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Uncover Latent PPP by Dynamic Factor Error Correction Model (DF-ECM) Approach: Evidence from five OECD countries

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Abstract:

This study explores a new modelling approach to bridge the gap between the bilateral setting of one ‘domestic’ economy facing one ‘foreign’ entity in theory and multilateral country data in reality. Under the approach, purchasing power parity (PPP) is embedded in latent disequilibrium factors, being extracted from a large set of bilateral price disparities; the factors are then used as error-correction leading indicators to explain exchange rate and inflation. Modelling experiments on five OECD countries using monthly data show promising results, which reverse the common belief that PPP is at best a very long-run relationship at the macro level.

JEL: PPP, law of one price, dynamic factor, error correction

Keywords: F31, C22, C33

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1. Introduction

It is widely observed that real exchange rates exhibit slow mean reversion and weak equilibrating power over the dynamic adjustments of nominal rates. The phenomenon forms the basis of the PPP (purchasing power parity) puzzle, i.e. empirical verification of the 'Law of One Price' (LOP) underlying PPP has been much weaker than expected, see (Obstfeld and Rogoff, 2000). The puzzle has been attributed to the considerable gap between what the PPP theory assumes and the conditions of available data, especially macro data, e.g. see (Taylor and Taylor, 2004). Two issues have come to the fore. The first is aggregation, namely that heterogeneity among types of traded goods, rates of trading costs as well as between traded and non-traded goods across different countries is simply too pronounced to be assumed away empirically. A direct solution is to study the theory at a micro level, e.g. see (Barrett, 2001), (Barrett and Li, 2002), and (Parsley and Wei, 2004); a more elaborate way is to try to filter out those heterogeneous features considered to be highly significant from disaggregate panel data before inferences on PPP at a certain aggregate level are made, e.g. see (Crucini *et al*, 2005) and (Imbs *et al*, 2005). The other issue concerns price rigidity due essentially to market imperfection, which is reflected in different prices having different dynamic features, e.g. see (Sarno, 2005). A common way of tackling the issue is to characterise the complicated price dynamics by nonlinear models, e.g. see (Taylor *et al*, 2001) and (Sarno *et al*, 2004).

The present study explores an alternative, novel route to tackle the issues at the macro level. We focus our attack on the gap between the theoretical concept of a 'foreign' entity, which acts as a single 'numéraire' in PPP-based bilateral models, and country-level data, which are generated from a world market where any one home country faces multilateral purchasing power disparities with different foreign economies, each under different policy barriers to trade in general. Acknowledging the ubiquitous existence of heterogeneity and market imperfection in data, we propose to regard PPP as statistically latent but identifiable via factor analysis.[1] Specifically, PPP is assumed to be embodied in the common factors of a dynamic factor model (DFM) comprising bilateral purchasing power disparities of a home country with a large number of foreign economies. This amounts to identify the heterogeneous and market-imperfect components in data with the country-specific or idiosyncratic factors of the DFM. Once the common factors are extracted, they are postulated as proxies of the disparities driving the price and exchange rate adjustment of the home country. The postulate is then tested via error-correction models (ECM). The ECM not only facilitates the commonly adopted presentation of PPP as a long-run equilibrium condition but also verifies the condition in a much more stringent manner than what mean-reversion tests or simple cointegration analysis can achieve, see e.g. (Johansen, 2006).

The above procedure is referred to as the dynamic-factor error-correction model (DF-ECM) approach. The DF-ECM approach is initiated by Qin *et al* (2006) for the purpose of measuring regional market integration, and its trial application to the developing Asian region has yielded encouraging results. The present study further develops the approach by applying it to the empirical verification of PPP for five OECD countries. Thirty foreign economies are chosen to represent the world market and their price disparities vis-à-vis each of the five countries form the basis of dynamic factor analysis (DFA). Monthly data of the period 1975-2005 are used.

The rest of the paper is organised as follows. The next section presents the DF-ECM approach. Section 3 describes practical issues pertinent to the implementation of the approach. Section 4 discusses the main findings from the five cases. The last section concludes with a short summary.

2. Method of Investigation: The DF-ECM Approach

2.1 The DF-ECM procedure

[1] Conventionally, the gap is filled by construction of a real and/or a nominal effective exchange rate for the home country. However, there is no unique way of constructing such measures. Different measures contain different problems, e.g. see (Ellis, 2001), (Chinn, 2006). Moreover, different measures may lead to different inferences with respect to the verification of PPP, e.g. see (Pipatchaipoom and Norrbin, 2006).

Let us denote the PPP hypothesis by:

$$e_d = \frac{p_f}{p_d} \tag{1}$$

where p_d denotes the aggregate price level of the domestic economy of interest, p_f denotes the price level of the corresponding foreign economy and e_d is the exchange rate between the two economies denominated in the domestic currency. Equation (1) leads to the definition of real exchange rate, q_d:

$$q_d = \frac{e_d p_d}{p_f} \tag{2}$$

Empirically, it is widely accepted that PPP should be regarded as a long-run equilibrium condition, see e.g. (Obstfeld and Rogoff, 2000). One way of testing this condition is via an ECM, say in a commonly used logarithm form:

$$\Delta \ln(e_d p_d)_t = \alpha(L)\Delta \ln(e_d p_d)_{t-1} + \beta(L)\Delta \ln(p_f)_t + \phi \ln(q_d)_{t-1} + \nu_t \tag{3}$$

where Δ denotes difference, $\alpha(L)$ and $\beta(L)$ are finite-order lag polynomials, ν_t is white-noise residual and ϕ is the feedback coefficient of the long-run PPP condition. In (3), PPP is shown to be at work when $\phi < 0$ and is statistically significant, as the coefficient signifies the foreign-currency denominated domestic price being regularly correcting the disequilibrium represented by the real rate such that the two price variables co-trend in the long run. An attractive feature of (3) is that its explanatory variables are presented by two types of structurally interpretable and empirically little collinear shocks – short-run shocks (the first two terms on the right-hand side) and a long-run disequilibrium shock (the third term), see (Qin and Gilbert, 2001).

Notice that (3) contains two variants in correspondence to two types of exchange rate regimes. When exchange rate is fixed or under tight control, PPP works primarily via p_d. Hence we have:

$$\Delta \ln(p_d)_t = \alpha_a(L)\Delta \ln(p_d)_{t-1} + \beta_a(L)\Delta \ln(p_f)_t + \delta_a(L)\Delta \ln(e_d)_t + \phi_a \ln(q_d)_{t-1} + \nu_{a,t} \tag{3a}$$

Whereas under the regime of a free-floating currency, the nominal exchange rate is expected to shoulder most of the adjustment with respect to PPP:

$$\Delta \ln(e_d)_t = \alpha_b(L)\Delta \ln(p_d)_t + \beta_b(L)\Delta \ln(p_f)_t + \delta_b(L)\Delta \ln(e_d)_{t-1} + \phi_b \ln(q_d)_{t-1} + \nu_{b,t} \tag{3b}$$

Whichever the regime, empirical verification of PPP lies with a significantly negative feedback coefficient for $\ln(q_d)_{t-1}$. Unfortunately, this is where problems have occurred with numerous empirical studies. The feedback coefficients are found either insignificant or extremely small when significant, suggesting highly persistent real rate deviations.

As mentioned in the previous section, a considerable gap between the extremely abstract PPP theory and the available aggregate data is regarded as a key culprit for the absence of strong empirical verification of PPP. Conventionally, real effective exchange rates (REER) are constructed using certain weights from trade and bilateral exchange rate statistics, and assumed as the statistical counterpart of q_d in aggregate studies. However, such measures are far from being free of the significant heterogeneity in country-level data. Here, we propose to regard both the long-run shock, $\ln(q_d)$, and the short-run shock, $\Delta \ln(p_f)$, in (3) as common shocks latent in the world economy, and extractable through DFA. Specifically, two DFMs are set up. The first is to extract common factors from all the observable, bilateral real rates of a domestic economy d vis-a-vis n foreign economies respectively. Defining the bilateral rates by $\ln(q_j) = \ln(e_d^j p_d) - \ln(p_j)$ with $j = 1, \cdots, n$ and letting $Q' = (\ln(q_1) \quad \cdots \quad \ln(q_n))$ be an n-vector, we assert:

$$\begin{aligned} Q_t &= \Gamma^* F_t^* + \varepsilon_t^* \\ F_t^* &= \Lambda^*(L) F_{t-1}^* + u_t^* \end{aligned} \tag{4}$$

In (4), $F^{*\prime} = (f_1^* \quad \cdots \quad f_m^*)$ is an m-vector of latent common factors with $m<<n$, which are thereafter referred to as the long-run factors, Γ^* is a parameter matrix and $\Lambda^*(L)$ is a vector of lag polynomial, both are to be estimated, ε^* and u^* are error terms with the former being an n-vector of idiosyncratic shocks of n foreign economies vis-a-vis economy d and the

latter an m-vector of common disequilibrium shocks to d. In factor analysis, Q_t is commonly referred to as the 'indicator set' or the set of 'manifest variables'.

The second type of common factors can be extracted in a similar way. Let:

$$\begin{aligned} P_t &= \Gamma F_t + \varepsilon_t \\ F_t &= \Lambda(L) F_{t-1} + u_t \end{aligned} \tag{5}$$

where the indicator set $P' = (\Delta \ln(p_1) \quad \cdots \quad \Delta \ln(p_n))$ is an n-vector of short-run shocks from the n foreign economies, and $F = (f_1 \quad \cdots \quad f_l)$ is an l-vector of latent common factors of P with l<<n, thereafter referred to as the short-run factors.

Introducing the common factors of (4) and (5) into model (3) leads to a DF-ECM model:

$$\Delta \ln(e_d p_d)_t = \alpha(L) \Delta \ln(e_d p_d)_{t-1} + B(L)' F_t + \Phi' F^*_{t-1} + \nu_t \tag{6}$$

where $B(L) = (\beta_1(L) \quad \cdots \quad \beta_l(L))$ is a l-vector of lag polynomial and $\Phi' = (\phi_1 \quad \cdots \quad \phi_m)$ is a m-vector of negative-feedback coefficients. Notice that F^*_{t-1}, the long-run factors, actually play the role of leading indicators in (6). The model also resembles a VAR (vector autoregression) model in a single-equation form. However, the two differ in that (6) involves the contemporaneous F_t, implying that these short-run shocks are regarded as exogenous.[2]

In practice, it is often more relevant to run DF-ECMs in correspondence to (3a) or (3b):

$$\Delta \ln(p_d)_t = \alpha_a(L) \Delta \ln(p_d)_{t-1} + B_a(L)' F_t + \delta_a(L) \Delta \ln(e_d)_t + \Phi'_a F^*_{t-1} + \nu_{a,t} \tag{6a}$$

$$\Delta \ln(e_d)_t = \alpha_b(L) \Delta \ln(e_d)_{t-1} + B_b(L)' F_t + \delta_b(L) \Delta \ln(p_d)_t + \Phi'_b F^*_{t-1} + \nu_{b,t} \tag{6b}$$

As the number of parameters in (6a) or (6b) rapidly increases when m and l are larger than two or three, the computer-automated model reduction software, PcGets, is employed for primary model simplification search, or 'testimation' using the software's terminology. The key advantage of PcGets is that it carries out testimation by the general → specific

[2] The main advantages of the DF-ECM approach are discussed in (Qin *et al*, 2006). In fact, similar approaches have been explored recently, e.g. the ALI (automated leading indicator) approach linking DFM with VAR by Camba-Mendez *et al* (2001), and the extended structural VAR models by common factors, see (Forni *et al*, 2003), (Bernanke *et al*, 2005), (Favero *et al*, 2005) and (Stock and Watson, 2005).

approach in a consistent and efficient manner such that the specific model resulted from testimation is guaranteed to be data-coherent and parsimoniously encompassing of the general model at the starting point, see (Hendry, 1995) and (Hendry and Krolzig, 2001). In other words, the specific model has survived all the commonly used diagnostic tests. Once the specific model is obtained, it is further simplified mainly through reparameterisation. Here, special attention is paid to the constancy of coefficient estimates, especially the feedback coefficients.

2.2 Useful Statistic Indicators

A number of statistics and parameter estimates are particularly useful to inform us about the power of PPP. Some are from the ECM procedure and the others from the DFMs.

The first and foremost is the vector of the feedback coefficients, Φ, in (6). Note that the signs of these coefficients depend upon the signs of the relevant coefficients in Γ^* of (4), e.g. ϕ_1 for f_1^* is expected to be negative if: $\sum_{i=1}^{n} \gamma_{i1}^* > 0$, $\Gamma^* = \{\gamma_{ij}^*\}_{m,n}$. Since there are more than one long-run factors in most cases, a simple linear combination of the significant factors through PcGets testimation is carried out during the reparameterisation stage. The combination yields one EC (error correction) term. Its time-evolving impact is monitored via recursive estimation of the corresponding feedback coefficient. Hansen parameter instability test (1992) is also used to check for the constancy of all the coefficient estimates.

The next sets of statistics are summary of the model fit from the PcGets testimation. These include the adjusted R^2, Schwarz information criterion, the numbers of parameters of the starting general model and of the specific model reached at the end of testimation respectively. Since PcGets conducts testimation based on an array of parsimonious encompassing tests, there is no need for us to check and report diagnostic tests here.

A popular means of verifying PPP empirically is univariate unit-root analysis of the real exchange rates. However, it has been shown that different testing methods can generate conflicting results, e.g. see (Pipatchaipoom and Norrbin, 2006) and that the unit-root approach may be too restrictive with respect to economic reasoning, see (Coakley *et al*, 2005). We believe that the ECM approach is more stringent than simple unit-root tests. Nevertheless, several unit-root tests are performed on the EC terms of the DF-ECMs at the final stage.

Two useful statistics are derived from the DFMs. The first is the correlation coefficient of each indicator variable, $\ln(q_j)$, with its fitted value by the DFMs. This statistic is referred to as 'communality' in factor analysis when all the indicator variables are standardised.[3] The second statistics is the temporal correlation coefficient of all the indicator variables with their fitted values in a DFM at time *t*, e.g. $\tau_t^2 = corr^2\left[Q_t, \left(\hat{\Gamma}^* \hat{F}^*\right)_t\right]$ if based on (4). This statistics exploits the fact that all indicator variables are of the same nature by definition. We refer to this statistics as the covariation coefficient. A time series of these coefficients is expected to show how the panel of bilateral PPPs for one economy co-moves with the set of the common factors over time.

3. Implementation of the DF-ECM Approach

The DF-ECM approach is applied to five OECD countries: Canada, France, Germany, Japan and UK. Monthly data are collected for the period of 1975-2005. These include consumer price indices (CPI) and dollar denominated exchange rates. Table 1 gives the details of all the series and their sources.

3.1 Implementation of DFMs

<u>Choice of the indicator set</u>: In addition to the five countries under study, twenty six economies are selected roughly on the basis of the total trade shares of these economies in the world according to the Trade Profile Statistics by the World Trade Organisation. This makes *n*=30 of the indicator set for each individual country under study (see Table 1), and the set covers 70%~80% of the external trade share of that country. All the indicator series

[3] See e.g. (Tucker and MacCallum, 1997) for detailed discussion about the statistics. As the number of long-run common factors may vary across different countries, adjusted R^2 is used here instead of the simple R^2.

are adjusted to zero-mean series but not standardised otherwise, since all the indicators are of the same definition.[4]

Determination of the number of factors: Two recently developed procedures of consistent estimators are utilized. One is developed by Bai and Ng (2005) and the other by Onatski (2005). The larger of the two estimates is adopted when they differ. Table 2 reports the estimated results of the two procedures.

Factor extraction: DFMs (4) and (5) are estimated using the technique developed by Camba-Mendez *et al* (2001). Basically, Kalman filter algorithm is used with the initial parameter estimates obtained via principal component analysis. One advantage of this is that the algorithm can handle an unbalanced data panel like ours, where the CPI data series start later than 1975M01 for countries like China and Czech Republic, and the Australian CPI is quarterly (see Table 1). As for the short-run indicator set, P_t, two types are extracted. One is month rate and the other quarterly rate. Rates of higher than annual frequencies are chosen here because PPP is known for lack of explanatory power in models using these types of data. The indicator set becomes n=29 in the monthly case as Australia drops out.

