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Non-Linear Exchange Rate Pass Through in Industrial Economies

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Abstract

This paper presents theoretical arguments for a non-linear pass-through relationship for import and export prices and investigates the relationship empirically. The theoretical argument is based on the menu-cost approach in which small absolute changes in exchange rates may not prompt price changes because the costs of doing so exceed the extra profits generated for firms involved in international trade. This relationship is investigated empirically using quarterly data for the period 1979q1 to 2015q1 for a sample of seventeen countries. In the case of import prices, evidence is found of non-linear adjustment consistent with the theoretical model in four out of seventeen cases. In the case of export prices, such a relationship is only evident for two economies in the sample. However, for both the import and export price cases, a significant positive non-linear relationship is found for the two largest economies in the sample i.e. the United States and Japan.

JEL codes: F31, F41

1. Introduction

Although purchasing power parity (PPP) continues to feature in many simple open economy models, it has long been recognised that this hypothesis has failed empirically. The overwhelming evidence is that the degree of pass-through, i.e. the extent to which prices change in response to a given change in the exchange rate, is considerably less than one hundred percent. In order to explain this, economists have looked to explanations rooted in the microeconomics of industrial structure as well as the nature of the macroeconomic environment within which firms operate.

Dornbusch (1987) provides an early theoretical discussion of how industrial structure can affect the degree of pass-through. He also provides an event based analysis of the degree of pass-through during the dollar appreciation of 1980-85. Unfortunately however, this does not enable him to distinguish between rival theoretical explanations of the limited degree of pass-through for the US economy. Although rooted in a closed economy world, Mankiw's (1985) model of price stickiness as the result of menu costs is a useful complement to Dornbusch's approach. This framework shows how excessive price stickiness can be an individually optimal strategy for firms in an imperfectly competitive market with menu costs. If importing firms face a downward sloping demand curve then it is relatively easy to extend Mankiw's framework to allow for the effects of changes in exchange rates and thereby demonstrate that it is not always optimal for the price of imports to adjust immediately in response to exchange rate movements. The size and speed of adjustment can be shown to depend on the magnitude and direction of the change in the exchange rate as well as the general macroeconomic environment.

Much of the recent empirical literature on this topic has been concerned with investigating the determinants of the degree of pass-through. Campa and Goldberg (2005a) find evidence of partial pass-through in import prices for a cross section of developed economies. They also find evidence that the degree of pass-through is positively related to exchange rate volatility, money growth and inflation. In Campa and Goldberg (2005b) however, they argue that the determinants of the degree of pass-through are more related to microeconomic factors such as the industrial structure of the economy in question rather than the macroeconomic

environment. In another key paper on this topic, Taylor (2000) argues that an observed decline in the degree of pass-through in the 1990s was due to the lower inflationary environment achieved by successful monetary policies in many industrial economies during this period.

In addition to explaining the determinants of varying degrees of pass-through among different economies and across time, there has also been a growing interest in whether adjustment is asymmetric between periods of depreciation and appreciation. Swamy and Thurman (1994) find evidence of an asymmetric effect of exchange rate changes on import prices with the pass-through effect being stronger in periods of depreciation relative to periods of appreciation. They interpret this as being due to the fact that profit margins are squeezed during periods of depreciation but increase due to appreciation. Another paper which investigates asymmetric adjustment is that of Choudhri and Hakura (2012) who use both regression and VAR based approaches for a cross-section of economies to show that pass-through is higher for import prices than for export prices.

The possibility of non-linear adjustment has also been investigated using models of threshold autoregressions. For example, Da Silva Correa and Minella (2006) investigate a non-linear model of pass-through from the exchange rate to inflation for Brazil. To do this they use a threshold autoregression (TAR) model which indicates that pass-through is higher when the economy is growing fast, when changes in the exchange rate exceed some threshold and when volatility is low. Similarly, Ben Cheikh (2012) has investigated a nonlinear pass-through model which links exchange rate changes to the aggregate CPI index for six European economies. The non-linearity takes the form of a Smooth Transition Autoregression (STAR) model in which the rate of output growth drives a shift between two alternative regimes. The emphasis on output growth as a determinant of the price adjustment regime has meant that this branch of the literature has tended to concentrate on the interaction of the exchange rate with the aggregate Phillips curve and the overall consumer price index rather than its effect on the price of imports and exports.

