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Adjustment Speeds of Nominal Exchange Rates and Prices toward Purchasing Power Parity

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Abstract

The conventional view, as expounded by sticky-price models, is that price adjustment determines the PPP reversion rate. Contrary to this, recent studies indicate that nominal exchange rates converge much more slowly to PPP than nominal prices. This paper investigates how adjustment speeds of nominal exchange rates and prices toward PPP are affected by exchange rate regimes by employing a vector error correction model (VECM). We find evidence from 22 OECD countries that the adjustment speed of nominal exchange rates toward PPP is faster than that of prices as nominal exchange rates are relatively stable. This suggests that nominal exchange rate volatility has significant bearings on the variables primarily driving adjustment toward the long-run equilibrium level defined by PPP. We also show that the real exchange rates converge faster to the long-run PPP level for the relatively stable exchange rates, consistent with the evidence to support the significant mean reversion of real exchange rates for the gold standard period.

JEL classification: F31.
Keywords: Purchasing power parity; Exchange rate regimes.

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1. Introduction

Since the collapse of the Bretton Woods system in 1973, real exchange rates among industrialized countries have been persistent and volatile. There are two explanations for this outcome, but neither is satisfactory. The first is that real productivity shocks and real demand shocks to economies have been very persistent. However, it is difficult to identify shocks that would lead to such great volatility of real exchange rates.

A second view builds on rational-expectations sticky-price (RESP) models of open economy in the tradition of Dornbusch (1976). Those models demonstrate that monetary shocks could lead to a high degree of real exchange rate volatility through the overshooting effect. Real exchange rates can be persistent because they adjust at the same rate as nominal prices adjust.

However, empirical studies of real exchange rate adjustment have found very long half-lives for transitory shocks to real exchange rates. Typically, half-life of real exchange rates is estimated to be from 2.5 to 5 years.[1] That adjustment seems to be too slow to be explained by stickiness of nominal prices. This puzzled is called "purchasing power parity puzzle", as defined by Rogoff (1996).

A recent study by Engel and Morley (2001) offers a refinement on the PPP puzzle. In contrast to standard rational-expectations sticky-price models, which impose the same reversion speeds for nominal exchange rates and prices, these researchers examine an empirical model that allows those variables to adjust at different speeds. Empirical results from state-space model estimation indicate that while prices converge to their equilibrium levels relatively fast, nominal exchange rates converge slowly. This finding is intriguing in that it challenges conventional belief in the price-stickiness explanation. The torpid rate of PPP reversion may result mainly from slow nominal exchange rate adjustment rather than from slow price adjustment. Cheung, Lai and Bergman (2004) also reach the same conclusions by using vector error correction (VEC) analysis.

These findings raise a new puzzle: why does the nominal exchange rate converge so slowly (Engel and Morley, 2001)? This paper tries to resolve this puzzle by presenting additional evidence on the adjustment speeds of nominal exchange rates and prices

[1] See Frankel (1986), Lothian and Taylor (1996), Wu (1996), Papell (1997), Cheung and Lai (2000), and Murray and Papell (2000).

toward PPP using 55 real exchange rates of 22 OECD countries, for which long-run PPP conditions hold.

Previous studies examined real exchange rates against the U.S. dollar, while our sample includes real exchange rates among European countries where nominal exchange rates have been kept relatively stable. This paper explores dynamics of real exchange rates with different exchange rate regimes that may have different implications for the convergence speeds of nominal exchange rates and prices toward PPP.

By employing a vector error correction model (VECM), we estimate impulse response functions to find the speeds at which the individual variables revert to their long-run values. Contrary to the previous studies, we find some cases where prices converge to their equilibrium levels more slowly than nominal exchange rates when the nominal exchange rates are relatively stable. Indeed, our regression results reveal that the relative adjustment speed of nominal exchange rates to prices is faster as nominal exchange rates become stable. This suggests that when nominal exchange rates are relatively fixed and prices are relatively flexible, prices converge more slowly to their long-run equilibrium values than nominal exchange rates.

Comparing the results from the flexible and fixed exchange rate regimes, we argue that the puzzle may result from the misunderstanding of the conventional sticky-price explanation. Under the flexible exchange rate regime, nominal exchange rates have a much larger innovation variance than prices. Hence, they deviate from their equilibrium more than prices do when there is a shock and adjust slowly than prices. By contrast, under the fixed exchange rate regime, prices have a larger innovation variance than exchange rates. The size of innovations plays a key role for the adjustment speeds of stochastic processes with unit roots, such as nominal exchange rates and prices.

We also find that the half-lives of system-wide shocks on real exchange rates are positively associated with nominal exchange rate volatility. This suggests that real exchange rates converge faster to the long-run PPP level under the fixed exchange rate regime. This seemingly puzzling finding is, however, consistent with the existing literature. Previous studies generally reported the absence of significant mean reversion of the real exchange rate for the recent floating period (Taylor, 1988; Mark, 1990), while they gained support of reversion toward PPP for the gold standard period (McClosky and

Zecher, 1984; Diebold, Husted and Rush, 1991). Under the fixed exchange rate regime, both exchange rate innovation and price innovation are relatively small, so that they adjust faster than the flexible exchange rate regime. These findings indicate that PPP reversion rate hinges on the exchange rate volatility.

The remainder of the paper is organized as follows. Section 2 outlines the theoretical framework and Section 3 describes the data and the sampling scheme. Section 4 reports the empirical results. Section 5 concludes.

2. Empirical framework

Suppose e_t as the logarithm of nominal exchange rate (expressed as domestic price of foreign currency) and p_t as the logarithm of the ratio of domestic to foreign prices, then the logarithm of real exchange rate (denoted by q_t), which captures the deviation from PPP, is measured by

$$q_t = e_t - p_t . \tag{1}$$

A relative version of long-run PPP postulates that q_t may have a non-zero mean but it has to be a realization of stationary process. Following Engel and Morley (2001) and Cheung, Lai and Bergman (2004), we assume that domestic and foreign prices have similar convergence speeds. If both the nominal exchange rate e_t and the relative price p_t has a stationary, invertible, non-deterministic ARMA representation after differencing once (i.e. $s_t , p_t \sim$I(1)), this definition of long-run PPP implies that e_t and p_t move together in the long-run and exhibit a common stochastic trend, cointegrating one cointegrating vector $\beta^{'} = [1 \quad -1]$.