Determination of the number of lags: The experiment starts from L=1 and moves on to L=2 and L=3. A lag number is then chosen with reference to information criteria, such as Akaike and Schwarz criteria. It is found through numerous DFM experiments that one lag is adequate for the extraction of the short-run factors by (5) whereas two or three lags are necessary for the long-run factors by (4). The results are given in Table 2.

3.2 Implementation of DF-ECMs

Models (6a) and (6b) are the focal point of experiments, though (6) is tried first for each country (the results are not reported to keep the paper short). As mentioned above, two types of rates are modelled for each case: monthly and quarterly rates.[5] Figure 1 plots the

[4] Standardised data are used in (Qin *et al*, 2006) following the convention of DFA. Two versions have been experimented in the present study: standardized data and nonstandardised zero-mean data. The latter is chosen for its better performance found during PcGets testimation.

[5] Annual rates are used in (Qin *et al*, 2006). Note that the data series are still monthly in frequency.

sample-series of both rates corresponding to the two equations for each country. Various lag lengths have been tried during PcGets testimation and six lags are found generally adequate.

Since model constancy is a major issue of concern, PcGets-based model search is run repeatedly while the sample period is adjusted, starting from the full sample, then for the sub-samples of 1980-2005 and 1985-2005 respectively (only part of the results are reported to save space, see Table 5). The default setting of model selection criteria is used for the testimation, see (Hendry and Krolzig, 2001). The resulting specific models are then used as the base for further simplification, mainly by means of reparameterisation, using PcGive. Two main tasks of this stage are: (i) to reduce the multiple long-run factors into one EC term, i.e. an estimated real exchange rate, $\ln(\hat{q}_d)$, from the latent long-run factors, and (ii) to monitor coefficient constancy via recursive estimation, especially the constancy of the feedback coefficient, $\hat{\delta}$.

In order to compare the DF-ECM results with conventional results, data series of the real effective exchange rate (REER) of the five countries are collected (see Table 1 for the detailed information) and used as the EC term in standard ECMs.

4. Application Results

4.1 General results

It is most noticeable from Tables 6-10 that all DF-based real rates, i.e. the long-run EC terms, are significant in the DF-ECMs, in sharp contrast to those simple ECMs using $\ln(REER)$, where almost all the long-run coefficients are insignificant from zero. Moreover, a high degree of constancy of the feedback coefficients of the EC terms in the DF-ECMs is discernible from the recursive estimation plots given in the lower four panels of Figures 3-7, as well as from the Hansen test statistics given under the coefficient estimates in Tables 6-10. In contrast, the Hansen statistics reveal coefficient instability with the only two cases where the $\ln(REER)$ term is significant, i.e. the inflation model of Japan and the exchange rate model of UK in Tables 9 and 10.[6] Figures 3-7 also show that the DF-based EC terms are far more volatile than $\ln(REER)$ (see the two panels of the second row as well as the sample standard deviations given in the notes), suggesting that the apparently small magnitudes of the feedback coefficients in the DF-ECMs are not directly comparable to those found in the conventional PPP models. As for the expected signs of the coefficients of the significant long-run factors, these can be checked against Table 11, where $\sum_{i=1}^{n}\gamma_{ij}^{*}$ ($j=m$) and the associate standard errors from DFM (4) are reported. Since all the standard errors are fairly large, the implied 95% confidence intervals are generally too wide to restrict any of the feedback coefficients in (6a) or (6b) within the strictly negative range.

The insignificance of $\ln(REER)$ in the standard ECMs is consistent with the extant finding in the literature. The cause is often attributed to the nonstationary feature of REER. This is reconfirmed by the unit-root tests on the $\ln(REER)$ series shown in Table 12. In the table, unit-root tests on some of the DF-based EC terms are also presented. It is easily seen that the nonstationary feature is more pronounced in $\ln(REER)$ than in the DF-based EC terms, though the test results on these latter terms are quite mixed, reinforcing the findings by Pipatchaipoom and Norrbin (2006).

In terms of the adjustment power of PPP, it is interesting to note that the feedback coefficient estimates of the exchange rate models (6b) are larger in absolute value than those of the inflation models (6a), except for the case of Germany, where the two are quite close. This evidence is in support of the common view that goods prices are far less responsive than nominal exchange rates to external shocks under the freely floating regime.

Another noticeable feature of the DF-ECMs is that the reduced EC terms differ between models (6a) and (6b) of the same country, and even differ slightly in the same model but with the explained variable in different frequency rates, i.e. monthly versus quarterly (see

[6] In fact, the ECMs using $\ln(REER)$ often suffer from unsatisfactory diagnostic tests, but these are not reported here.

the top two panels of Figures 3-7). This finding supports the view that the PPP principle is deeply latent in aggregate data with complicated dynamics, which results from aggregation of numerous, heterogeneous trading activities in one country vis-a-vis a multitude of partners from various foreign economies. DFA provides us with a power means to identify the latent feature and the complicated dynamics is partially reflected in the different long-run coefficient estimates in ECMs.

It is worth noting also that the short-run common factors play an important role in the DF-ECMs as well. This is particularly striking when the R^2 statistics between the monthly rate DF-ECMs and the corresponding REER-based ECMs are compared (see Tables 6-10). On the whole, exchange rates are more responsive to the short-run factors and react to them in a more instantaneous manner than inflation, as seen from comparison of (6a) and (6b). In particular, the first factor, and especially its current term, tends to be highly significant in the exchange rate DF-ECMs, e.g. see the cases of France, Germany and Japan in Tables 7, 8 and 9. This feature renders strong support to the version of relative PPP.

As five short-run factors and five to six long-run factors are found necessary for each country, automated model reduction by PcGets becomes highly essential, as shown from Table 5. In fact, a great deal more of testimation experiments have been carried out than what is reported here. One particular feature easily revealed during PcGets testimation is that the DF-ECMs do not fit well with samples including the prior 1980 period for some countries, e.g. Japan. On the whole, the DF-ECMs fit better with post 1980 sub-samples than the full sample. If the adjusted R^2 statistics in Table 5 are compared with those of the DF-ECMs in Tables 6-10, one can easily see that further model reduction through reparameterisation helps to improve model fit moderately.

Let us now turn to the statistics derived from the DFMs. Tables 3 and 4 present the ordered sequences of the correlation coefficients between the indicator sets and their explained parts by DFMs (4) and (5) respectively over the sample period. Two features are worth commenting. First, the correlation coefficients in Table (3) are substantially larger than those in Table (4), manifesting that slow mean reversion must prevail in bilateral real rate series, which comprise the indicator set of DFM (4). Secondly, the correlation rankings across countries are far more similar in Table 4 than in Table 3. This is because the short-run indicator sets differ from each other only by one indicator, namely that of the home country under study. Notice also that France, Germany and Japan rank fairly high in the coefficient sequences of Table 4. That helps to explain why short-run common factors play such a significant role in the DF-ECMs of these three countries.

Finally, Figure 2 presents the series of covariation coefficients of DFMs (4) and (5). Discernibly, a great similarity is present among the series of the short-run DFMs (5) (the right-hand panels), due to the close similarity of the indicator sets. As for the covariation coefficient series of (4) (the left-hand side panels), these remain low and erratic, except probably for Japan. This evidence demonstrates that idiosyncratic shocks form a substantial part of the data deviation from the common factors at each observation point, in spite of the fact that the long-run factors co-move fairly closely with the time series of each bilateral price disparity indicator, as reflected in Table 3. The relative advantage of DFA over the conventional method of constructing REERs is therefore implied, as the former facilitates conveniently the removal of heterogeneous information.

4.2 Individual countries

Canada: The DF-ECMs show reasonable fit for almost the full sample (see Table 6) with fairly constant long-run coefficients (see Figure 3). The long-run coefficients in (6a) are clearly consistent with the positive coefficients of f_2^*, f_4^* and f_5^* from DFM (4) shown in Table 11. As for f_1^*, the large standard error of 1.132 (Table 11) makes its 95% confidence interval cover as low as -1.65, well allowing for the positive feedback coefficient of +0.0002 in (6a) of Table 6. The feedback coefficients of (6b) are about three to four times of those of (6a), indicating a much stronger PPP response in the exchange rate dynamics than the inflation dynamics.

France: Remarkably, the monthly exchange rate model fits almost as well as the quarterly rate model (see (6b) in Table 7), in sharp contrast to the poor fit of the REER based ECMs. The reduced EC terms are identical for (6b) and almost identical for (6a). The signs of the long-run coefficients in (6a) and (6b) are consistent with those from (4) implied in Table 11. The long-run feedback coefficients demonstrate high degree of constancy (see the lower four panels of Figure 4).

Germany: Again, the monthly exchange rate model fits almost as well as the quarterly rate model (see (6b) in Table 8), but the DF-based EC terms are the weakest in terms of the surviving significant factors, i.e. only f_3^* remains. This is also reflected in the unit-root test results of the EC term for the monthly exchange rate model in Table 12. Compared with those REER based ECMs, it is apparent that the very good fit is crucially due to the explanatory power of the short-run common factors. Remarkably, the overall fit of (6b) even exceeds that of (6a).

Japan: PcGets testimation reveals that sensible DF-ECMs become possible only for post-1980 sub-samples. In fact, only the current-period, first short-run factor survives in the full-sample experiment of the monthly exchange rate DF-ECM (see Table 5). This is also discernible from the recursive estimation graphs in the lower panels of Figure 6, where convergence to constancy of the feedback coefficients occurs around the end of the 1980s. The REER term becomes significant in the monthly inflation model but its coefficient fails the constancy test (see Table 9).

UK: Noticeably from Figure 7, the dynamic pattern of $\ln(REER)$ resembles that of the DF-based EC term of the exchange rate models, except for the post 2000 period. This may help to explain why the REER based EC terms are significant in the exchange rate ECMs, the only case so far. But the coefficients suffer from non-constancy (see Table 10). The covariation coefficients turn out to be the smallest of the five countries on the whole (see

Figure 2), a feature alternatively revealed in the unexpectedly low rankings of the country in the correlation coefficient sequences in Tables 3 and 4.

5. Concluding Comments

This study explores a new modelling approach of empirically verifying the equilibrating power of PPP. Under the new approach, PPP is found to be significantly at work in a fairly robust and constant manner. The finding is based on aggregate data of monthly frequency for five OECD countries. It reverses the commonly held belief, based on numerous previous results, that PPP is at best a very long-run relationship at the macro level, verifiable only with low-frequency data over very long sample periods.

A key reason for the present PPP evidence is that the new approach provides a more appropriate and convenient means, as compared to previously available means, to fill in the gap between the theoretical assumption of one foreign numéraire under a perfect market condition and the reality of one home country facing numerous dissimilar foreign economies under imperfect market conditions. By identifying the price disparities embodying PPP with latent dynamic factors, we are able to filter out, as idiosyncratic shocks, those heterogeneous, economy-specific parts of information from aggregate data without resorting to more disaggregate data information.

Another advantage of the new approach is the combination of dynamic factors with the ECM approach. Conceptually, the long-run common factors match with the leading indicator interpretation of the EC term in an ECM, and the ECM lends its structural interpretation conveniently to both the long-run and the short-run factors. Empirically, the ECM and the associate general-to-specific modelling strategy renders more robust and straightforward empirical results than those by various means of nonstationarity tests or nonlinear models.

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Table 1: Variable and Data Sources

Economy	Variable and source	Particulars
Australia	CPI and US$ exchange rate from Datastream; CPI is from Australian Bureau of Statistics	CPI is quarterly
Austria	CPI = OEI64 of IFS; US$ exchange rate from Datastream	
Belgium	CPI = BGI64 of IFS; US$ exchange rate from Datastream	
Brazil	CPI = BRI64 of IFS; US$ exchange rate from Datastream	CPI sample starts from: 1980M02
Canada	CPI = CNI64 of IFS; US$ exchange rate from Datastream REER from Datastream (OECD source)	
China	CPI = CHI64 of IFS; US$ exchange rate from Datastream; For data prior to 1993 are from State Bureau of Statistics of China	CPI sample starts from: 1982M01
Czech Republic	CPI = CZI64 of IFS; US$ exchange rate from Datastream	CPI sample starts from: 1991M01; exchange rate starts from: 1993M01
Denmark	CPI = DKI64 of IFS; US$ exchange rate from Datastream	
France	CPI = FRI64 of IFS; US$ exchange rate from Datastream REER from Datastream (OECD source)	REER sample starts from: 1980M01
Germany	CPI = BDI64 of IFS; US$ exchange rate from Datastream REER from Datastream (OECD source)	
Hong Kong	CPI = HKI64 of IFS; US$ exchange rate from Datastream	
India	CPI = INI64 of IFS; US$ exchange rate from Datastream	
Ireland	CPI = IRI64 of IFS; US$ exchange rate from Datastream	
Italy	CPI = ITI64 of IFS; US$ exchange rate from Datastream	
Japan	CPI = JPI64 of IFS; US$ exchange rate from Datastream REER from Datastream (OECD source)	
Korea, South	CPI = KOI64 of IFS; US$ exchange rate from Datastream	
Malaysia	CPI = MYI64 of IFS; US$ exchange rate from Datastream	
Mexico	CPI = MXI64 of IFS; US$ exchange rate from Datastream	
Netherlands	CPI = NLI64 of IFS; US$ exchange rate from Datastream	
Norway	CPI = NWI64 of IFS; US$ exchange rate from Datastream	
Poland	CPI = POI64 of IFS; US$ exchange rate from Datastream	Sample for both series: 1988M1 — 2005M12
Saudi Arabia	CPI = SII64 of IFS; US$ exchange rate from Datastream	CPI sample: 1980M2 — 2005M12
Singapore	CPI = SPI64 of IFS; US$ exchange rate from Datastream	
Spain	CPI = ESI64 of IFS; US$ exchange rate from Datastream	
Sweden	CPI = SDI64 of IFS; US$ exchange rate from Datastream	
Switzerland	CPI = SWI64 of IFS; US$ exchange rate from Datastream	
Taiwan	CPI and US$ exchange rate from Datastream; CPI is from Directorate General of Budgets, Accounting and Statistics, Executive Yuan of Taiwan	
Thailand	CPI = THI64 of IFS; US$ exchange rate from Datastream	
Turkey	CPI = TKI64 of IFS; US$ exchange rate from Datastream	
UK	CPI = UKI64 of IFS; US$ exchange rate from Datastream REER from Datastream (OECD source)	
USA	CPI = USI64 of IFS	

Note: All the series are monthly for the period of 1975M1 — 2005M12 except for those noted in the particulars. IFS denotes *International Financial Statistics* by IMF.

Table 2. Specification of the DFMs (4) and (5)

	Number of factors (Onatski procedure / Bai-Ng procedure)			Lag length for DFM (4)
	Long run	Short run (quarterly)	Short run (monthly)	
Canada	5 / 3	5 / 1	5 / 1	2
France	6 / 6	5 / 1	5 / 1	3
Germany	6 / 3	5 / 1	5 / 1	2
Japan	6 / 3	5 / 1	5 / 1	3
UK	6 / 5	5 / 1	5 / 1	2

Note: The larger number is adopted for the number of factors when the estimates of the two procedures differ. The lag length for DFM (5) remains one.

