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WORKING PAPER SERIES

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February 2008

Working Paper 2008-13
http://www.frbsf.org/publications/economics/papers/2008/wp08-13bk.pdf

Understanding Changes in Exchange Rate Pass-Through

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First Draft: July 2003
This Draft: February 2008

Abstract Recent research suggests that there has been a decline in the extent to which firms "pass through" changes in exchange rates to prices. Beyond providing further evidence in support of this claim, this paper proposes an explanation for the phenomenon. It then presents empirical evidence of a structural break during the 1990s in the relationship between the real exchange rate and CPI inflation for a set of fourteen OECD countries. It is suggested that the recent reduction in the real exchange rate pass-through can be attributed in part to the low-inflation environment of the 1990s.

Key words: Pass-Through; Inflation; Exchange Rate; Monopolistic Competition; Staggered Price Setting.
JEL classification: E31, E52, F41.

[1] The author thanks Laurence Ball, Louis Maccini, Christopher Carroll, Carl Christ, Benjamin Dennis, Thomas Lubik, Eva Sierminska and participants in the Johns Hopkins University Macroeconomics Lunch Seminar, 39th Annual Meetings of the Canadian Economics Association, 80th Annual Conferences of the Western Economics Association International, and 39th Global Conference on Business and Economics. All errors are her own.

1 INTRODUCTION

In open economies, exchange rate fluctuations affect the behavior of inflation. This makes the exchange rate pass-through (defined as the effect of exchange rate changes on domestic inflation) an important consideration with respect to monetary policy. Several authors claim that even considerably large changes in exchange rates during the 1990s had a surprisingly weak effect on domestic inflation in some small open economies.[2] This puzzlingly weak effect might be explained by the presence of other forces, for instance, deviations of output from its natural level. Nevertheless, it has been suggested that the recently observed reduction in the exchange rate pass-through is too large and pervasive to be explained by special factors (Taylor 1999).

While the literature on exchange rate pass-through is voluminous,[3] it is also important to note that there is no uniform definition of the term "pass-through." Much of the existing research focuses on the relationship between movements in nominal exchange rates and import prices. A smaller but equally important strand of the literature concentrates on the macroeconomic exchange rate pass-through to aggregate price indices (Bachetta and van Wincoop 2003, Campa and Goldberg 2006, Gagnon and Ihrig 2004). This paper also focuses on the relationship between aggregate prices and inflation, but departs from existing studies by using a Phillips curve framework to analyze exchange rate pass-through and focusing on the link between the real exchange rate and inflation.

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[2] Cunningham and Haldane (2000) show evidence of a reduced pass-through in the United Kingdom, Sweden and Brazil. Garcia and Restrepo (2001) discuss the low pass-through in Chile. McCarthy (1999) studies exchange rate pass-through in nine developed countries and concludes that exchange rates "have not assumed a bigger role in domestic consumer price inflation in recent years, and may even have had a smaller role."

[3] For a survey of the literature on the exchange rate pass-through to import prices, see Goldberg and Knetter (1997). Examples of studies done on the pass-through to domestic producer and consumer prices are Woo (1984), Feinberg (1986, 1989), and McCarthy (1999).

The remainder of this paper is organized as follows. In the next section, I present an empirical framework that motivates subsequent empirical work. I derive an open economy Phillips curve by extending a standard sticky-price model to an open economy. The theoretical work shows that there are four factors determining the degree of exchange rate pass-through: the degree of openness of the economy, the fraction of flexible-price firms in the economy, the credibility of the central bank, and the degree of exchange rate pass-through at the level of the firm.

The third section discusses the empirical approach. My sample consists of 14 OECD countries from the International Financial Statistics (IFS) database. To allow for the correlation of residuals across countries, I estimate a seemingly unrelated regression model. I then compare average Phillips curve coefficients and average dynamic inflation responses to a real exchange rate shock over time. This methodology differs from those previously used in the literature.[4] The advantage of using this technique is that it draws some general conclusions about the recent change in the nature of the relationship between the exchange rate and the consumer price index (CPI) inflation, rather than concentrating on individual country results (which are not informative because only short samples are available).

Section 4 describes the results of the empirical investigation, focusing on two crucial points. First for the set of countries investigated as a group, evidence indicates that a reduction in the exchange rate pass-through indeed took place beginning the 1990s. Second, this change in the relationship between the exchange rate and inflation was caused by a reduction in the fraction of firms that are flexible to change their prices every period. Section 5 concludes the paper.

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[4] Past estimation techniques include ordinary least squares, panel data, vector autoregression, cointegration analysis, and error correction models, as well as state-space models (Garcia and Restrepo 2001).

2 THEORETICAL FRAMEWORK

This section presents the derivation of an open economy Phillips curve. First, I define two types of firms (foreign and domestic), and find a solution for the profit-maximizing price for each firm-type. Once I derive optimal prices for the foreign and domestic firms, I am able to obtain a solution for the aggregate price indices for domestic goods and imports. I then aggregate price indices for both sectors into the aggregate price index. Finally, I derive an open economy Phillips curve and analyze inflation dynamics.

2.1 Optimal Prices

In this stylized model, I designate countries and, likewise, types of firms as domestic and foreign. I define foreign firms as those that produce their goods in the foreign country and then sell them in the domestic country. Thus, all the costs of production for foreign firms are incurred in the foreign country. Domestic firms, on the other hand, both produce and sell their goods in the domestic country. For simplicity, I assume that each domestic and foreign firm produces only one good.

I begin by considering the optimal price for the good of the foreign firm. I use P_{it}^F as the price that the foreign firm *i* charges for its good expressed in domestic currency, and Y_{it} as the real output of this firm. The firm's nominal revenue (in domestic currency) then is $P_{it}^F Y_{it}$. Let C_{it} denote firm *i*'s real cost, P^* the foreign aggregate price level expressed in foreign currency, and E_t^N the nominal exchange rate defined as units of foreign currency per one unit of domestic currency. The nominal cost the foreign firm faces is $C_{it} P_t^*$ if stated in foreign currency, and $\frac{C_{it} P_t^*}{E_t^N}$ if expressed in domestic currency.

The nominal profit of the foreign firm (in domestic currency) is the difference between the nominal revenue and nominal cost:

$$\Pi_{it}^{N} = P_{it}^{F} Y_{it} - \frac{C_{it} P_{t}^{*}}{E_{t}^{N}}.$$

The real profit, Π_{it}, function then becomes:

$$\Pi_{it} = \frac{P_{it}^{F} Y_{it}}{P_{t}} - \frac{C_{it} P_{t}^{*}}{E_{t}^{N} P_{t}}. \tag{1}$$

At this point, it is helpful to define the real exchange rate, Q_t:

$$Q_{t} = \frac{E_{t}^{N} P_{t}}{P_{t}^{*}}. \tag{2}$$

Under this definition, an increase in the real exchange rate is interpreted as a real appreciation of the domestic currency. The real profit function can now be rewritten to incorporate the definition of the real exchange rate:

$$\Pi_{it} = \frac{P_{it}^{F} Y_{it}}{P_{t}} - \frac{C_{it}}{Q_{t}}. \tag{1'}$$

To complete the foreign firm's problem, it is necessary to specify the demand and cost functions faced by the firm. Demand for the foreign firm's good is assumed to be guided by two factors — aggregate real income (Y_t) and the good's relative price ($\frac{P_{it}^{F}}{P_{t}}$).

Demand for the good increases with aggregate spending in the economy and declines with the relative price of the good. For the sake of tractability, demand for good *i* is assumed to be log-linear:

$$Y_{it} = Y_{t} \left(\frac{P_{it}^{F}}{P_{t}} \right)^{-\varepsilon}, \varepsilon > 1. \tag{3}$$

Real cost in the model is an increasing function of the firm's output. Similar to the demand function, real cost is assumed to be log-linear:

$$C_{it} = \frac{\varepsilon - 1}{\gamma\varepsilon} Y_{it}^{\gamma}, \gamma > 1. \tag{4}$$

The foreign firm chooses for its good the price that maximizes the real profit function (equation 1') subject to the real demand function (equation 3) and the real cost function (equation 4). Solving the foreign firm's maximization problem yields its optimal price (the derivation is presented in detail in Appendix A):

$$p_{it}^{*F} = p_t + k_1 y_t - k_2 q_t, \tag{5}$$

where $k_1 = \frac{\gamma - 1}{\varepsilon(\gamma - 1) + 1}$, $k_2 = \frac{1}{\varepsilon(\gamma - 1) + 1}$, and all variables are in logs.