Finally, there have been a number of papers which have examined the relationship between exchange rates and prices in terms of models of exchange rate adjustment rather than price

adjustment. Taylor and Peel (2000) present a non-linear model of exchange rate adjustment towards a fundamental equilibrium defined by purchasing power parity and the monetary model. Adjustment in their model is driven by the STAR formulation. Similarly Taylor, Peel and Sarno (2001) investigate a non-linear adjustment model of the real exchange rate for the US dollar vis-a-vis Sterling, the Deutschemark, the French Franc and the Yen. They find evidence that the real exchange rate is close to a random walk process for values close to the equilibrium but that adjustment becomes stronger the further the starting point is from equilibrium.

2. A Simple Theoretical Model of Pass-Through

Consider a firm which imports a foreign good and resells it in the domestic market. The price of the good in foreign currency is equal to p^* which is assumed to be constant. The price of a unit of foreign currency is equal to e and therefore the marginal cost of production in this case is equal to p^*e which is assumed to be exogenous from the point of view of the firm. The firm sells q units of the good in the domestic market at price $p(q)$ where $p'(q) < 0$. The firm's profit function is therefore given by:

$$\pi(q) = p(q)q - (p^*e)q \quad (1)$$

The first-order condition for a maximum $\pi'(q) = 0$ yields the following expression:

$$\frac{p - p^*e}{p} = \frac{1}{\eta} \quad (2)$$

where p^*e is the marginal cost and $\eta = -p/qp'(q)$ is the price elasticity of demand. This is a familiar expression in industrial economics where the left hand side of (2) is the price-cost mark up and the right-hand side is the degree of monopoly i.e. the extent of market power the firm possesses which is, in turn, determined by the elasticity of demand it faces in the domestic market. If the elasticity of demand is constant then a change in marginal cost, for

whatever reason, should be met with a proportional increase in price. In particular, there should be full pass-through of any exchange rate changes into domestic prices. It is important to recognise however, that this is a long-run argument in which there are no market frictions which might prevent domestic prices changing. Since the work of Mankiw (1985) it has been recognised that market frictions such as the existence of menu costs can lead to situations in which it may be optimal not to adjust prices immediately in response to changes in marginal costs. Building on this approach, it is possible to develop plausible explanations for why full pass-through of exchange rate changes into domestic prices may not be optimal, particularly in the short-run.

Consider an initial equilibrium for an exchange rate e_1 . The first order condition for profit maximisation yields $p_1 - p^* e_1 = p_1 / \eta$. Now suppose the exchange rate depreciates, increasing marginal cost to the firm. If the firm adjusts price then $p_2 - p^* e_2 = p_2 / \eta$ and quantity falls from q_1 to some lower value q_2 . The gain in profit obtained by increasing the price is:

$$(p_2 - p_1)q_2 - (p_1 - p^* e_2)(q_1 - q_2) \quad (3)$$

Let $e_2 = e_1 + \Delta e$, substituting into (3) and rearranging yields:

$$(p_2 - p^* e_2)q_2 - (p_1 - p^* e_1)q_1 + q_1 p^* \Delta e \quad (4)$$

Suppose there is a fixed menu cost ε associated with changing price. The firm will only find it optimal to change price when the menu cost is less than the gain in profit. Therefore, using the result that $p_i - p^* e_i = p_i / \eta$; $i=1,2$ at the profit maximising price, prices will be sticky when:

$$\varepsilon > \frac{1}{\eta}(p_2q_2 - p_1q_1) + q_1p^* \Delta e \quad (5)$$

Under imperfect competition the price elasticity of demand must be greater than one for marginal revenue to be positive and declining in the output level. It follows that $p_2q_2 - p_1q_1 < 0$ when we consider our example of a devaluation. Therefore, an increase in the degree of monopoly (i.e. a fall in η) will reduce the value of the right-hand side of the expression in (5) and therefore reduce the probability that prices will adjust in response to a change in the exchange rate. The extent of pass-through therefore depends on the competitiveness of the domestic market with less competition being associated with sticky prices.

