. This reflects the small share of country i in the world market.

The residual demand in (5) also indicates the importance of prices of imports from competing exporters. To be precise, a rise in the price of imports from competing exporters acts as a demand shock shifting the demand curve outward through the intercept term in (5). The cross-price elasticity of demand with respect to competing exporters in country j is:

$$\theta_{ijd} = \frac{\partial q_{id}}{\partial p_{jd}^d} \frac{p_{jd}^d}{q_{id}} = \frac{\gamma N_j p_{jd}^d}{(\beta - \gamma)(\beta + \gamma(N-1)) q_{id}}. \tag{7}$$

The cross-price elasticity of demand is high when (1) the number of competing exporters is large; and (2) competing exporters charge high price.

2.2 Exporters' Price Setting

Assume a linear production function with constant marginal cost. Let c_i be marginal cost denominated in the exporter's currency. p^i_{id} denotes the price of exports from Country i to Country d in seller's currency. Then we can write profit function as:

$$\pi_i = q_{id}[p^i_{id} - c_i].$$

The representative exporter from country i has monopoly power in country j, because we assume that products are differentiated by location of production. The exporter takes the residual demand in (5) and exchange rates as given. Exchange rate e_{id} is defined as units of currency d per unit of currency i. Assume no trade frictions to simplify the model, so the buyer's currency price becomes:

$$p^d_{id} = e_{id} p^i_{id}. \tag{8}$$

Hence, the monopolist exporter sets the seller's currency price p^i_{id} to maximize profits taking as given the residual demand in (5) and the buyer's currency price in 8. The first-order condition gives the optimal price setting rule:

$$p^i_{id} = \frac{\theta_{id}}{\theta_{id} - 1} c_i, \tag{9}$$

where θ_{id} is given by (6).

2.3 Exchange Rate Pass-through Elasticity

First, we consider the effect of an exogenous depreciation of currency d relative to currency i or $dln(e_{id}) > 0$, on the price set by exporters in country i. The price setting rule in (9) and the buyer's currency price in (8) imply that a depreciation of currency d acts as an adverse cost shock:

$$dln(p_{id}^{d}) = dln\left(\frac{\theta_{id}}{\theta_{id}-1}\right) + dln(c_i) + dln(e_{id}) \tag{10}$$

Figure 1 illustrates this effect as the upward shift of the cost curve from MC to MC'. Thus the price moves upward along the residual demand curve D, depending on where the marginal revenue schedule (MR) intersects with MC'. Hence, an appreciation of currency i moves the equilibrium from point 1 to point 2. In the existing pricing to market (PTM) literature with only two countries, this is the full effect. But we have $M > 2$ countries, therefore currency d may fall against both currency i and other currencies. For example, suppose currency d also depreciate against currency j, or $dln(e_{jd}) > 0$ for all $j \neq i$. Similar to (10), a depreciation of currency d acts as an adverse cost shock for exporter j:

$$dln(p_{jd}^{d}) = dln\left(\frac{\theta_{jd}}{\theta_{jd}-1}\right) + dln(c_j) + dln(e_{jd}) \tag{11}$$

From the perspective of exporters in country i, (11) implies that the cost of a substitute product has risen. This shifts the intercept term in the residual demand for product i through the cross-price elasticity of demand in (7). This cross-price effect corresponds to the upward shift of the demand curve in Figure 1 from D to D'. Thus, the depreciation of currency d simultaneously shocks the MC curve for i and its residual demand. Consequently, the equilibrium following the appreciation of both currency i and currency j is now point 3. When we compare the consumer price at each point, $p_{id}^{d}(1) < p_{id}^{d}(2) < p_{id}^{d}(3)$. This ranking suggests that an appreciation of currency j causes exporters in country i to reduce the degree of PTM.

Of course, currency d might depreciate against currency i and appreciate against currency j at the same time. In this case, the cost of a substitute for product i has fallen, shifting the demand curve to the left, as in Figure 2. In this case, $p_{id}^{d}(1) < p_{id}^{d}(3) < p_{id}^{d}(2)$. The ranking implies that the exporter from country i reduces markup even further, and in extreme cases could even lower its currency d prices below $p_{id}^{d}(1)$ following an appreciation of currency j.

We next formulate this logic in an M country world in which currencies do not move in isolation and exchange rates are correlated. We express co-movement as follows:

$$dln(e_{jd}) = \eta_{ji} dln(e_{id}),$$

where $\eta_{ji} \neq 0$. The parameter η_{ji} measures the elasticity of changes in currency j's exchange rate with respect to currency i's exchange rate. Assume for simplicity that exchange rate movements are the only type of exogenous shocks. The total derivative of the exporter's price depends on the movement of all exchange rates:

$$
\begin{aligned}
dln(p^i_{id}) &= \frac{\partial ln(p^i_{id})}{\partial ln(e_{id})} dln(e_{id}) + \sum_{j\neq i} \frac{\partial ln(p^i_{id})}{\partial ln(e_{jd})} dln(e_{jd}) \\
&= \left[\frac{\partial ln(p^i_{id})}{\partial ln(e_{id})} + \sum_{j\neq i} \eta_{ji} \frac{\partial ln(p^i_{id})}{\partial ln(e_{jd})} \right] dln(e_{id}). \qquad (12)
\end{aligned}
$$

