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Fundamental determinants of the long run real exchange rate: The case of Norway

Hilde C. Bjørnland and Håvard Hungnes*

Abstract: Modelling the Norwegian exchange rate against a basket of currencies, we find a robust long-term link between the real exchange rate and real interest differential that is consistent with purchasing power parity (PPP) and uncovered interest parity (UIP). However, PPP alone is rejected. These findings are confirmed focusing on the Norwegian bilateral exchange rate with Germany and (possibly) Sweden, but rejected against the UK and the US. We argue that rejection of bilateral relationships may result from idiosyncratic shocks in the different countries that may be negligible when modelling against a basket of currencies.

Keywords: Purchasing power parity, uncovered interest parity, cointegration VAR.

JEL classification: C32, F31.

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1. Introduction

Ever since Meese and Rogoff (1983) reported that a comprehensive range of exchange rate models were unable to outperform a random walk, the role of economic fundamentals in explaining exchange rate behaviour has been scrutinized. Economic theory typically predicts that the behaviour of the real exchange rate should be closely related to the behaviour of deviations from purchasing power parity (PPP). According to the PPP theory, nominal exchange rates adjust to offset changes in relative prices. If this is correct, then the real exchange rate will be stationary and fluctuate around the mean in the long run.

However, there seems to be a widespread agreement that substantial deviations from PPP have occurred since the abandonment of the Bretton Woods fixed exchange rate system. In particular, recent empirical evidence for this period has shown that the real exchange rate is not only very volatile in the short run, the speed of convergence to PPP in the long run is extremely slow, (see e.g. Rogoff (1996) or Froot and Rogoff (1995) for a survey).[1] Studies spanning longer periods of time (say a century or more), have traditionally found more evidence in favour of PPP than the studies of the post Bretton Woods period. However, recently many studies have found persistent deviations from PPP also in the long run (see e.g. Serletis and Zimonopoulus (1997), Cuddington and Liang (2000), Engel (2000) and Rogoff et al. (2001)).

How is it possible to reconcile the enormous short term volatility of real exchange rates with the very slow rates at which these shocks seem to disappear? The persistent deviation from PPP casts doubt on the Dornbusch (1976) open macroeconomic (overshooting) model, which explains short run real exchange rate volatility with sticky prices and monetary disturbances. Instead, long run deviation from PPP suggests the influence of real shocks with large permanent effects. The fact that many empirical studies do not reject the hypothesis of a unit root in the real exchange rate, also supports the argument that the variation in the real exchange rate is attributed to permanent shocks.[2]

The PPP condition has its roots in the goods market. Another central parity condition for the exchange rate that plays a crucial role in capital market models is uncovered interest parity (UIP). A test of UIP, refers to a test of the interest rate differential as an optimal predictor of the rate of depreciation, providing the conditions of rational expectations and risk neutrality are satisfied. However, empirical

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[1] The rejections are less clear-cut using panel data, see e.g. Frankel and Rose (1997) among many others. However, see O'Connell (1998) and Chortareas and Driver (2001) for critical assessments of these panel data studies. See also the rercent study by Holmes (2001), who using a new panel data unit root test, finds clear evidence against PPP.

[2] This finding is also consistent with e.g. Mark (1995), who forecasts the nominal exchange rate at long horizons by predicting that it returns to a target level, which, however, is not the PPP value. Further, Mark and Choi (1997) find that models that allow the long-run real exchange rate to vary over time have a better out of sample forecasting power than models in which long-run PPP holds.

evidence has also generally led to a strong rejection of the UIP condition in the Post Bretton Woods period (see e.g. McCallum (1994), Lewis (1995) and Engel (1996) for recent surveys).

During the last three decades, a lot of effort has been devoted to testing these two equilibrium conditions separately. Recently, however, Johansen and Juselius (1992) have suggested that one possible reason why so many researches have failed to find evidence in support of these parity conditions, is the fact that researchers have ignored the links between goods and capital markets when modelling the exchange rate. By modelling the whole system jointly within a full information maximum likelihood framework, one is better able to capture the interactions between the nominal exchange rate, the price differential and the interest rate differentials, as well as allowing for different short and long run dynamics, see also MacDonald and Marsh (1997, 1999b) and Juselius and MacDonald (2000) for recent applications.