Let $X_t = [e_t \quad p_t]^{'}$. The long-run PPP restriction on X_t is that $\beta^{'} X_t = e_t - p_t$ is stationary. The VEC model is in general given by

$$\Delta X_t = \mu - \Pi X_{t-1} + \Gamma(L)\Delta X_{t-1} + \varepsilon_t \tag{2}$$

where $\Delta X_t = X_t - X_{t-1}$, Π can be written as $\Pi = \alpha\beta^{'}$, and $\Gamma(L)$ is a 2×2 matrix polynomial, and a vector of white noise processes with covariance matrix Q, $\varepsilon_t \sim$

$NID(0,\ Q)$. α is a 2×1 vector. Since β is restricted, we estimate the parameters α and $\Gamma(L)$ using maximum likelihood procedures.

To examine the dynamic adjustment in response to shocks through impulse response functions, the general impulse response approach recommended by Pesaran and Shin (1998) is applied. Unlike traditional impulse response analysis, which considers orthogonal shocks based on the Cholesky decomposition, this new approach desirably yields unique impulse response function (IRFs) that are invariant to the ordering of variables. The generalized IRF for $X_t = [e_t \quad p_t]'$ with respect to a unit innovation to the j th variable ($j = e$ for a nominal exchange rate innovation and $j = p$ for a price innovation) is given by

$$\psi_{Xj} = C_t Q \gamma_j / \sigma_{jj}, \quad t = 0,1,2,.... \tag{3}$$

where C_t is defined by a recursive equation:

$$C_t = A_1 C_{t-1} + A_2 C_{t-2} + \cdots + A_k C_{t-k}, \quad t = 1,2,...$$

with $C_0 = I$ and $C_t = 0$ for $t < 0$. The matrix $\{C_t, t = 1,2,\ldots\}$ constitute the coefficient matrix of the moving-average representation of X_t. The estimates of C_t can be backed out from the estimates of the α and $\Gamma(L)$. γ_j is a selection vector with unity as its j th element and zeros elsewhere, and σ_{jj} is the j th diagonal element of Q. The VEC model specification is selected using the usual Akaike information criterion. Based on ψ_{Xj}, we compute the first 240 impulse responses, which correspond to a time span of 20 years for monthly data. $\psi_{Xj}(t)$ gives the separate IRFs for nominal exchange rate and price adjustments (denoted by $\psi_{ej}(t)$ and $\psi_{pj}(t)$, respectively). The generalized IRFs for real exchange rate adjustment in response to a unit innovation to the j th variable is given by

$$\psi_{qj} = \beta' C_t \Sigma \gamma_j / \sigma_{jj}, \quad t = 0,1,2,.... \tag{4}$$

A shock to PPP can come about as an exchange rate innovation or a price innovation. An increase in q can be induced by either a negative innovation to p or a positive innovation of e. In fact, the IRFs of q, p and e are linked to one another as follows:

$$\psi_{qj}(t) = \psi_{ej}(t) - \psi_{pj}(t), \quad j = p, e.$$

At the PPP equilibrium, we have $\psi_{qj}(t^*) = \psi_{ej}(t^*) - \psi_{pj}(t^*) = 0$ at time $t = t^*$. We can measure how fast these variables adjust and converge to their respective long-run equilibrium values by examining the adjustment paths of individual variables subsequent to an innovation at time $t = 0$. In finite sample estimation, $\psi_{ej}(t^*)$ and $\psi_{pj}(t^*)$ will be estimated based on a sufficient large t_τ. We estimate $\psi_{ej}(t^*)$ and $\psi_{pj}(t^*)$ as follows:

$$\psi_{ej}(t^*) = \psi_{pj}(t^*) = \{\psi_{ej}(t_\tau) + \psi_{pj}(t_\tau)\}/2$$

where $t_\tau = 240$ months and $|\psi_{ej}(t) - \psi_{pj}(t)|$ is very close to zero as $t \to t_\tau$.

A measure of persistence of q, p and e is their half-lives. We estimate the half-lives of the convergence of q, p and e in response to unit innovations of nominal exchange rates and prices. We then run regressions to empirically examine their relationship with exchange rate volatility.

3. Data

The data set used in this study comprises monthly observations for the nominal exchange rate (domestic price of foreign currency) and the price levels based on the consumer price index (CPI) for 22 OECD countries. Our data set is obtained from the International Financial Statistics of the International Monetary Fund. From these data we calculate the logarithm of nominal exchange rates, relative prices, and real exchange rates, as defined in equation (1). The sample covers the post-Bretton Woods period, from April 1973 to November 2004.

4. Empirical results

4.1. Unit root tests and cointegration

In this section, as recommended by Froot and Rogoff (1995), we rely on the unit root test on the real exchange rate q, instead of cointegration tests, in order to examine cointegration relationship between e and p. One reason is that cointegration tests such as Johansen's (1991) cannot uniquely identify the cointegration vector. In addition, the PPP restriction tests on the cointegrating vector have poor size properties. If q is stationary and e and p are non-stationary, then e and p are cointegrated and have a VEC representation with $\beta' = [1 \quad -1]$. While there is no strictly uniformly most powerful invariant test for the unit root hypothesis, a modified ADF test called ADF-GLS test developed by Elliot et al. (1996) is approximately uniformly most powerful invariant against the local alternatives. The superior performance of this test is documented by Pantula et al. (1994) and Stock (1994). We therefore test for q, e and p using the ADF-GLS test.

As reported in Table 1, the unit-root null can be rejected in 71 of the 231 real exchange rates (22 × (22-1)/2). We exclude 16 cases from 71 because e or/and p are stationary. In the end, we have 55 real exchange rates for which long-run PPP holds and e and p are cointegrated. The sample country pairs are presented in Table 2.

4.2. Impulse response functions

The impulse response functions of q, e and p with respect to a nominal exchange rate innovation and a price innovation are displayed in Figure 1 and 2. In Figure 1-A presents the IRFs of UK pounds/ JP yen rate. The shape of the IRF for q largely reflects that of the IRFs for e in response to both innovations, confirming that the nominal exchange rate is the prime engine for PPP reversion. By contrast, in Figure 1-B (UK/Greece), the shape of the IRF for q largely reflects that of the IRFs for p. The adjustment speed for PPP reversion depends mainly on the slow convergence of p.