Table 3. Ranked correlation coefficients between the indicators in Q_t and the fitted $\left(\hat{\Gamma}^* \hat{F}_t^*\right)$ of DFM (4)

	Canada	France	Germany	Japan	UK
1	0.973 USA	0.967 Austria	0.971 Malaysia	0.977 Malaysia	0.970 Belgium
2	0.963 Malaysia	0.965 Malaysia	0.970 Austria	0.976 India	0.962 Germany
3	0.958 Denmark	0.958 Saudi Arabia	0.969 Czech Repub.	0.975 Belgium	0.962 Malaysia
4	0.952 Austria	0.957 Czech Repub.	0.968 Saudi Arabia	0.973 Netherlands	0.961 Netherlands
5	0.948 Belgium	0.955 USA	0.954 USA	0.970 Germany	0.955 Austria
6	0.943 Netherlands	0.948 India	0.953 India	0.969 France	0.953 India
7	0.942 France	0.941 Singapore	0.946 Hong Kong	0.969 Czech Repub.	0.950 Denmark
8	0.941 Germany	0.933 China	0.941 Singapore	0.965 USA	0.950 France
9	0.939 Thailand	0.923 Denmark	0.935 China	0.965 Thailand	0.941 China
10	0.937 Singapore	0.921 Taiwan	0.931 Thailand	0.961 Denmark	0.941 Thailand
11	0.932 Poland	0.921 Ireland	0.926 Ireland	0.954 Austria	0.940 Saudi Arabia
12	0.928 Switzerland	0.920 Thailand	0.925 Netherlands	0.952 Sweden	0.938 USA
13	0.912 India	0.916 Belgium	0.920 Italy	0.951 Taiwan	0.936 Singapore
14	0.912 Taiwan	0.910 Netherlands	0.919 Taiwan	0.951 Norway	0.935 Taiwan
15	0.910 Italy	0.910 Poland	0.882 Poland	0.948 Italy	0.921 Sweden
16	0.907 Spain	0.908 Italy	0.880 Sweden	0.948 Ireland	0.907 Norway
17	0.884 China	0.886 Germany	0.867 Spain	0.938 Canada	0.903 Canada
18	0.884 Ireland	0.883 Hong Kong	0.847 Denmark	0.938 Spain	0.893 Italy
19	0.875 Norway	0.870 Canada	0.844 Canada	0.930 China	0.887 Czech Repub.
20	0.875 Japan	0.861 Switzerland	0.833 UK	0.917 Australia	0.885 Hong Kong
21	0.873 Saudi Arabia	0.858 Spain	0.823 Japan	0.914 Saudi Arabia	0.879 Spain
22	0.863 Czech Repub.	0.839 Japan	0.822 Norway	0.913 Hong Kong	0.877 Ireland
23	0.858 Hong Kong	0.830 UK	0.821 Belgium	0.897 Switzerland	0.877 Switzerland
24	0.832 Turkey	0.820 Sweden	0.811 Switzerland	0.895 Singapore	0.830 Poland
25	0.822 Sweden	0.801 Turkey	0.797 Turkey	0.892 Turkey	0.829 Mexico
26	0.771 UK	0.759 Norway	0.764 France	0.873 Poland	0.821 Australia
27	0.747 South Korea	0.673 Australia	0.736 Australia	0.872 South Korea	0.820 South Korea
28	0.697 Mexico	0.672 South Korea	0.735 South Korea	0.842 Mexico	0.805 Turkey
29	0.497 Australia	0.601 Mexico	0.735 Mexico	0.834 UK	0.785 Japan
30	0.063 Brazil	0.074 Brazil	0.069 Brazil	0.048 Brazil	0.066 Brazil

Note: Adjusted R^2 is used, instead of the simple R^2 in order to make comparable the cases with different numbers of factors.

Table 4. Ranked correlation coefficients between the indicators in P_t and the fitted $\left(\hat{\Gamma}\hat{F}_t\right)$ of DFM (5) using quarterly rates

	Canada	France	Germany	Japan	UK
1	0.538 Malaysia	0.552 Malaysia	0.537 Malaysia	0.535 Malaysia	0.519 South Korea
2	0.469 France	0.469 Denmark	0.469 Denmark	0.469 Denmark	0.467 Denmark
3	0.457 Norway	0.457 Norway	0.455 Belgium	0.457 Norway	0.453 Netherlands
4	0.456 Belgium	0.454 Belgium	0.454 Norway	0.455 Belgium	0.453 Belgium
5	0.452 Hong Kong	0.450 Hong Kong	0.444 Austria	0.452 Germany	0.450 Germany
6	0.449 Austria	0.446 Austria	0.431 France	0.448 Austria	0.445 Austria
7	0.441 Japan	0.410 Germany	0.429 Hong Kong	0.431 France	0.428 France
8	0.436 Germany	0.403 Japan	0.412 Japan	0.412 Italy	0.404 USA
9	0.390 Italy	0.388 Italy	0.395 Italy	0.408 South Korea	0.399 Italy
10	0.379 Singapore	0.382 Singapore	0.384 Singapore	0.401 Ireland	0.381 Hong Kong
11	0.374 Netherlands	0.371 India	0.373 Taiwan	0.383 Singapore	0.377 Norway
12	0.373 Taiwan	0.369 Taiwan	0.367 Switzerland	0.371 Taiwan	0.368 Ireland
13	0.360 Switzerland	0.367 Switzerland	0.366 India	0.366 Switzerland	0.365 Switzerland
14	0.359 Sweden	0.340 Sweden	0.346 Sweden	0.362 Hong Kong	0.357 Sweden
15	0.356 Poland	0.323 USA	0.327 Turkey	0.348 Turkey	0.342 Spain
16	0.356 Denmark	0.323 Turkey	0.320 USA	0.344 Sweden	0.328 Thailand
17	0.343 Mexico	0.318 Mexico	0.316 Poland	0.328 Mexico	0.326 Malaysia
18	0.324 Ireland	0.315 Poland	0.313 Mexico	0.326 USA	0.314 Poland
19	0.324 Turkey	0.302 Ireland	0.296 Thailand	0.319 India	0.292 Singapore
20	0.313 USA	0.290 Spain	0.286 Spain	0.309 Poland	0.292 Taiwan
21	0.310 India	0.288 Thailand	0.284 Ireland	0.287 Spain	0.285 Canada
22	0.291 Thailand	0.228 Canada	0.230 Canada	0.286 Thailand	0.249 Turkey
23	0.235 Spain	0.188 South Korea	0.193 South Korea	0.238 Canada	0.194 Japan
24	0.196 South Korea	0.175 Netherlands	0.172 Netherlands	0.170 Netherlands	0.167 Mexico
25	0.141 Czech Repub.	0.145 Brazil	0.141 Brazil	0.153 Brazil	0.144 India
26	0.129 Saudi Arabia	0.107 Czech Repub.	0.102 Czech Repub.	0.112 Czech Repub.	0.143 Brazil
27	0.089 Brazil	0.085 Saudi Arabia	0.083 Saudi Arabia	0.082 Saudi Arabia	0.112 Australia
28	0.078 Australia	0.070 Australia	0.079 UK	0.064 Australia	0.087 Czech Repub.
29	0.062 UK	0.068 UK	0.078 Australia	0.057 UK	0.064 Saudi Arabia
30	0.038 China	0.035 China	0.044 China	0.021 China	0.034 China

Note: Adjusted R^2 is used, instead of the simple R^2 in order to make comparable the cases with different numbers of factors.

Table 5. Summary statistics of model-fit via PcGets testimation of (6a) and (6b)

Country	Equation	Sample starting point	General model Adjusted R^2	General model Schwarz criterion	Specific model Adjusted R^2	Specific model Schwarz criterion	Number of parameters from general → specific
Canada	$\Delta_3 \ln(e_d)_t$	1975M10	0.6044	-7.5155	0.6141	-8.0683	54 → 14
		1980M01	0.6247	-7.4651	0.6419	-8.0892	54 → 15
	$\Delta \ln(e_d)_t$	1975M08	0.0692	-7.7213	0.076	-8.3877	54 → 4
		1980M01	0.0701	-7.6551	0.1104	-8.3971	54 → 7
	$\Delta_3 \ln(p_d)_t$	1975M10	0.8342	-10.492	0.8322	-11.008	54 → 14
		1980M01	0.8516	-10.426	0.8125	-11.032	54 → 10
	$\Delta \ln(p_d)_t$	1975M08	0.3019	-10.668	0.3027	-11.315	54 → 5
		1980M01	0.2663	-10.591	0.2703	-11.325	54 → 5
France	$\Delta_3 \ln(e_d)_t$	1975M10	0.9771	-8.8107	0.9769	-9.1792	55 → 26
		1980M01	0.9880	-9.2605	0.9877	-9.6195	55 → 29
	$\Delta \ln(e_d)_t$	1975M10	0.9413	-9.0411	0.9414	-9.5694	55 → 15
		1980M01	0.9665	-9.4696	0.9648	-9.9344	55 → 20
	$\Delta_3 \ln(p_d)_t$	1975M10	0.9523	-11.46	0.9507	-11.968	55 → 14
		1980M01	0.9543	-11.594	0.9536	-12.109	55 → 19
	$\Delta \ln(p_d)_t$	1975M10	0.6818	-11.493	0.6765	-12.071	55 → 10
		1980M01	0.7147	-11.673	0.7011	-12.188	55 → 17
Germany	$\Delta_3 \ln(e_d)_t$	1975M10	0.9930	-9.943	0.993	-10.286	55 → 29
		1980M01	0.9944	-10.006	0.9943	-10.418	55 → 26
	$\Delta \ln(e_d)_t$	1975M08	0.978	-9.9772	0.9789	-10.478	55 → 20
		1980M01	0.9831	-10.127	0.9827	-10.663	55 → 17
	$\Delta_3 \ln(p_d)_t$	1975M10	0.7726	-10.892	0.7665	-11.366	55 → 17
		1980M01	0.7993	-10.934	0.8013	-11.461	55 → 20
	$\Delta \ln(p_d)_t$	1975M08	0.2045	-11.024	0.2109	-11.597	55 → 12
		1980M01	0.2522	-10.974	0.2429	-11.598	55 → 12
Japan	$\Delta_3 \ln(e_d)_t$	1975M10	0.7386	-6.1799	0.735	-6.6134	55 → 21
		1980M01	0.7386	-6.086	0.7252	-6.6428	55 → 14
	$\Delta \ln(e_d)_t$	1975M08	0.3116	-6.4049	0.3134	-7.1198	55 → 1
		1985M01	0.3704	-6.2411	0.3633	-7.0829	55 → 6
	$\Delta_3 \ln(p_d)_t$	1975M10	0.7758	-9.9873	0.7798	-10.307	55 → 32
		1980M01	0.7414	-10.115	0.7300	-10.619	55 → 18
	$\Delta \ln(p_d)_t$	1975M08	0.3198	-10.307	0.3109	-10.901	55 → 14
		1980M01	0.3437	-10.502	0.3228	-11.216	55 → 12
UK	$\Delta_3 \ln(e_d)_t$	1975M10	0.7993	-6.678	0.8042	-7.1501	55 → 21
		1980M01	0.8066	-6.6176	0.8102	-7.1977	55 → 17
	$\Delta \ln(e_d)_t$	1975M08	0.5651	-7.0798	0.5755	-7.7225	55 → 8
		1980M01	0.5666	-6.9828	0.5636	-7.7184	55 → 5
	$\Delta_3 \ln(p_d)_t$	1975M10	0.8611	-9.8515	0.8565	-10.266	55 → 21
		1980M01	0.8225	-9.9047	0.814	-10.465	55 → 14
	$\Delta \ln(p_d)_t$	1975M08	0.3824	-10.013	0.3547	-10.547	55 → 11
		1980M01	0.3895	-10.21	0.3629	-10.729	55 → 17

Note: six lags are used in the general models. All samples end at 2005M12.

Table 6. Specific models of (6a) and (6b) versus ECMs of *REER*: Canada

(6a)

$$\Delta_3 \ln\left(\hat{p}_d\right)_t = \underset{\substack{(0.0005)\\(0.1089)}}{0.0026} + \underset{\substack{(0.0375)\\(0.1451)}}{0.8991}\,\Delta_3 \ln\left(p_d\right)_{t-1} - \underset{\substack{(0.0512)\\(0.2417)}}{0.5165}\,\Delta\Delta_3 \ln\left(p_d\right)_{t-3} - \underset{\substack{(0.0364)\\(0.2035)}}{0.1471}\,\Delta_3 \ln\left(p_d\right)_{t-5} + \underset{\substack{(0.00009)\\(0.0444)}}{0.0002}\, f_{1,t-6}$$

$$- \underset{\substack{(0.0002)\\(0.3773)}}{0.0006}\,\Delta_4 f_{5,t} + \underset{\substack{(0.0004)\\(0.4097)}}{0.0017}\,\Delta f_{5,t-1} + \underset{\substack{(0.0005)\\(0.2539)}}{0.0029}\,\Delta f_{5,t-4} - \underset{\substack{(0.0003)\\(0.2118)}}{0.0011}\,\Delta_2 f_{5,t-4} + \underset{\substack{(0.00003)\\(0.0775)}}{0.0002}\ln\left(\hat{q}_d\right)_{t-3}$$

$$\ln\left(\hat{q}_d\right)_{t-3} = \left(f_1^* - 4f_2^* - f_4^* - f_5^*\right)_{t-3}; \qquad R^2 = 0.8382 \quad \overline{R}^2 = 0.8331$$

$$\Delta \ln\left(\hat{p}_d\right)_t = \underset{\substack{(0.00025)\\(0.1398)}}{0.003} + \underset{\substack{(0.0506)\\(0.3827)}}{0.1695}\,\Delta \ln\left(p_d\right)_{t-4} - \underset{\substack{(0.00006)\\(0.3045)}}{0.0002}\, f_{1,t-2} + \underset{\substack{(0.00002)\\(0.0963)}}{0.0002}\ln\left(\hat{q}_d\right)_{t-1}$$

$$\ln\left(\hat{q}_d\right)_{t-1} = \left(f_1^* - 4f_2^* - 0.5f_4^* - 2f_5^*\right)_{t-1}; \qquad R^2 = 0.3305 \quad \overline{R}^2 = 0.3249$$

Using *REER*:

$$\Delta_3 \ln\left(\hat{p}_d\right)_t = \underset{\substack{(0.0089)\\(0.5783)^*}}{0.0091} + \underset{\substack{(0.024)\\(0.4444)}}{0.9173}\,\Delta_3 \ln\left(p_d\right)_{t-1} - \underset{\substack{(0.0469)\\(0.2899)}}{0.4175}\,\Delta\Delta_3 \ln\left(p_d\right)_{t-3} + \underset{\substack{(0.0458)\\(0.0616)}}{0.1098}\,\Delta\Delta_3 \ln\left(p_d\right)_{t-4}$$

$$- \underset{\substack{(0.0081)\\(0.1484)}}{0.0179}\,\Delta_3 \ln\left(e_d\right)_{t-2} - \underset{\substack{(0.0019)\\(0.5666)^*}}{0.0018}\ln\left(REER\right)_{t-3} \qquad R^2 = 0.8088$$

$$\Delta \ln\left(\hat{p}_d\right)_t = \underset{\substack{(0.0078)\\(1.0824)^{**}}}{0.0035} + \underset{\substack{(0.0233)\\(1.3596)}}{0.1555}\,\Delta_3 \ln\left(p_d\right)_{t-1} + \underset{\substack{(0.0527)\\(1.5807)^{**}}}{0.2623}\,\Delta \ln\left(p_d\right)_{t-4} - \underset{\substack{(0.0087)\\(0.1596)}}{0.0267}\,\Delta\Delta \ln\left(e_d\right)_{t-1}$$

$$- \underset{\substack{(0.0016)\\(1.0707)^{**}}}{0.0005}\ln\left(REER\right)_{t-1} \qquad R^2 = 0.28$$