This paper clarifies and calculates the concept of the long run (equilibrium) real exchange rate in Norway, by combining the purchasing power parity condition from the goods market with the uncovered interest parity condition in the capital market. By combining these two conditions, persistent deviations from PPP can now be explained by real factors that work through the interest rate differential. Further, since Norway is a dominant oil exporting country, the oil price is also included in the analysis, so as to investigate whether any changes in the real price of oil has forced the real exchange rate to deviate from its long run equilibrium level.

Our main hypothesis is to test whether the PPP condition holds against the basket of Norway's trading partners, or if not, any deviations from it can be explained by the UIP condition and/or any oil price changes. We thereafter test whether the obtained results (or lack of results) hold bilaterally against Norway's main trading partners. By testing the parity conditions bilaterally between Norway and the individual trading partners, we also test indirectly if the parity conditions hold between the trading partners themselves.

Previous studies of the determination of the real exchange rate in Norway, have generally rejected the notion of simple PPP using conventional (time series or panel data) unit root tests (see e.g. Serletis and Zimonopoulus (1997), Papell (1997) and Chortareas and Driver (2001)),[3] or by testing for PPP in multivariate studies (see e.g. Jore et al. (1998), Bjørnland (1998a) and Alexius (2001)).

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[3] Papell (1997), analysing a series of countries including Norway, cannot reject the unit root hypothesis in the real exchange rate for Norway at the 5% level. However, using a panel of 20 countries, he finds more evidence of PPP. However, as was also discussed in footnote 1, see O'Connell (1998) and Chortareas and Driver (2001) for critical assessments of these panel data studies.

Akram (2000a) on the other hand, using a multivariate cointegrating framework, finds some evidence of PPP for Norway. In a model comprising four cointegrating vectors, he can (barely) not reject the hypothesis of strong form PPP when testing each cointegrating vector separately (keeping the others unrestricted). However, he does not test the hypothesis of all four vectors together, and judging by the reported test statistics, to do so would probably lead to rejection of strong form PPP.[4]

Empirical tests for the UIP condition, also finds little evidence supporting this parity condition for Norway (see e.g. Holden and Vikøren (1994), Jore et al. (1998), Nessen (1997) and Flood and Rose (2001)).

The rest of this paper is organised as follows. In section two we discuss the hypothesis of PPP and possible sources of deviations from PPP. Section three discusses the different exchange rate regimes pursued in Norway, and the implications they have for the modelling of the real exchange. In section four we identify the econometric model used to estimate the long run exchange rate. Section five presents the empirical results, testing for economic fundamentals against a basket of currencies. In section six we thereafter examine if the results hold bilaterally against each of Norway's four main trading partners (Germany, Sweden, US and UK), and perform some other sensitivity tests. Section seven summarises and concludes.

2. Fundamentals and long run exchange rates

A natural starting point for discussing the relationship between exchange rates and fundamentals is the concept of PPP, which is attributed to Cassel (1921, 1922). Assuming there are no costs in international trade, then domestic prices would equal foreign prices multiplied by the exchange rate. The expression for PPP can then be written (in log-form) as:[5]

$$v_t = p_t - p_t^*, \tag{1}$$

where p_t is the log of the domestic price, p_t* is the log of the foreign price, and v_t is the log of the nominal exchange rate. However, since trade is costly, PPP will not hold continuously. It is therefore informative to define the real exchange rate as:

$$r_t = v_t - p_t + p_t^*, \tag{2}$$

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[4] However, by continuing the analysis with a conditional VAR model, Akram (2000a) can accept the hypothesis of PPP together with other economic interpretable cointegration vectors.

