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Exchange Rates and Perfect Competition

by

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Abstract

We consider two types of firms both operating in two countries. The demand side of the markets of the two countries are separated and each type of firm produces its good in one of these countries. We study the effect of an exchange rate change on the competitive equilibrium prices in each country. When producing for the foreign market causes the same costs as producing for the home market then the 'Law of one Price' holds and an exchange rate change is completely offset by price changes. Furthermore when cost functions are additively separable between producing for the home and producing for the foreign market then prices move in the 'right' direction in response to an exchange rate change. However, with general cost structures, even in this simple competitive model, any direction of price changes can result from an exchange rate change.

1 Introduction

The 'Law of one Price' asserts that the price of a commodity expressed in one currency is the same as the price of that commodity expressed in any other currency multiplied by the exchange rate between the two currencies. Were the Law of one Price to hold, then a change in the exchange rate would result in a completely offsetting change of local currency prices.

Empirical evidence, however, supports that the pass-through of changes in the exchange rate into export prices is typically 'incomplete' and can even go into the wrong direction (cf. Dunn (1970), Mann (1986), Krugmann (1987), Froot and Klemperer (1989), Knetter (1989), (1993), Marston (1990), Kirman and Schueller (1990)). According to this evidence a revaluation typically leads to a less than proportional decrease in domestic prices for imports and it may even increase domestic import prices. In the latter case some authors call the price reaction to exchange rate changes 'perverse' (cf. Froot and Klemperer (1989), Knetter (1989), Hens, Kirman and Phlips (1994)).

The phenomenon of incomplete or even 'perverse' pass-through, which is also referred to as 'pricing to market' has often been attributed to imperfect competition. Moreover, most of the literature on this phenomenon seems to take it for granted that a model of perfect competition cannot be used as an explanation, and explicit statements in this sense can be found in Dunn (1970, p. 150), Krugmann (1987, p. 69) and Knetter (1993, p. 484). E.g. Krugman (1987) states on page 69: *"Explaining pricing to market is not as simple as one might hope. It seems clear that a perfectly competitive model will not do the trick."*

The empirical evidence on the relationship of the degree of exchange rate pass-through and the market structure, however, is ambigious. E.g. Feinberg (1986), (1989), and (1991) finds some support for the hypothesis that pass-through is more incomplete when a market is less competitive. However Fisher (1989) in his study of the behaviour of German and Japanese firms observes that *"The tests show that there is weak evidence to support this hypothesis during the last year of the yen's and mark's depreciations, but evidence is mixed during the first year of these currencies' current appreciations."* Fisher (1989, p. 82). On page 85 he concludes that *"..., the theory about the effects of industry concentration during an appreciation did not fare well"*. Fisher seems to suggest a technological explanation instead.

In this note we demonstrate that the phenomenon of incomplete pass-through or even 'perverse' reactions of prices on changes in the exchange rate can also be generated in a simple static international trade model of perfect competition.

There may be many good reasons not to believe in perfect competition, but as we intend to show in this note, the phenomenon of incomplete pass-through or 'perverse' price reactions as such cannot be used to dismiss the hypothesis of perfect competition. Our model suggests that these reactions to changes in the exchange rate can also be seen as some general equilibrium phenomenon. In contrast to most of the literature on incomplete pass-through, we do not only consider a single market in isolation but emphasize the role of spill-over effects between the home and the foreign market on which firms compete simultaneously. Simultaneous competition in both markets seems to be the rule for most of the industries for which incomplete pass-through has been observed.