As a result,

$$
\frac{dln(p^i_{id})}{dln(e_{id})} = \frac{\partial ln(p^i_{id})}{\partial ln(e_{id})} + \sum_{j\neq i} \eta_{ji} \frac{\partial ln(p^i_{id})}{\partial ln(e_{jd})}. \qquad (13)
$$

In other words, we can decompose ERPT denoted by ϵ_i into the pass-through from shocks on exporter i's exchange rate or ϵ_{ii}, and the pass-through from shocks on exchange rate of competing exporters or ϵ_{ij}.

$$
\epsilon_i = \epsilon_{ii} + \sum_{j\neq i} \epsilon_{ij}\eta_{ji}, \qquad (14)
$$

where $\epsilon_{ii} = \frac{\partial ln(p^i_{id})}{\partial ln(e_{id})}$ and $\epsilon_{ij} = \frac{\partial ln(p^i_{id})}{\partial ln(e_{jd})}$. Henceforth, let us refer to ϵ_{ii} and ϵ_{ji} as the own ERPT and the cross ERPT, respectively.

The quadratic utility model allows us to calculate the theoretical values of η_{ii} and η_{ij}. Given the price setting rule in (9) and the effects of exchange rate shocks in (10) and (11), we can show that the own ERPT and the cross ERPT depends on the own-price and the cross-price elasticities as follows.

$$
\begin{aligned}
\epsilon_{ii} &= -0.5 - \frac{0.5}{\theta_{id}}, \qquad (15) \\
\epsilon_{ij} &= 0.5 \frac{\theta_{ijd}}{\theta_{id}} \left(\frac{\theta_{jd} - 1}{\theta_{jd}} \right) \qquad (16)
\end{aligned}
$$

Proposition 1 *Suppose* $1 < \theta_{id} < \infty$. *Then* $\epsilon_{ii} \in (-1, -0.5)$.

Proof. $d\epsilon_{ii}/d\theta_{id} > 0$, so ϵ_{ii} is monotonic in θ_{id}. When $\theta_{id} = 1$, $\epsilon_{ii} = -1$. Also, $\lim_{\theta_{id} \to \infty} \epsilon_{ii} = -0.5$. ■ The negative range of the own ERPT indicates that the exporter practices PTM by reducing the own-currency price to absorb currency appreciation. In the limit case in which $\theta_{id} = 1$, the consumers maintain constant expenditure share of each variety, so the exporter absorbs all exchange rate shocks and the own ERPT becomes -1.

Proposition 2 *Suppose* $1 < \theta_{id} < \infty$. *Then* $d\epsilon_{ii}/d\theta_{id} > 0$.

Proof. From (15), $d\epsilon_{ii}/d\theta_{id} = 0.5/(\theta_{id})^2 > 0$ ■ This proposition suggests that low demand elasticity generates low ERPT or high degree of PTM. This is because low demand elasticity means high market power and high markup, so in this case the exporter can sharply reduce price to absorb currency appreciation.

Proposition 3 $d\epsilon_{ii}/dN > 0$.

Proof. $d\epsilon_{ii}/dN = (d\epsilon_{ii}/d\theta_{id})\, d\theta_{id}/dN$. From (6), $d\theta_{id}/dN > 0$. From Proposition 2, $d\epsilon_{ii}/d\theta_{id} > 0$. ■ The effect of the number of world exporters works through its effect on the own price elasticity of demand. A large number of world exporters raises the own price elasticity, since it shrinks the share of each exporters in the destination market. Therefore, a large number of world exporters results in low market power, low degree of PTM and high ERPT.

Proposition 4 *Suppose* $\theta_{jd} > 1$. *Then* $\epsilon_{ij} > 0$

Proof. When $\theta_{jd} > 1$, $\theta_{jd} - 1 > 0$. ■ An appreciation of competing exporters' currency reduces the market share of competitors. Hence, an appreciation of competing exporters' currency allows exporters from country i to raise price. This is the reason why the cross ERPT takes positive values.

The cross ERPT has a significant implication for the methodology for estimating the ERPT elasticity. To be specific, omitting an appreciation of currency of competing exporters from the estimating equation yields a biased estimate. From (14), the size of bias clearly depends on the cross-exchange rate elasticity η_{ji} or the co-movement between currency i and currency j. This result suggests that the typical estimating equation in the pass-through literature gives a biased estimate of the own-price ERPT.