(6b)

$$\Delta_3 \ln\left(\hat{e}_d\right)_t = \underset{\substack{(0.0008)\\(0.0917)}}{0.0007} + \underset{\substack{(0.0376)\\(0.3448)}}{0.7554}\,\Delta_3 \ln\left(e_d\right)_{t-1} - \underset{\substack{(0.0498)\\(0.142)}}{0.517}\,\Delta_3 \ln\left(e_d\right)_{t-3} + \underset{\substack{(0.05)\\(0.092)}}{0.379}\,\Delta_3 \ln\left(e_d\right)_{t-4} - \underset{\substack{(0.0367)\\(0.1139)}}{0.1866}\,\Delta_3 \ln\left(e_d\right)_{t-6}$$

$$+ \underset{\substack{(0.0005)\\(0.335)}}{0.0028}\,\Delta f_{1,t} - \underset{\substack{(0.0007)\\(0.3426)}}{0.0023}\, f_{2,t} + \underset{\substack{(0.0013)\\(0.0693)}}{0.0046}\,\Delta f_{2,t-1} + \underset{\substack{(0.0011)\\(0.0714)}}{0.0038}\,\Delta f_{2,t-4} - \underset{\substack{(0.0007)\\(0.4102)}}{0.0016}\, f_{4,t} - \underset{\substack{(0.0001)\\(0.3773)}}{0.0008}\ln\left(\hat{q}_d\right)_{t-3}$$

$$\ln\left(\hat{q}_d\right)_{t-3} = \left(f_1^* - f_2^* - 1.3f_3^* - f_4^* + 3f_5^*\right)_{t-3}; \qquad R^2 = 0.6332; \quad \overline{R}^2 = 0.6228$$

$$\Delta \ln\left(\hat{e}_d\right)_t = \underset{\substack{(0.0007)\\(0.111)}}{0.0006} - \underset{\substack{(0.051)\\(0.2195)}}{0.0986}\,\Delta \ln\left(e_d\right)_{t-2} + \underset{\substack{(0.0003)\\(0.4243)}}{0.0012}\, f_{1,t} + \underset{\substack{(0.0006)\\(0.0404)}}{0.0016}\,\Delta f_{2,t} + \underset{\substack{(0.0013)\\(0.8646)^{**}}}{0.0026}\, f_{3,t} - \underset{\substack{(0.001)\\(0.2023)}}{0.0019}\, f_{4,t} - \underset{\substack{(0.0001)\\(0.18)}}{0.0006}\ln\left(\hat{q}_d\right)_{t-1}$$

$$\ln\left(\hat{q}_d\right)_{t-1} = \left(f_1^* - f_2^* - f_3^* - f_4^* + 2f_5^*\right)_{t-1}; \qquad R^2 = 0.1274; \quad \overline{R}^2 = 0.112$$

Using *REER*:

$$\Delta_3 \ln\left(\hat{e}_d\right)_t = \underset{\substack{(0.0388)\\(0.4092)}}{0.0478} + \underset{\substack{(0.0397)\\(0.1274)}}{0.8209}\,\Delta_3 \ln\left(e_d\right)_{t-1} - \underset{\substack{(0.0546)\\(0.2461)}}{0.51}\,\Delta_3 \ln\left(e_d\right)_{t-3} + \underset{\substack{(0.0545)\\(0.1312)}}{0.4002}\,\Delta_3 \ln\left(e_d\right)_{t-4}$$

$$- \underset{\substack{(0.0398)\\(0.1188)}}{0.1434}\,\Delta_3 \ln\left(e_d\right)_{t-6} - \underset{\substack{(0.0082)\\(0.4031)}}{0.0102}\ln\left(REER\right)_{t-3} \qquad R^2 = 0.5611$$

$$\Delta \ln\left(\hat{e}_d\right)_t = \underset{\substack{(0.033)\\(0.2789)}}{0.0332} - \underset{\substack{(0.0525)\\(0.2104)}}{0.139}\,\Delta \ln\left(e_d\right)_{t-9} - \underset{\substack{(0.007)\\(0.2724)}}{0.0071}\ln\left(REER\right)_{t-1} \qquad R^2 = 0.0222$$

Note: Samples used for DF-ECMs: 1976M01-2005M12; Samples for *REER* equations: 1977M01-2005M12. $\overline{R}^2$ denotes adjusted R^2. The intercept term is kept in all models irrespective of its statistical significance in order to obtain the R^2 statistics. The statistics in the upper brackets under the coefficient estimates are the standard errors; those in the lower brackets are Hansen parameter instability test statistics. Its 5% critical value is 0.47. Statistical significance at the 5% and 1% levels are marked by * and ** respectively.

Table 7. Specific models of (6a) and (6b) versus ECMs of *REER*: France

(6a)

$$\Delta_3 \ln(\hat{p}_d)_t = \underset{\substack{(0.0004)\\(0.0432)}}{0.0029} + \underset{\substack{(0.0309)\\(0.209)}}{0.79}\, \Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.0533)\\(0.3475)}}{0.3917}\, \Delta\Delta_3 \ln(p_d)_{t-1} - \underset{\substack{(0.0432)\\(0.1529)}}{0.4797}\, \Delta\Delta_3 \ln(p_d)_{t-3}$$

$$+ \underset{\substack{(0.0503)\\(0.1341)}}{0.1778}\, \Delta\Delta_3 \ln(p_d)_{t-4} - \underset{\substack{(0.0097)\\(0.0842)}}{0.0459}\, \Delta\Delta_3 \ln(e_d)_t + \underset{\substack{(0.0002)\\(0.0773)}}{0.001}\, \Delta f_{1,t} + \underset{\substack{(0.000046)\\(0.1234)}}{0.0002}\, f_{1,t-5}$$

$$- \underset{\substack{(0.00009)\\(0.0355)}}{0.0003}\, f_{4,t-2} - \underset{\substack{(0.0001)\\(0.0765)}}{0.0009}\, \ln(\hat{q}_d)_{t-3}$$

$$\ln(\hat{q}_d)_{t-3} = \left(f_1^* + 0.8 f_3^* + 0.24 f_4^* + 0.2 f_5^* + 0.2 f_6^*\right)_{t-3}; \qquad R^2 = 0.9554 \quad \overline{R}^2 = 0.9541$$

$$\Delta \ln(\hat{p}_d)_t = \underset{\substack{(0.0003)\\(0.0192)}}{0.0024} + \underset{\substack{(0.0472)\\(0.1157)}}{0.1633}\, \Delta \ln(p_d)_{t-1} + \underset{\substack{(0.0447)\\(0.0657)}}{0.2965}\, \Delta \ln(p_d)_{t-6} - \underset{\substack{(0.0148)\\(0.085)}}{0.0817}\, \Delta \ln(e_d)_t - \underset{\substack{(0.0002)\\(0.0986)}}{0.0009}\, f_{1,t}$$

$$+ \underset{\substack{(0.00002)\\(0.4901)^*}}{0.0001}\left[f_{1,t-5} + f_{1,t-6}\right] + \underset{\substack{(0.00016)\\(0.1205)}}{0.0005}\, f_{3,t-3} + \underset{\substack{(0.0001)\\(0.2132)}}{0.0004}\, f_{5,t-4} - \underset{\substack{(0.00009)\\(0.0209)}}{0.0006}\, \ln(\hat{q}_d)_{t-1}$$

$$\ln(\hat{q}_d)_{t-1} = \left(f_1^* + f_3^* + 0.24 f_4^* + 0.2 f_5^* + 0.2 f_6^*\right)_{t-1}; \qquad R^2 = 0.7204 \quad \overline{R}^2 = 0.7133$$

Using *REER*:

$$\Delta_3 \ln(\hat{p}_d)_t = -\underset{\substack{(0.014)\\(0.1588)}}{0.0001} + \underset{\substack{(0.0509)\\(0.542)^*}}{0.8027}\, \Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.084)\\(0.3855)}}{0.51}\, \Delta\Delta_3 \ln(p_d)_{t-1} - \underset{\substack{(0.0696)\\(0.4037)}}{0.4335}\, \Delta\Delta\Delta_3 \ln(p_d)_{t-3}$$

$$+ \underset{\substack{(0.0506)\\(0.1741)}}{0.1464}\, \Delta_3 \ln(p_d)_{t-6} - \underset{\substack{(0.0023)\\(0.0457)}}{0.0047}\, \Delta_3 \ln(e_d)_t + \underset{\substack{(0.003)\\(0.1599)}}{0.00009}\, \ln(REER)_{t-3} \qquad R^2 = 0.938$$

$$\Delta \ln(\hat{p}_d)_t = -\underset{\substack{(0.0132)\\(0.174)}}{0.0087} + \underset{\substack{(0.0443)\\(0.6086)^*}}{0.3128}\, \Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.0457)\\(0.4105)}}{0.1603}\, \Delta \ln(p_d)_{t-3} + \underset{\substack{(0.0462)\\(0.1593)}}{0.388}\, \Delta \ln(p_d)_{t-6}$$

$$- \underset{\substack{(0.0039)\\(0.2664)}}{0.0092}\, \Delta \ln(e_d)_{t-1} + \underset{\substack{(0.0028)\\(0.1773)}}{0.0019}\, \ln(REER)_{t-1} \qquad R^2 = 0.6257$$

(6b)

$$\Delta_3 \ln(\hat{e}_d)_t = \underset{\substack{(0.0013)\\(0.0442)}}{0.0146} + \underset{\substack{(0.0315)\\(0.2355)}}{0.5785}\, \Delta_2\Delta_3 \ln(e_d)_{t-1} + \underset{\substack{(0.0214)\\(0.049)}}{0.1815}\left[\Delta_3 \ln(e_d)_{t-2} + \Delta_3 \ln(e_d)_{t-4}\right] - \underset{\substack{(0.0855)\\(0.0297)}}{1.0758}\, \Delta_3 \ln(p_d)_t$$

$$+ \underset{\substack{(0.0981)\\(0.4545)}}{0.6979}\, \Delta_2\Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.0002)\\(0.2056)}}{0.00212}\, f_{1,t} - \underset{\substack{(0.0007)\\(0.2895)}}{0.0127}\, \Delta_2 f_{1,t-1} - \underset{\substack{(0.0005)\\(0.0951)}}{0.0039}\left[f_{1,t-2} + f_{1,t-4}\right] - \underset{\substack{(0.0004)\\(0.0578)}}{0.0044}\, f_{2,t}$$

$$- \underset{\substack{(0.0005)\\(0.1167)}}{0.002}\, \Delta f_{2,t} + \underset{\substack{(0.0004)\\(0.0482)}}{0.0025}\, \Delta_2 f_{2,t-1} - \underset{\substack{(0.0004)\\(0.5386)^*}}{0.0011}\, f_{3,t-4} + \underset{\substack{(0.0007)\\(0.0639)}}{0.0022}\, \Delta f_{3,t-5} + \underset{\substack{(0.0005)\\(0.1511)}}{0.0011}\, \Delta f_{4,t-2} - \underset{\substack{(0.0003)\\(0.1118)}}{0.0023}\, \ln(\hat{q}_d)_{t-3}$$

$$\ln(\hat{q}_d)_{t-3} = \left(f_1^* + 0.2 f_2^* + 1.5 f_3^* + 0.6 f_4^* + f_5^*\right)_{t-3}; \qquad R^2 = 0.9864; \quad \overline{R}^2 = 0.9858$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.0007)\\(0.0573)}}{0.0056} - \underset{\substack{(0.0447)\\(0.4127)}}{0.155}\, \Delta \ln(e_d)_{t-4} - \underset{\substack{(0.069)\\(0.0599)}}{0.6915}\left[\Delta \ln(p_d)_t + \Delta \ln(p_d)_{t-4}\right] + \underset{\substack{(0.0001)\\(0.3084)}}{0.0103}\, f_{1,t} + \underset{\substack{(0.0005)\\(0.4472)}}{0.0018}\, f_{1,t-4}$$

$$- \underset{\substack{(0.0003)\\(0.2187)}}{0.0025}\, f_{2,t} - \underset{\substack{(0.0003)\\(0.3293)}}{0.0007}\, f_{2,t-4} - \underset{\substack{(0.0004)\\(0.0547)}}{0.0014}\, \Delta f_{3,t} + \underset{\substack{(0.0003)\\(0.0913)}}{0.0017}\, \Delta_3 f_{3,t} - \underset{\substack{(0.0004)\\(0.1786)}}{0.0015}\, \Delta f_{3,t-2} + \underset{\substack{(0.0005)\\(0.0522)}}{0.0012}\, f_{3,t-4} - \underset{\substack{(0.0001)\\(0.0407)}}{0.0007}\, \ln(\hat{q}_d)_{t-1}$$

$$\ln(\hat{q}_d)_{t-1} = \left(f_1^* + 0.2 f_2^* + 1.5 f_3^* + 0.6 f_4^* + f_5^*\right)_{t-1}; \qquad R^2 = 0.9629; \quad \overline{R}^2 = 0.9616$$

Using *REER*:

$$\Delta_3 \ln(\hat{e}_d)_t = \underset{\substack{(0.2299)\\(0.1602)}}{0.3088} + \underset{\substack{(0.043)\\(0.0179)}}{0.87}\, \Delta_3 \ln(e_d)_{t-1} - \underset{\substack{(0.0628)\\(0.2249)}}{0.5313}\, \Delta_3 \ln(e_d)_{t-3} + \underset{\substack{(0.0625)\\(0.149)}}{0.3667}\, \Delta_3 \ln(e_d)_{t-4}$$

$$- \underset{\substack{(0.0423)\\(0.1302)}}{0.0987}\, \Delta_3 \ln(e_d)_{t-6} - \underset{\substack{(0.2544)\\(0.0275)}}{0.5737}\, \Delta_3 \ln(p_d)_t - \underset{\substack{(0.0492)\\(0.1592)}}{0.065}\, \ln(REER)_{t-3} \qquad R^2 = 0.6222$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.1895)\\(0.1593)}}{0.3189} - \underset{\substack{(0.5249)\\(0.1152)}}{1.373}\, \Delta \ln(p_d)_t - \underset{\substack{(0.0405)\\(0.1586)}}{0.0674}\, \ln(REER)_{t-1} \qquad R^2 = 0.0356$$

Note: Samples used for DF-ECMs: 1979M01-2005M12; Samples for *REER* equations: 1980M01-2005M12. See also the note in Table 6.