The intuition for equation (5) is consistent with that in standard models of monopolistic competition (Romer 2001) - the foreign firm's desired price increases with the aggregate price level one-to-one and with the total spending in the economy. In addition, the foreign firm's optimal price declines as the domestic currency appreciates, because appreciation of the domestic currency acts like a reduction in the cost of production.

The problem of the domestic firm is analogous to that of the foreign firm, with one exception: the real exchange rate plays no role in the decision of the domestic firm, as all costs of production are incurred in the domestic country. I assume that the domestic firm is facing the same elasticities of demand and cost functions as the foreign firm. Therefore, the problem of the foreign firm can be modified to correspond with that of the domestic firm by letting Q_t=1 for all t, and the optimal price of the domestic firm is

$$p_{it}^{*D} = p_t + k_1 y_t, \tag{6}$$

where k_t is the same as in equation (5), and all variables are in logs. This expression for the desired price of the firm is widely used in the literature., as in Mankiw and Reis (2002), Blanchard and Kyotaki (1987), and Romer (2001).

2.2 Aggregation

After solving for the optimal prices of domestic and foreign firms, I proceed to find an expression for the aggregate price level and subsequently, aggregate inflation. To begin with, it is reasonable to allow firms to differ with respect to the frequency of price adjustment, as in Ball (2000). In particular, some firms update their prices every period. I refer to such firms as "flexible-price" firms throughout the paper. The remaining firms update their prices one period in advance and set their prices equal to the expected optimal price; I refer to these firms as "fixed-price firms." Note that flexible-price firms can take current economic conditions into account when setting their prices, whereas fixed-price firms cannot.

I assume that a fraction δ of foreign firms are flexible-price firms, and the rest are fixed-price ones. Under this assumption, the log of the aggregate price index for the foreign goods is simply a weighted average of the logs of the prices set by flexible and fixed-price firms:

$$p_t^F = \delta p_{it}^{*F} + (1-\delta) E_{t-1} p_{it}^{*F} . \tag{7}$$

For simplicity, I assume that the fraction of domestic firms that are flexible-price firms is also δ. Thus, the log of the aggregate price index for domestic goods is analogous to that for foreign goods:

$$p_t^D = \delta p_{it}^{*D} + (1-\delta) E_{t-1} p_{it}^{*D} . \tag{8}$$

Finally, I assume that μ percent of the goods in the CPI basket are imports. Then the aggregate price index is a weighted average of domestically produced good and imports:

$$p_t = \mu p_t^F + (1-\mu) p_t^D . \tag{9}$$

As shown in Appendix A, one can substitute equations (5) and (6) into equations (7) and (8) respectively to obtain solutions for the aggregate price indices for domestic and foreign goods as functions of aggregate output, aggregate price level, and the real exchange rate. One can then substitute the resulting two equations into equation (9) to find the aggregate price index. Some more algebra yields the following expression for aggregate inflation:

$$\pi_t = E_{t-1}\pi_t + \frac{\delta k_1}{1-\delta} y_t + k_1 E_{t-1} y_t - \frac{\mu\delta k_2}{1-\delta} q_t - \mu k_2 E_{t-1} q_t . \tag{10}$$

The next step is to solve for expected real output, the expected real exchange rate, and the expected inflation rate in equation (10). I begin by assuming that the real exchange rate follows a random walk.[5] Therefore, agents set their expectations for the next period's real exchange rate equal to the level of the real exchange rate prevailing at the time expectations are formed:

$$E_{t-1} q_t = q_{t-1} . \tag{11}$$

I define the "no-shock output level" (denoted by y^N) as the level of output that prevails when prices are flexible (meaning that $p_i = p_i^*$ for all i) and there are no current shocks to the real exchange rate (implying that $q_t = q_{t-1}$). This definition is similar to that for the "natural level of unemployment "found in Ball, Mankiw, and Reis (2002). This level of output is derived in Appendix A, and the final result is as follows:

[5] While assuming exogeneity of exchange rates is hardly plausible from a theoretical standpoint, empirical studies show that macroeconomic variables have little explanatory power over exchange rates (Rogoff 1992, Meese and Rogoff 1983, and Enders 1995).

$$y_t^N = \frac{\mu k_2}{k_1} q_{t-1}. \tag{12}$$

Note that y^N varies with the last period's real exchange rate. An increase in the last period's real exchange rate acts like a decline in the cost of production and thereby raises the "no-shock output level."

I assume that the monetary authority sets an inflation target (either implicitly or explicitly). This inflation target is denoted by π^T, and it is assumed to be time-invariable. Since this is a highly stylized model, I assume the following process for output:

$$y_t = y_t^N - \omega(\pi_t - \pi^T) + \varepsilon_t^Y, \tag{13}$$

where ε^y is demand shock and the rest of the terms are as previously defined. Equation tells us that when there are no demand shocks in this economy and inflation is at its target level, output will be at its no-shock level. If inflation is above target, the monetary authority responds by tightening, which depresses output (hence, a negative relationship between inflation gap and output). Parameter ω represents the strength of the monetary authority's response to deviations of inflation from its target.

Consequently, the expected output level can be found as:

$$E_{t-1}y_t = E_{t-1}\left(y_t^N - \omega\pi_t + \omega\pi^T + \varepsilon_t^Y\right) = \frac{\mu k_2}{k_1} q_{t-1} - \omega E_{t-1}\pi_t + \omega\pi^T \tag{14}$$

Last, I assume that agents set expected inflation equal to some weighted average of the aggregate inflation rate prevailing in the economy at the time of expectation formation and the inflation target set by the central bank (expectations here are near-rational, as discussed by Ball 2000):

$$E_{t-1}\pi_t = \alpha\pi^T + (1-\alpha)\pi_{t-1}. \tag{15}$$

I interpret parameter α as the "credibility parameter," because this parameter changes with the degree of the agent's trust in the monetary authority. The more credible the monetary authority, the more important the inflation target becomes in the agents' inflation expectation formation. Thus, α increases with the credibility of the monetary authority.

Substituting equations (11), (14), and (15) into equation (10) yields an open economy Phillips curve (the derivation of which can be found in Appendix A):

$$\pi_t = [\alpha - (1-\alpha)k_1\omega]\pi^T + (1-\alpha)(1-k_1\omega)\pi_{t-1} + \frac{\delta k_1}{1-\delta}(y_t - y_t^N) - \frac{\mu\delta k_2}{1-\delta}\Delta q_t. \qquad (16)$$

Equation (16) shows that current aggregate inflation depends on expected inflation (the weighted average of the last period's inflation and inflation target), output gap, and the real exchange rate growth rate. This open economy Phillips curve is similar to those found in the literature. Similar to Ball (1999) and Svensson (1998), the equation proposed here exhibits inflation inertia. As Mankiw and Reis (2002) point out, a theoretical Phillips curve must allow for inflation inertia if it has any hope of explaining the data. As in Ball (1999), Svensson (1998), and Razin and Yuen (2001), equation (16) shows that the inflation rate in an open economy is influenced by the real exchange rate. In particular, a real appreciation of domestic currency puts a downward pressure on the inflation rate. Again, as in Ball (1999), Svensson (1998), and Razin and Yuen (2001), the strength of inflation's reaction to changes in the real exchange rate depends on the degree of openness of the economy (i.e., the fraction of imported goods in the CPI). As in Razin and Yuen (2001), the degree of real exchange rate pass-through is also determined by the fraction of flexible-price firms in the economy — the more flexible-price firms there are, the more pronounced is the aggregate real exchange rate pass-through.