Specifically, the typical estimating equation in the pass-through literature such as Feenstra (1989), Knetter (1993) and Campa and Goldberg (2005) takes the following form.

$$dln(p^i_{id}) = \beta_0 + \beta_1^{id} dln(e_{id}) + v_i \tag{17}$$

The estimate $\hat{\beta}_1^{id}$ has been viewed as the ERPT elasticity ϵ_i. Substituting our model-based ϵ_i in (14) into the above equation yields the following equation.

$$dln(p^i_{id}) = \beta_0 + \epsilon_{ii} dln(e_{id}) + \sum_{j \neq i} \epsilon_{ij} d\ln(e_{jd}) + v_i$$

Substitute (16), (6) and (7) into the cross ERPT ϵ_{ij}. Hence,

$$\begin{aligned} dln(p_{id}^i) &= \beta_0 + \epsilon_{ii} dln(e_{id}) + \frac{0.5\gamma}{(\beta + \gamma(N - N_i - 1))p_{id}^d} \sum_{j \neq i} N_j c_j e_{jd} d\ln(e_{jd}) + v_i \\ &= \beta_0 + \epsilon_{ii} dln(e_{id}) + \frac{0.5\gamma N_i(\theta_{id} - 1)}{(\beta + \gamma(N - N_i - 1))\theta_{id}} \sum_{j \neq i} \frac{N_j c_j e_{jd}}{N_i c_i e_{id}} d\ln(e_{jd}) + v_i \end{aligned} \quad (18)$$

Finally, the estimating equation is as follows.

$$dln(p_{id}^i) = \beta_0 + \beta_1^{id} dln(e_{id}) + \beta_2^{id} \sum_{j \neq i} \frac{N_j c_j e_{jd}}{N_i c_i e_{id}} d\ln(e_{jd}) + v_i, \quad (19)$$

where $\beta_1^{id} = \epsilon_{ii}$ or the own ERPT, and $\beta_2^{id} = 0.5\gamma N_i(\theta_{id} - 1)/[(\beta + \gamma(N - N_i - 1))\theta_{id}]$. The implied cross ERPT can be calculated as $\epsilon_{ij} = \beta_2^{id} N_j c_j e_{jd}/[N_i c_i e_{id}]$.

Our model suggests that it is necessary to include other exchange rates in the estimation in order to obtain unbiased estimate of own ERPT elasticities. The weight assigned to exporter j's exchange rate appreciation is the cost of Exporter j relative to Exporter i adjusted by the number of exporters. Since exchange rate movements act as cost shocks, high-cost exporters intuitively carry larger weights than low-cost exporters. Also, since the weight represents the importance of each exchange rate, the higher the number of competing exporters, the higher the implied cross ERPT.

Our work is also related to the exchange rate regimes as follows.

Proposition 5 *Suppose $\theta_{jd} > 1$. Then $d\epsilon_i/d\eta_{ji} > 0$.*

Proof. $d\epsilon_i/d\eta_{ji} = \sum_{j \neq i} \epsilon_{ij}$. From Proposition 4, $\epsilon_{ij} > 0$. ■ The overall ERPT is increasing in the elasticity of j's exchange rate with respect to currency i's exchange rate. This is because high exchange rate elasticity implies a large appreciation of currency j

following an appreciation of currency i. According to Proposition 4, that must raise the cross ERPT and the overall ERPT as well. Alternatively, the higher the exchange rate elasticity, the larger the demand shocks in Figure 1.

This positive relationship between the overall ERPT and the cross-currency co-movement has a significant implication for the role of exchange rate regimes. This implication is different from the role of monetary stability in the general equilibrium two-country model by Devereux et al. (2004). In their study, with the assumption of price stickiness, money shocks drive exchange rate and monetary stability in the exporting and importing countries influences the choice of currency of pricing. In our work, the exchange rate flexibility in question is the flexibility of currency of competing exporters, not flexibility of exchange rate between the exporting and importing countries. Our model then implies that there is ERPT even within a currency union, because currencies of competing exporters outside the currency union fluctuate over time. This new channel comes from the multi-country aspect of trade, which has been neglected in open-economy macroeconomics.

Other recent macroeconomic models of PTM also adopt a general equilibrium two-country framework. Bacchetta and van Wincoop (2005) assume that money supply shocks drive exchange rates, like Devereux et al. (2004). Note that both Devereux et al. (2004) and Bacchetta and van Wincoop (2005) assume the CES preferences and monopolistic competition. Bacchetta and van Wincoop (2005) find that the exporter is likely to price in the exporter's currency when the market share is large. Moreover, their model predicts that the degree of PTM is decreasing in the price elasticity of demand, as in our study.

However, the recent macroeconomic model of PTM by Atkeson and Burstein (2008) departs from the literature by assuming the nested CES preferences and Cournot competition. Their simulated degree of pass-through is decreasing in the elasticity of substitution. However, this testable hypothesis is applicable to only the dataset in which the number of large exporters is small enough to permit strategic interactions assumed in their model. Our work is more general in a sense that we do not impose any restrictions on the number of firms.

The general equilibrium model by Taylor (2000) focuses on the role of expected persistence of inflation and persistence of exchange rate fluctuations, as previously emphasized by the partial equilibrium framework in Baldwin (1988). Taylor (2000) shows that the ERPT is increasing in persistence of inflation and exchange rate depreciation, which in turn is increasing in the inflation rate given a specific monetary rule.