Table 8. Specific models of (6a) and (6b) versus ECMs of *REER*: Germany

(6a)

$$\Delta_3 \ln(\hat{p}_d)_t = \underset{\substack{(0.0004)\\(0.0762)}}{0.0039} + \underset{\substack{(0.0366)\\(0.3516)}}{0.8194}\,\Delta_3 \ln(p_d)_{t-1} - \underset{\substack{(0.052)\\(0.1212)}}{0.565}\,\Delta_3 \ln(p_d)_{t-3} + \underset{\substack{(0.0521)\\(0.0798)}}{0.3526}\,\Delta_3 \ln(p_d)_{t-4} - \underset{\substack{(0.0349)\\(0.0726)}}{0.1977}\,\Delta_3 \ln(p_d)_{t-6}$$

$$- \underset{\substack{(0.0029)\\(0.4976)^{*}}}{0.0088}\,\Delta_3 \ln(e_d)_t - \underset{\substack{(0.000065)\\(0.4679)}}{0.0002}\, f_{1,t-3} + \underset{\substack{(0.0001)\\(0.1162)}}{0.0006}\, f_{3,t-4} - \underset{\substack{(0.0001)\\(0.4192)}}{0.0005}\, f_{5,t-1} + \underset{\substack{(0.0002)\\(0.0724)}}{0.0011}\,\Delta f_{5,t-3} - \underset{\substack{(0.00005)\\(0.0779)}}{0.0005}\,\ln(\hat{q}_d)_{t-3}$$

$$\ln(\hat{q}_d)_{t-3} = \left(f_1^* - 0.3 f_2^* + 1.2 f_3^* - 0.3 f_4^* - 2 f_5^*\right)_{t-3}; \qquad R^2 = 0.7745 \qquad \overline{R}^2 = 0.7681$$

$$\Delta \ln(\hat{p}_d)_t = \underset{\substack{(0.0002)\\(0.0794)}}{0.0025} - \underset{\substack{(0.0507)\\(0.216)}}{0.1201}\,\Delta \ln(p_d)_{t-4} - \underset{\substack{(0.0234)\\(0.2537)}}{0.0743}\,\Delta \ln(e_d)_t + \underset{\substack{(0.00026)\\(0.1796)}}{0.0007}\, f_{1,t} - \underset{\substack{(0.0001)\\(0.3281)}}{0.0005}\left[f_{3,t-4} + f_{3,t-5}\right]$$

$$- \underset{\substack{(0.0001)\\(0.311)}}{0.0005}\left[f_{4,t-1} + f_{4,t-6}\right] + \underset{\substack{(0.0001)\\(0.0453)}}{0.0005}\, f_{5,t-6} - \underset{\substack{(0.00003)\\(0.059)}}{0.0003}\,\ln(\hat{q}_d)_{t-1}$$

$$\ln(\hat{q}_d)_{t-1} = \left(f_1^* - 0.6 f_2^* + f_3^* - 2.7 f_5^*\right)_{t-1}; \qquad R^2 = 0.2458 \qquad \overline{R}^2 = 0.2309$$

Using *REER*:

$$\Delta_3 \ln(\hat{p}_d)_t = - \underset{\substack{(0.0147)\\(0.673)^{*}}}{0.0312} + \underset{\substack{(0.0368)\\(1.1976)^{**}}}{0.968}\,\Delta_3 \ln(p_d)_{t-1} - \underset{\substack{(0.0589)\\(0.5795)^{*}}}{0.5749}\,\Delta_3 \ln(p_d)_{t-3} + \underset{\substack{(0.0586)\\(0.2714)}}{0.4407}\,\Delta_3 \ln(p_d)_{t-4}$$

$$- \underset{\substack{(0.036)\\(0.3364)}}{0.1273}\,\Delta_3 \ln(p_d)_{t-6} - \underset{\substack{(0.0037)\\(0.1428)}}{0.0097}\,\Delta_3 \ln(e_d)_{t-3} + \underset{\substack{(0.0045)\\(0.1756)}}{0.0115}\,\Delta\Delta_3 \ln(e_d)_{t-5} + \underset{\substack{(0.0031)\\(0.6819)^{*}}}{0.007}\,\ln(REER)_{t-3}$$

$$R^2 = 0.7059$$

$$\Delta \ln(\hat{p}_d)_t = - \underset{\substack{(0.0127)\\(0.4861)^{*}}}{0.0255} + \underset{\substack{(0.0525)\\(2.0975)^{**}}}{0.1472}\,\Delta \ln(p_d)_{t-1} + \underset{\substack{(0.0527)\\(0.7301)^{*}}}{0.1003}\,\Delta \ln(p_d)_{t-3} - \underset{\substack{(0.0051)\\(0.0446)}}{0.0125}\,\Delta \ln(e_d)_{t-4}$$

$$+ \underset{\substack{(0.0027)\\(0.4969)^{*}}}{0.0057}\,\ln(REER)_{t-1} \qquad R^2 = 0.0741$$

(6b)

$$\Delta_3 \ln(\hat{e}_d)_t = \underset{\substack{(0.0004)\\(0.0223)}}{0.001} + \underset{\substack{(0.0268)\\(0.1187)}}{0.818}\,\Delta_3 \ln(e_d)_{t-1} + \underset{\substack{(0.0083)\\(0.2369)}}{0.0457}\,\Delta\Delta_3 \ln(e_d)_{t-2} - \underset{\substack{(0.0409)\\(0.2173)}}{0.3573}\,\Delta\Delta_3 \ln(e_d)_{t-3} - \underset{\substack{(0.0482)\\(0.0371)}}{0.1117}\,\Delta_3 \ln(p_d)_t + \underset{\substack{(0.0006)\\(0.111)}}{0.003}\, f_{1,t}$$

$$+ \underset{\substack{(0.0006)\\(0.0665)}}{0.019}\,\Delta f_{1,t} + \underset{\substack{(0.00016)\\(0.0509)}}{0.0008}\, f_{1,t-3} + \underset{\substack{(0.0009)\\(0.1586)}}{0.0078}\,\Delta f_{1,t-3} - \underset{\substack{(0.0004)\\(0.1746)}}{0.0079}\,\Delta f_{2,t} - \underset{\substack{(0.0005)\\(0.5777)^{*}}}{0.0043}\,\Delta f_{2,t-3} - \underset{\substack{(0.0002)\\(0.1301)}}{0.001}\left[f_{2,t} + f_{2,t-5}\right]$$

$$+ \underset{\substack{(0.0005)\\(0.0511)}}{0.0031}\,\Delta f_{3,t} + \underset{\substack{(0.0003)\\(0.2434)}}{0.0018}\, f_{3,t-3} - \underset{\substack{(0.0003)\\(0.0743)}}{0.0009}\, f_{3,t-5} - \underset{\substack{(0.00035)\\(0.1683)}}{0.0023}\,\Delta f_{4,t} + \underset{\substack{(0.0003)\\(0.0496)}}{0.0023}\,\Delta f_{5,t} - \underset{\substack{(0.00017)\\(0.0606)}}{0.0005}\,\ln(\hat{q}_d)_{t-3}$$

$$\ln(\hat{q}_d)_{t-3} = f^*_{3,t-3}; \qquad R^2 = 0.9936; \qquad \overline{R}^2 = 0.9932$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.0003)\\(0.1906)}}{0.0019} - \underset{\substack{(0.0076)\\(0.3011)}}{0.0183}\,\Delta \ln(e_d)_{t-1} + \underset{\substack{(0.0388)\\(0.3682)}}{0.105}\,\Delta \ln(e_d)_{t-6} - \underset{\substack{(0.0528)\\(0.3201)}}{0.2083}\left[\Delta \ln(p_d)_t + \Delta \ln(p_d)_{t-3}\right]$$

$$+ \underset{\substack{(0.00008)\\(0.0641)}}{0.0107}\, f_{1,t} - \underset{\substack{(0.0004)\\(0.3766)}}{0.0012}\, f_{1,t-6} - \underset{\substack{(0.0002)\\(0.5609)^{*}}}{0.0032}\, f_{2,t} - \underset{\substack{(0.0004)\\(0.0396)}}{0.0024}\, f_{3,t} - \underset{\substack{(0.0003)\\(0.1107)}}{0.001}\left[f_{3,t-1} + f_{3,t-3}\right]$$

$$- \underset{\substack{(0.0003)\\(0.1204)}}{0.0012}\, f_{4,t-3} + \underset{\substack{(0.0003)\\(0.0484)}}{0.0021}\, f_{5,t} + \underset{\substack{(0.0002)\\(0.0877)}}{0.001}\left[f_{5,t-1} + f_{5,t-3}\right] - \underset{\substack{(0.0001)\\(0.0523)}}{0.0004}\,\ln(\hat{q}_d)_{t-1}$$

$$\ln(\hat{q}_d)_{t-1} = f^*_{3,t-1}; \qquad R^2 = 0.9827\ ; \qquad \overline{R}^2 = 0.9821$$

Using *REER*:

$$\Delta_3 \ln(\hat{e}_d)_t = \underset{\substack{(0.1583)\\(0.3044)}}{0.2461} + \underset{\substack{(0.0398)\\(0.0268)}}{0.8632}\,\Delta_3 \ln(e_d)_{t-1} - \underset{\substack{(0.0537)\\(0.1285)}}{0.4946}\,\Delta_3 \ln(e_d)_{t-3} + \underset{\substack{(0.0504)\\(0.1075)}}{0.2925}\,\Delta_3 \ln(e_d)_{t-4}$$

$$- \underset{\substack{(0.3787)\\(0.0695)}}{1.148}\,\Delta_3 \ln(p_d)_t + \underset{\substack{(0.5987)\\(0.0814)}}{1.9037}\,\Delta\Delta_3 \ln(p_d)_{t-2} + \underset{\substack{(0.3736)\\(0.0943)}}{0.8469}\,\Delta_3 \ln(p_d)_{t-5} - \underset{\substack{(0.0337)\\(0.3009)}}{0.0514}\,\ln(REER)_{t-3}$$

$$R^2 = 0.5998$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.1292)\\(0.2253)}}{0.2043} - \underset{\substack{(0.0516)\\(0.0777)}}{0.102}\,\Delta \ln(e_d)_{t-7} - \underset{\substack{(0.4237)\\(0.0553)}}{1.1374}\,\Delta\Delta \ln(p_d)_{t-1} - \underset{\substack{(0.0274)\\(0.223)}}{0.043}\,\ln(REER)_{t-1} \qquad R^2 = 0.0348$$

Note: Samples used for DF-ECMs of (6b): 1977M08-2005M12; Samples for all the other models: 1975M01-2005M12. See also the note in Table 6.

Table 9. Specific models of (6a) and (6b) versus ECMs of *REER*: Japan

(6a)

$$\begin{aligned}
\Delta_3 \ln(\hat{p}_d)_t = {} & \underset{\substack{(0.0004)\\(0.1704)}}{0.0033} + \underset{\substack{(0.0571)\\(0.0411)}}{0.260}\Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.0304)\\(0.0734)}}{0.3668}\Delta_2\Delta_3 \ln(p_d)_{t-1} - \underset{\substack{(0.0287)\\(0.1244)}}{0.2563}\Delta_2\Delta_3 \ln(p_d)_{t-2} + \underset{\substack{(0.00009)\\(0.3686)}}{0.0004}\Delta_4 f_{1,t} \\
& - \underset{\substack{(0.00016)\\(0.0722)}}{0.0005}\Delta f_{1,t-2} - \underset{\substack{(0.00018)\\(0.1433)}}{0.0008} f_{2,t} - \underset{\substack{(0.0003)\\(0.3824)}}{0.001}\Delta f_{2,t-3} - \underset{\substack{(0.0002)\\(0.0133)}}{0.0008} f_{2,t-6} - \underset{\substack{(0.0002)\\(0.1402)}}{0.0012} f_{4,t} + \underset{\substack{(0.0002)\\(0.2360)}}{0.001} f_{5,t-6} \\
& - \underset{\substack{(0.00009)\\(0.0535)}}{0.0007}\ln(\hat{q}_d)_{t-3}
\end{aligned}$$

$$\ln(\hat{q}_d)_{t-3} = \left(f_1^* - 0.3 f_2^* - f_4^* + 0.5 f_5^* - 0.5 f_6^*\right)_{t-3}; \quad R^2 = 0.7596 \quad \bar{R}^2 = 0.7511$$

$$\begin{aligned}
\Delta \ln(\hat{p}_d)_t = {} & \underset{\substack{(0.0003)\\(0.0329)}}{0.0028} + \underset{\substack{(0.0487)\\(0.0629)}}{0.1048}\Delta_2 \ln(p_d)_{t-1} - \underset{\substack{(0.0336)\\(0.0660)}}{0.1664}\Delta_4 \ln(p_d)_{t-1} - \underset{\substack{(0.0685)\\(0.0385)}}{0.3657}\Delta \ln(p_d)_{t-2} \\
& + \underset{\substack{(0.00005)\\(0.0909)}}{0.00014}\Delta_4 f_{1,t} + \underset{\substack{(0.0002)\\(0.2632)}}{0.0005} f_{2,t} + \underset{\substack{(0.0002)\\(0.0492)}}{0.0005} f_{2,t-2} - \underset{\substack{(0.0003)\\(0.0514)}}{0.001} f_{3,t-5} + \underset{\substack{(0.0003)\\(0.2688)}}{0.0008} f_{4,t} + \underset{\substack{(0.0003)\\(0.0293)}}{0.0008} f_{4,t-1} \\
& + \underset{\substack{(0.0003)\\(0.3928)}}{0.00085} f_{4,t-2} + \underset{\substack{(0.0003)\\(0.0574)}}{0.0007} f_{4,t-3} - \underset{\substack{(0.0003)\\(0.0486)}}{0.0006} f_{5,t-1} - \underset{\substack{(0.0003)\\(0.2147)}}{0.0007} f_{5,t-3} - \underset{\substack{(0.00006)\\(0.0555)}}{0.0007}\ln(\hat{q}_d)_{t-1}
\end{aligned}$$

$$\ln(\hat{q}_d)_{t-1} = \left(f_1^* + 0.7 f_3^* - f_4^* + 0.3 f_5^* - 0.8 f_6^*\right)_{t-1}; \quad R^2 = 0.3988 \quad \bar{R}^2 = 0.3716$$

Using *REER*:

$$\begin{aligned}
\Delta_3 \ln(\hat{p}_d)_t = {} & \underset{\substack{(0.0103)\\(0.4239)}}{0.0246} + \underset{\substack{(0.0498)\\(0.086)}}{0.8761}\Delta_3 \ln(p_d)_{t-1} - \underset{\substack{(0.0721)\\(0.1613)}}{0.3455}\Delta_3 \ln(p_d)_{t-2} - \underset{\substack{(0.069)\\(0.1943)}}{0.3313}\Delta_3 \ln(p_d)_{t-3} \\
& + \underset{\substack{(0.0528)\\(0.1611)}}{0.5138}\Delta_3 \ln(p_d)_{t-4} - \underset{\substack{(0.0542)\\(0.0294)}}{0.1453}\Delta\Delta_3 \ln(p_d)_{t-5} - \underset{\substack{(0.0044)\\(0.6836)*}}{0.0134}\Delta_3 \ln(e_d)_{t-2} - \underset{\substack{(0.0021)\\(0.4424)}}{0.005}\ln(REER)_{t-3} \\
& R^2 = 0.669
\end{aligned}$$

$$\begin{aligned}
\Delta \ln(\hat{p}_d)_t = {} & \underset{\substack{(0.0079)\\(0.9539)**}}{0.0345} + \underset{\substack{(0.0545)\\(0.1017)}}{0.1038}\Delta \ln(p_d)_{t-1} - \underset{\substack{(0.0521)\\(0.1282)}}{0.2728}\Delta \ln(p_d)_{t-2} - \underset{\substack{(0.0344)\\(0.0409)}}{0.1374}\Delta_3\Delta \ln(p_d)_{t-3} \\
& + \underset{\substack{(0.005)\\(1.494)**}}{0.0142}\Delta\Delta \ln(e_d)_{t-1} - \underset{\substack{(0.0016)\\(0.9779)**}}{0.007}\ln(REER)_{t-1} \qquad R^2 = 0.2062
\end{aligned}$$

(6b)

$$\begin{aligned}
\Delta_3 \ln(\hat{e}_d)_t = {} & \underset{\substack{(0.00186)\\(0.1625)}}{0.00449} + \underset{\substack{(0.0419)\\(0.0658)}}{0.7052}\Delta_3 \ln(e_d)_{t-1} + \underset{\substack{(0.0437)\\(0.3582)}}{0.1672}\Delta\Delta_3 \ln(e_d)_{t-2} - \underset{\substack{(0.0438)\\(0.0288)}}{0.2035}\Delta\Delta_3 \ln(e_d)_{t-3} + \underset{\substack{(0.0010)\\(0.4907)*}}{0.0141} f_{1,t} \\
& - \underset{\substack{(0.0012)\\(0.1239)}}{0.0096} f_{1,t-1} - \underset{\substack{(0.0012)\\(0.1552)}}{0.0032} f_{2,t-6} + \underset{\substack{(0.0027)\\(0.0648)}}{0.0095}\Delta f_{3,t} - \underset{\substack{(0.0013)\\(0.0686)}}{0.0039} f_{4,t} - \underset{\substack{(0.0026)\\(0.2119)}}{0.0092}\Delta f_{5,t} + \underset{\substack{(0.0025)\\(0.0898)}}{0.009}\Delta f_{5,t-1} \\
& - \underset{\substack{(0.0004)\\(0.0539)}}{0.0016}\ln(\hat{q}_d)_{t-3}
\end{aligned}$$

$$\ln(\hat{q}_d)_{t-3} = \left(f_1^* - 1.6 f_3^* + 1.6 f_4^* + 2.5 f_5^*\right)_{t-3}; \quad R^2 = 0.7419; \quad \bar{R}^2 = 0.7398$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.0017)\\(0.0656)}}{0.0037} + \underset{\substack{(0.0493)\\(0.0476)}}{0.1207}\Delta \ln(e_d)_{t-2} + \underset{\substack{(0.0005)\\(0.3366)}}{0.0061} f_{1,t} + \underset{\substack{(0.0004)\\(0.0799)}}{0.0072} f_{3,t} - \underset{\substack{(0.00039)\\(0.0427)}}{0.00089}\ln(\hat{q}_d)_{t-1}$$

$$\ln(\hat{q}_d)_{t-1} = \left(f_1^* - f_3^* + 2 f_4^* + f_5^*\right)_{t-1}; \quad R^2 = 0.3552; \quad \bar{R}^2 = 0.3455$$

Using *REER*:

$$\begin{aligned}
\Delta_3 \ln(\hat{e}_d)_t = {} & \underset{\substack{(0.0751)\\(0.1259)}}{0.0796} + \underset{\substack{(0.0427)\\(0.0416)}}{0.8684}\Delta_3 \ln(e_d)_{t-1} - \underset{\substack{(0.0628)\\(0.3849)}}{0.5053}\Delta_3 \ln(e_d)_{t-3} + \underset{\substack{(0.0624)\\(0.3845)}}{0.3308}\Delta_3 \ln(e_d)_{t-4} \\
& - \underset{\substack{(0.0428)\\(0.0401)}}{0.130}\Delta_3 \ln(e_d)_{t-6} - \underset{\substack{(0.0157)\\(0.1287)}}{0.016}\ln(REER)_{t-3} \qquad R^2 = 0.5929
\end{aligned}$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.0625)\\(0.1346)}}{0.0662} - \underset{\substack{(0.0565)\\(0.0401)}}{0.1156}\Delta \ln(e_d)_{t-6} - \underset{\substack{(0.0131)\\(0.1367)}}{0.0133}\ln(REER)_{t-1} \qquad R^2 = 0.0187$$

Note: Samples used for all the models: 1980M01-2005M12. See also the note in Table 6.