Despite the many similarities with the open economy Phillips curves derived by other authors, the one presented here has two important features that are unique. First, it accounts for the influence of central bank credibility on the real exchange rate pass-through. The more credible the central bank, the quicker inflation returns to its steady-state level from before it suffered a shock. Second, the model presented here does not assume a complete pass-through at the level of the individual foreign firm. Whether and how much each individual foreign firm increases its price in response to a real depreciation of the domestic currency, depends on the elasticities of the demand and cost functions faced by the firm.

Last, in the model proposed in this paper, the real exchange rate is what matters in the determination of CPI inflation. This finding is similar to the treatment of supply shocks by others (Ball and Mankiw 1995, Staiger, Stock, and Watson 1997, and Gordon 1997, for example), but the pass-through literature usually addresses nominal exchange rate pass-through. Real and nominal exchange rates, however, tend to be highly correlated. Thus, estimation results should not differ dramatically whether one uses nominal or real exchange rates.[6]

2.3 Inflation Dynamics

I now turn to a discussion of inflation dynamics. The open-economy Phillips curve presented above allows for a distinction between two types of pass-through — short-term and long-term. The short-term pass-through is the immediate reaction of inflation to a change in the real exchange rate. Thus, $\frac{\mu\delta k_2}{1-\delta}$ measures short-term exchange rate pass-

[6] I estimated the model using nominal exchange rates as well and found no qualitative differences in the estimation results.

through. The long-term pass-through is the overall response of inflation to a real exchange rate shock, measured as $\dfrac{\frac{\mu\delta k_2}{1-\delta}}{1-(1-\alpha)(1-\kappa_1\omega)} = \dfrac{\mu\delta k_2}{(1-\delta)(\alpha + k_1\omega - k_1\omega\alpha)}$.

Both short-term and long-term pass-through are guided by parameters μ, δ, and k_2. It is easy to see why a lower degree of openness in the economy (μ) would cause the response of inflation to real exchange rate fluctuations to be weaker. The only type of firms that update their prices in response to real exchange rate movements are foreign firms. Thus, a decline in the fraction of foreign firms in the economy causes a reduction in real exchange rate pass-through at the aggregate level. A decline in the fraction of flexible-price firms (δ) has a similar effect. The intuition behind this is also straightforward: only flexible-price firms have the ability to incorporate information about current exchange rate shocks when setting prices for their goods. Thus, if the fraction of flexible-price firms goes down, exchange rate shocks have less of an effect on aggregate inflation.

Finally, a decline in the aggregate real exchange rate pass-through could be caused by a reduction of real exchange rate pass-through at the level of the individual firms (k_2). As noted earlier, only foreign firms change their prices in response to real exchange rate fluctuations. Thus, if each foreign firm begins to respond less to real exchange rate changes, the aggregate response of prices will also be dampened. The decline in an individual foreign firm's responsiveness to real exchange rate fluctuations, in turn, can be caused by an increase in either the elasticity of the demand function (ε) or the elasticity of the cost function (γ). An increase in either ε or γ can be interpreted as a loss of monopoly power by the firm. Thus, the responsiveness of an individual foreign firm's prices to real exchange rate shocks declines when the firm loses its monopoly power.

In addition to the three parameters described above, the long-term exchange rate pass-through it is affected by parameters α , k_1 and ω. Equation (16) reveals that inflation persistence declines with increases in the central bank credibility parameter (α), degree of real rigidity (k_1), and the central bank's commitment to low inflation (ω). A reduction in inflation persistence would cause a decline in the long-term effect of real exchange rate fluctuations on inflation.

Note that this paper is not the first one to consider possible theoretical explanations for changes in exchange rate pass-through. Taylor (1999) presents a microeconomic model of staggered price setting. He shows that a lower perceived persistence of cost changes causes lower pass-through. It is possible to interpret Taylor's finding using the model proposed in this paper. One could argue that it is the increase in central bank credibility that reduces inflation persistence, and, therefore, the perceived persistence of cost changes. Gagnon and Ihrig (2004) also point to the link between exchange rate pass-through to monetary authority credibility and strength in responding to inflation deviations from target.

3 EMPIRICAL APPROACH

In this section, I present the empirical model used in this study, explain the proposed estimation method is then given and describe the data.

3.1 Empirical Model

Equation (16) provides the base for my empirical model. However, this equation implies a very tight contemporaneous relationship between the inflation rate and two of its determinants, the output gap and the real exchange rate growth rate. Other authors have shown that inflation adjusts sluggishly to changes in the economy (Gordon 1997, Staiger, Stock and Watson 1997).

Thus, I follow equation (16) qualitatively, though adding more lags of explanatory variables. I also include supply shock variables. The empirical model I estimate is

$$\pi_{jt} = c_{j0} + \sum_{i=1}^{3} c_{ji}^{\pi} \pi_{jt-i} + \sum_{i=0}^{3} c_{ji}^{y} (y_{jt-i} - y_{jt-i}^{N}) + \sum_{i=0}^{3} c_{ji}^{q} \Delta q_{jt-i} + \sum_{i=1}^{4} c_{ji}^{z} \Delta z_{t-1} + \varepsilon_t, \quad (17)$$

where z denotes supply shock variables, j indexes countries, and c_i^{π}, c_i^{y}, c_i^{q} , and c_i^{z} are constants.

In this paper, I will focus on the long-run pass-through coefficient (denoted by c_j^q, where j indexes countries), which is defined as

$$\varphi_q = \frac{\sum_{i=0}^{3} c_{ji}^{q}}{1 - \sum_{i-0}^{3} c_{i,j}^{\pi}}. \quad (18)$$

3.2 Estimation Methodology

I estimate equation (17) for all the countries in the sample. Instead of estimating an open economy Phillips curve for each country in the sample, I estimate the equations as a system. There appears to be no justification for restricting the coefficients in the system in any way. There is no reason to assume that the Phillips curve coefficients are the same for all the countries in the sample. It seems plausible, however, to allow for a correlation of the residuals across countries. Since the equations in the system are linked only by their disturbances, the resulting model is a seemingly unrelated regression (SUR) model.

Though the covariance matrix of the disturbances is unknown, I use feasible generalized least squares (FGLS) estimators. I estimate the system in two steps. I use the least squares residuals are used to estimate the elements of the variance-covariance matrix of the residuals consistently. With such estimates in hand, I can then proceed as usual to estimate the system using the FGLS (Greene 1997).

The procedure generates open economy Phillips curve estimates for all the countries in the sample. While the individual country coefficient estimates are presented, my discussion focuses on average coefficients across countries. The main reason for using such an approach is that the goal of this paper is to address fairly recent changes in the structure of the open economy Phillips curve. As a result, only short samples for each individual country are available. With such limited data, individual country estimation results are not especially informative. On the other hand, the average coefficient estimates are more precise. This approach also allows for some general conclusions to be made about the structural break in the open economy Phillips curve since the 1990s.

The average coefficients are computed as follows:

$$\hat{c}_i^{\,x} = \frac{1}{n}\sum_{j=1}^{n}\hat{c}_{ij}^{x}, \tag{18}$$

where n stands for the number of countries in the sample, $x=\pi$, y, or q, j indexes countries, and "^" over a parameter denotes its estimated value. The standard errors for the average coefficients can also be computed:

$$S.E.(c^x) = \sqrt{\left(\frac{1}{n^2}\sum_{j=1}^{n}\hat{V}(c_{ij}^{x}) + \frac{2}{n^2}\sum_{j=1}^{n}\sum_{k=j+1}^{n}\hat{C}(c_{ij}^{x}, c_{ik}^{x})\right)}, \tag{19}$$

where $S.E.$ stands for standard error, V for variance, and C for covariance. Details of the derivation of equation (19) can be found in Appendix B. The variances and covariances of the individual countries' coefficients can be obtained from an FGLS estimate of the system of Phillips curve equations for the panel of countries.