The difference in results between Figure 1-A and B may result from the characteristics of exchange rates and prices. The standard deviations of the first differences in the logged nominal exchange rates are 3.33 (UK/JP) and 2.72 (UK/Greece). And, the sums of the average inflation between the two countries are 9.84% (UK/JP) and 20.19% (UK/Greece) . These data may suggest that nominal exchange rate volatility and inflation play significant roles in determining the variable to delay the PPP reversion rate

Figure 2-A and Figure 2-B provides the similar results to the above. The nominal exchange rate is the prime engine for PPP reversion for the Norway/France real exchange rate, while the prices are the prime engine for PPP reversion for the Luxembourg/France real exchange rate.

4.3. Regression analysis with half-life estimates

In this section, we analyze the relationship between half-life estimates and nominal exchange rate volatility. The specification of our cross-county regressions is

$$HL_i = \alpha + \beta_1 \operatorname{var}_i + \beta_2 \inf_i + \beta_3 open_i + \beta_4 gov_i + \beta_5 dis_i + \beta_6 adj_i + \varepsilon_i \,. \qquad (5)$$

We have six half-life estimates, all measured in years: a half-life of IRFs of a nominal exchange rate shock to a nominal exchange rate (*HL(e,e)*), that of a price to a nominal exchange rate shock (*HL(e,p)*), that of a nominal exchange rate to a price shock (*HL(p,e)*), that of a price to a price shock (*HL(p,p)*), that of a real exchange rate to a nominal exchange rate shock (*HL(q,e)*), and that of a real exchange rate to a price shock (*HL(q,p)*). In addition, we use the ratio of *HL(e,e)* to *HL(e,p)* and that of *HL(p,e)* to *HL(p,p)* in order to compare the adjustment speeds of nominal exchange rates and prices in response to the same shocks.

The variable *var* in the equation (5) represents the exchange rate volatility. It is the standard deviation of logged first-differences of the nominal exchange rate between the two countries. We pay attention to the effect of exchange rate regimes on real exchange rate persistence.

The speed of parity reversion depends on how quickly goods prices are adjusted. A higher inflation can lead to a more rapid price adjustment (Ball and Mankiw, 1994). Consequently, empirical evidence indicates that PPP holds well for high inflation countries (Frankel, 1978; McNown and Wallace, 1989). Hence, the equation (4) includes *inf*, which is defined as the sum of the average inflation rates of the two countries.

The fundamental idea of long-run PPP is that goods arbitrage ensures the parity condition across countries over a certain time horizon. Faruqee (1995) and Bergin and Feenstra (1999) show that an increase in openness encourages price adjustment of firms to offset exchange rate changes, and hence reduces real exchange rate persistence. We thus include the variable *open*, which is defined as the sum of the sample average ratios of the imports and exports to the GDP between the two countries.

Some structural models of PPP deviations consider government spending as an important demand-side factor that creates a home goods bias (Froot and Rogoff, 1991; Rogoff, 1992). Bergin and Feenstra (1999) suggest that a strong home bias leads to more persistent real exchange rate behavior. The variable *gov* is included, which denotes the average of the ratios of government spending to GDP between the two countries.

A popular view of PPP (LOP) deviations is that transportation cost creates a wedge between prices in two countries. It follows that a greater geographical distance can lead to larger PPP (LOP) deviations if transportation costs are proportional to distances (Wei and Parsley, 1995). We add the variable *dis*, which is the geographical distance in kilometer between the capitals of the two countries to capture the transportation cost effect.

Adjacency is a dummy variable that assumes the value of one if the countries share a common boarder and zero otherwise. Adjacency captures not only the transportation effect but the closeness of preference toward tradable goods.

The regression results are presented in Table 4. Most notably, the nominal exchange rate volatility has a statistically significant positive effect on the half-lives of convergence for e and p. The last two regression results show that the nominal exchange rate responses to both the nominal exchange rate innovation and the price innovation adjust slowly than price responses to them as nominal exchange rate becomes volatile, suggesting that the variables primarily driving adjustment toward PPP may change according to the nominal exchange rate regimes.

As also consistent with the prior, the effect of inflation is negative but insignificant for most regression results. Trade openness also has a insignificantly negative effect on the half-lives of impulse responses for e and p. What is more significant is the geographical distance for most of regression results. It is negative and significant, consistent with the hypothesis on the transportation cost effect.

In Table 5, we provide the results of the half-lives of IRFs of a real exchange rate to a nominal exchange rate shock and a price shock. The exchange rate volatility has a positive and significant effect on the half-life of the real exchange rates. This suggests that real exchange rates converge faster to the long-run PPP level under the fixed exchange rate regime, a result consistent with those of McClosky and Zecher (1984) and Diebold, Husted and Rush (1991), who find the support of reversion toward PPP for the gold standard period.

The findings that the convergence speeds of nominal exchange rates and prices depend on nominal exchange rate volatility provide us with some insights on the puzzle advocated by Engel and Morley (2001). Under the flexible exchange rate regime, nominal exchange rates have a much larger innovation variance than prices. Hence, they deviate from their equilibrium more than prices do when there is a shock and adjust slowly than prices. By contrast, under the fixed exchange rate regime, prices have a larger innovation variance than exchange rates. The size of innovations plays an important role for the adjustment speeds of stochastic processes with unit roots, such as nominal exchange rates and prices. Comparing the results from the flexible and fixed exchange rate regimes, we conclude that the puzzle may result from the misunderstanding of the conventional sticky-price explanation.

5. Conclusion

This paper presents additional evidence on the adjustment speeds of nominal exchange rates and prices toward PPP using 55 real exchange rates of 22 OECD countries, for which long-run PPP conditions hold. By employing a vector error correction model (VECM), we estimate impulse response functions to find the speeds at which the individual variables revert to their long-run values. Contrary to the previous studies, we find some cases where prices converge to their equilibrium levels more slowly than nominal exchange rates when the nominal exchange rates are relatively stable. Indeed, our regression results reveal that the relative adjustment speed of nominal exchange rates to prices is faster as nominal exchange rates become stable.