In our model demand is assumed to be separated across countries so that arbitration by consumers is not possible. Thus the Law of one Price does not need to hold and incomplete pass-through is not ruled out a priori. Markets are linked via the supply decisions of firms. We consider two types of firms: Firms of type one (two) exclusively produce in market one (two). Both type of firms sell in both markets. The supply decisions crucially depend on the technological characteristics of the firms, which we model in terms of their cost functions. It is important to note that in specific cases 'cost functions' can be quite complicated since they will have to incorporate e.g. transportation costs, import taxes and costs in order to adapt to foreign consumer habits or technological standards. It is shown that when one neglects these aspects of a cost function so that producing for the foreign market causes exactly the same costs as producing for the home market[1], then in a competitive equilibrium the Law of one Price does hold. Furthermore when cost functions are additively separable across markets, i.e. the marginal cost of producing for the home (foreign) market is not affected by the level of output supplied for the foreign (home) market, then the two markets are completely separated. This assumption which is sometimes made in the literature (cf. Dornbusch (1987), Sibert (1992), Kirman and Schueller (1990)) rules out spill-over effects. And consequently, in a competitive equilibrium the price in the market of the currency which is revalued decreases, while the price in the devaluating market increases. The degree of pass-through will, however, depend on the characteristics of the markets. Yet with general cost functions spill-over effects will make a difference and incomplete pass-through and even perverse reactions can occur.

In the next section we will present a simple model of international trade with perfect competition. This model is similar to the model chosen in Hens, Kirman and Phlips (1994). An important difference is that in their paper the authors consider a Cournot Duopoly instead of perfect competition. After that we will

[1]This assumption is sometimes used in the literature (cf. Knetter (1989), Marston (1990)).

derive the comparative statics of a competitive equilibrium.

2 The Model

We consider two markets, market 1 and market 2, which are separated so that arbitration by consumers is not possible. We examine the case in which there are two types of firms. Firms of type one are located in market 1, selling x_{11} in market 1 and x_{12} in market 2 and firms of type two are located in market 2, selling x_{21} in market 1 and x_{22} in market 2. The commodity is homogeneous within each market.

The profit function of firms located in market 1, expressed in market 1 currency, is

$$\Pi_1 = p_1 x_{11} + e p_2 x_{12} - c_1(x_{11}, x_{12}) \ , \tag{1}$$

where p_j denotes the price of the product in market j, $j = 1, 2$. The exchange rate e, is the value in market 1 currency of the currency used in market 2. (Thus if arbitration by consumers were possible, then prices of the commodities must be such that $p_1 = ep_2$, i.e. the Law of one Price holds.) $c_1(x_{11}, x_{12})$ are the costs of firm 1 expressed in currency 1 when it produces the bundle of goods (x_{11}, x_{12}). Analogously, firms located in market 2 have the profit function

$$\Pi_2 = p_1 x_{21} + e p_2 x_{22} - e c_2(x_{21}, x_{22}) \ . \tag{2}$$

It is important to note that firms choose quantities x_{ij}, $i, j = 1, 2$ so as to maximize profits given the prices p_1, p_2, e. Market prices are determined by inverse demand functions $P_j : \mathbb{R}_+ \to \mathbb{R}_+$ where $p_j = P_j(x_{1j} + x_{2j})$, i.e. the price in market j depends on the total output of firms of type 1 and firms of type 2 selling in market j, $j = 1, 2$. Because the markets are separated, quantities sold in the other market are irrelevant in this respect.

To summarize, our international market is described by $\mathcal{E} = (P_1, P_2, c_1, c_2)$ and e.

We shall make the following assumptions concerning the demand functions and the cost functions. Numbers as superscripts denote derivatives with respect to the argument which is given by that number.

A.1

The inverse demand functions $P_j(x_j)$, $j = 1, 2$ are continuous for all $x_j > 0$. For every j there exists $\bar{x}_j$ so that $P_j(x_j) = 0$ for all $x_j \geq \bar{x}_j$ and $P_j(x_j) > 0$ for $x_j < \bar{x}_j$. Furthermore, $P_j(0) = \bar{P}_j < \infty$ and for all x_j so that $0 < x_j < \bar{x}_j$, $P_j(x_j)$ has a continous derivative P_j' and $P_j'(x_j) < 0$ for all x_j.

A.2

The cost function of the i-th firm $c_i(x_{i1}, x_{i2})$ is convex and continuous for all output levels $x_{i1} \geq 0$, $x_{i2} \geq 0$. $c_i(0,0) \geq 0$, and c_i has continuous first and second partial derivatives for all x_{i1}, $x_{i2} \geq 0$. Furthermore, $c_i^1 > 0$ and $c_i^2 > 0$ for all $x_{i1} \geq 0$ and $x_{i2} \geq 0$.