Of most importance, these macro models all predict that the ERPT is in the 0 and -1 range, while the estimates in the literature range from -2.26 and 2.55 (Feenstra, 1989; Froot and Klemperer, 1989; Knetter, 1993; Feenstra, Gagnon and Knetter, 1996; Goldberg and Knetter, 1997; Campa and Goldberg, 2005). Unlike the existing studies, our model has a potential to expand the range of ERPT to match the range in the empirical literature, because the cross ERPT is positive and the exchange rate elasticity can take either negative or positive values.

The other advantage of our model is that it offers various explanations for long-run instability of ERPT. Taylor (2000) argues that the structural decline in ERPT found in the U.S. case is caused by low inflation as a result of successful monetary policy. In our work, Propositions 2, 3 and 5 suggest various reasons. To be precise, Proposition 2 predicts that a fall in the price elasticity of demand for U.S. exports is a reason. According to Proposition 3, that results from a fall in the number of world exporters and rising share of U.S. exporters. Finally, Proposition 5 suggests a shift in the exchange rate policy in other countries away from the dollar peg system as a potential explanation.

Given that the cross ERPT is non-linear in parameters such as the number of exporters and the own-price elasticities of demand, we simulate the model to derive the quantitative predictions in the next section.

3 Simulation Results

This section simulated the ERPT when the world consists of three countries. In the benchmark simulation, we assume symmetric parameters for the two exporting countries: $N_i = 50, \alpha = 100, \beta = \gamma = 6, c_i = 5$ and $e_{id} = 1$ for $i = 1, 2$. For simplicity, we assume that the destination market produces only the numeraire good. With these parameter values, the own-price elasticity of demand in equilibrium is 3.4416. Then we perturb the exchange rate e_{id} by 1 percent and allow the exchange rate elasticity η_{21} to vary from -10 to 10. Figure 3 plots the simulated ERPT against the exchange rate elasticity.

There are two findings in Figure 3. First, the simulated EPRT is within the range -2.82 to 1.78, which largely overlaps with the range -2.26 and 2.55 in the literature. In the absence of shocks on the competing exchange rate ($\eta_{21} = 0$), the ERPT falls in the range

-1 and -0.5 marked by the grid lines, as predicted by Proposition 1. Thus, shocks on the competing exchange rates offer an explanation why the ERPT elasticity vary widely and takes both positive and negative values in the empirical literature.

Second, consistent with Proposition 5, the simulated ERPT is increasing in the exchange rate elasticity of currency j with respect to currency i. This finding confirms the intuition that appreciation of other currencies act as positive demand shocks that raise the exporter price. Hence, our finding has significant implication for the methodology for estimating ERPT. To be precise, the larger the appreciation of other currencies, the larger the bias in the ERPT estimate obtained without controlling for these appreciations, consistent with Proposition 4. In Figure 3, the bias can be larger than 400 percent (= -2.82/-0.52 -1) of the estimate.

Next, we vary the number of world exporters by maintaining the relative number of exporters in each country at 1. As predicted by Proposition 3, Figure 4 confirms that an increase in the number of world exporters raises the ERPT or reduces the degree of PTM.

Finally, we vary the number of exporters in country 1. Figure 4 and 5 illustrate that there are no monotonic relationship between the ERPT and the number of exporters in a specific country or the relative number of exporters, respectively.

To summarize, our multi-country framework highlights the point that we cannot generate a wide range of ERPT elasticity to match the empirical estimates without taking into account pricing decisions of all exporters before aggregating their prices into an index. The quantitative predictions imply that the ERPT estimate obtained without controlling for fluctuations of competing currencies has a bias, and the bias is increasing in the magnitude of fluctuations of competing currencies. Finally, we provide testable hypotheses related to the exchange rate regime and the number of world exporters.

4 Concluding Remarks

We re-examine the theoretical determination of ERPT by combining the micro and the macro factors. By doing so, our framework can explain the range of ERPT estimates which have not been explained by the existing theory. Our work provides insights into international pricing at the firm level, but also has macro implications.

The macro explanations for cross-country differences in the ERPT elasticity have been the volatility and persistence of exchange rate depreciation, the level and persistence of CPI inflation and the industry composition of trade (Baldwin 1988; Froot and Klemperer, 1989; Taylor, 2000; Devereux et al. 2004; Bacchetta and van Wincoop (2005); Campa and Goldberg, 2005). The literature relies on dynamic two-country models to explore the role of monetary policy in the endogenous determination of ERPT. However, these studies all predict the ERPT in the range 0 and -1.

Our work highlights the importance of the multi-country aspect of trade, which has been ignored in the macro literature. We show that fluctuations of currency of competing exporters provide an additional channel for strategic interactions in pricing. The assumed quadratic utility permits such interactions without imposing restrictions on the number of firms like the CES preferences, and extends the range of ERPT to match the empirical estimates.