[5] Since we use price indices in the estimation, we can only test relative PPP.

where r_t is the real exchange rate. If PPP shall hold, this will imply that the real exchange rate is stationary and fluctuates around a fixed value in the short run. In a univariate framework, PPP can be tested by simply testing for whether the real exchange rate is stationary or not. Alternatively, PPP can be cast in a multivariate framework by applying cointegration methods to an equation like (3):

$$v_t = \alpha_0 + \alpha_1 p_t + \alpha_2 p_t^* + \varepsilon_t \qquad (3)$$

Assuming v_t, p_t and p_t* are non-stationary, integrated processes, I(1), then *weak-form* PPP implies that the residual term of an estimated version of (3) is stationary, I(0). Adding symmetry, implies α_1=-α_2. *Strong-form* (*pure*) PPP exists if, in addition to the above condition, homogeneity is satisfied, α_1 =1, α_2=-1.[6]

The massive empirical testing of PPP has generally cast doubt on long run PPP, either by rejecting the hypothesis that PPP follows a stationary process, or by suggesting that the real exchange rate adjusts too slowly back to a long run equilibrium rate to be consistent with traditional PPP (the half time is normally found to be 3-4 years, see e.g. Rogoff (1996)).[7] Instead, long run deviation from PPP suggests the influence of real factors with large permanent effects, like productivity differentials, fiscal policy and other relevant variables, again see Rogoff (1996) for a survey. These factors will work through the current account, and thereby push the real exchange rate away from PPP.

However, as several authors has emphasised, (see e.g. MacDonald and Marsh (1997) and Juselius and MacDonald (2000)), the balance of payment constraint implies that any imbalances in the current account has to be financed through the capital account. Shocks that force the real exchange rate away from PPP has to be captured through the movements in interest rates, since they reflect expectations of future purchasing power. Hence, massive movements in capital flows in response to interest rate differentials can keep the exchange rate away form purchasing power for long periods. The PPP condition in the goods market will therefore be strongly related to the central parity condition in the capital market, namely that of UIP.

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[6] The distinction between weak-form and strong-form PPP, is due to MacDonald (1993), although one could question whether it is reasonable to argue that one has support for a form of PPP, if homogeneity is not satisfied.

[7] In a recent study, Murray and Papell (2002) also find the half life of deviations from PPP for each of 20 countries (including Norway) to lie between 3-5 years. However, their confidence intervals are much larger than previously reported, implying in fact that univariate methods provide virtually no information regarding the size of half life.

This can be formalised in the following way. According to the UIP condition, the interest rate differential will be an optimal predictor of the rate of depreciation, providing the conditions of rational expectations and risk neutrality are satisfied, hence:

$$\Delta v_{t+1}^{e} = i_t - i_t^{*}, \tag{4}$$

where Δv_{t+1}^{e} is the expected depreciation rate from period t to t+1, i_t is the domestic interest rate and i_t^{*} is the foreign interest rate.

Assume that Δv_{t+1}^{e} is a function of the deviation of v_t from its equilibrium value $\bar{v}_t$, then (4) can be replaced by:

$$\begin{aligned} \Delta v_{t+1}^{e} &= i_t - i_t^{*} \\ &= -\lambda(v_t - \bar{v}_t), \end{aligned} \tag{5}$$

In the long run, the equilibrium exchange rate will be given by relative prices according to PPP, hence $\bar{v}_t = p_t - p_t^{*}$. Substituting in for the equilibrium exchange rate in (5), we obtain the following equation for the nominal exchange rate:[8]

$$v_t = p_t - p_t^{*} - \upsilon\left(i_t - i_t^{*}\right), \tag{6}$$

where $\upsilon=1/\lambda$. Equation (6) states that the nominal exchange rate is a function of both the price level differential and the interest rate differential, where the speed of adjustment to the interest rate differential is given by υ. Another way to interpret (6) is that the non-stationarity of the real exchange rate (v_t-p_t+p_t*) can be removed by the non-stationarity of the interest rate differential (i_t-i_t*).