Table 10. Specific models of (6a) and (6b) versus ECMs of *REER*: UK

(6a)

$$\Delta_3 \ln(\hat{p}_d)_t = \underset{\substack{(0.0006)\\(0.0674)}}{0.0054} + \underset{\substack{(0.0337)\\(0.7457)^{**}}}{0.7875}\,\Delta_2\Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.023)\\(0.3537)}}{0.1455}\,\Delta_5\Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.0413)\\(0.1301)}}{0.5933}\,\Delta_3 \ln(p_d)_{t-4} + \underset{\substack{(0.0002)\\(0.0252)}}{0.0007}\, f_{2,t}$$

$$- \underset{\substack{(0.0003)\\(0.0862)}}{0.0012}\, f_{4,t} - \underset{\substack{(0.0004)\\(0.1429)}}{0.001}\,\Delta f_{4,t-3} - \underset{\substack{(0.00004)\\(0.0292)}}{0.0002}\,\ln(\hat{q}_d)_{t-3}$$

$$\ln(\hat{q}_d)_{t-3} = \left(f_1^* - 3.5 f_2^* - 1.8 f_3^* - f_4^* + f_6^*\right)_{t-3}; \qquad R^2 = 0.8235 \quad \overline{R}^2 = 0.8188$$

$$\Delta \ln(\hat{p}_d)_t = \underset{\substack{(0.0004)\\(0.0459)}}{0.0037} + \underset{\substack{(0.0364)\\(0.1399)}}{0.1793}\,\Delta_2 \ln(p_d)_{t-1} + \underset{\substack{(0.0469)\\(0.0390)}}{0.211}\,\Delta \ln(p_d)_{t-6} + \underset{\substack{(0.00008)\\(0.1943)}}{0.0003}\, f_{1,t} - \underset{\substack{(0.00008)\\(0.0875)}}{0.00018}\, f_{1,t-1}$$

$$- \underset{\substack{(0.0004)\\(0.1097)}}{0.0014}\, f_{3,t} + \underset{\substack{(0.0003)\\(0.0278)}}{0.0009}\, f_{3,t-2} - \underset{\substack{(0.0003)\\(0.535)}}{0.0013}\, f_{3,t-3} + \underset{\substack{(0.0003)\\(0.0627)}}{0.0012}\,\Delta_6 f_{4,t} - \underset{\substack{(0.0002)\\(0.3105)}}{0.0007}\,\Delta_2 f_{5,t} - \underset{\substack{(0.00006)\\(0.0627)}}{0.0004}\,\ln(\hat{q}_d)_{t-1}$$

$$\ln(\hat{q}_d)_{t-1} = \left(f_1^* - 1.8 f_2^* - 1.2 f_3^* - 0.7 f_4^* + 0.7 f_6^*\right)_{t-1}; \qquad R^2 = 0.4063 \quad \overline{R}^2 = 0.3866$$

Using *REER*:

$$\Delta_3 \ln(\hat{p}_d)_t = \underset{\substack{(0.014)\\(0.2376)}}{0.019} + \underset{\substack{(0.0319)\\(0.3824)}}{0.9861}\,\Delta_3 \ln(p_d)_{t-1} - \underset{\substack{(0.0496)\\(0.1011)}}{0.7054}\,\Delta_3 \ln(p_d)_{t-3} + \underset{\substack{(0.043)\\(0.0286)}}{0.5831}\,\Delta_3 \ln(p_d)_{t-4}$$

$$- \underset{\substack{(0.0031)\\(0.2366)}}{0.0039}\,\ln(REER)_{t-3} \qquad R^2 = 0.7856$$

$$\Delta \ln(\hat{p}_d)_t = \underset{\substack{(0.0124)\\(0.3919)}}{0.0126} + \underset{\substack{(0.052)\\(0.4165)}}{0.2321}\,\Delta \ln(p_d)_{t-1} + \underset{\substack{(0.0531)\\(0.1799)}}{0.1025}\,\Delta \ln(p_d)_{t-5} + \underset{\substack{(0.0499)\\(0.0994)}}{0.2794}\,\Delta_3\Delta \ln(p_d)_{t-6}$$

$$- \underset{\substack{(0.0028)\\(0.3929)}}{0.0025}\,\ln(REER)_{t-1} \qquad R^2 = 0.2167$$

(6b)

$$\Delta_3 \ln(\hat{e}_d)_t = -\underset{\substack{(0.0021)\\(0.0992)}}{0.0017} + \underset{\substack{(0.0298)\\(0.0899)}}{0.8651}\,\Delta_3 \ln(e_d)_{t-1} - \underset{\substack{(0.0505)\\(0.0551)}}{0.4303}\,\Delta\Delta_3 \ln(e_d)_{t-3} - \underset{\substack{(0.0295)\\(0.031)}}{0.0993}\,\Delta_3 \ln(e_d)_{t-5}$$

$$+ \underset{\substack{(0.143)\\(0.0468)}}{0.3946}\,\Delta_3 \ln(p_d)_{t-1} + \underset{\substack{(0.0007)\\(0.6139)^*}}{0.0132}\,\Delta f_{1,t} + \underset{\substack{(0.0009)\\(0.0381)}}{0.006}\,\Delta f_{1,t-3} + \underset{\substack{(0.0014)\\(0.0288)}}{0.003}\, f_{4,t-3} - \underset{\substack{(0.0004)\\(0.1735)}}{0.0026}\,\ln(\hat{q}_d)_{t-3}$$

$$\ln(\hat{q}_d)_{t-3} = \left(f_1^* + 0.5 f_2^* - f_4^* - 0.75 f_6^*\right)_{t-3}; \qquad R^2 = 0.8054; \quad \overline{R}^2 = 0.8003$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.0011)\\(0.0706)}}{0.0018} - \underset{\substack{(0.0363)\\(0.3327)}}{0.07}\,\Delta \ln(e_d)_{t-6} - \underset{\substack{(0.1903)\\(0.1142)}}{0.4614}\,\Delta\Delta \ln(p_d)_t + \underset{\substack{(0.0004)\\(0.461)}}{0.0078}\, f_{1,t} - \underset{\substack{(0.0018)\\(0.3076)}}{0.0071}\, f_{3,t}$$

$$+ \underset{\substack{(0.0017)\\(0.0257)}}{0.0065}\, f_{4,t} + \underset{\substack{(0.0016)\\(0.1531)}}{0.0032}\, f_{4,t-2} - \underset{\substack{(0.0014)\\(0.2534)}}{0.0065}\, f_{5,t} - \underset{\substack{(0.0013)\\(0.0405)}}{0.003}\, f_{3,t-6} - \underset{\substack{(0.0002)\\(0.0674)}}{0.0009}\,\ln(\hat{q}_d)_{t-1}$$

$$\ln(\hat{q}_d)_{t-1} = \left(f_1^* + f_2^* - 1.3 f_4^* - f_6^*\right)_{t-1}; \qquad R^2 = 0.6064; \quad \overline{R}^2 = 0.5947$$

Using *REER*:

$$\Delta_3 \ln(\hat{e}_d)_t = \underset{\substack{(0.0980)\\(0.4903)^*}}{0.1961} + \underset{\substack{(0.0419)\\(0.0616)}}{0.8416}\,\Delta_3 \ln(e_d)_{t-1} - \underset{\substack{(0.0593)\\(0.1057)}}{0.5114}\,\Delta_3 \ln(e_d)_{t-3} + \underset{\substack{(0.0590)\\(0.1333)}}{0.3791}\,\Delta_3 \ln(e_d)_{t-4}$$

$$- \underset{\substack{(0.0407)\\(0.0165)}}{0.1492}\,\Delta_3 \ln(e_d)_{t-6} - \underset{\substack{(0.0218)\\(0.5177)^*}}{0.0439}\,\ln(REER)_{t-3} \qquad R^2 = 0.5912$$

$$\Delta \ln(\hat{e}_d)_t = \underset{\substack{(0.0821)\\(0.4680)}}{0.1856} - \underset{\substack{(0.0183)\\(0.4916)^*}}{0.0415}\,\ln(REER)_{t-1} \qquad R^2 = 0.0164$$

Note: Samples used for DF-ECMs: 1980M01-2005M12; Samples for *REER* equations: 1979M10-2005M12. See also the note in Table 6.

Table 11. Coefficient estimates of the long-run factors based on DFM (4)

Country	Long-run factors	f_1^*	f_2^*	f_3^*	f_4^*	f_5^*	f_6^*
Canada	$\sum_{i=1}^{30}\gamma_{ij}^*$	0.6081	0.9977	0.4802	0.6178	0.6992	N/A
	Standard error	(1.1320)	(1.7913)	(1.6057)	(1.6186)	(1.3635)	
France	$\sum_{i=1}^{30}\gamma_{ij}^*$	1.7250	-0.6758	0.2060	1.4969	0.1618	0.0617
	Standard error	(3.1159)	(2.9753)	(2.4701)	(2.7346)	(5.2093)	(3.5536)
Germany	$\sum_{i=1}^{30}\gamma_{ij}^*$	0.6645	-0.8278	0.4149	0.3089	0.6127	0.1842
	Standard error	(8.8665)	(3.2152)	(4.9475)	(6.5889)	(5.4767)	(1.9901)
Japan	$\sum_{i=1}^{30}\gamma_{ij}^*$	2.8930	-0.5342	0.1620	1.9058	-0.2133	-0.2055
	Standard error	(3.3003)	(5.7676)	(6.2744)	(5.9941)	(6.0424)	(4.9895)
UK	$\sum_{i=1}^{30}\gamma_{ij}^*$	1.5919	-0.0701	1.1703	-0.0926	0.9258	0.0793
	Standard error	(4.7444)	(14.6691)	(4.3594)	(3.5113)	(2.6611)	(4.3556)

Table 12. Unit-root test statistics on a selected EC terms

Country	Tests	$\ln(\hat{q}_d)$ for $\Delta\ln(e_d)$ equation	$\ln(\hat{q}_d)$ for $\Delta\ln(p_d)$ equation	$\ln(REER)$
Canada	ADF	-3.1624*** (2)	-1.3151 (2)	-1.4901 (0)
	Phillip-Perron	-2.5309** [4]	-1.3392 [6]	-1.5705 [1]
	DF-GLS	-0.883 (2)	-0.1323 (2)	-1.4478 (0)
	Ng-Perron (MZ_t)	-0.8229 (2)	-0.1446 (2)	-1.4405 (0)
France	ADF	-3.3505*** (4)	-2.5951*** (1)	-2.5925* (1)
	Phillip-Perron	-3.4732*** [18]	-2.5452** [7]	-2.4999 [1]
	DF-GLS	0.0816 (4)	0.4408 (1)	-0.7230 (1)
	Ng-Perron (MZ_t)	0.0742 (4)	0.468 (1)	-0.7272 (1)
Germany	ADF	-1.4513 (1)	-1.8253* (1)	-2.0515 (0)
	Phillip-Perron	-1.6748* [9]	-2.0562** [8]	-2.394 [5]
	DF-GLS	-1.1219 (1)	-1.7822 (1)	-1.8122 (0)
	Ng-Perron (MZ_t)	-1.211 (1)	-1.7844* (1)	-1.7963* (0)
Japan	ADF	-2.5068** (0)	-2.2115** (0)	-2.3792 (1)
	Phillip-Perron	-2.86*** [8]	-2.2115** [2]	-1.9717 [1]
	DF-GLS	-1.0756 (0)	-0.2969 (0)	-1.1135 (1)
	Ng-Perron (MZ_t)	-1.0683 (0)	-0.2860 (0)	-1.0986 (1)
UK	ADF	-2.3913** (1)	-2.1424** (1)	-1.9726 (1)
	Phillip-Perron	-2.3059** [3]	-1.9461** [9]	-1.7762 [3]
	DF-GLS	-2.3262** (1)	1.1856* (0)	-1.9292* (1)
	Ng-Perron (MZ_t)	-2.3006** (1)	1.2203 (0)	-1.9279* (1)

Note: The sample periods used correspond to those used in the model estimation and reduction (see Tables 6-10). ADF denotes augmented Dickey-Fuller test; DF-GLS is Elliott-Rothenberg-Stock test (1996); Only MZ_t out of the four tests in (Ng-Perron, 2001) is reported to save space. *, ** and *** indicate rejection of the unit-root null hypothesis at 10%, 5% and 1% respectively. The numbers in parentheses are the number of lags used in the tests and these numbers are chosen on the basis of information criteria. The number in the square brackets of Phillip-Perron test (1988) is bandwidth determined by means of Bartlett kernel.