Comparing the results from the flexible and fixed exchange rate regimes, we argue that the puzzle may result from the misunderstanding of the conventional sticky-price explanation. Under the flexible exchange rate regime, nominal exchange rates have a much larger innovation variance than prices. Hence, they deviate from their equilibrium more than prices do when there is a shock and adjust slowly than prices. By contrast, under the fixed exchange rate regime, prices have a larger innovation variance than exchange rates. The size of innovations plays a key role for the adjustment speeds of stochastic processes with unit roots, such as nominal exchange rates and prices.

We also find that the half-lives of system-wide shocks on real exchange rates are positively associated with nominal exchange rate volatility. This suggests that real exchange rates converge faster to the long-run PPP level under the fixed exchange rate regime. This seemingly puzzling finding is, however, consistent with the existing evidence supporting mean reversion for the gold standard period (McClosky and Zecher, 1984; Diebold, Husted and Rush, 1991). These findings indicate that PPP reversion rate hinges on the exchange rate volatility.

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Table 1. Unit root tests

			Real exchange rate			Nominal exchange rate			Price differencial		
	Country-pairs		DF-GLS unit root test			DF-GLS unit root test			DF-GLS unit root test		
			Lag	Statistic		Lag	Statistic		Lag	Statistic	
1	Austria	United States	11	-1.752	*	11	-2.352		12	-2.594	*
2	Belgium	United States	16	-2.641	***	16	-2.773	*	12	-5.114	***
3	Canada	United States	16	-1.227		16	-1.943		16	-1.078	
4	Denmark	United States	11	-2.308	**	13	-2.467		12	-0.588	
5	Finland	United States	11	-2.099	**	11	-3.077	**	15	-0.847	
6	France	United States	11	-2.58	***	7	-1.842		12	-1.032	
7	Germany	United States	11	-2.557	**	11	-2.434		12	-1.482	
8	Greece	United States	14	-2.226	**	15	-2.102		16	-1.149	
9	Italy	United States	11	-2.732	***	11	-2.366		13	-0.426	
10	Japan	United States	11	-0.968		10	-2.533		12	-2.315	
11	Korea	United States	11	-1.82	*	11	-2.469		15	-0.987	
12	Luxembourg	United States	11	-2.343	**	16	-2.773	*	16	-4.945	***
13	Mexico	United States	10	-0.553		11	-1.112		5	-0.914	
14	Netherlands	United States	11	-2.471	**	16	-2.571	*	14	-2.078	
15	Norway	United States	11	-2.294	**	11	-2.477		13	-1.961	
16	Portugal	United States	12	-1.814	*	11	-2.075		16	-0.912	
17	Spain	United States	16	-1.712	*	7	-1.752		14	-0.793	
18	Sweden	United States	14	-1.764	*	14	-2.527		12	-0.965	
19	Switzerland	United States	11	-1.258		7	-1.439		12	-1.602	
20	Turkey	United States	7	-1.194		16	-1.612		13	-1.261	
21	United Kingdom	United States	14	-1.446		14	-1.696		14	-0.718	
22	Belgium	Austria	12	0.201		12	-0.771		12	-0.687	
23	Canada	Austria	11	-0.973		11	-2.197		12	-1.031	
24	Denmark	Austria	15	-0.544		4	0.116		14	-0.466	
25	Finland	Austria	10	-1.807	*	10	-1.715		16	-0.72	
26	France	Austria	15	0.193		9	-0.517		16	-1.174	
27	Germany	Austria	16	1.203		10	-2.122		12	-0.841	
28	Greece	Austria	14	-1.412		8	0.136		16	-1.037	
29	Italy	Austria	6	-0.974		6	-0.063		13	-0.527	
30	Japan	Austria	16	-1.16		16	-1.793		14	-1.035	
31	Korea	Austria	9	-2.442	**	9	-2.164		15	-1.165	
32	Luxembourg	Austria	12	0.41		12	-0.771		12	-1.564	
33	Mexico	Austria	10	-0.571		10	-1.592		5	-0.91	
34	Netherlands	Austria	16	0.132		8	-0.448		13	-1.833	
35	Norway	Austria	13	-0.997		2	-1.021		13	-0.963	
36	Portugal	Austria	16	-2.331	**	12	-0.791		16	-0.743	
37	Spain	Austria	14	-2.633	***	15	-0.613		15	-1.133	
38	Sweden	Austria	14	-0.042		13	-1.334		12	-0.525	
39	Switzerland	Austria	14	-1.14		14	-1.485		12	-1.73	
40	Turkey	Austria	14	-0.325		15	-1.013		13	-1.344	
41	United Kingdom	Austria	7	-2.388	**	7	-0.978		16	-0.671	
42	Canada	Belgium	11	-2.071	**	11	-2.907		12	-2.384	
43	Denmark	Belgium	15	0.025		6	-1.018		12	-1.27	
44	Finland	Belgium	14	-1.797		14	-2.934	**	13	-0.46	
45	France	Belgium	15	-2.162	**	15	-0.646		16	-1.153	
46	Germany	Belgium	12	-2.173	**	12	-0.8		15	-1.139	
47	Greece	Belgium	14	-0.972		8	-0.312		14	-1.033	
48	Italy	Belgium	10	-1.769	*	16	-0.784		13	-0.451	
49	Japan	Belgium	16	-0.573		15	-1.932		12	-1.887	
50	Korea	Belgium	9	-2.799	***	9	-3.157	**	16	-1.47	
51	Luxembourg	Belgium	16	-0.342			Fixed		16	-1.049	
52	Mexico	Belgium	10	-0.732		10	-1.66		1	-0.671	
53	Netherlands	Belgium	16	-0.364		13	-0.861		16	-0.869	
54	Norway	Belgium	16	-2.348	**	16	-2.631	*	12	-2.112	
55	Portugal	Belgium	12	-1.385		12	-0.984		16	-0.729	
56	Spain	Belgium	8	-0.69		15	-1.123		15	-1.1	
57	Sweden	Belgium	13	-1.188		13	-2.682	*	12	-1.451	
58	Switzerland	Belgium	13	-1.939		13	-0.775		12	-1.287	
59	Turkey	Belgium	14	-0.757		15	-0.966		13	-1.368	
60	United Kingdom	Belgium	7	-1.382		7	-1.555		14	-0.887	
61	Denmark	Canada	2	-0.971		7	-2.411		15	-0.674	
62	Finland	Canada	11	-1.196		11	-3.563	***	12	-0.812	
63	France	Canada	2	-1.701	*	2	-2.117		16	-0.574	
64	Germany	Canada	11	-2.097	**	11	-2.306		12	-0.801	
65	Greece	Canada	12	-0.909		11	-1.261		16	-1.231	
66	Italy	Canada	2	-1.545		2	-1.685		12	-0.264	
67	Japan	Canada	13	-0.679		13	-2.471		12	-2.536	
68	Korea	Canada	9	-1.065		9	-2.81		15	-1.48	
69	Luxembourg	Canada	11	-2.399	**	11	-2.907		12	-1.832	
70	Mexico	Canada	10	-0.665		10	-1.676		1	-0.686	