Equation (6) is clearly a simplification of how the exchange rate market may adjust. In particular, it may be a strong assumption that all real shocks that force the real exchange rate away from PPP, has to be captured through the movements in interest rates in the long run. For an oil producing country like Norway, the oil price may also have important effects on the real exchange rate that may lead to deviations from PPP not captured in the interest rates in the long run. More specifically, a higher real oil price will increase natural wealth and raise demand. If the economy is operating at full employment (as Norway did in the early 1970s when the oil discoveries in the North Sea were made), the additional

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[8] The same expression could easily be obtained from a simple balance of payment equilibrium condition, (see MacDonald and Marsh 1997).

demand can only be met if the relative prices change in favour of foreign goods, so that the currency experiences a real appreciation (see e.g. Corden and Neary (1982)). This may squeeze the tradable sector, a phenomenon that has been termed the "Dutch Disease" in the economic literature, see Bjørnland (1998b) for an empirical application to Norway.[9]

To account for the possibility that the Norwegian krone may be a "petrocurrency", which appreciates when the oil price is high and depreciates with a low oil price, we therefore include the real oil price into the model as an additional variable.

3. The Norwegian experience

Since the collapse of the Bretton Woods agreement, Norway has pursued different exchange rate policies, albeit the policy of maintaining stable exchange rates against a basket of currencies has always been important. In 1972, Norway joined the EU countries in their European exchange rate regime, and from 1978 (when EU established the EMS), switched to hold the Norwegian krone fixed against a basket of currencies also including US dollars. However, the Norwegian exchange rate was devaluated frequently during this period (in particular in 1982, 1984 and in 1986).

In October 1990, Norway switching to a basket of currencies that represented the (theoretical) ECU. However, due to several speculative attacks, by the end of 1992, the Norwegian government had to let the Norwegian krone float. The floating period was only intended to be temporary. When it turned out to be difficult to return to a normal fixed exchange rate system, Norway formalised the floating regime in May 1994.[10] The Norwegian krone came under appreciation pressure by the end of 1996, and Norges Bank abandoned its attempt to stabilise the krone by intervening in the exchange market in January 1997. From the end of 1997 until August 1998, the Norwegian krone depreciated significantly, leading Norges Bank to increase its interest rates by 4.5 percentage points in that period, see Figure 1 and 2.

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[9] This explanation is also related to the argument for why productivity differentials may appreciate the real exchange rate in the long run, cf. Balassa (1964) and Samuelson (1964). The Balassa-Samuelson hypothesis states that the real exchange rate may appreciate if there are exceptionally large difference between productivity growth in the traded and the non-traded sector. A rise in productivity in the traded goods sector will lead to a wage effect only (as prices are tied down by the world price level). With no corresponding increase in productivity in the non-traded sector, prices in the non-traded sector must rise (to match the higher wage level), appreciating the real exchange rate.

[10] Note that, although the exchange rate could now float, Norges Bank should still aim to stabilise the Norwegian krone. However, there were no target zones for the Norwegian krone, and the exchange rate instruction did not explicitly state which currencies the krone should be stabilised against (though it was generally assumed to be the theoretical ECU).

Figure 1: Nominal (v) and real exchange rate (r) (against Norway's trading partners)