3.3 Data

This study considers the 1980 -2007 time period and uses data from 14 OECD countries: Australia, Canada, Denmark, Finland, France, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, the United Kingdom, and the United States. The sample begins with the first quarter of 1980 in order to exclude the Great Inflation of the 1970s. I chose only those countries for which data for all variables of interest was available starting in 1980

The series employed are those for the rate of inflation, the output gap, the real exchange rate growth rate, and the growth rate for the prices of food and energy. Data come from the OECD, and Appendix C provides details on the specific databases used. I compute the rate of inflation as the annualized growth rate of the CPI (i.e. inflation is defined as $\pi_t = 400 * (\ln P_t - \ln P_{t-1})$, where P is CPI). The output gap is the difference between the actual and potential gross domestic product (GDP) as a per cent of potential GDP (I use OECD estimates of potential output). Supply shock variables are the growth rate in the relative prices of food and energy computed as $100*(lnP_t-lnP_{t-1})-100*(lnP^c_t-lnP^c_{t-1}$, where P is CPI and P^c is core CPI.

For the real exchange rate, I use two series. The first one is the real effective exchange rate series computed by the OECD. The effective exchange rate index is a chain-linked index. Percentage changes in the index are calculated by comparing the change in the index based on consumer prices for the country concerned (expressed in U.S. dollars at market exchange rates) to a weighted average of changes in its competitors' indices (also expressed in U.S. dollars), using the weighting matrix of the current year. The indices of real effective exchange rates are then calculated from a starting period by cumulating percentage changes. This gives a set of real effective exchange rates based on moving weights.

To check the robustness of my estimation results with respect to the choice of the real exchange rate data, I also compute an alternative measure of the real exchange rate defined as in equation (2). I use the U.S. dollar as the foreign currency in the computations; i.e., the CPI of the country in question is a measure of *P*, the nominal exchange rate between the currency of the country under consideration and the U.S. dollar is a measure of E^N, and the U.S. CPI is used to measure *P** to compute the real exchange rate between the currency of the country in question and the U.S. dollar. In comparison to the real effective exchange rate series, this alternative is a narrower measure of the real exchange rate, which makes it perhaps less appealing theoretically. On the other hand, given the problems with the real effective exchange rate measurement, this measure is more reliable.

The study compares the relationship between inflation and the real exchange rate growth over two periods: 1980:Q1 to 1989:Q4 (referred to as the 1980s) and the second from 1990:Q1 to 2007:Q2 (which for brevity I refer to as the 1990s). Summary statistics for CPI inflation, the output gap and the real exchange rate growth rate are summarized in Table 1. For all the countries in the sample, average inflation in the first subperiod is higher than in the later period. With the exception of the Netherlands, the difference between means is significant at a 1% level. Moreover, the later subperiod is also marked by lower inflation volatility (with the exception of Sweden and Australia, the variance of inflation is significantly higher in the first period). For most countries, the average gap is negative (indicating that actual output is below potential) for both periods (the output gap is positive only for Finland in the first period). In terms of output gap variability, the results are mixed. For Canada, Denmark, Finland, Italy, Netherlands, U.K. and the U.S., the variance of the output gap is significantly lower in the second period. For Ireland and New Zealand, the opposite is true. Real exchange rate growth rate series exhibit significantly higher volatility in the first subperiod for Australia, Denmark, France, New Zealand, U.K., and the U.S. and significantly higher volatility in the second subperiod for Canada, Finland, and Italy.

4 RESULTS

This section presents the evidence supporting the claim that a structural break in the relationship between inflation and the real exchange rate occurred during the 1990s. I then investigate explanations for this phenomenon.

4.1 Evidence of a Decline in the Real Exchange Rate Pass-Through

I estimate the model for each real exchange rate series over each subperiod. Table 2a shows the sums of estimated coefficients on inflation, output gap, and the real exchange rate. The table shows that inflation persistence (measured by the sum of coefficients on the three lags of inflation) has declined significantly in eight countries in the sample (Canada, Finland, France, Ireland, Netherlands, New Zealand, Norway, and Sweden) from the 1980s to the later period. The sum of coefficients on the real exchange rate terms has declined significantly for Canada, Japan, and New Zealand. Estimation results obtained with the alternative measure of real exchange rates are qualitatively similar and reported in Table 2b.

Table 3a summarizes estimates of long-run exchange rate pass-through coefficients (given by equation 18) for each country in the sample. As shown in the table, although estimation results for many countries suggest a decline in the exchange rate pass-through, the decline is significant for Japan only. When estimation is performed with the alternative real exchange rate measure (results summarized in Table 3b), significant decline in exchange rate pass-through is observed for Finland and Japan.

As shown in Tables 2 and 3, individual country coefficients tend to be estimated rather imprecisely. Therefore, in Table 4 I showthe average Phillips curve coefficient estimates, which I consider more informative (see Section 3 for discussion). The first panel of Table 4 shows estimation results obtained with OECD real effective exchange rate data, and the second panel presents estimation results obtained using the alternative real exchange rate data. The table reports the sum of coefficients on inflation (denoted with π in the table), output gap (denoted with y), and the real exchange rate growth rate (Δq). The last column in the table shows the long-run pass-through coefficient (denoted with LRPT) for the average Phillips curve (denoted with φ).

As shown in Table 4, for the countries as a group, both inflation persistence (measured by the sum of coefficients on inflation lags) and the link between the real exchange rate growth rate and inflation (measured by the sum of coefficients on the real exchange rate) declined significantly between the two periods. The decline in inflation persistence is consistent with other researchers' findings of a reduction in inflation persistence over time (Ball and Sheridan 2003, Sheridan 2001). Recall that while a decline in the persistence of inflation does not change the impact effect of real exchange rate shocks on inflation, it does reduce the long-term effect. Thus, it is no surprise that we see a significant decline in the long-run pass-through coefficient. This conclusion is robust with respect to real exchange rate measure. When the OECD real effective exchange rate is used, the estimation results suggest that a 1-percent real appreciation of domestic currency (increase in real exchange rate) eventually leads to a 0.92-percent decline in inflation in the earlier subperiod. The long-run pass-through coefficient for the second subperiod is not significantly different from zero, indicating no significant effect of real exchange rate changes on inflation during the later period. With the alternative real exchange rate, a 1-

percent appreciation of domestic currency (increase in the real exchange rate) is estimated to lead to a 0.45-percent decline in inflation. As with the OECD real exchange rate, the long-run exchange rate pass-through coefficient estimated with the alternative real exchange rate is not significantly different from zero.

4.2 The Determinants of Real Exchange Rate Pass-Through: Time Series Cross-Section Results

The theoretical model presented in Section 2 of this paper suggests four possible determinants for the magnitude of the real exchange rate pass-through to CPI inflation: the degree of pass-through of real exchange rate changes to the prices of goods at the level of the individual foreign firms (which, in turn, depends on the elasticity of the demand function and the elasticity of the cost function faced by the firms), the proportion of the imported goods in the CPI basket, the credibility of the monetary authority, and the fraction of flexible-price firms in the economy.

Data on the elasticities of the demand and cost functions for all the countries in the sample are not readily available. Therefore, this paper does not analyze whether the degree of real exchange rate pass-through on the level of individual firms has changed across this period, and whether this change is the cause of the deterioration in the relationship between aggregate inflation and the real exchange rate. Additionally, finding a measure for central bank credibility for every country in the sample proved unviable; One suggestion for future research would be to construct such a measure by relating central bank credibility to central bank independence.

It is possible to explore the other two determinants of the degree of pass-through of real exchange rate changes to CPI inflation, but it is necessary to use proxies, both for the share of imported goods in the CPI basket and for the fraction of firms that update their prices every period for each country in the sample, as the data for these variables are not available. I use the share of imports in GDP as a proxy for the share of imported goods in the CPI basket.

I use average inflation for the decade as a proxy for the fraction of flexible-price firms in the economy. This choice of proxy is based on previous research on the frequency of price adjustment. Ball, Mankiw, and Romer (1988) argue that, theoretically, in the presence of a higher average rate of inflation, firms adjust prices more frequently to keep up with the rising price level. They then go on to show the empirical aggregate evidence supporting this theoretical claim. The microeconomic literature also shows evidence supporting a positive relationship between the average inflation for a period and the fraction of flexible-price firms (Cecchetti 1986). Hence, it is reasonable to conjecture that there are more flexible-price firms in an economy where average inflation is higher.