71	Netherlands	Canada		2	-1.237			11	-2.446			12	-1.138	
72	Norway	Canada		6	-1.055			2	-2.59			12	-1.972	
73	Portugal	Canada		6	-0.372			2	-0.538			16	-0.605	
74	Spain	Canada		16	-0.789			16	-2.153			15	-0.915	
75	Sweden	Canada		14	-2.409	**		14	-2.43			14	-1.212	
76	Switzerland	Canada		11	-0.74			13	-1.68			12	-1.094	
77	Turkey	Canada		15	-1.48			15	-1.03			13	-1.246	
78	United Kingdom	Canada		14	-0.479			14	-2.167			14	-0.876	
79	Finland	Denmark		12	-1.794	*		14	-2.755	*		14	-0.925	
80	France	Denmark		14	-0.094			14	-1.719			15	-0.873	
81	Germany	Denmark		15	0.293			4	0.102			12	-0.593	
82	Greece	Denmark		4	-2.255	**		8	-0.438			16	-1.414	
83	Italy	Denmark		11	-1.441			11	-0.845			12	-0.507	
84	Japan	Denmark		16	-0.947			16	-1.543			15	-2.463	*
85	Korea	Denmark		9	-2.946	***		9	-3.78			12	-1.708	
86	Luxembourg	Denmark		12	0.172			6	-1.018			12	-0.898	
87	Mexico	Denmark		10	-0.63			10	-1.697			10	-1.305	
88	Netherlands	Denmark		15	-0.8			13	-0.218			14	-0.392	
89	Norway	Denmark		1	-1.95	*		16	-1.748			13	-1.277	
90	Portugal	Denmark		12	-2.585	***		15	-1.035			16	-0.772	
91	Spain	Denmark		14	-1.288			15	-1.591			14	-0.854	
92	Sweden	Denmark		13	-0.262			13	-2.78	*		15	-1.444	
93	Switzerland	Denmark		16	-0.456			15	-0.463			12	-0.863	
94	Turkey	Denmark		15	-0.464			15	-0.897			13	-1.272	
95	United Kingdom	Denmark		1	-2.188	**		7	-1.94			12	-1.704	
96	France	Finland		14	-1.57			10	-2.094			13	-2.497	
97	Germany	Finland		14	-1.855	*		14	-2.245			12	-0.972	
98	Greece	Finland		16	-1.331			13	-0.89			14	-1.651	
99	Italy	Finland		4	-1.447			4	-0.85			16	-0.964	
100	Japan	Finland		16	-1.167	*		16	-2.316			16	-0.857	
101	Korea	Finland		9	-3.151	***		9	-3.507	***		15	-2.843	*
102	Luxembourg	Finland		14	-1.434			14	-2.934	**		13	-0.624	
103	Mexico	Finland		10	-0.573			10	-1.679			6	-1.001	
104	Netherlands	Finland		12	-2.089	**		10	-2.115			12	-0.712	
105	Norway	Finland		13	-1.708	*		10	-2.439			12	-1.158	
106	Portugal	Finland		14	-1.106			14	-0.721			16	-0.866	
107	Spain	Finland		3	-1.183			9	-1.155			12	-1.719	
108	Sweden	Finland		10	-0.532			12	-2.361			15	-1.347	
109	Switzerland	Finland		12	-1.441			10	-1.293			12	-0.88	
110	Turkey	Finland		14	-0.64			15	-0.975			13	-1.28	
111	United Kingdom	Finland		7	-1.666	*		7	-1.886			14	-2.346	
112	Germany	France		9	-3.854	***		9	-0.575			14	-1.212	
113	Greece	France		16	-0.384			1	-0.634			16	-1.524	
114	Italy	France		3	-1.778	*		16	-1.269			12	-0.008	
115	Japan	France		16	-0.507			15	-1.469			12	-2.637	
116	Korea	France		9	-2.914	***		9	-3.884	***		15	-2.247	
117	Luxembourg	France		15	-1.777	*		15	-0.646			12	-0.728	
118	Mexico	France		10	-0.677			10	-1.657			1	-0.685	
119	Netherlands	France		15	-0.99			15	-0.356			14	-1.242	
120	Norway	France		1	-1.797	*		1	-1.362			13	-1.261	
121	Portugal	France		15	-0.639			15	-1.039			16	-0.701	
122	Spain	France		16	0.011			16	-1.892			15	-1.052	
123	Sweden	France		7	-1.237			7	-2.285			12	-1.502	
124	Switzerland	France		13	0.004			7	-0.331			12	-1.097	
125	Turkey	France		15	-0.882			15	-0.903			13	-1.277	
126	United Kingdom	France		1	-1.136			7	-2.052			13	-2.019	
127	Greece	Germany		14	-0.419			13	-0.256			16	-0.87	
128	Italy	Germany		10	-1.896	*		16	-0.348			13	-0.457	
129	Japan	Germany		16	-0.464			16	-1.867			16	-0.917	
130	Korea	Germany		9	-2.592	***		9	-2.266			15	-1.007	
131	Luxembourg	Germany		12	-1.691			12	-0.8			16	-1.162	
132	Mexico	Germany		10	-0.76			10	-1.61			5	-0.911	
133	Netherlands	Germany		12	0.208			15	-0.857			13	-1.465	
134	Norway	Germany		12	-2.09	**		16	-1.504			13	-0.812	
135	Portugal	Germany		12	-1.477			12	-0.925			16	-0.808	
136	Spain	Germany		15	-0.54			15	-0.717			15	-1.187	
137	Sweden	Germany		1	-1.369			13	-1.564			15	-0.297	
138	Switzerland	Germany		14	0.256			14	-1.25			16	-2.299	
139	Turkey	Germany		14	-0.828			15	-1.012			13	-1.308	
140	United Kingdom	Germany		7	-1.303			7	-1.043			14	-0.77	