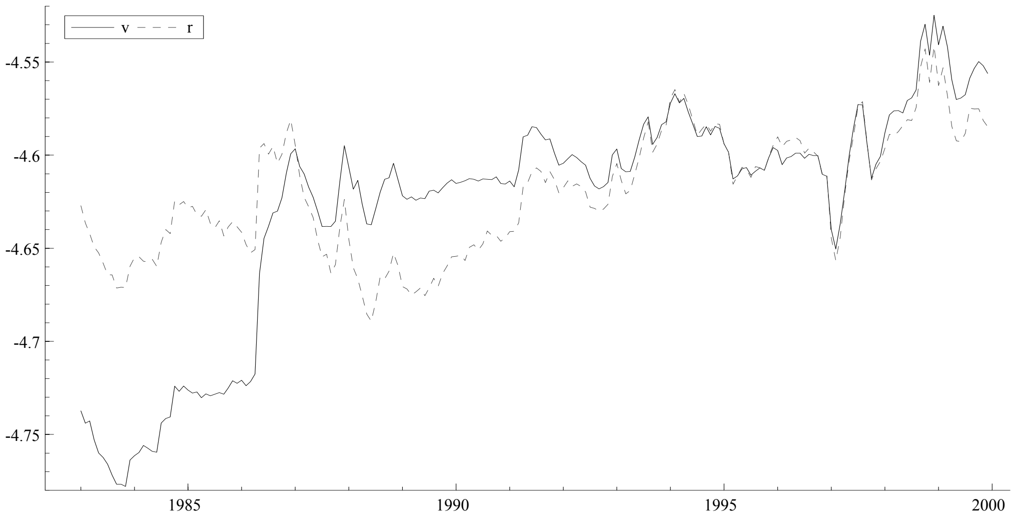

Figure 1 plots the monthly nominal and real exchange rate index of Norway's main trading partner, from January 1983 to December 1999, as defined by the IMF's trading weights (se Table A-1 in Appendix A). The figure shows that these two indices follow each other rather closely, and the correlation coefficient for the whole sample is 0.6. This clearly indicates that the nominal and the real exchange rate are not independent of each other in the short run. However, whether they are independent in the long run (as implied by the PPP theory) or whether the theory needs to be modified in a way to explicitly take account of real factors that influence the equilibrium exchange rate, is a question which has to be answer through the econometric analysis below.

Figure 2: Norwegian interest rate (i) and that of the trading partners (i*)

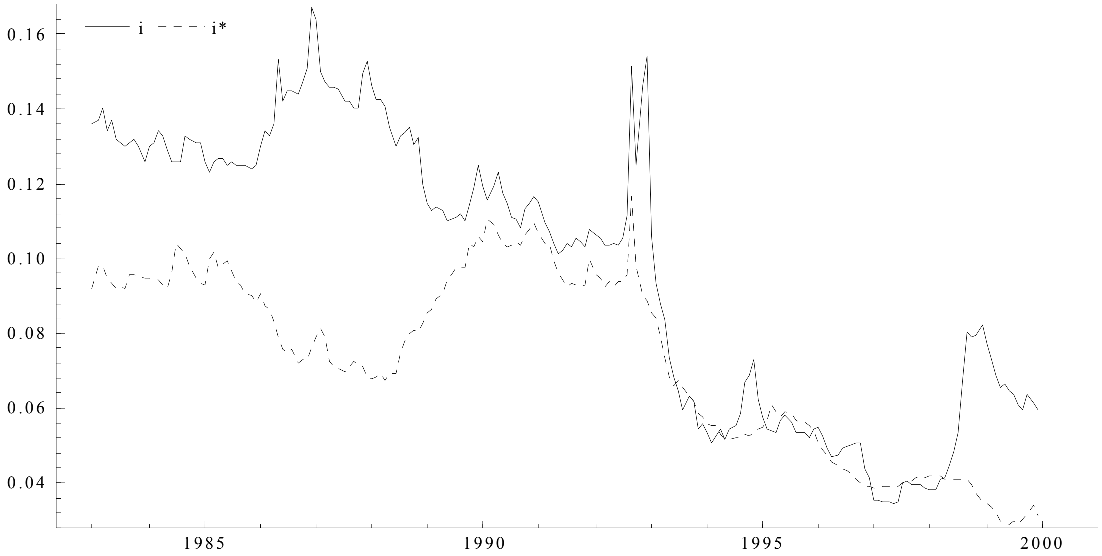

Figure 1 also clearly emphasizes that the real exchange rate does not fluctuate around a fixed value in the short run, but instead wanders wildly. This picture suggests that the real exchange rate has a non-stationary stochastic trend. Hence, one cannot use the PPP measure to find a base period in which the real exchange rate is believed to be in equilibrium. Testing for non-stationary using the Augmented Dickey Fuller (ADF) unit-root test confirms our suspicion that the real exchange rate in Norway has a non-stationary stochastic trend. In particular, we cannot reject the hypothesis that the real exchange rate is non-stationary against the stationary hypothesis (see Table A-2 in Appendix A). This result holds also against each of the major trading partners.