If there are many importing firms, with a distribution of menu costs, then (5) naturally gives rise to a nonlinear pass through function. Faced with a given devaluation, some firms will find it optimal to adjust price while some will keep it fixed. As the magnitude of the devaluation increases, the proportion of firms which adjust their domestic currency price also increases, leading to a larger degree of pass through. Hence the aggregate pass through function takes the form $\Delta p^d = g(\Delta e)$ where $g' \geq 0$ and $g'' > 0$.

3. Data and the Empirical Model

In this section of the paper the equations which will be estimated are discussed along with the data which will be used. The equations estimated are motivated by the theoretical discussion of the previous section. The aim is to test for the presence of nonlinear adjustment, with larger changes in the exchange rate leading to a higher degree of pass-through into domestic prices. The data used to estimate the equations are taken from the *IMF International Financial Statistics* database. They are quarterly, beginning in 1979, which is the earliest date for which data on import prices, export prices and the nominal exchange rate for seventeen industrial economies could be obtained. The import price index in most cases is the IMF's index of import prices which is coded 76-X-ZF. In some cases however, this series was not available and the unit value of imports 75-ZF has been substituted. Similarly, the export price

index in most cases is the IMF's index of export prices 76-ZF. In cases where this was not available the unit value of imports index 74-DZF was used. The exchange rate index is the nominal effective exchange rate NECZF. Preliminary testing indicated that all of these series contain a single unit root. Since the regressions are conducted using first differences of logarithms however, this is not an issue.

As a starting point a symmetric linear model of the form:

$$\Delta p_t^i = \beta_1 + \beta_2 \Delta e_t^i + u_t^i \quad (6)$$

is estimated, where i indicates a particular economy $i=1,\dots,17$ and t is a time index $t=1979q1,\dots,2015q1$. p is the logarithm of either the import or export price index and e is the logarithm of the nominal effective exchange rate. For each country the model is estimated using the longest period of time for which data is available. Experiments were also conducted in which the rate of change of real Gross Domestic Product (as measured by either by series 99BVRZF or 99BVPZF) was included as an additional control variable. However, this had very little effect and the results are not reported here.

Next a non-linear relationship between price changes and exchange rate changes is estimated. This takes the form:

$$\Delta p_t^i = \beta_1 + \beta_2 \Delta e_t^i + \beta_3 (\Delta e_t^i)^3 + u_t^i \quad (7)$$

The results are reported and discussed in the next section.

4. Empirical Results

Estimates of price equations based on equation (6) for import and export prices are reported in Tables 1 and 2. The standard errors and t-ratios reported in these tables are based on White's adjusted covariance matrix in order to allow for the presence of serial correlation in

the estimated equations. Note that the sample is curtailed for Belgium and France for both price indices because of missing data in the early part of the sample. It is also worth noting that the results for these two economies are the least satisfactory in both cases. Another possibility was investigated by including the rate of change of real GDP as an additional control variable in the regressions. The results were virtually unchanged and are not reported here.

First, consider the import price equation estimates presented in Table 1. The rate of change of the exchange rate is significant and positive at the 5% level in all cases except those of Belgium and France for which there is a much reduced sample. There is therefore evidence of at least partial pass-through to import prices for fifteen out of seventeen economies. It is possible to test whether there is complete pass-through by testing the null hypothesis $H_0: \beta_2 = 1$ against the alternative $H_1: \beta_2 < 1$. This is rejected in thirteen cases, with the exceptions being Denmark, Japan, the Netherlands and Spain for which the null that there is complete pass-through cannot be rejected. The average pass-through coefficient is 0.5394 when Belgium and France are included and 0.6085 when these countries are excluded.