141	Italy	Greece		14	-1.246			8	-1.067			16	-1.491	
142	Japan	Greece		16	-1.097			16	-0.576			15	-1.646	
143	Korea	Greece		9	-2.073			9	-1.372			15	-2.069	
144	Luxembourg	Greece		12	-0.694			8	-0.312			16	-1.146	
145	Mexico	Greece		10	-0.505			10	-1.998			1	-0.816	
146	Netherlands	Greece		14	-1.666			8	0.015			16	-1.436	
147	Norway	Greece		16	-0.764			12	-0.218			15	-1.026	
148	Portugal	Greece		12	-2.609	***		12	-1.201			16	-1.212	
149	Spain	Greece		14	-1.525			1	-0.918			15	-1.837	
150	Sweden	Greece		16	0.504			16	-0.72			16	-1.317	
151	Switzerland	Greece		13	-1.203			7	0.019			14	-0.396	
152	Turkey	Greece		14	-0.327			15	-0.747			13	-1.084	
153	United Kingdom	Greece		12	-2.396	**		7	-1.183			14	-1.468	
154	Japan	Italy		16	-0.807			16	-0.893			15	-1.506	
155	Korea	Italy		9	-2.796			9	-3.027	**		15	-1.837	
156	Luxembourg	Italy		6	-1.338			16	-0.784			13	-0.199	
157	Mexico	Italy		10	-0.656			10	-1.756			1	-0.693	
158	Netherlands	Italy		10	-1.739	*		6	-0.177			14	-0.474	
159	Norway	Italy		1	-2.327	**		1	-0.726			14	-0.351	
160	Portugal	Italy		16	-1.304			10	-1.217			16	-0.955	
161	Spain	Italy		16	-0.465			16	-1.822			14	-2.734	*
162	Sweden	Italy		13	-0.593			13	-1.04			14	-0.428	
163	Switzerland	Italy		3	-0.816			3	-0.27			13	-0.65	
164	Turkey	Italy		14	-0.683			15	-0.758			16	-1.225	
165	United Kingdom	Italy		1	-1.416			1	-2.094			14	-0.905	
166	Korea	Japan		15	-1.051			15	-2.457			15	-1.727	
167	Luxembourg	Japan		16	-0.448			15	-1.932			14	-1.733	
168	Mexico	Japan		10	-0.478			10	-1.49			1	-0.673	
169	Netherlands	Japan		16	-0.779			16	-1.959			12	-1.136	
170	Norway	Japan		14	-0.937			14	-1.92			12	-2.577	*
171	Portugal	Japan		14	-1.481			7	-0.759			16	-1.027	
172	Spain	Japan		16	-1.525			14	-1.734			15	-1.42	
173	Sweden	Japan		16	-0.433			16	-1.762			12	-2.299	
174	Switzerland	Japan		7	-2.483	**		7	-1.837			12	-0.995	
175	Turkey	Japan		15	-0.61			15	-1.228			13	-1.303	
176	United Kingdom	Japan		9	-1.792	*		9	-1.897			16	-1.081	
177	Luxembourg	Korea		9	-2.264	**		9	-3.157	**		15	-1.4	
178	Mexico	Korea		10	-0.552			10	-1.658			5	-0.896	
179	Netherlands	Korea		9	-3.297	***		9	-2.515			15	-1.058	
180	Norway	Korea		9	-3.393	***		9	-2.674	*		15	-1.879	
181	Portugal	Korea		9	-1.93	*		9	-1.385			16	-1.648	
182	Spain	Korea		9	-2.497	**		9	-3.428	**		15	-3.108	**
183	Sweden	Korea		11	-1.522			9	-3.323	**		12	-1.756	
184	Switzerland	Korea		9	-1.767	*		9	-1.77			15	-1.117	
185	Turkey	Korea		4	-1.163			15	-1.038			13	-1.201	
186	United Kingdom	Korea		9	-2.478	**		9	-3.316	**		13	-2.399	
187	Mexico	Luxembourg		10	-0.789			10	-1.66			5	-0.908	
188	Netherlands	Luxembourg		15	0.05			13	-0.861			12	-1.456	
189	Norway	Luxembourg		16	-1.627			16	-2.631	*		12	-1.754	
190	Portugal	Luxembourg		12	-0.988			12	-0.984			16	-0.549	
191	Spain	Luxembourg		14	-0.249			15	-1.123			15	-0.787	
192	Sweden	Luxembourg		13	-1.764	*		13	-2.682	*		12	-0.876	
193	Switzerland	Luxembourg		14	0.182			13	-0.775			16	-1.355	
194	Turkey	Luxembourg		14	-0.928			15	-0.966			13	-1.329	
195	United Kingdom	Luxembourg		7	-1.042			7	-1.555			13	-1.044	
196	Netherlands	Mexico		10	-0.658			10	-1.615			5	-0.896	
197	Norway	Mexico		10	-0.574			10	-1.592			1	-0.712	
198	Portugal	Mexico		10	-0.379			10	-1.72			2	-0.778	
199	Spain	Mexico		10	-0.474			10	-1.613			5	-0.921	
200	Sweden	Mexico		10	-0.79			10	-1.685			5	-0.973	
201	Switzerland	Mexico		10	-0.485			10	-1.533			5	-0.911	
202	Turkey	Mexico		14	-0.731			10	-1.29			8	-1.174	
203	United Kingdom	Mexico		4	-0.387			10	-1.554			5	-0.929	
204	Norway	Netherlands		16	-3.034	***		16	-1.734			12	-1.432	
205	Portugal	Netherlands		12	-2.054	**		12	-0.809			16	-0.873	
206	Spain	Netherlands		14	-1.21			15	-0.781			15	-0.924	
207	Sweden	Netherlands		5	-0.498			13	-1.891			12	-0.856	
208	Switzerland	Netherlands		16	-0.045			13	-1.147			12	-1.842	
209	Turkey	Netherlands		14	-0.556			15	-0.989			16	-1.401	
210	United Kingdom	Netherlands		7	-1.967	*		7	-1.152			14	-0.58	