A competitive equilibrium for the international market $\mathcal{E}$ is a set of quantities $(x_{11}, x_{12}, x_{21}, x_{22})$, and a set of prices (p_1, p_2) with the result that firms optimize and markets clear; i.e. equations $(3)-(8)$ are satisfied.

$$\begin{aligned}
\Pi_1^1 &= p_1 - c_1^1(x_{11}, x_{12}) = 0 && (3)\\
\Pi_1^2 &= ep_2 - c_1^2(x_{11}, x_{12}) = 0 && (4)\\
\Pi_2^1 &= p_1 - ec_2^1(x_{21}, x_{22}) = 0 && (5)\\
\Pi_2^2 &= ep_2 - ec_2^2(x_{21}, x_{22}) = 0 && (6)
\end{aligned}$$

$$\begin{aligned}
p_1 - P_1(x_{11} + x_{21}) &= 0 && (7)\\
p_2 - P_2(x_{12} + x_{22}) &= 0 && (8)
\end{aligned}$$

It is easily proved that, given A.1 and A.2, a competitive equilibrium exists. Furthermore, for e close to 1 the equilibrium is unique.

3 Comparative Statics

In this section we derive the comparative statics of competitive equilibria. To this end we compute the Jacobian of the system $(3)-(8)$ and obtain the following matrix equation for comparative statics[2]:

$$\begin{bmatrix}
-c_1^{11} & -c_1^{12} & 0 & 0 & 1 & 0\\
-c_1^{21} & -c_1^{22} & 0 & 0 & 0 & e\\
0 & 0 & -ec_2^{11} & -ec_2^{12} & 1 & 0\\
0 & 0 & -c_2^{21} & -c_2^{22} & 0 & 1\\
-P_1' & 0 & -P_1' & 0 & 1 & 0\\
0 & -P_2' & 0 & -P_2' & 0 & 1
\end{bmatrix}
\begin{pmatrix} dx_{11}\\ dx_{12}\\ dx_{21}\\ dx_{22}\\ dp_1\\ dp_2 \end{pmatrix}
=
\begin{pmatrix} 0\\ -p_2\\ c_2^1\\ 0\\ 0\\ 0 \end{pmatrix} de$$

[2]To simplify expressions we have divided equation (6) by e.

Straightforward computations lead to the solution of $dp = \begin{pmatrix} dp_1 \\ dp_2 \end{pmatrix}$ in terms of de

$$dp = \left\{ \begin{bmatrix} -\frac{1}{P_1'} & 0 \\ 0 & -\frac{1}{P_2'} \end{bmatrix} + H_1^{-1} \begin{bmatrix} 1 & 0 \\ 0 & e \end{bmatrix} + H_2^{-1} \begin{bmatrix} \frac{1}{e} & 0 \\ 0 & 1 \end{bmatrix} \right\}^{-1} \left[H_2^{-1} \begin{bmatrix} \frac{1}{e} & 0 \\ 0 & 1 \end{bmatrix} \begin{pmatrix} c_2^1 \\ 0 \end{pmatrix} - H_1^{-1} \begin{pmatrix} 0 \\ p_2 \end{pmatrix} \right] de,$$

where $H_i := \begin{pmatrix} c_i^{11} & c_i^{12} \\ c_i^{21} & c_i^{22} \end{pmatrix}$ is the Hessian of c_i, $i = 1, 2$.

To simplify notation, let $d^j = -\frac{1}{P_j'}$, and $H_1^{-1} = \begin{bmatrix} h_1 & h_3 \\ h_3 & h_2 \end{bmatrix}$, $H_2^{-1} = \begin{bmatrix} k_1 & k_3 \\ k_3 & k_2 \end{bmatrix}$.