Turning next to the export price equations presented in Table 2, it is again the case that Belgium and France perform poorly. For the remaining equations however, only the Canadian equation fails to indicate the rejection of some degree of pass-through to export prices on the basis of a one-tailed test and a 5% significance level. When testing for full pass-through, the null hypothesis is rejected in all seventeen cases. The average pass-through coefficient is 0.3790 when Belgium and France are included and 0.4241 when they are excluded.

Having considered the linear form of the model, the next stage is to consider a non-linear specification in which a cubic term in the log difference of the exchange rate is added to the equation. This follows the specification shown in equation (7). If the cubic term is positive, $\beta_3 > 0$, then this implies that price adjustment is faster for changes in the exchange rate which are large in absolute value as predicted by the menu-cost model. Table 3 presents the results for the import price equation. In four out of seventeen cases the cubic term is positive

and significant. The economies for which this is the case are Finland, Japan, Sweden and the United States. In the case of the United States, it is only the cubic term which is significant, with the linear term becoming statistically insignificant. Although relatively few economies exhibit a significant cubic term, those that do include the United States and Japan which are the two largest economies in the sample. Finally, it should be noted that Italy exhibits a significant negative cubic term. This indicates that adjustment slows down as the absolute size of the exchange rate change increases. Although this is hard to explain on the basis of the theoretical model, it should be noted that its effect appears to be quite limited. It is only at the very extremes of the range of observed exchange rate changes for the Italian economy that the cubic term has any noticeable effect.

When cubic terms are added to the regression equation in Table 4, then the results are less consistent with expectations. In this case only the United States and Japan exhibit a positive significant cubic term. Again, it should be noted that these are the two largest economies in the sample and that the relationship for the United States appears to be a simple cubic relationship with the linear term becoming statistically insignificant. In three cases the cubic term is negative and significant i.e. Canada, Ireland and Spain. It is again difficult to explain this in terms of the theoretical arguments put forward in the second part of the paper.

5. Conclusions

This paper puts forward theoretical arguments for a non-linear pass-through relationship for import and export prices. This is based on the menu-cost approach in which small absolute changes in exchange rates may not prompt price changes because the costs of doing so exceed the extra profits generated for firms involved in international trade. The hypothesis is investigated using quarterly data for seventeen industrial economies for the period 1979q1 to 2015q1. In the case of import prices, evidence is found of non-linear adjustment consistent with theory in four out of seventeen cases. In the case of export prices, such a relationship is only evident for two economies in the sample. However, for both the import and export price cases, a significant positive non-linear relationship is observed for the two largest economies in the sample i.e. the United States and Japan.

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	$\hat{\beta}_2$	$SE(\hat{\beta}_2)$	T-Ratio $H_0 : \beta_2 = 0$	T-Ratio $H_0 : \beta_2 = 1$	R-Squared	Durbin- Watson Statistic	Number of Observations
Australia	0.5952	0.0353	16.87 ***	-11.47 ***	0.60	1.13	144
Belgium	-0.1618	0.2764	-0.59	-4.20 ***	0.00	2.13	87
Canada	0.4927	0.0705	6.99 ***	-7.20 ***	0.21	1.48	144
Denmark	0.7315	0.1718	4.26 ***	-1.56	0.30	1.03	144
Finland	0.3881	0.0952	4.08 ***	-6.43 ***	0.11	1.04	144
France	0.2038	0.3306	0.62	-2.41 ***	0.01	1.11	63
Germany	0.6535	0.1342	4.87 ***	-2.58 **	0.23	0.93	143
Ireland	0.7836	0.0787	9.95 ***	-2.75 ***	0.43	1.30	143
Italy	0.7212	0.1476	4.89 ***	-1.89	0.21	1.16	144
Japan	0.9144	0.1358	6.73 ***	-0.63	0.51	1.06	144
Netherlands	0.8600	0.1944	4.42 ***	-0.72	0.21	1.31	143
New Zealand	0.7012	0.0705	9.95 ***	-4.24 ***	0.50	1.73	144
Spain	0.8707	0.2276	3.83 ***	-0.57	0.15	1.49	144
Sweden	0.3712	0.0985	3.77 ***	-6.38 ***	0.23	1.14	144
Switzerland	0.2990	0.0727	4.11 ***	-9.64 ***	0.18	1.04	144
United Kingdom	0.3337	0.0855	3.90 ***	-7.79 ***	0.19	1.25	144
United States	0.4117	0.1406	2.93 ***	-4.18 ***	0.19	1.09	144