The goal of this exercise is to determine whether two of the proposed theoretical determinants of the real exchange rate pass-through — i.e., the proportion of flexible-price firms and the openness of the economy — do indeed influence the response of inflation to real exchange rate fluctuations. Consequently, the dependent variable in the analysis is the long-run pass-through coefficient.

For each country in the sample, I already have long-run pass-through coefficient estimates (shown in Table 3). I also calculate for each subperiod the average import share in GDP and the average inflation for each country. With the panel data set constructed, I estimate the following model:

$$\varphi_{jt} = \alpha_j + \beta s_{jt}^{AVG} + \gamma \pi_{jt}^{AVG} + d_t + \varepsilon_{jt}, \tag{20}$$

where j is the index for countries, t is the index for decades, φ stands for the long-run pass-through coefficient, s^{AVG} denotes the average share of imports in GDP for the decade, π^{AVG} is the average inflation for the decade, and d is the dummy for the sample period (equal to 1 for the first sample period and 0 otherwise).

The Hausman test results suggest that a random-effects model be estimated. I estimate the model twice and compute the total response of inflation from the coefficients estimated using the OECD and alternative real exchange rate data. The estimation results are presented in Table 5. The table shows that the average inflation for the subperiod has a statistically significant impact on the response of inflation to real exchange rate fluctuations. For the estimation performed with the real exchange rate series prepared by the OECD, a 1-percentage-point increase in the average inflation for the subperiod yields a 1.27-percent increase in the long-run exchange rate pass-through. Using the self-constructed real exchange rate data, a 1-percent increase in the average inflation rate yields an additional 0.29-percent increase in the same parameter. When the long-run exchange rate pass-through coefficient is obtained using the OECD real effective exchange rate series, the subperiod dummy also has a significant effect on the long-run exchange rate pass-through, indicating that the pass-through was higher in the 1990s than in the later period. When the alternative real exchange rate is used, the coefficient on import share in GDP is significantly different from zero and is positive, indicating that an increase in inflation openness reduced exchange rate pass-through. This is counterintuitive: as the theoretical framework suggests, an increase in inflation openness ought to increase aggregate inflation sensitivity to inflation fluctuations. However, the coefficient is very small and this result is not robust to the measure of exchange rate chosen.

Based on these observations, it is possible to conclude that the low-inflation environment beginning in the 1990s led to a reduction in the fraction of flexible-price firms in the economy. This reduction in turn contributed to a decline in the pass-through of real exchange rate changes to inflation. This conclusion stands irrespective of the choice of real exchange rate series.

4.3 How Much Do Determinants of Real Exchange Rate Pass-Through Explain?

The final question addressed in this empirical study is how much of the decline in the real exchange rate pass-through can be explained by the reduction in the frequency of price updating by firms. I begin by considering the estimate of exchange rate pass-through obtained with OECD real effective exchange rate series. The average exchange rate pass-through fell by 0.57 (see Table 3a), which is 15 percent of the standard deviation, which is approximately 3.9 for the period. Coefficient estimates given in equation (20) suggest that if average inflation falls by 1 standard deviation, which is approximately 2.36 percent for the first period, long-run pass-through would fall by 80 percent of standard deviations. Thus, in this case average inflation overexplains the decline in exchange rate pass-through.

Using the alternative real exchange rate series, the average decline in estimated long-run pass-through is 0.61 (see Table 3b), which is approximately 41 percent of the standard deviations. Coefficient estimates (presented in Table 5) suggest that if average inflation for the subperiod falls by 1 standard deviation then long-run pass-through would fall by 36 percent of the standard deviations. Thus, in this case, inflation decline does a reasonable job explaining a decline in exchange rate pass-through.

5 CONCLUSIONS

This paper presents a theoretical framework for analyzing exchange rate pass-through, and an empirical investigation of the possibility that exchange rate pass-through declined beginning in the 1990s as compared to the 1980s. The theoretical framework highlights the fact that the Phillips curve in an open economy is different from that in a closed economy. This is because, in addition to output, the real exchange rate influences the path of inflation. Therefore, in an open economy, real exchange rate fluctuations will cause fluctuations in the inflation rate. The proposed theoretical framework suggests that the degree of real exchange rate pass-through to aggregate CPI inflation is determined by four factors. These are the degree of real exchange rate pass-through to the prices of individual firms (which in turn depends on the elasticities of the demand and cost functions faced by individual firms), the fraction of imports in the CPI basket, the fraction of flexible-price firms in the economy, and the credibility of the monetary authority.

The empirical investigation for fourteen OECD countries confirms the suggestion made by other authors about the decline in the exchange rate pass-through during the 1990s (for example, Cunningham and Haldane 2000, Garcia and Restrepo 2001, McCarthy 1999). This paper attempts to look for an explanation for the weakening in the relationship between the real exchange rate and CPI inflation. A hypothesis is that the decline in the exchange rate pass-through is in part caused by a reduction in the fraction of flexible-price firms in the economy. I propose that the firms updated their prices less frequently during the 1990s period as compared to the previous decade, due to the recent unusually low inflation environment. This finding is consistent with the conclusions of Taylor (1999), who claims that "the decline in the pass-through or pricing power is due to the low inflation environment that has been recently achieved in many countries."

The implication of the analysis presented in this paper is that the observed reduction in the real exchange rate pass-through cannot be regarded as a permanent change. Should the inflation level and inflation persistence increase in the future (as some fear might happen in the U.S. in the near future) we would see an increase in the real exchange rate pass-through. As Taylor (1999) points out, such an increase in real exchange rate pass-through could expedite inflationary pressures again.

Appendix A – Deriving the Open Economy Phillips Curve

Deriving the Optimal Price of the Foreign Firm

The real profit function is the difference between real revenues and real costs:

$$\Pi_{it} = \frac{P_{it}^F Y_{it}}{P_t} - \frac{C_{it} P_t^*}{P_t E_t^N} = \frac{P_{it}^F Y_{it}}{P_t} - \frac{C_{it}}{Q_t}. \tag{A.1}$$

The foreign firm maximizes its real profit, and the price of its good (P_{it}^F) is the firm's choice variable. Substituting equations (3) and (4) into (A.1) yields

$$\Pi_{it} = Y_t \left(\frac{P_{it}^F}{P_t}\right)^{1-\varepsilon} - \frac{\varepsilon - 1}{\gamma\varepsilon} Y_t^{\gamma} Q_t^{-1} \left(\frac{P_{it}^F}{P_t}\right)^{-\gamma\varepsilon}. \tag{A.2}$$

Taking the first order conditions with respect to P_{it}^F

$$\frac{\partial \Pi_{it}}{\partial P_{it}^F} = (1-\varepsilon)\left(\frac{P_{it}^F}{P_t}\right)^{-\varepsilon} Y_t \frac{1}{P_t} + (\varepsilon - 1) Y_t^{\gamma} Q_t^{-1} \left(\frac{P_{it}^F}{P_t}\right)^{-\gamma\varepsilon - 1} \frac{1}{P_t} = 0. \tag{A.3}$$

Rearranging equation (A.3),

$$\left(\frac{P_{it}^F}{P_t}\right)^{-\varepsilon + \gamma\varepsilon + 1} = Y_t^{\gamma - 1} Q_t^{-1}. \tag{A.4}$$

Taking the logs and re-arranging the terms, I get

$$p_{it}^F = p_t + \frac{\gamma - 1}{\varepsilon(\gamma - 1) + 1} y_t - \frac{1}{\varepsilon(\gamma - 1) + 1} q_t. \tag{A.5}$$

If I let $k_1 = \frac{\gamma - 1}{\varepsilon(\gamma - 1) + 1}$ and $k_2 = \frac{1}{\varepsilon(\gamma - 1) + 1}$, then

$$p_{it}^{*F} = p_t + k_1 y_t - k_2 q_t. \tag{A.6}$$

Equation (A.6) is the solution for the optimal price level of the foreign firm. It is equation (5) in the text.