Using this notation we obtain the following two conditions for price reactions to exchange rate changes:

Lemma 1

If at equilibrium both cost functions' Hessian matrices are invertible and if (i) e is close to one or (ii) $h_1k_2 + k_1h_2 \geq h_3 + k_3$, then

$$\frac{dp_1}{de} > 0 \quad \text{iff} \quad (d^2 + eh_2 + k_2)(c_2^1 k_1 - eh_3p_2) > (eh_3 + k_3)(c_2^1 k_3 - eh_2p_2) \qquad (9)$$

$$\frac{dp_2}{de} > 0 \quad \text{iff} \quad (ed^1 + eh_1 + k_1)(c_2^1 k_3 - eh_2p_2) > (eh_3 + k_3)(c_2^1 k_1 - eh_3p_2) \qquad (10)$$

Proof

Rewriting the solution of dp as a function of de in terms of the simplifying notation achieves

$$dp = \left\{ \begin{matrix} d^1 + h_1 + \frac{k_1}{e} & eh_3 + k_3 \\ h_3 + \frac{k_3}{e} & d^2 + eh_2 + k_2 \end{matrix} \right\}^{-1} \left[\frac{c_2^1}{e} \begin{pmatrix} k_1 \\ k_3 \end{pmatrix} - p_2 \begin{pmatrix} h_3 \\ h_2 \end{pmatrix} \right] de.$$

If e is equal to one then the determinant of the matrix in curved brakets is positive since by A.1 and A.2 this matrix is the sum of positive definite matrices. On the other hand, given A.1 and A.2 there is an open interval around 1 of values for e so that the determinant is still positive . The size of this interval depends on the 'degree of positive definiteness' of the matrices involved. In particular note that the size of the interval increases with the slope of the demand functions, i.e. with d^1 and d^2. For arbitrary values of e given A.1 and A.2 this determinant is positive if $h_1k_2 + k_1h_2 \geq h_3 + k_3$. The claim of Lemma 1 then follows from the formula of the inverse of a 2×2 matrix.

2

We get definite restrictions for price reactions when cost functions are additively separable and when all the firms' products are homogeneous with respect to production costs. Therefore, we give the following definitions:

Definition 1 (additively separable cost functions)

We say that cost functions are *additively separable* if for $i = 1, 2$ they can be written as $c_i(x_{i1}, x_{i2}) = c_{i1}(x_{i1}) + c_{i2}(x_{i2})$ for all $(x_{11}, x_{12}) \geq 0$.

Many commonly applied cost functions are of this type. A second, theoretically interesting case is that when producing for market 1 or market 2 does not make any difference with regarding the costs incurred.

Definition 2 (homogeneous products)

We say that *products are homogeneous* with respect to the cost function of firm i, if its cost function can be written as $c_i(x_{i1}, x_{i2}) = \tilde{c}_i(x_{i1} + x_{i2})$ for all $(x_{i1}, x_{i2}) \geq 0$.

Given these definitions, we are in a position to state our first result:

Proposition 1

In an international market $\mathcal{E} = (P_1, P_2, c_1, c_2), e$ satisfying assumptions 1 and 2 the Law of one Price holds if for some firm products are homogeneous.

Proof

With homogeneous products for, say firm 1, we observe that $c_1^j(x_{11}, x_{12}) = \tilde{c}_1'(x_{11} + x_{12}), \quad j = 1, 2$. Thus the first order conditions of maximizing Π_1, equations (3) and (4), imply $p_1 = ep_2$.

2

Remark

A slight generalization of cost functions is to consider $c_i(x_{i1}, x_{i2}) = \tilde{c}_i(a_{i1}x_{i1} + a_{i2}x_{i2})$ for all $(x_{i1}, x_{i2}) \geq 0$ for some positive scalars a_{i1}, a_{i2}. In this case the Law of one Price does not need to hold, but pass-through is still complete. From the equations $(3), (4)$ we now achieve that $p_1 = \frac{a_{i1}}{a_{i2}} ep_2$. Thus an $\alpha\%$ increase of e will result in an $\alpha\%$ increase in $(\frac{p_1}{p_2})$.