211	Portugal	Norway		16	-1.056			15	-0.524			16	-0.597	
212	Spain	Norway		14	-1.07			15	-1.111			15	-1.16	
213	Sweden	Norway		1	-0.483			1	-2.639	*		12	-2.439	
214	Switzerland	Norway		13	-0.65			13	-1.064			12	-1.16	
215	Turkey	Norway		15	-0.706			15	-0.975			16	-1.289	
216	United Kingdom	Norway		15	-1.273			15	-1.211			16	-1.301	
217	Spain	Portugal		9	-1.556			16	-0.609			16	-0.875	
218	Sweden	Portugal		14	0.892			15	-0.495			16	-0.392	
219	Switzerland	Portugal		14	-1.452			15	-0.726			16	-0.807	
220	Turkey	Portugal		14	-0.202			15	-0.71			16	-1.256	
221	United Kingdom	Portugal		11	-2.076	**		1	-0.605			16	-1.096	
222	Sweden	Spain		14	0.697			5	-1.191			12	-0.931	
223	Switzerland	Spain		16	-1.81	*		2	-0.508			15	-1.369	
224	Turkey	Spain		14	-0.233			15	-0.833			13	-1.255	
225	United Kingdom	Spain		16	-1.664	*		15	-1.822			12	-1.93	
226	Switzerland	Sweden		14	-0.144			3	-1.296			14	-0.478	
227	Turkey	Sweden		14	-1.085			15	-0.842			16	-1.293	
228	United Kingdom	Sweden		15	0.202			15	-1.425			16	-1.202	
229	Turkey	Switzerland		14	-0.234			15	-1.013			13	-1.303	
230	United Kingdom	Switzerland		1	-1.851	*		1	-0.718			14	-0.877	
231	United Kingdom	Turkey		14	-0.425			15	-1.007			16	-1.381	

Table 2. Selected country pairs

1	Denmark	United States
2	France	United States
3	Germany	United States
4	Greece	United States
5	Italy	United States
6	Korea	United States
7	Norway	United States
8	Portugal	United States
9	Spain	United States
10	Sweden	United States
11	Finland	Austria
12	Korea	Austria
13	Portugal	Austria
14	Spain	Austria
15	United Kingdom	Austria
16	Canada	Belgium
17	France	Belgium
18	Germany	Belgium
19	Italy	Belgium
20	France	Canada
21	Germany	Canada
22	Luxembourg	Canada
23	Sweden	Canada
24	Greece	Denmark
25	Korea	Denmark
26	Norway	Denmark
27	Portugal	Denmark
28	United Kingdom	Denmark
29	Germany	Finland
30	Japan	Finland
31	Netherlands	Finland
32	Norway	Finland
33	United Kingdom	Finland
34	Germany	France
35	Italy	France
36	Luxembourg	France
37	Norway	France
38	Italy	Germany
39	Korea	Germany
40	Norway	Germany
41	Portugal	Greece
42	United Kingdom	Greece
43	Netherlands	Italy
44	Norway	Italy
45	Switzerland	Japan
46	United Kingdom	Japan
47	Netherlands	Korea
48	Switzerland	Korea
49	Norway	Netherlands
50	Portugal	Netherlands
51	United Kingdom	Netherlands
52	United Kingdom	Portugal
53	Switzerland	Spain
54	United Kingdom	Spain
55	United Kingdom	Switzerland

Table 3. Summary Statistics

	mean	std. dev.	min	max
Panel A:				
HL(e to q) (year)	4.238	2.297	0.583	9.000
HL(p to q) (year)	4.320	3.179	0.417	15.667
HL(e to e) (year)	4.091	2.375	0.250	10.000
HL(e to p) (year)	3.997	2.254	0.167	9.000
HL(p to e) (year)	4.330	3.708	0.167	20.000
HL(p to p) (year)	4.535	3.007	0.167	15.500
HL(e to e)/HL(e to p)	2.084	7.958	0.086	60.000
HL(p to e)/HL(p to p)	1.079	0.732	0.029	4.333
Panel B:				
Exch. rate volatility	180.264	784.705	0.700	4389.437
Inflation (%)	12.230	3.507	5.681	25.618
Trade openness	1.017	0.323	0.480	1.749
Government spending	0.597	0.170	0.094	0.899
Geographical distance (Km)	3849.145	3204.989	266.000	11185.000
Adjacency dummy	0.109	0.315	0.000	1.000

Note: HL (.) denotes a half life in years. HL(e to q) denotes a half life of impulse response function of a real exchange rate to a nominal exchange rate innovation.

Exchange rate volatility is the standard deviation of the nominal exchange rate gowth rate (%). Inflation is the sum of the average inflation rate (%) between two countries. Trade openness is the sum of the import plus export as a share of GDP between two countries. Government spending is the sum of the government spending as a share of GDP between two countries.

Table 4.