Figure 1. Modelled variables for (6a) and (6b) (in monthly frequencies)

Solid curve: $\Delta \ln(e_d)_t$; dotted curve: $\Delta_3 \ln(e_d)_t$	Solid curve: $\Delta \ln(p_d)_t$; dotted curve: $\Delta_3 \ln(p_d)_t$

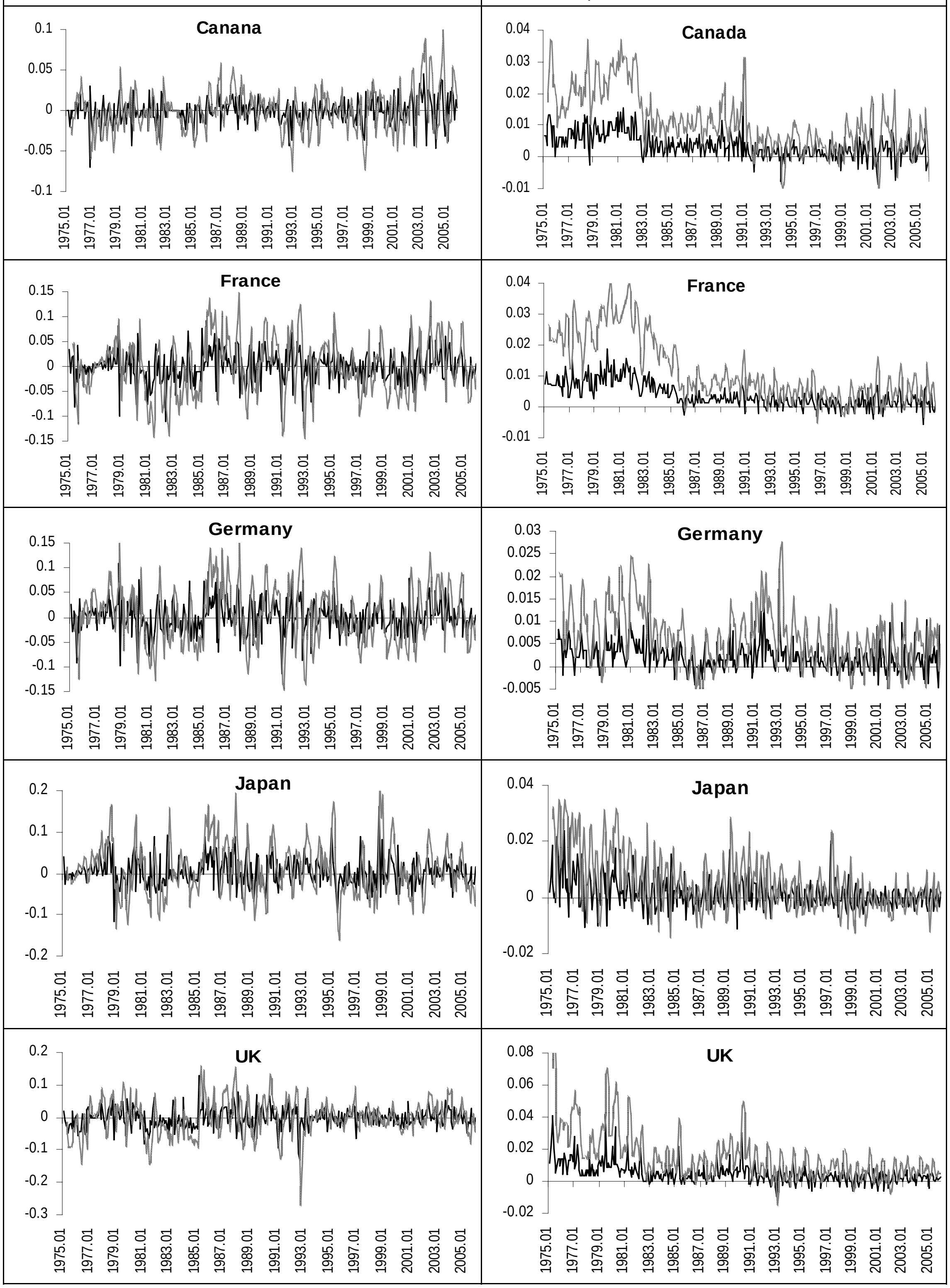
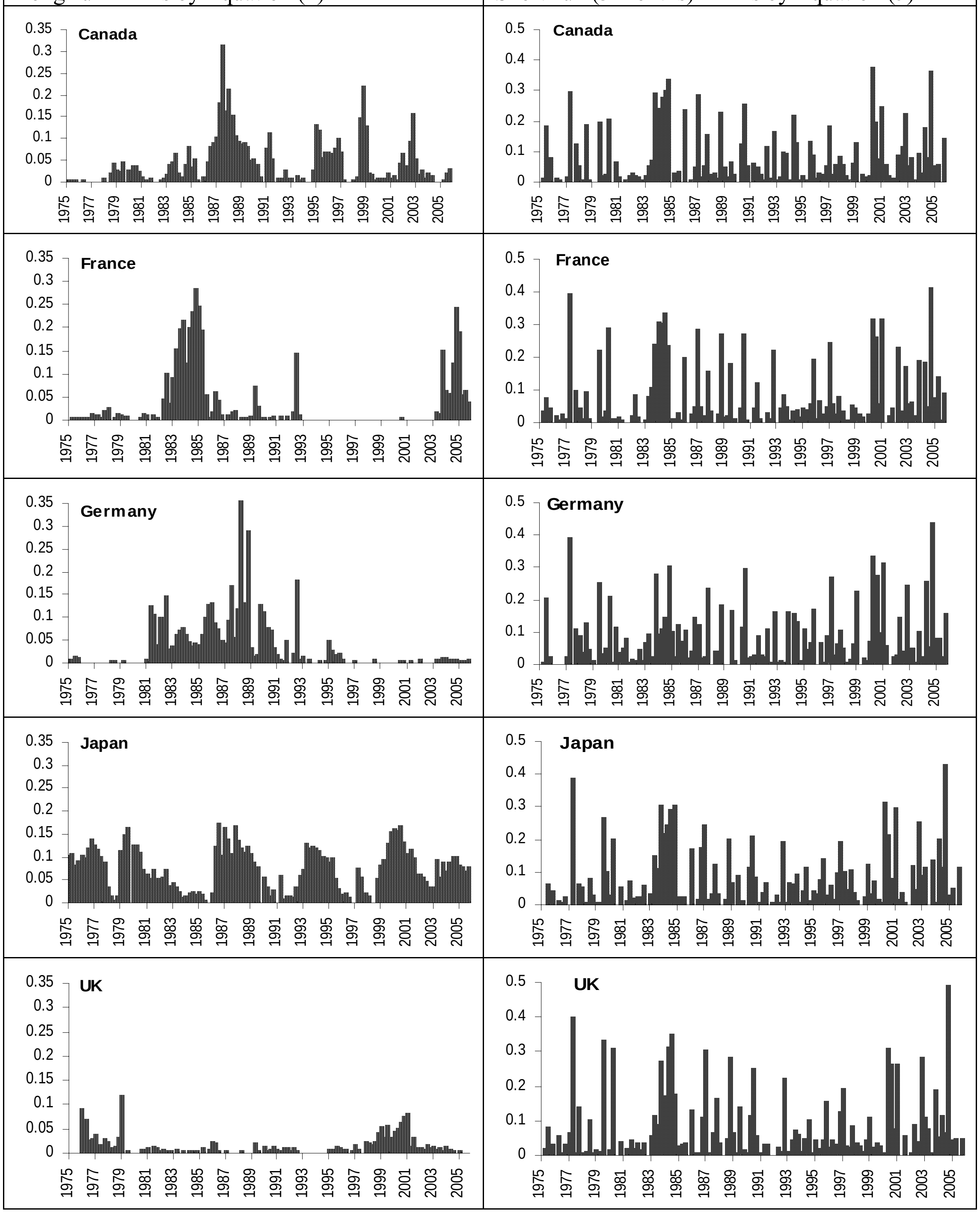


Figure 2. Covariation coefficient series, { τ_t^2 }

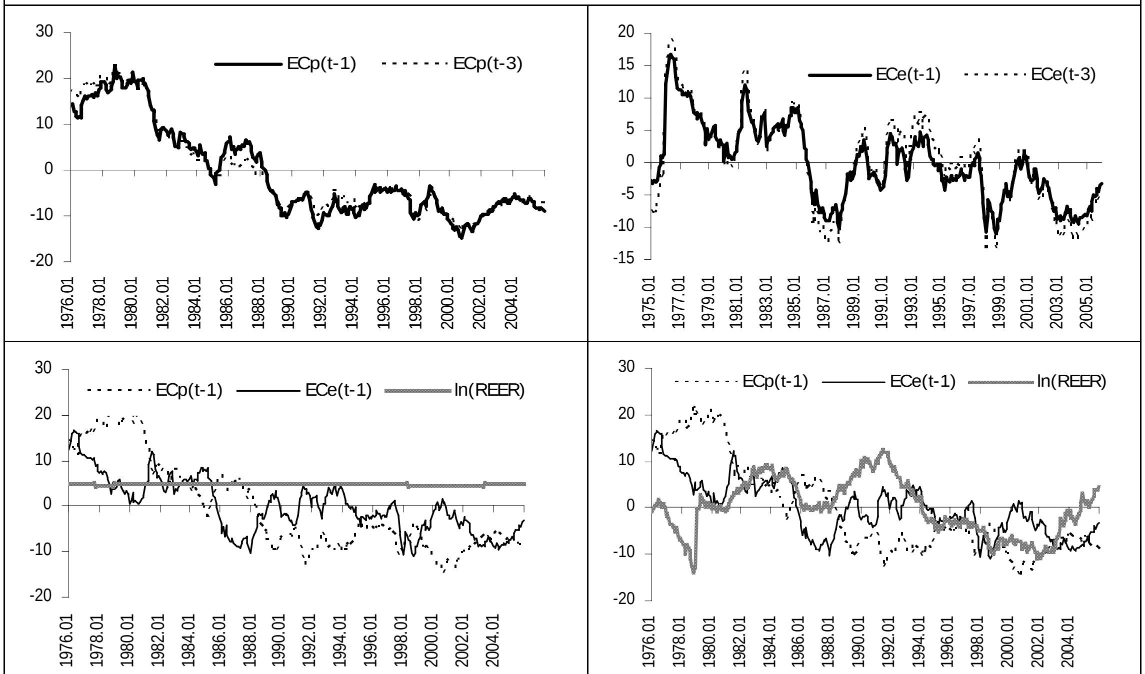
Long-run DMFs by Equation (4)	Short-run (3 months) DMFs by Equation (5)



Note: The coefficients are only available in quarterly frequency because of the quarterly Australian CPI data.

Figure 3. The EC terms of DF-ECMs: Canada

EC terms (i.e. $\ln(\hat{q}_d)$) versus ln(REER)



Note: $\ln(REER)_t$ in the lower right panel is rescaled by the mean and standard deviation (SD) of ECe_t.
SD($\ln(REER)_t$) = 0.11; SD(ECp(t-1)) = 10.81; SD(ECe(t-1)) = 5.92.

Recursive estimates of the feedback coefficients of the EC terms (see Table 5) with their 95% confidence intervals marked by dotted curves

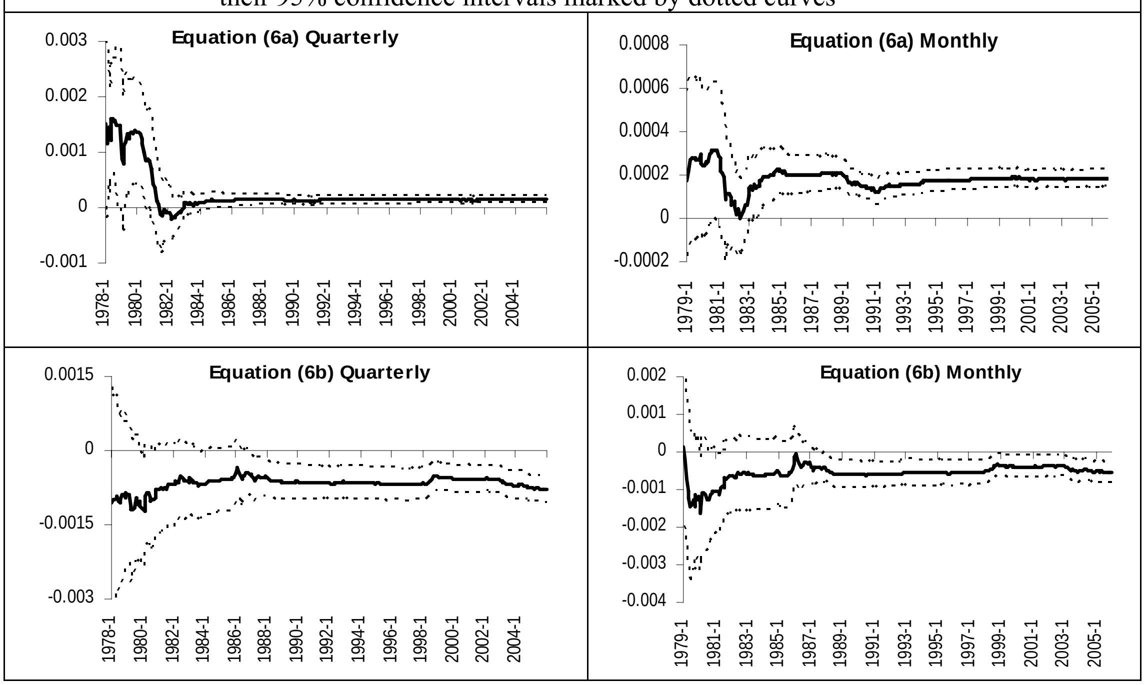
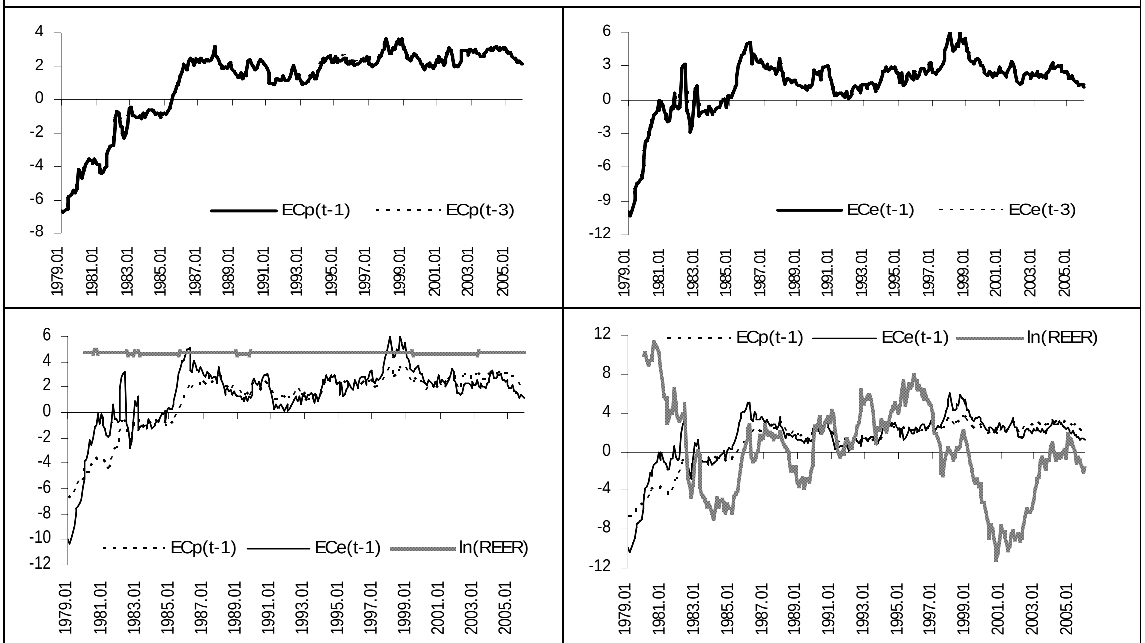


Figure 4. The EC terms of DF-ECMs: France

EC terms (i.e. $\ln(\hat{q}_d)$) versus ln(REER)



Note: $\ln(REER)_t$ in the lower right panel is rescaled by the mean and standard deviation (SD) of ECe_t.
SD($\ln(REER)_t$) = 0.04; SD(ECp(t-1)) = 3.53; SD(ECe(t-1)) = 4.72.