In addition, our model predicts a monotonic relationship between the ERPT and the elasticity of competing exchange rate with respect to own exchange rate and also between the ERPT and number of world exporters. These monotonic relationships are alternative explanations for cross-country variations in ERPT and long-run instability of ERPT. Also, the predicted range of ERPT in our model yields variations in the degree of price stickiness in the buyer's currency in Devereux et al. (2004) and Bacchetta and van Wincoop (2005). Finally, we can extend the model to a general equilibrium setup to study the impacts of various shocks on the dynamics of real exchange rate and current account.

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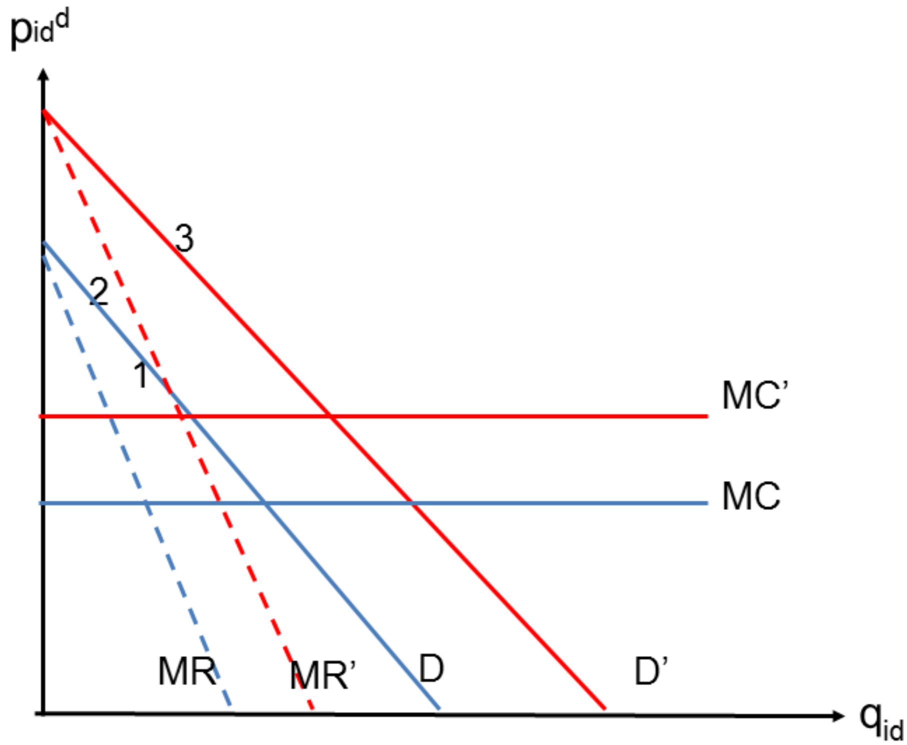
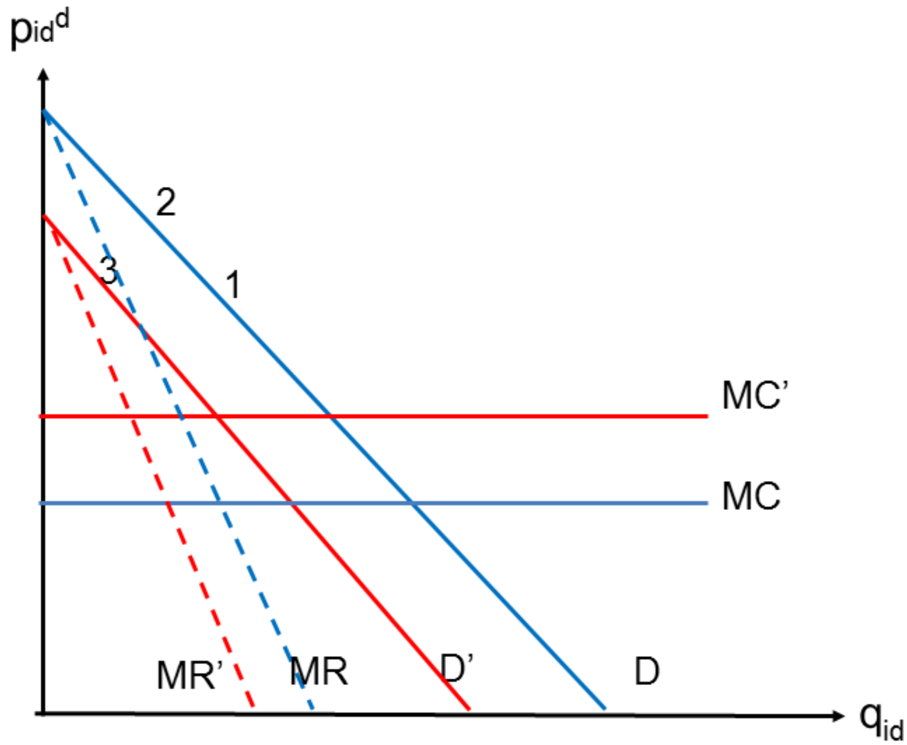
Figure 1: Effects of cross-currency appreciation and own-currency appreciation on the buyer's currency price