	HL(e to e)	HL(e to p)	HL(p to e)	HL(p to p)	HL(e to e)/ HL(e to p)	HL(p to e)/ HL(p to p)
Constant	7.56345 ***	7.20620 ***	11.40311 ***	8.99488 ***	0.94604	1.36332
	(1.90028)	(1.98245)	(3.78173)	(3.01763)	(2.22851)	(0.70561)
Exch. rate volatility	0.00020 *	0.00059 ***	0.00090 **	0.00111 ***	0.00110 **	0.00072 *
	(0.00013)	(0.00019)	(0.00046)	(0.00025)	(0.00050)	(0.00043)
Inflation	-0.17914 *	-0.07633	-0.13250	-0.13683	-0.22307	0.01105
	(0.09133)	(0.10222)	(0.14306)	(0.13462)	(0.22430)	(0.04134)
Trade openness	-1.89088 **	-0.66400	-0.30362	-0.69537	-4.01791	-0.14067
	(0.89303)	(0.83791)	(1.21980)	(1.16043)	(4.02800)	(0.19435)
Government spending	2.37922	-0.28739	-3.83611	-1.41019	9.77324	0.08797
	(1.95814)	(1.73483)	(2.83662)	(2.40399)	(9.83409)	(0.51099)
Geographical distance	-0.00016	-0.00035 ***	-0.00070 ***	-0.00033 *	0.00062	-0.00007 *
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0006)	(0.0000)
Adjacency	-1.47729	-1.65802	-2.98926 *	-1.40918	-0.59260	-0.57774 **
	(0.99612)	(1.07392)	(1.68924)	(1.46926)	(0.86083)	(0.27599)
R2	0.1559	0.1785	0.1961	0.1205	0.0613	0.1277

Note: HL (.) denotes a half life in years. HL(e to p) denotes a half life of impulse response function of a price to a nominal exchange rate innovation. HL (.)/HL(.) denotes a relative half life ratio.

Table 5.

	HL(e to q)		HL (p to q)	
Constant	7.67631	***	10.37526	***
	(1.89800)		(3.37723)	
Exch. rate volatility	0.00043	**	0.00125	***
	(0.00019)		(0.00022)	
Inflation	-0.10935		-0.21612	**
	(0.10177)		(0.10688)	
Trade openness	-1.33025		-0.57480	
	(0.85431)		(1.20978)	
Government spending	0.77637		-1.85635	
	(1.78198)		(3.03754)	
Geographical distance	-0.00029	*	-0.00045	**
	(0.0001)		(0.0002)	
Adjacency	-1.73777		-1.84110	
	(1.04900)		(1.66295)	
R2	0.1629		0.1732	

Note: HL (.) denotes a half life in years.
HL(e to q) denotes a half life of impulse response function of a real exchange rate to a nominal exchange rate innovation.

Figure 1-A

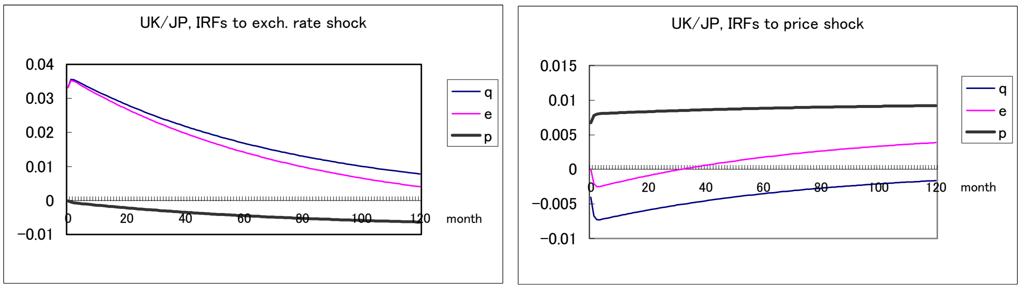


Figure 1-B

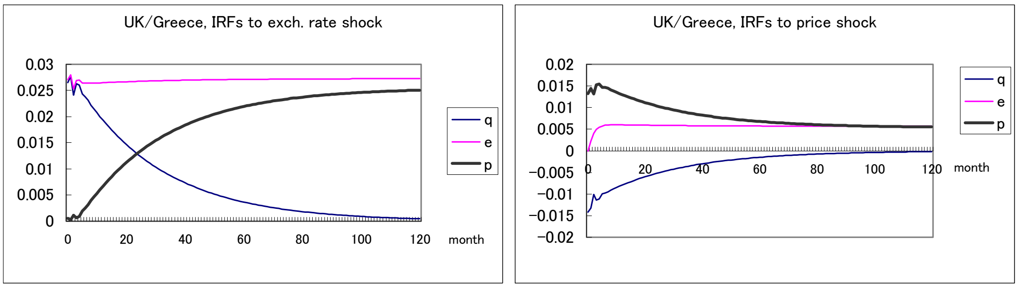


Figure 2-A

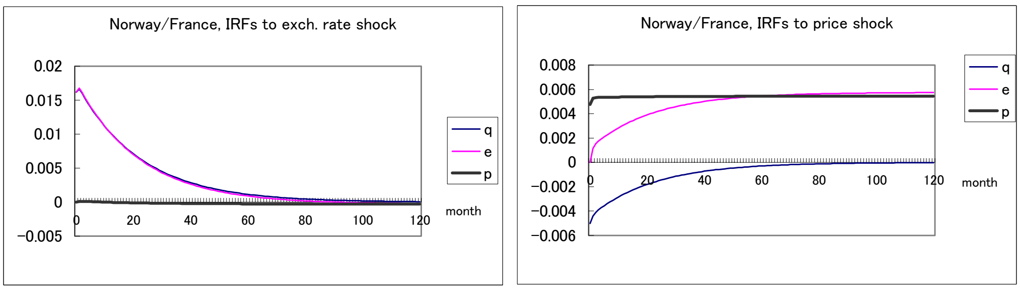
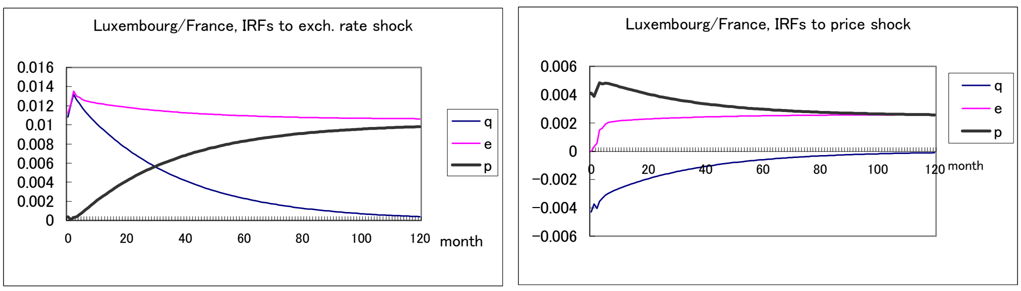


Figure 2-B



Note: q denotes an impulse response of real exhange rate, e that of nominal exchange rate, and p that of price.