Recursive estimates of the feedback coefficients of the EC terms (see Table 6) with their 95% confidence intervals marked by dotted curves

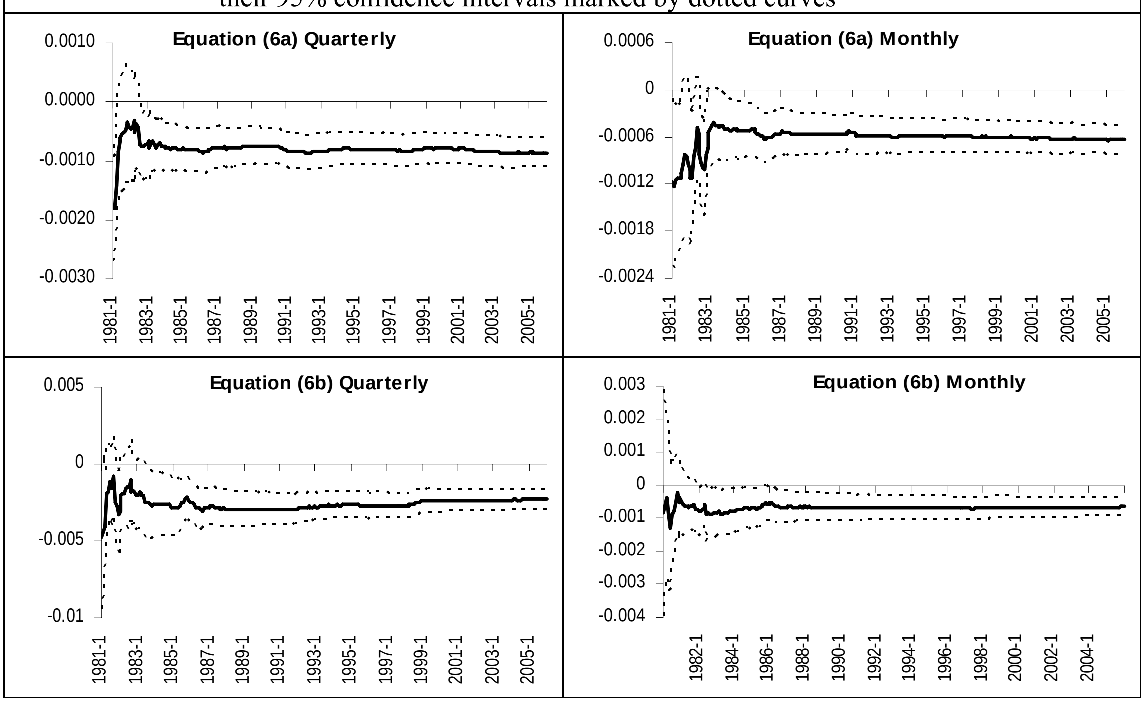
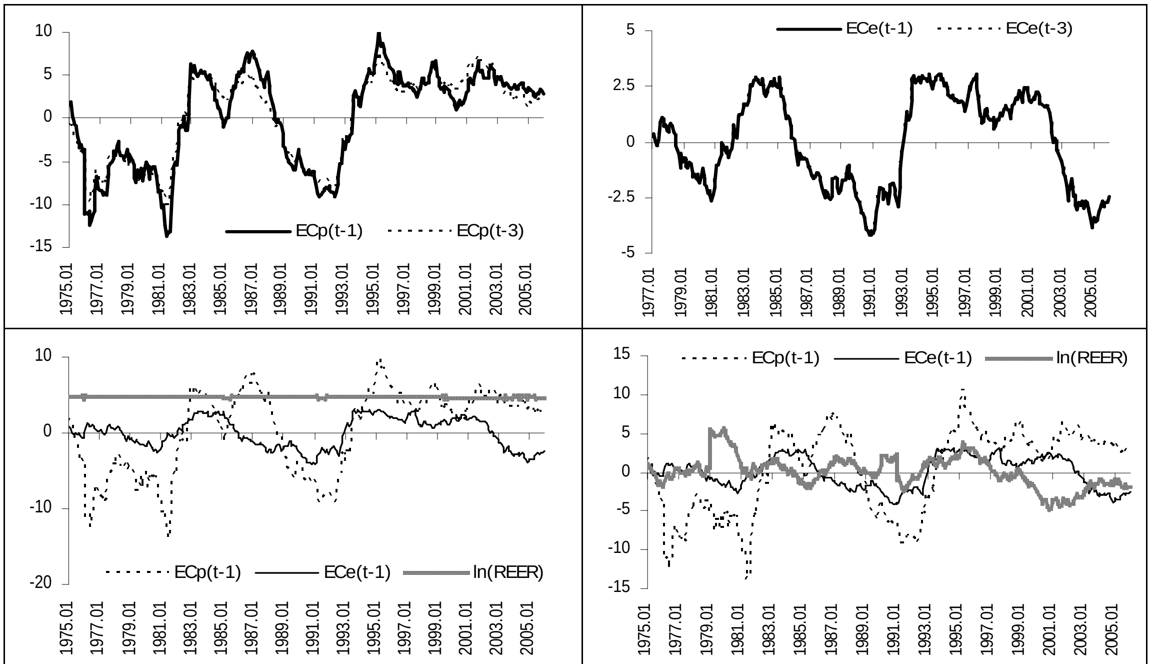


Figure 5. The EC terms of DF-ECMs: Germany

EC terms (i.e. $\ln(\hat{q}_d)$) versus ln(REER)



Note: $\ln(REER)_t$ in the lower right panel is rescaled by the mean and standard deviation (SD) of ECe_t.
SD($\ln(REER)_t$) = 0.06; SD(ECp(t-1)) = 5.52; SD(ECe(t-1)) = 2.00.

Recursive estimates of the feedback coefficients of the EC terms (see Table 7) with their 95% confidence intervals marked by dotted curves

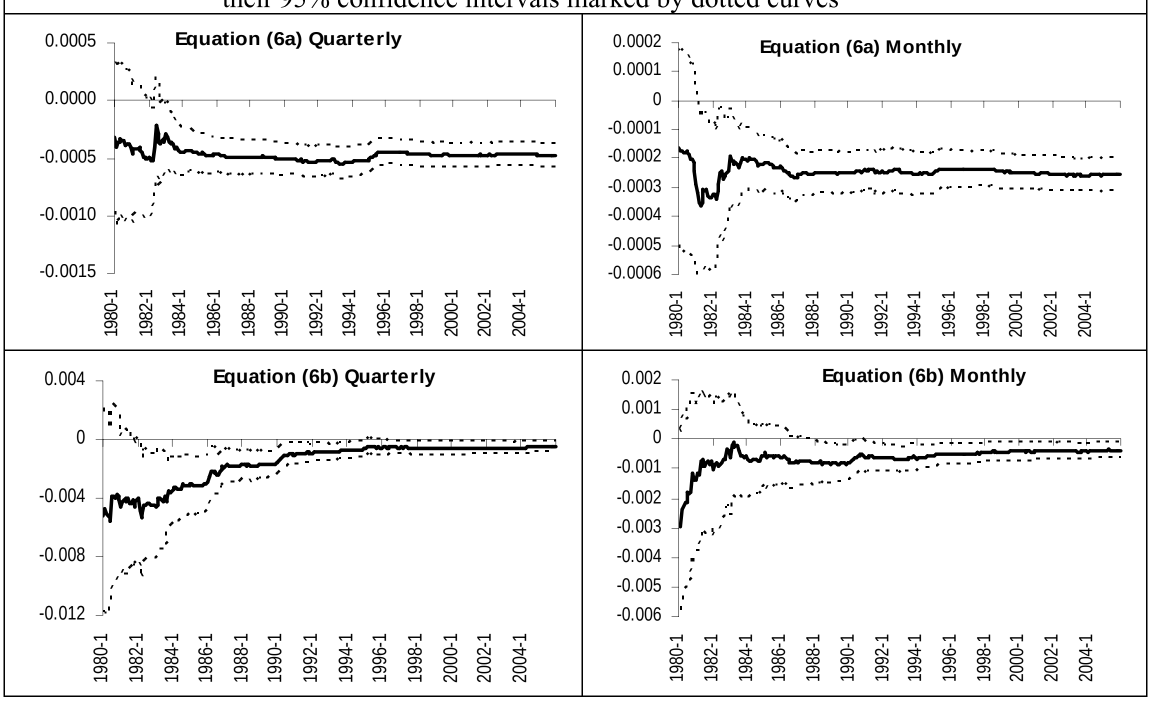
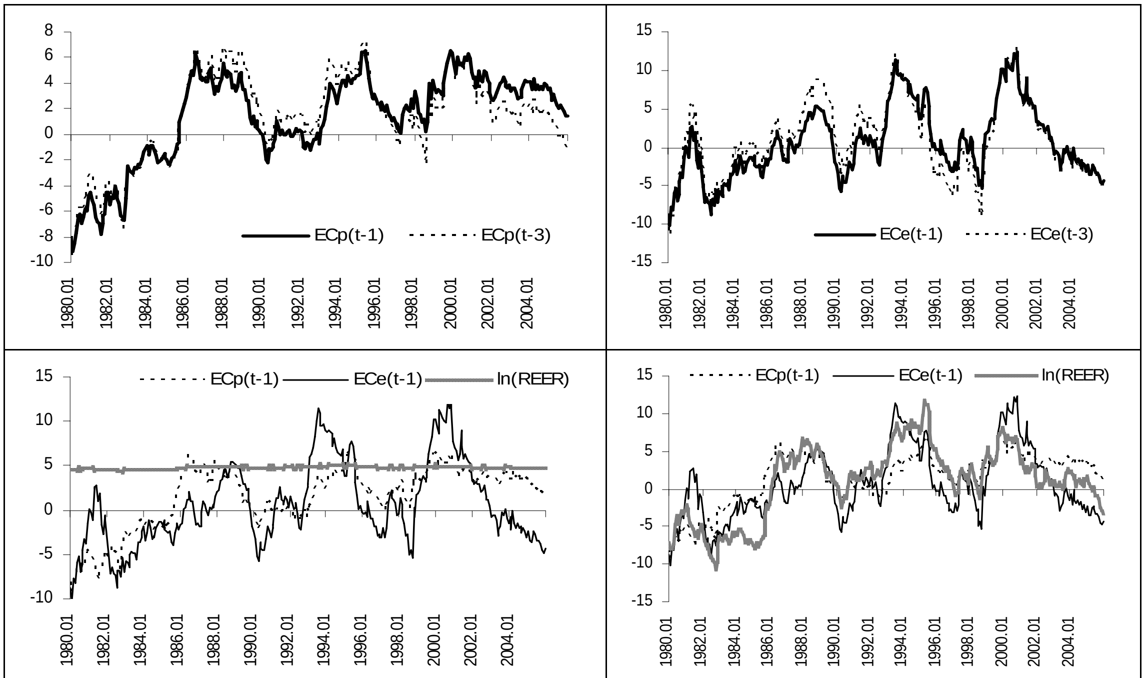


Figure 6. The EC terms of DF-ECMs: Japan

EC terms (i.e. $\ln(\hat{q}_d)$) versus ln(REER)



Note: $\ln(REER)_t$ in the lower right panel is rescaled by the mean and standard deviation (SD) of ECe_t.
SD($\ln(REER)_t$) = 0.16; SD(ECp(t-1)) = 4.60; SD(ECe(t-1)) = 5.12.

Recursive estimates of the feedback coefficients of the EC terms (see Table 8) with their 95% confidence intervals marked by dotted curves

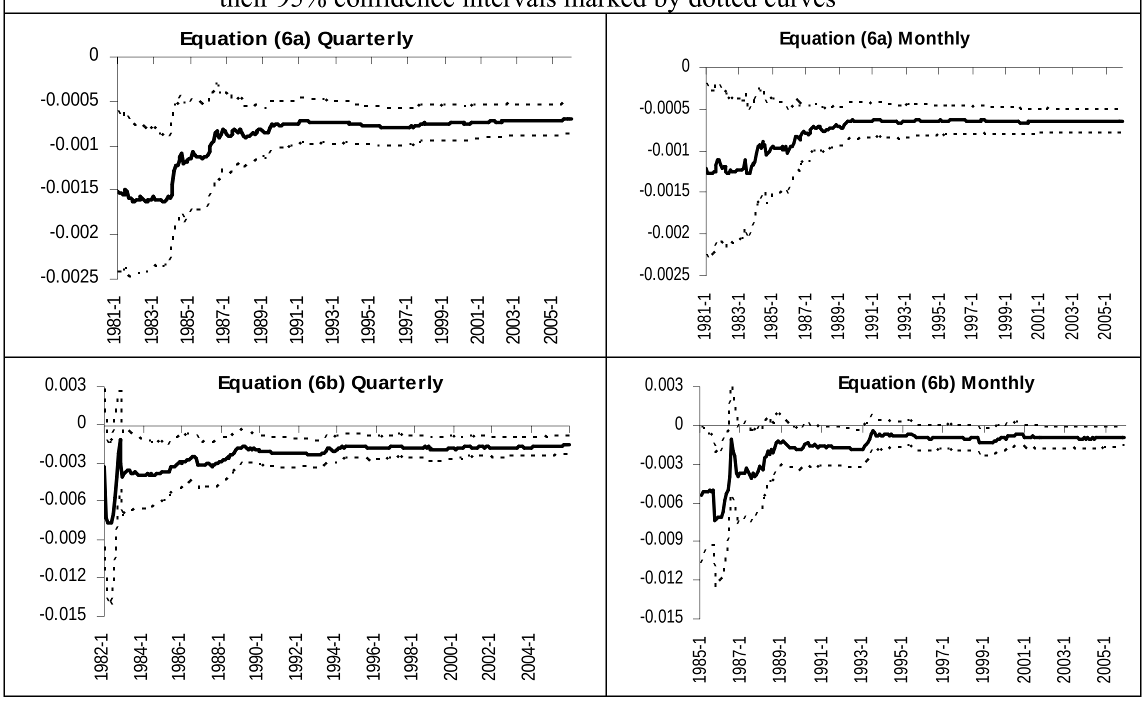
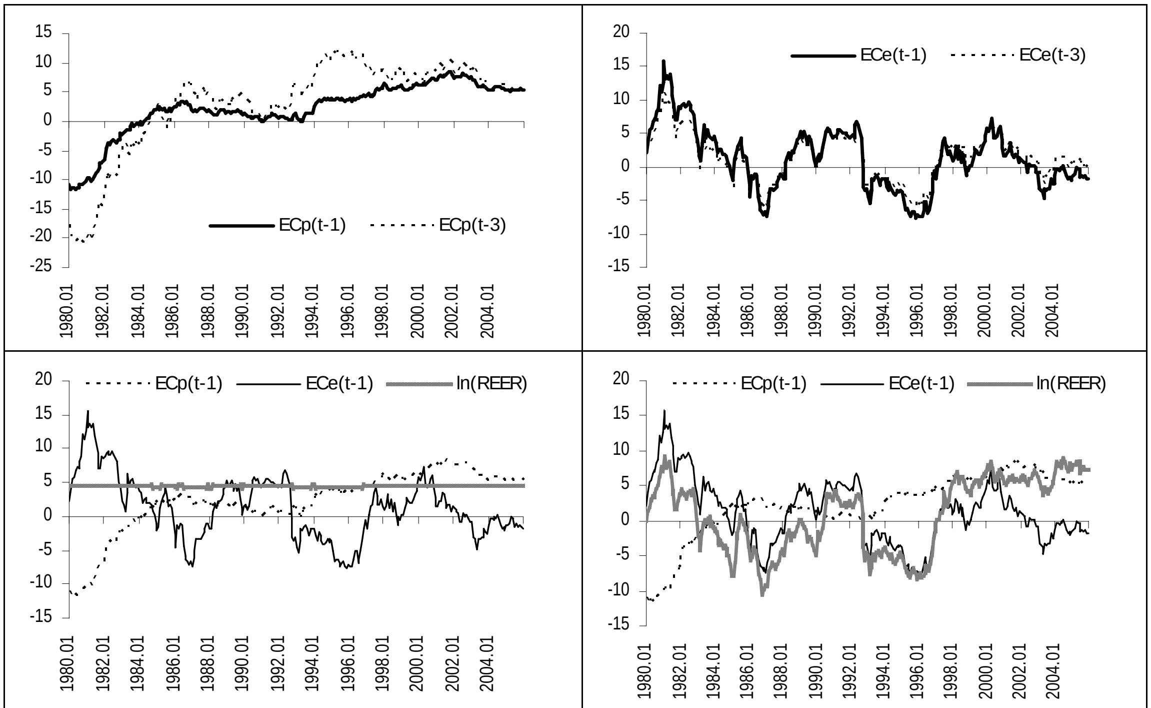


Figure 7. The EC terms of DF-ECMs: UK

EC terms (i.e. $\ln(\hat{q}_d)$) versus ln(REER)



Note: $\ln(REER)_t$ in the lower right panel is rescaled by the mean and standard deviation (SD) of ECe_t.
SD($\ln(REER)_t$) = 0.09; SD(ECp(t-1)) = 6.58; SD(ECe(t-1)) = 5.21.

Recursive estimates of the feedback coefficients of the EC terms (see Table 9) with their 95% confidence intervals marked by dotted curves