Deriving the No-Shock Output Level

The no-shock level of output is defined in the text as the level of output that prevails when the following two conditions hold:

1. for all i, prices are flexible (implying $p_i^F = p_i^{*F}$), and
2. there are no current real exchange rate shocks (implying that $q_t = q_{t-1}$, as the real exchange rate is assumed to follow a random walk).

Under these conditions, equation (5) can be written as

$$p_{it}^{*F} = p_t + k_1 y_t^N - k_2 q_{t-1}.$$

Since the right-hand side of the above equation is the same for all i, $p_i^F = p^F$. Therefore,

$$p_t^F = p_t + k_1 y_t^N - k_2 q_{t-1}. \tag{A.7}$$

Similarly, from equation (6) in the text, one can derive

$$p_t^D = p_t + k_1 y_t^N. \tag{A.8}$$

Substituting equations (A.7) and (A.8) into equation (9) yields

$$p_t = p_t + k_1 y_t^N - \mu k_2 q_{t-1}. \tag{A.9}$$

Solving for y^N,

$$y_t^N = \frac{\mu k_2}{k_1} q_{t-1}. \tag{A.10}$$

Deriving the Aggregate Price Index

Substituting equation (5) into equation (7), I get:

$$p_t^F = \delta(p_t + k_1 y_t - k_2 q_t) + (1-\delta) E_{t-1}(p_t + k_1 y_t - k_2 q_t). \tag{A.11}$$

Substituting equation (6) into equation (8),

$$p_t^D = \delta(p_t + k_1 y_t) + (1-\delta) E_{t-1}(p_t + k_1 y_t). \tag{A.12}$$

Substituting equations (A.11) and (A.12) into equation (9) gives

$$p_t = \delta(p_t + k_1 y_t) + (1-\delta)E_{t-1}(p_t + k_1 y_t) - \mu\delta k_2 q_t - \mu(1-\delta)k_2 E_{t-1}q_t. \quad \text{(A.13)}$$

Collecting the terms together,

$$p_t = E_{t-1}p_t + \frac{\delta k_1}{1-\delta}y_t + k_1 E_{t-1}y_t - \frac{\mu\delta k_2}{1-\delta}q_t - \mu k_2 E_{t-1}q_t.$$

Subtracting p_{t-1} from both sides results in

$$\pi_t = E_{t-1}\pi_t + \frac{\delta k_1}{1-\delta}y_t + k_1 E_{t-1}y_t - \frac{\mu\delta k_2}{1-\delta}q_t - \mu k_2 E_{t-1}q_t. \qquad \text{(A.14)}$$

The above equation is equation (10) in the text.

Equation (A.14) can be rewritten as

$$\pi_t = E_{t-1}\pi_t + \frac{\delta k_1}{1-\delta}(y_t - y_t^N) + k_1 E_{t-1}(y_t - y_t^N) - \frac{\mu\delta k_2}{1-\delta}q_t - \mu k_2 E_{t-1}q_t + \frac{\delta k_1}{1-\delta}y_t^N + k_1 E_{t-1}y_t^N.$$

Under the assumptions made in the text, $E_{t-1}(y_t - y_t^N) = -\omega E_{t-1}\pi_t + \omega\pi^T$. By utilizing the definition of the no-shock output level, it can be shown that

$-\frac{\mu\delta k_2}{1-\delta}q_t + \frac{\delta k_1}{1-\delta}y_t^N = -\frac{\mu\delta k_2}{1-\delta}\Delta q_t$, and that $-\mu k_2 E_{t-1}q_t + k_1 E_{t-1}y_t^N = 0$. Therefore, the above equation reduces to

$$\pi_t = [\alpha - (1-\alpha)k_1\omega]\pi^T + (1-k_1\omega)(1-\alpha)\pi_{t-1} + \frac{\delta k_1}{1-\delta}(y_t - y_t^N) - \frac{\mu\delta k_2}{1-\delta}\Delta q_t. \quad \text{(A.15)}$$

Equation (A.15) is equation (16) in the text.

Appendix B – Computing Standard Errors for Average Coefficients

The average coefficient is defined as

$$c_i^x = \frac{1}{n}\sum_{j=1}^{n} c_{ij}^x, \tag{B.1}$$

where $x=\pi$, y, or q, n is the number of countries in the sample, and j indexes the countries. The variance of the average coefficient (denoted with V) can be found as follows:

$$V(c_i^x) = E(c_i^x)^2. \tag{B.2}$$

Substituting equation (B.1) into equation (B.2),

$$V(c_i^x) = E\left(\frac{1}{n}\sum_{j=1}^{n} c_{ij}^x\right)^2 = \frac{1}{n^2} E\left(\sum_{j=1}^{n}\left(c_{ij}^x\right)^2 + 2\sum_{j=1}^{n}\sum_{k=j+1}^{n}\left(c_{ij}^x c_{ik}^x\right)\right). \tag{B.3}$$

Since $E\left(c_i^x\right)^2 = V(c_i^x)$ and $E\left(c_{ij}^x c_{ik}^x\right) = C(c_{ij}^x c_{ik}^x)$ (where C stands for covariance), equation (B.3) can be rewritten as

$$V(c^x) = E\left(\frac{1}{n}\sum_{j=1}^{n} c_{ij}^x\right)^2 = \frac{1}{n^2}\left(\sum_{j=1}^{n} V\left(c_{ij}^x\right)^2\right) + \frac{2}{n^2}\left(\sum_{j=1}^{n}\sum_{k=j+1}^{n} C\left(c_{ij}^x c_{ik}^x\right)\right). \tag{B.4}$$

The standard error of the average coefficient becomes simply

$$S.E.(c_i^x) = \sqrt{V(c_i^x)}. \tag{B.5}$$

Substituting (B.4) into (B.5) results in equation (19) in the text

$$S.E.(c^x) = \sqrt{\left(\frac{1}{n^2}\sum_{j=1}^{n} V(c_{ij}^x) + \frac{2}{n^2}\sum_{j=1}^{n}\sum_{k=j+1}^{n} C(c_{ij}^x, c_{ik}^x)\right)}. \tag{B.6}$$

Appendix C – Data Sources

Variable	Source	Description
Consumer Prices	OECD Main Economic Indicators Database	Two series are used in this study. **Consumer price index (CPI)**: **all items** is used to measure inflation. **CPI "all items non-food non-energy"** provides an indication about the ***core*** inflation as used by the OECD.
Output gap	OECD Economic Outlook Database (this study uses Economic Outlook No. 81)	The difference between actual and potential GDP as a per cent of potential GDP. Potential GDP is defined in the *Economic Outlook* as the level of output that an economy can produce at a constant inflation rate.
Real Effective Exchange Rate	OECD Main Economic Indicators (MEI)	Real effective exchange rates take account of price level differences between trading partners. Movements in real effective exchange rates provide an indication of the evolution of a country's aggregate external price competitiveness.

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Table 1: Summary Statistics

	INFLATION				OUTPUT GAP				EXCH. RATE GROWTH			
Country	**Period 1**		**Period 2**		**Period 1**		**Period 2**		**Period1**		**Period 2**	
	μ	**σ**	**μ**	**σ**	**μ**	**σ**	**μ**	**σ**	**μ**	**σ**	**μ**	**σ**
Australia	7.97	3.04	2.61	2.53	-1.23	2.00	-1.24	2.18	-0.17	4.84	0.03	3.22
Canada	6.10	3.19	2.15	2.24	-0.76	2.99	-0.75	2.15	0.27	1.51	-0.17	2.31
Denmark	6.31	3.71	2.01	1.57	-0.26	2.37	-0.43	1.31	-0.02	1.95	0.07	1.29
Finland	6.83	3.55	1.80	2.07	1.09	2.24	-3.00	4.76	0.52	1.81	-0.50	2.43
France	6.74	4.22	1.76	1.28	-1.44	1.51	-0.86	1.39	-0.19	1.70	-0.03	1.10
Ireland	8.36	7.08	2.93	2.17	-2.04	2.37	0.46	3.27	0.29	2.49	0.16	2.11
Italy	10.04	5.48	3.24	1.75	-0.93	2.16	-0.66	1.48	0.49	1.42	-0.14	2.41
Japan	2.36	3.23	0.45	2.31	-1.12	1.80	0.05	2.25	0.84	4.61	-0.19	4.55
Netherlands	2.68	3.05	2.31	1.43	-1.08	1.85	-0.02	2.03	-0.26	1.81	0.09	1.48
New Zealand	10.80	6.22	2.15	1.78	0.56	1.56	-0.48	2.32	0.12	4.68	0.14	3.02
Norway	7.89	3.87	2.13	2.52	-1.65	2.35	-0.90	3.13	0.27	1.59	-0.07	2.04
Sweden	7.45	3.95	2.31	3.84	-0.71	2.38	-1.95	2.42	-0.11	2.80	-0.31	2.83
U.K.	6.36	5.01	2.43	3.15	-2.12	3.57	-0.70	1.45	-0.15	4.23	0.17	2.64
U.S.	5.05	3.49	2.79	1.70	-1.22	2.58	-0.65	1.34	-0.07	3.20	0.06	2.09