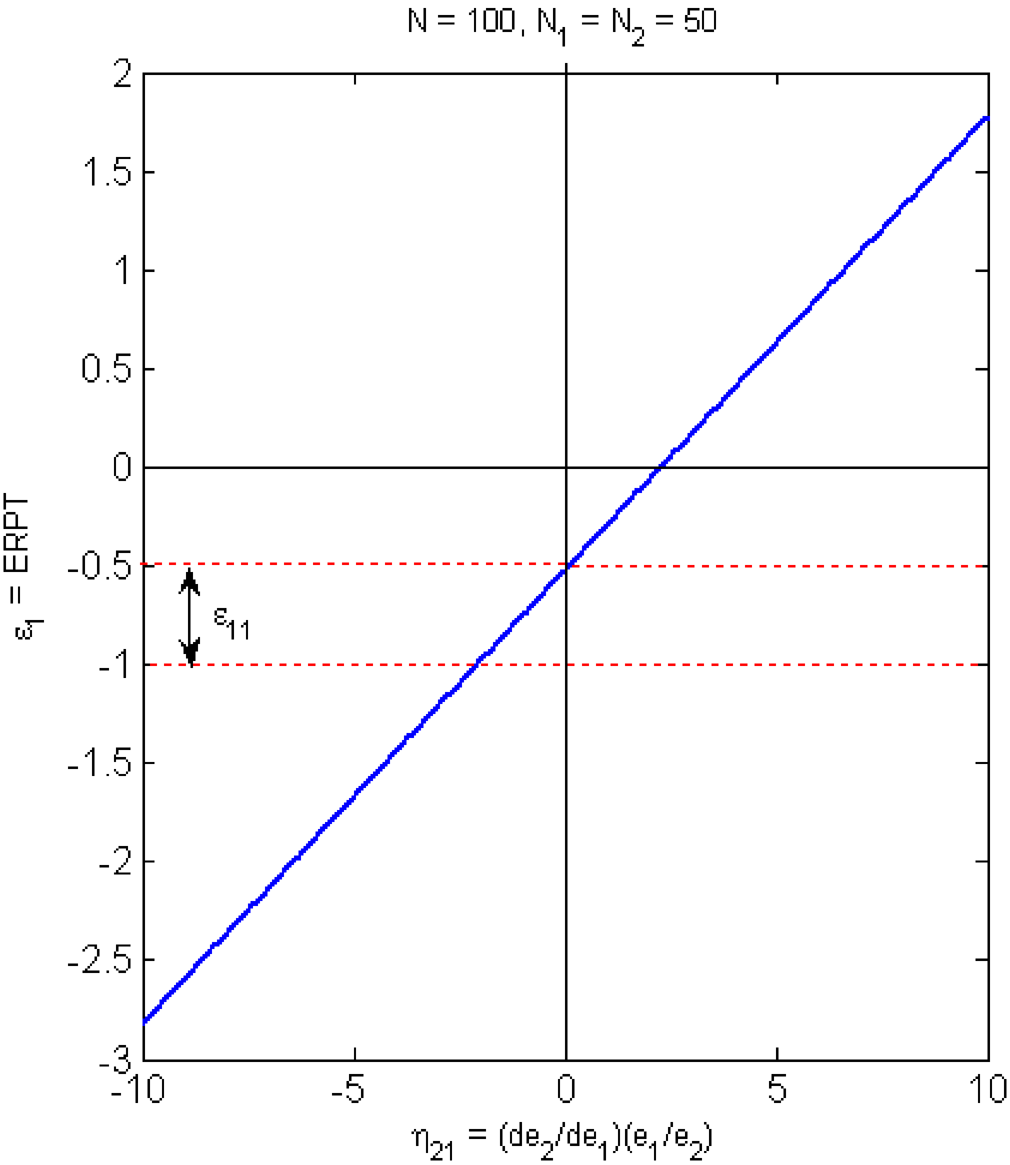
Notes:
(1) D is demand, MR is marginal revenue and MC is marginal cost.
(2) Superscript′ corresponds to shifts caused by exchange rate shocks.

Figure 2: Effects of cross-currency depreciation and own-currency appreciation on the buyer's currency price



Notes:
(1) D is demand, MR is marginal revenue and MC is marginal cost.
(2) Superscript′ corresponds to shifts caused by exchange rate shocks.