In the case of additively separable cost functions prices react normal to a change in the exchange rate.

Proposition 2

In an international market $\mathcal{E} = (P_1, P_2, c_1, c_2), e$ satisfying assumptions 1 and 2 the price whose currency appreciates decreases, while the price in the devaluating market increases if cost functions are additively separable.

Proof

Additive separability implies that the marginal cost of any good is independent from the production level of the other good, i.e. $h_3 = k_3 = 0$, case (ii) of Lemma 1 applies, and the characterizations given in Lemma 1 reduce to:

$$\frac{dp_1}{de} > 0 \quad \text{iff} \quad (d^2 + eh_2 + k_2)c_2^1 k_1 > 0$$

$$\frac{dp_2}{de} < 0 \quad \text{iff} \quad -(ed^1 + eh_1 + k_1)eh_2 p_2 < 0$$

Observe that by assumptions 1 and 2, $d^j > 0,\ j = 1,2,\ h_i, k_i > 0,\ i = 1,2$ and $c_2^1 > 0$, so that a normal reaction ($\frac{dp_1}{de} > 0$ and $\frac{dp_2}{de} < 0$) occurs.

2

Finally we demonstrate that with general cost functions satisfying Assumption 2 any direction of price changes can result from a change in the exchange rate.

Proposition 3

For any direction of price changes and any value of the exchange rate international markets $\mathcal{E} = (P_1, P_2, c_1, c_2)$ exist satisfying assumptions 1 and 2 so that in response to a change in the exchange rate competitive equilibrium prices move in the preassigned direction.

Proof

In Proposition 2 we have already stated international markets for which prices move in such a way that $\frac{dp_1}{de} > 0$ and $\frac{dp_2}{de} < 0$. Thus it remains to argue that both prices can move into the same direction and that they can move in such a way that $\frac{dp_1}{de} < 0$ and $\frac{dp_2}{de} > 0$.

To abbreviate expressions, let

$$\begin{aligned} a^1 &= ed^1 + eh_1 + k_1 \\ a^2 &= d^2 + eh_2 + k_2 \\ b^1 &= c_2^1 k_1 - eh_3 p_2 \\ b^2 &= c_2^1 k_3 - eh_2 p_2 \\ c &= eh_3 + k_3 \,. \end{aligned}$$

Then the characterization in Lemma 1 can be written as

$$\begin{aligned} \frac{dp_1}{de} > 0 \quad &\Leftrightarrow \quad a^2 b^1 > cb^2 \\ \frac{dp_2}{de} < 0 \quad &\Leftrightarrow \quad a^1 b^2 < cb^1 \,. \end{aligned}$$

Note that from A.1 and A.2 $a^1 > 0$ and $a^2 > 0$. Furtheron d^1 and d^2 will not enter in our reasoning. Thus, as we have demonstrated in the proof of Lemma 1, by choice of d^1 and d^2 being sufficiently large for any value of e we can guarantee that Lemma 1 applies.

Now, let $|c| = 0$.[3] Then prices move into same direction if $\operatorname{sign}(b^1) = \operatorname{sign}(b^2)$.

When the sign is positive, it follows that $c_2^1 k_1 > eh_3 p_2$ and $c_2^1 k_3 > eh_2 p_2$.

Thus choosing $h_3 < 0 < k_3$ and $h_3 > \frac{eh_2 p_2}{c_2^1}$ fulfils both inequalities.

When the sign is negative, it follows that the reverse inequalities hold and choosing $k_3 < 0 < h_3$ and $h_3 > \frac{c_2^1 k_1}{ep_2}$ fulfils both inequalities.

In both cases we can therefore find parameters being consistent with A.1 and A.2.