Period 1 refers to 1980:Q1-1989:Q4. Period 2 refers to 1990:Q1-2007:Q2
μ denotes mean, σ denotes standard deviation

Table 2a. Sums of Estimated Coefficients (Real Exchange Rate Data Source: OECD) Standard errors are in parentheses

Equation estimated: $$\pi_t = c_0 + \sum_{i=1}^{3} c_i^{\pi} \pi_{t-i} + \sum_{i=0}^{3} c_i^{y} (y_{t-i} - y_{t-i}^{N}) + \sum_{i=0}^{3} c_i^{q} \Delta q_{t-i} + \sum_{i=1}^{4} c_i^{z} \Delta z_{t-i} + \varepsilon_t$$

Estimates of the Sums of coefficients

	Inflation			Output gap			Real exchange rate		
	Period1	**Period2**	**difference**	**Period1**	**Period2**	**difference**	**Period1**	**Period2**	**difference**
Australia	0.21	0.32 *	-0.10	1.22 ***	0.27 *	0.96 ***	-0.42 ***	-0.23	-0.20
	(0.16)	(0.17)	(0.23)	(0.20)	(0.14)	(0.24)	(0.11)	(0.15)	(0.18)
Canada	1.15 ***	-0.05	1.21 ***	0.11	0.24 **	-0.13	-0.39 *	0.14	-0.53 **
	(0.18)	(0.17)	(0.25)	(0.08)	(0.11)	(0.14)	(0.21)	(0.16)	(0.27)
Denmark	0.36	-0.76 ***	1.12 **	-0.37	0.44 ***	-0.82	-0.39	-0.17	-0.22
	(0.45)	(0.19)	(0.48)	(0.52)	(0.15)	(0.54)	(0.66)	(0.17)	(0.69)
Finland	0.65 ***	0.34 **	0.32 *	0.28 *	0.13 ***	0.15	-0.21	-0.21 *	0.00
	(0.12)	(0.13)	(0.18)	(0.17)	(0.05)	(0.18)	(0.33)	(0.11)	(0.35)
France	0.82 ***	0.31 *	0.51 **	0.26	0.10	0.17	-0.38	-0.14	-0.24
	(0.12)	(0.16)	(0.20)	(0.21)	(0.09)	(0.23)	(0.36)	(0.17)	(0.39)
Ireland	0.68 ***	0.11	0.57 ***	0.53	0.23 ***	0.30	-0.19	-0.30 *	0.12
	(0.12)	(0.18)	(0.21)	(0.34)	(0.07)	(0.35)	(0.42)	(0.16)	(0.44)
Italy	0.84 ***	0.83 ***	0.00	0.08	0.03	0.06	-0.88 *	-0.21 ***	-0.68
	(0.12)	(0.06)	(0.14)	(0.18)	(0.07)	(0.19)	(0.45)	(0.06)	(0.46)
Japan	-0.40	-0.60 **	0.19	-0.32	0.70 ***	-1.02 ***	-0.26 ***	0.07	-0.33 ***
	(0.33)	(0.24)	(0.41)	(0.24)	(0.14)	(0.27)	(0.10)	(0.06)	(0.12)
Netherlands	1.12 ***	-0.20	1.32 ***	0.12	0.36 ***	-0.24	-0.56 **	-0.18	-0.38
	(0.23)	(0.20)	(0.30)	(0.17)	(0.08)	(0.19)	(0.29)	(0.15)	(0.32)
New Zealand	0.88 ***	0.48 ***	0.40 **	0.30	0.15	0.15	-1.36 ***	-0.11	-1.25 ***
	(0.13)	(0.11)	(0.17)	(0.46)	(0.09)	(0.47)	(0.24)	(0.12)	(0.27)
Norway	0.53 **	-0.26	0.79 **	0.40 *	-0.05	0.45 *	0.63	0.51 **	0.12
	(0.21)	(0.25)	(0.33)	(0.24)	(0.08)	(0.25)	(0.58)	(0.24)	(0.62)
Sweden	0.87 ***	0.34 ***	0.53 *	0.23	-0.01	0.24	-0.07	-0.16	0.09
	(0.26)	(0.13)	(0.29)	(0.36)	(0.17)	(0.40)	(0.33)	(0.20)	(0.39)
U.K.	0.25	0.04	0.21	-0.26	-0.14	-0.11	0.24	0.09	0.15
	(0.18)	(0.19)	(0.26)	(0.21)	(0.20)	(0.29)	(0.19)	(0.16)	(0.25)
U.S.	0.90 ***	0.58 ***	0.32	0.26 **	0.21 *	0.05	0.21	-0.24 **	0.45 **
	(0.13)	(0.15)	(0.20)	(0.11)	(0.11)	(0.16)	0.14	0.11	(0.18)

Note: ***, **, * indicate that the sum of coefficients is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Period 1 refers to 1980:Q1-1989:Q4. Period 2 refers to 1990:Q1-2007:Q2

Table 2b. Sums of Estimated Coefficients (Real Exchange Rate Data Source: Self-Constructed) Standard errors are in parentheses

Equation estimated: $$\pi_t = c_0 + \sum_{i=1}^{3} c_i^{\pi} \pi_{t-i} + \sum_{i=0}^{3} c_i^{y} (y_{t-i} - y_{t-i}^{N}) + \sum_{i=0}^{3} c_i^{q} \Delta q_{t-i} + \sum_{i=1}^{4} c_i^{z} \Delta z_{t-i} + \varepsilon_t$$