Table 1: Import Price Pass Through Equations – Linear Specification 1979.1-2015.1

Standard Errors and T-Ratios are calculated using White's Adjusted Covariance Matrix

, ** and * indicate rejection of the null hypothesis at the 10%, 5% and 1% level respectively on the basis of a two-tailed test*

	$\hat{\beta}_2$	$SE(\hat{\beta}_2)$	T-Ratio $H_0 : \beta_2 = 0$	T-Ratio $H_0 : \beta_2 = 1$	R-Squared	Durbin- Watson Statistic	Number of Observations
Australia	0.5980	0.1127	5.31 ***	-3.57 ***	0.30	1.05	144
Belgium	-0.0553	0.2095	-0.26	-5.04 ***	0.00	2.23	87
Canada	0.1770	0.1453	1.22	-5.66 ***	0.02	1.48	144
Denmark	0.6230	0.0958	6.50 ***	-3.94 ***	0.31	1.62	144
Finland	0.2310	0.0624	3.70 **	-12.32 ***	0.09	0.77	144
France	0.1369	0.1194	1.15	-7.23 ***	0.01	1.55	99
Germany	0.1918	0.0334	5.75 ***	-24.20 ***	0.19	0.78	143
Ireland	0.7916	0.0983	8.05 ***	-2.12 ***	0.41	1.71	143
Italy	0.4300	0.0949	4.53 ***	-6.01 ***	0.18	1.81	144
Japan	0.6132	0.0280	21.91 ***	-13.81 ***	0.84	1.10	144
Netherlands	0.6789	0.1856	3.66 ***	-1.73 *	0.17	1.23	143
New Zealand	0.6230	0.0607	10.26 ***	-6.21 ***	0.35	1.17	144
Spain	0.4030	0.0758	5.32 ***	-7.88 ***	0.13	1.91	144
Sweden	0.3200	0.0296	10.82 ***	-22.97 ***	0.31	0.94	144
Switzerland	0.3747	0.1472	2.55 **	-4.25 ***	0.07	1.83	35
United Kingdom	0.1642	0.0961	1.71*	-8.70 ***	0.04	1.29	144
United States	0.1415	0.0624	2.27 ***	-13.76 ***	0.10	1.00	144

Table 2: Export Price Pass Through Equations – Linear Specification 1979.1-2015.1