Prices move such that $\frac{dp_1}{de} < 0$ and $\frac{dp_2}{de} > 0$ if one chooses $b^1 < 0 < b^2$ and $c > 0$. This choice is equivalent to the inequalities (11), (12), (13):

$$c_2^1 k_1 < eh_3 p_2 \tag{11}$$

$$eh_2 p_2 < c_2^1 k_3 \tag{12}$$

$$eh_3 + k_3 > 0 \tag{13}$$

Note that in $(11) - (13)$ neither h_1 nor k_2 enters. Thus we can always choose those values so as to guarantee convexity of the cost functions, i.e. so that $h_1 h_2 > (h_3)^2$ and $k_1 k_2 > (k_3)^2$.

Now suppose $h_3 > 0$ and $k_3 > 0$, then (13) follows. Furthermore, (11) and (12) reduce to

$$p_2 > \frac{c_2^1 k_1}{eh_3} \tag{14}$$

$$p_2 < \frac{c_2^1 k_3}{eh_2} \tag{15}$$

Thus, by choice of h_2, h_3, k_1, k_3 so that $h_3 k_3 > k_1 h_2$, both inequalities are satisfied for some appropriately chosen p_2.

Finally, note that for any value of $p_2, c_2^1, e, P_j',\ j = 1,2$ and $H_i, i = 1,2$ satisfying A.1 and A.2 we can always find an international market $\mathcal{E}$ which definitely has these equilibrium values. This is because the following terms are not restricted in the comparative statics equations: $c_1^1, c_1^2, p_1, c_2^2, P_1, P_2$.[4] Thus,

[3] This does not seem to be a robust case. Note however, that our argument will still work for $|c|$ being positive but negligibly small as compared to a^1, a^2, b^1, b^2.

[4] Use c_1^1 to satisfy equation (3), use c_1^2 to satisfy equation (4),..., use P_2 to satisfy equation (8).

by choosing appropriate values for these terms in line with assumptions 1 and 2 we can still solve equations $(3) - (8)$. Having chosen the values of the functions $c_i, P_j,\ i,j = 1,2$ recognizing assumptions 1 and 2 it is possible to extend those functions satisfying A.1 and A.2 on the entire domain.

2

Remark

Note that sufficiently general cost functions with which any direction of price changes can be obtained are of the form $c_i(x_{i1}, x_{i2}) = \tilde{c}_i(\eta_{i1}(x_{i1}) + \eta_{i2}(x_{i2}))$ for all $(x_{i1}, x_{i2}) \geq 0,\ i = 1,2$. For these cost functions $c_i^1 = \eta'_{i1}\tilde{c}'_i,\ c_i^2 = \eta'_{i2}\tilde{c}'_i$ and $H_i = \begin{bmatrix} \eta''_{i1}\tilde{c}'_i & 0 \\ 0 & \eta''_{i2}\tilde{c}'_i \end{bmatrix} + \tilde{c}''_i \begin{bmatrix} \eta'_{i1}\eta'_{i1} & \eta'_{i1}\eta'_{i2} \\ \eta'_{i2}a'_{i1} & \eta'_{i2}\eta'_{i2} \end{bmatrix},\ i = 1,2$ is obtained.

Fix $\tilde{c}'_i$ and consider any 'target values' for marginal costs c_i^1, c_i^2 and any 'target values' for the Hessian matrices, i.e. for $c_i^{11}, c_i^{12}, c_i^{22},\ i = 1,2$. Then we are able to generate those values by the choice

$$\begin{aligned}
\eta'_{ij} &= \frac{c_i^j}{\tilde{c}'_i} \\
\eta''_{ij} &= \frac{c_i^{jj} - c_i^{ij}}{\tilde{c}'_i} \\
\tilde{c}''_i &= \frac{c_i^{12}\tilde{c}'_i\tilde{c}'_i}{c_i^1 c_i^2}
\end{aligned}$$

for $j = 1,2$ and $i = 1,2$.

4 Conclusion

We have demonstrated that in the analysis of price reactions to exchange rate changes it is important to consider the home and the foreign market simultaneously. In general, even with perfect competition, spill-over effects between markets will then be able to allow for any direction of price changes. The actual direction in which prices move as a reaction to exchange rate changes will depend on the technological characteristics of the firm. Thus further empirical research should perhaps put more emphasize to the technological characteristics of the firms rather than to the market structure.

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