Figure 3: Simulated exchange rate pass-through with two symmetric exporting countries

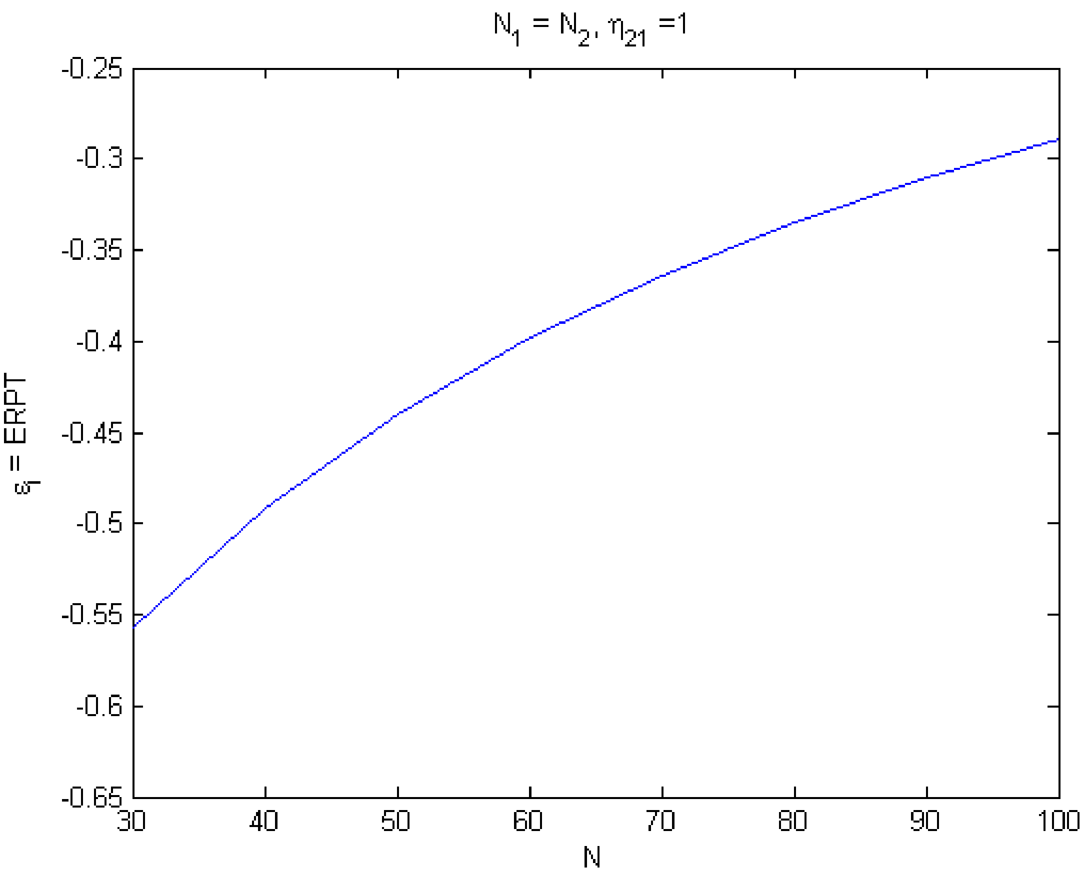


Notes:

(1) ERPT(ϵ_1) = Own ERPT(ϵ_{11}) + Cross ERPT(ϵ_{21}) x Exchange rate elasticity(η_{21}).

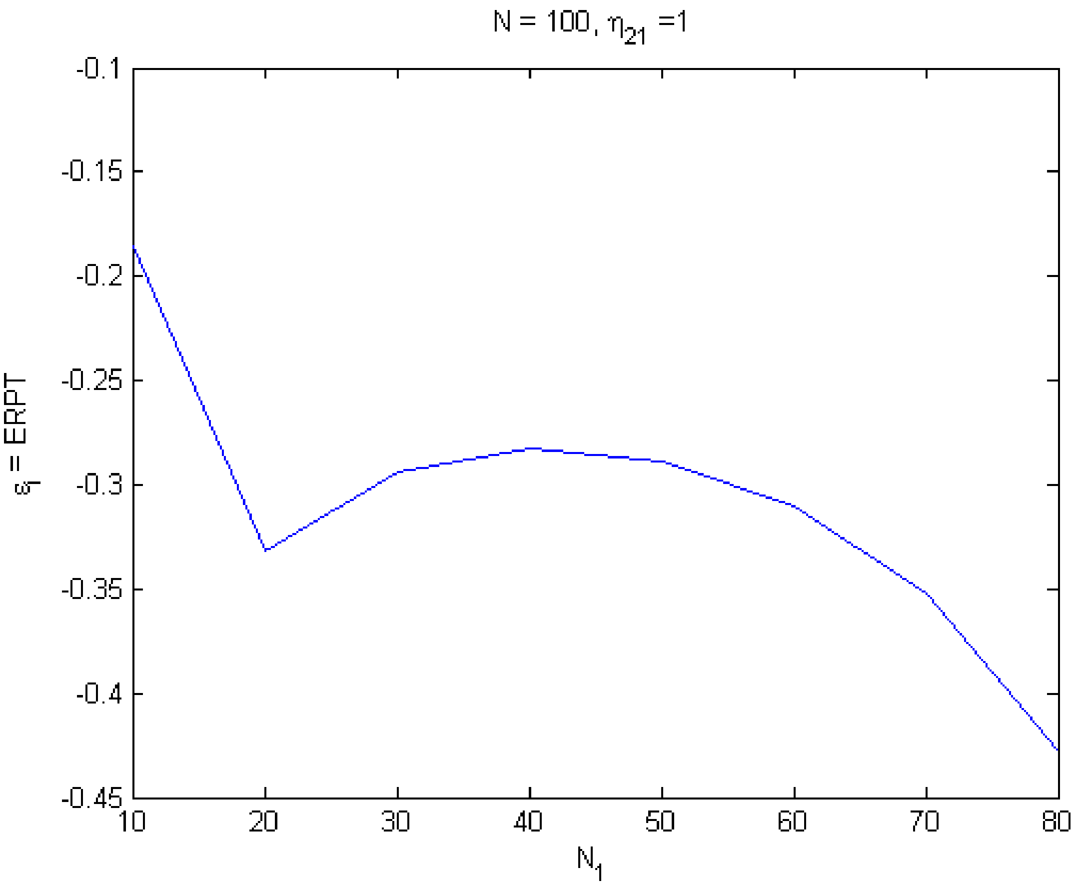
(2) Benchmark parameters: $\beta = \gamma = 6$, $\alpha = 100$, $N_1 = N_2 = 50$, $e_1 = e_2 = 1$ and $c_1 = c_2 = 5$. In equilibrium, the own price elasticity of demand $\theta_{13} = \theta_{23} = 3.4416$.