	Estimates of the sums of coefficients								
	Inflation			**Output gap**			**Real exchange rate**		
	Period1	**Period2**	**difference**	**Period1**	**Period2**	**difference**	**Period1**	**Period2**	**difference**
Australia	0.58	0.45 ***	0.13	0.66	0.18	0.48 **	-0.25	-0.05	-0.19
	(0.13)	(0.16)	(0.21)	(0.15)	(0.14)	(0.21)	(0.21)	(0.20)	(0.29)
Canada	0.98	-0.13	1.11 ***	0.11	0.31 **	-0.20	-0.10	-0.07	-0.03
	(0.14)	(0.19)	(0.23)	(0.07)	(0.12)	(0.14)	(0.07)	(0.07)	(0.10)
Denmark	-0.25	-0.79 ***	0.54	-0.86	0.50 ***	-1.36 **	-0.04	-0.02	-0.02
	(0.41)	(0.19)	(0.46)	(0.59)	(0.14)	(0.61)	(0.28)	(0.05)	(0.29)
Finland	0.32 *	0.25 *	0.07	0.42 **	0.10 **	0.32 *	-0.37 ***	-0.13 **	-0.25 *
	(0.17)	(0.14)	(0.22)	(0.17)	(0.05)	(0.18)	(0.12)	(0.06)	(0.14)
France	0.88 ***	0.32 *	0.56 ***	0.30	0.04	0.25	-0.31 ***	0.01	-0.31 ***
	(0.10)	(0.17)	(0.20)	(0.18)	(0.09)	(0.21)	(0.10)	(0.05)	(0.11)
Ireland	0.39 ***	0.02	0.36 *	1.00 ***	0.23 ***	0.77 **	-0.34 *	-0.15 *	-0.18
	(0.12)	(0.18)	(0.21)	(0.32)	(0.07)	(0.33)	(0.18)	(0.08)	(0.19)
Italy	0.68 ***	0.82 ***	-0.15	0.13	-0.03	0.16	-0.25 *	-0.02	-0.23 *
	(0.12)	(0.06)	(0.13)	(0.16)	(0.08)	(0.18)	(0.13)	(0.04)	(0.14)
Japan	-0.13	-0.55 **	0.41	-0.05	0.70 ***	-0.75 ***	-0.18 **	0.07	-0.25 ***
	(0.31)	(0.23)	(0.39)	(0.21)	(0.13)	(0.25)	(0.07)	(0.06)	(0.09)
Netherlands	1.08 ***	-0.41 *	1.49 ***	0.29	0.34 ***	-0.05	-0.26 ***	-0.10 *	-0.16
	(0.24)	(0.21)	(0.32)	(0.19)	(0.08)	(0.21)	(0.09)	(0.05)	(0.10)
New Zealand	0.72 ***	0.45 ***	0.27	0.56	0.15 *	0.41	-0.45 ***	-0.04	-0.41 **
	(0.13)	(0.12)	(0.18)	(0.52)	(0.08)	(0.53)	(0.17)	(0.08)	(0.19)
Norway	0.54 **	-0.20	0.74 **	0.16	0.05	0.11	0.19	0.00	0.19
	(0.25)	(0.24)	(0.35)	(0.34)	(0.08)	(0.35)	(0.24)	(0.11)	(0.26)
Sweden	0.78 ***	0.36 ***	0.42 *	0.25	0.00	0.25	-0.30 **	-0.03	-0.27
	(0.20)	(0.12)	(0.24)	(0.28)	(0.16)	(0.32)	(0.14)	(0.11)	(0.18)
U.K.	-0.01	0.07	-0.08	0.45 **	-0.10	0.55 *	-0.25 **	-0.05	-0.20
	(0.18)	(0.21)	(0.28)	(0.22)	(0.22)	(0.31)	(0.13)	(0.15)	(0.20)

Note: ***, **, * indicate that the sum of coefficients is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Period 1 refers to 1980:Q1-1989:Q4. Period 2 refers to 1990:Q1-2007:Q2

Table 3a. Estimates of Long-Run Real Exchange Rate Pass-Through Coefficien
Real Exchange Rate Data Source: OECD

Standard errors are in parentheses

	Period 1	Period 2	difference
Australia	-0.54 ***	-0.33	-0.21
	(0.18)	(0.23)	(0.29)
Canada	2.55	0.14	2.41
	(2.64)	(0.15)	(2.64)
Denmark	-0.61	-0.10	-0.51
	(1.29)	(0.10)	(1.30)
Finland	-0.60	-0.31 *	-0.28
	(1.03)	(0.16)	(1.04)
France	-2.09	-0.21	-1.88
	(1.94)	(0.26)	(1.96)
Ireland	-0.58	-0.34 *	-0.24
	(1.35)	(0.21)	(1.37)
Italy	-5.38	-1.22 **	-4.16
	(4.50)	(0.49)	(4.52)
Japan	-0.19 ***	0.04	-0.23 ***
	(0.07)	(0.04)	(0.08)
Netherlands	4.86	-0.15	5.01
	(9.99)	(0.12)	(9.99)
New Zealand	-11.59	-0.22	-11.37
	(13.47)	(0.25)	(13.47)
Norway	1.34	0.40 **	0.94
	(1.40)	(0.19)	(1.42)
Sweden	-0.51	-0.24	-0.27
	(3.18)	(0.32)	(3.20)
U.K.	0.32	0.09	0.23
	(0.24)	(0.16)	(0.29)
U.S.	2.08	-0.57 *	2.65
	(2.72)	(0.31)	(2.74)
Average	-0.78	-0.22 ***	-0.57
	(1.34)	0.07	(1.34)

Note: ***, **, * designate that long-run pass-through coefficient or the difference between coefficients is significantly different from zero at the 1%, 5%, and 10% level respectively.

Period 1 refers to 1980:Q1-1989:Q4. Period 2 refers to 1990:Q1-2007:Q2

Table 3b. Estimates of Long-Run Real Exchange Rate Pass-Through Coefficients
Real Exchange Rate Data Source: Alternative

Standard errors are in parentheses

	Period 1	Peroid 2	difference
Australia	-0.58	-0.09	-0.49
	(0.58)	(0.36)	(0.69)
Canada	-3.95	-0.06	-3.89
	(22.71)	(0.06)	(22.71)
Denmark	-0.03	-0.01	-0.02
	(0.23)	(0.03)	(0.23)
Finland	-0.55 ***	-0.17 **	-0.38 **
	(0.14)	(0.08)	(0.16)
France	-2.58	0.01	-2.59
	(2.06)	(0.07)	(2.06)
Ireland	-0.55 **	-0.16 *	-0.39
	(0.26)	(0.09)	(0.27)
Italy	-0.78 **	-0.13	-0.65
	(0.38)	(0.21)	(0.44)
Japan	-0.15 **	0.05	-0.20 ***
	(0.06)	(0.03)	(0.07)
Netherlands	3.26	-0.07 *	3.33
	(9.75)	(0.04)	(9.75)
New Zealand	-1.60	-0.07	-1.53
	(1.06)	(0.14)	(1.06)
Norway	0.42	0.00	0.42
	(0.63)	(0.09)	(0.63)
Sweden	-1.36	-0.05	-1.31
	(1.25)	(0.18)	(1.26)
U.K.	-0.25 *	-0.05	-0.20
	(0.13)	(0.17)	(0.21)
Average	-0.67	-0.06	-0.61
	(1.86)	0.05	(1.86)

Note: ***, **, * designate that long-run pass-through coefficient or the difference between coefficients is significantly different from zero at the 1%, 5%, and 10% level respectively.

Period 1 refers to 1980:Q1-1989:Q4. Period 2 refers to 1990:Q1-2007:Q2

Table 4a. Average Phillips Curve Estimates (Real Exchange Rate Data Source: OECD)
Standard errors in parentheses

	Sums of Coefficients on:			
	π	y	Δq	φ
Period 1	0.63 ***	0.20 ***	-0.29 ***	-0.92 ***
	(0.06)	(0.08)	(0.09)	(0.12)
Period 2	0.10 *	0.19	-0.08	-0.19
	(0.05)	(0.04)	(0.04)	(0.07)
Difference	0.53 ***	0.02	-0.21 **	-0.73 ***
	(0.08)	(0.09)	(0.10)	(0.14)

Table 4b. Average Phillips Curve Estimates (Real Exchange Rate Data Source: Alternative)
Standard errors in parentheses

	Sums of Coefficients on:			
	π	y	Δq	φ
Period 1	0.50 ***	0.26 ***	-0.22 ***	-0.45 ***
	(0.06)	(0.08)	(0.05)	(0.11)
Period 2	0.05	0.19 ***	-0.05	-0.05
	(0.06)	(0.04)	(0.04)	0.04
Difference	0.45 ***	0.07	-0.18 ***	-0.40 ***
	(0.08)	(0.09)	(0.06)	(0.12)

Note: ***, **, * designate that long-run pass-through coefficient or the difference between coefficients is significantly different from zero at the 1%, 5% ,and 10% level, respectively.

Period 1 refers to 1980:Q1-1989:Q4. Period 2 refers to 1990:Q1-2007:Q2
φ stands for long-run pass-through coefficient (see equation 18 in the text)

Table 5. Determinants of Long-Run Real Exchange Rate Pass-Through
Standard errors in parentheses

	Measures of Exchange Rate	
	OECD	Self-Constructed
Constant	12.09 ***	1.41
	(2.67)	(1.59)
Subperiod Dummy	-5.36 ***	-0.86
	(1.18)	(0.72)
Average Inflation	-1.27 ***	-0.29 **
	(0.22)	(0.12)
Import Share in GDP	0.04	0.03 *
	(0.03)	(0.02)

Note: ***, **, * designate that the coefficient is significantly different from zero at the 1%, 5%, and 10% level respectively