	$\hat{\beta}_2$	$SE(\hat{\beta}_2)$	T-Ratio $H_0 : \beta_2 = 0$	$\hat{\beta}_3$	$SE(\hat{\beta}_3)$	T-Ratio $H_0 : \beta_3 = 0$	R-Squared	Durbin-Watson
Australia	0.6312	0.0444	14.22 ***	-2.4154	2.4740	-0.98	0.60	1.13
Belgium	-0.1970	0.4991	-0.39	84.1943	834.0147	0.10	0.00	2.13
Canada	0.4845	0.0993	4.88 ***	2.2122	10.7695	0.21	0.21	1.48
Denmark	0.5886	0.1665	3.54 ***	193.7922	235.3938	0.82	0.30	1.03
Finland	0.1537	0.1437	1.07	63.6669	28.3113	2.25 **	0.14	1.02
France	0.1403	0.3529	0.40	208.4426	1084.0910	0.19	0.01	1.11
Germany	0.6581	0.1859	3.54 ***	-7.3062	150.6182	-0.05	0.23	0.93
Ireland	0.8161	0.1460	5.59 ***	-24.2644	84.7881	-0.29	0.43	1.30
Italy	0.8977	0.1948	4.61 ***	-35.9970	16.2650	-2.21 **	0.23	1.21
Japan	0.7203	0.1455	4.95 ***	19.4188	5.5076	3.53 ***	0.54	1.12
Netherlands	0.7651	0.2496	3.07 ***	176.0469	176.3958	1.00	0.21	1.30
New Zealand	0.6931	0.0909	7.62 ***	0.9549	4.8343	0.20	0.50	1.73
Spain	1.1258	0.3662	3.07 ***	-86.6654	72.1819	-1.20	0.16	1.50
Sweden	0.2155	0.0958	2.25 **	16.4050	4.2652	3.85 ***	0.26	1.14
Switzerland	0.3088	0.1038	2.98 ***	-3.1297	18.6221	-0.17	0.18	1.05
United Kingdom	0.3383	0.1225	2.76 ***	-0.8865	11.3372	-0.08	0.19	1.25
United States	0.0896	0.1115	0.80	102.1257	32.8143	3.11 ***	0.29	1.06

Table 3: Import Price Pass Through Equations – Cubic Specification 1979.1-2015.1

	$\hat{\beta}_2$	$SE(\hat{\beta}_2)$	T-Ratio $H_0 : \beta_2 = 0$	$\hat{\beta}_3$	$SE(\hat{\beta}_3)$	T-Ratio $H_0 : \beta_3 = 0$	R-Squared	Durbin-Watson
Australia	0.5967	0.1364	4.37 ***	0.0874	2.5057	0.03	0.30	1.05
Belgium	-0.2935	0.3769	-0.78	569.3608	693.7302	0.82	0.01	2.22
Canada	0.4000	0.1272	3.14 ***	-60.3494	14.5823	-4.14 ***	0.07	1.56
Denmark	0.6767	0.1190	5.69 ***	-72.8540	154.7684	-0.47	0.31	1.61
Finland	0.1437	0.1070	1.34	23.7053	16.6713	1.42	0.10	0.77
France	0.3043	0.2489	1.22	-462.1256	478.0890	-0.97	0.02	1.55
Germany	0.2475	0.0533	4.64 ***	-89.0540	51.7811	-1.72	0.20	0.82
Ireland	0.9589	0.1276	7.51 ***	-124.8866	52.2273	-2.39 ***	0.42	1.72
Italy	0.5117	0.1475	3.47 ***	-16.6594	11.8587	-1.40	0.19	1.83
Japan	0.5485	0.0315	17.40 ***	6.4657	1.5382	4.20 ***	0.85	1.14
Netherlands	0.8137	0.2498	3.26 ***	-250.0104	191.1728	-1.31	0.17	1.26
New Zealand	0.6298	0.0810	7.77 ***	-0.7959	3.3177	-0.24	0.35	1.17
Spain	0.5407	0.1169	4.63 ***	-46.7739	20.6470	-2.27 **	0.15	1.92
Sweden	0.3081	0.0565	5.45 ***	1.2519	5.1027	0.25	0.31	0.94
Switzerland	0.4671	0.2984	1.57	-22.8478	41.9606	-0.54	0.08	1.83
United Kingdom	0.2411	0.1443	1.67 *	-14.6168	12.0312	-1.21	0.05	1.26
United States	0.0238	0.0566	0.42	37.3068	16.2116	2.30 **	0.16	0.92

Table 4: Export Price Pass Through Equations – Cubic Specification 1979.1-2015.1