Figure 4: Simulated exchange rate pass-through and the number of world exporters



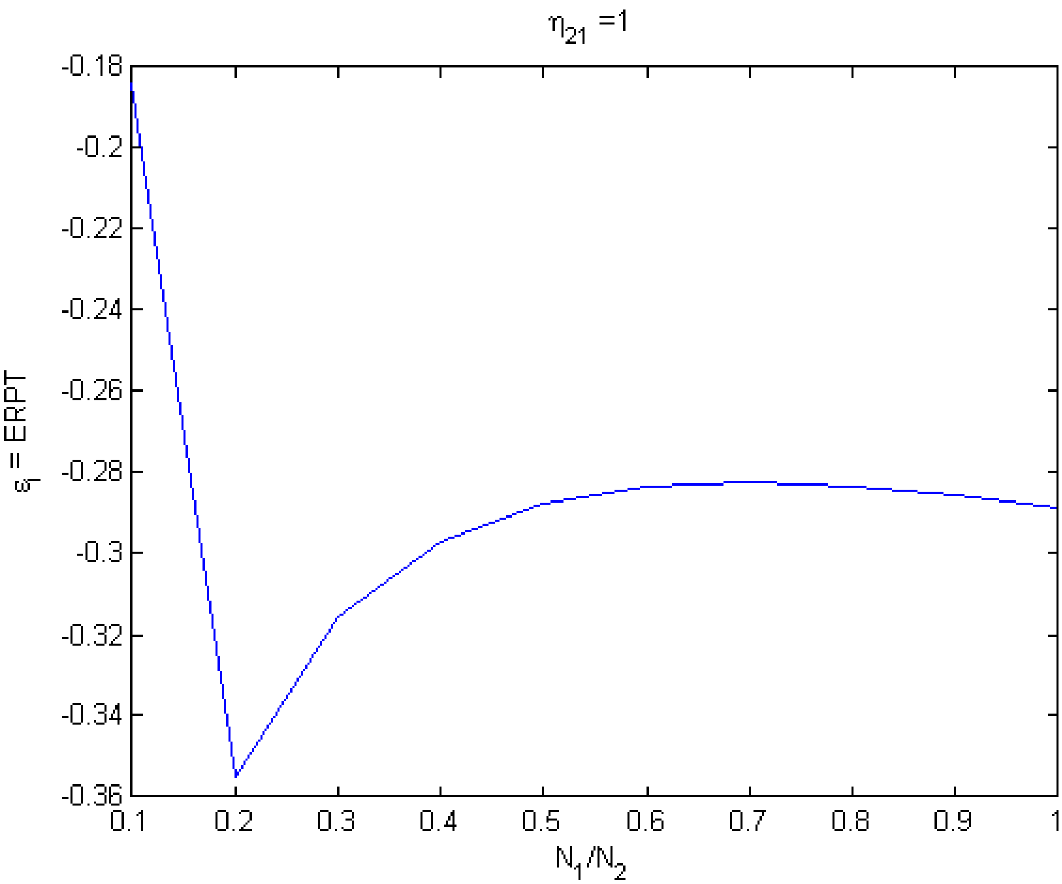
Note: Exchange rate elasticity $\eta_{21} = 1$. Symmetric number of exporters: $N_1 = N_2$.

Figure 5: Simulated exchange rate pass-through and the number of own exporters



Note: Exchange rate elasticity $\eta_{21} = 1$. Number of world exporters: $N = 100$.

Figure 6: Simulated exchange rate pass-through and the number of own exporters relative to the number of competing exporters



Note: Exchange rate elasticity $\eta_{21} = 1$.