4. Econometric model

Until early 1990s, testing of PPP was conducted within a single equation framework, either by modelling a univariate process of the real exchange rate (as was done above) or by modelling a dynamic equation between the nominal exchange rate and prices. The former approach implicitly assumes that the variables have common roots, see e.g. Kremers et al. (1992). The latter approach will only yield the best unbiased estimates if the chosen endogenous variable (normally the exchange rate) is the only variable that adjusts back to the long run equilibrium exchange rate level. If, on the other hand, more than one of the variables adjusts according to the cointegration vector, one will get a more precise estimate of the coefficients in this vector by estimating the variables jointly in a system.

Here we model the whole system jointly within a full information maximum likelihood (FIML) framework, see Johansen (1988). We first define the vector stochastic process as $z_t = \left(v_t, p_t, p_t^*, i_t, i_t^*, oil_t\right)'$, where *v, p, p**, *i* and *i** are defined as above, and *oil* is the real oil price. Let us assume that this process can be reparameterised as a vector equilibrium correction model (VEqCM):

$$\Delta z_t = \mu + \Gamma_1 \Delta z_{t-1} + \Gamma_2 \Delta z_{t-2} + \ldots + \Gamma_{p-1} \Delta z_{t-p+1} + \Pi z_{t-1} + \gamma t + \Psi D_t + u_t, \qquad (7)$$

where $u_t \sim IN(0, \Sigma)$. μ is a vector of constants, *t* is the trend and D_t is a vector of unrestricted deterministic variables, comprising a vector of centred seasonal dummies, *S*, a vector of general impulse dummies, D_G, and a vector of country specific dummies, D_{CS}, i.e. $D_t = \left(S_t', D_{G,t}', D_{CS,t}'\right)'$. The null hypothesis of *r* cointegrating vectors can then be formulated as:

$$H_0 : \Pi = \alpha \beta', \qquad (8)$$

where α and β are $6 \times r$ matrices of rank r, ($r<6$), $\beta' z_t$ comprises r cointegration I(0) relations, and α contains the loading parameters. In the estimation, we will restrict the trend to lie in the cointegrating space, whereas the vectors of constants and seasonally dummies are left unrestricted. Hence, z_t has seven components, and β will be a $7 \times r$ matrix with rank r and where the last row corresponds to the deterministic trend variable.

In the subsequent sections we will use this framework in the following way. We first estimate the number of cointegrating relations in a well specified VEqCM for the Norwegian nominal exchange rate relative to a basket of trading partners. Thereafter, we test whether the following set of hypotheses of the cointegration vectors are stationary:[11]

I Test of no trend

$\beta' = (1,*,*,*,*,*,0)$

II Test of pure (strong-form) PPP

$\beta' = (1,-1,1,0,0,0,0)$

III Test of interest rate differential (implied by the UIP condition)

$\beta' = (0,0,0,a,-a,0,0)$

IV Test of no oil price

$\beta' = (1,*,*,*,*,0,0)$

V Test of PPP augmented by interest rate differential (from UIP) and oil price

$\beta' = (1,-1,1,a,-a,*,0)$

The first hypothesis tests if the trend in the cointegrating space can be omitted. If that is the case, we will continue the inference on the cointegrating space without incorporating the trend. We thereafter test for PPP, interest rate differential, the significance of the oil price and finally a combination of these hypotheses.

5. Empirical results[12]

In the discussion above (c.f. Figure 1), we emphasised how the nominal and real exchange rate seemed to be dependent on each other in the short run. Now we will turn to the issue of whether they are dependent also in the long run, that is, do we need to modify PPP to explicitly take account of real factors that influence the equilibrium exchange rate? Throughout the analysis, the Norwegian

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[11] Hypotheses II-V assume that we can restrict the trend in the cointegrating space to be zero. This will of course be tested in each application.

[12] The empirical estimations are conducted using PcGive 9.10 and PcFIML 9.10, see Doornik and Hendry (1996,1997).

exchange rate is measured against a basket of trading partners. In the next section, we will repeat the procedure for analogues models where the foreign country is represented by each of Norway's main trading partners.

The variables used in the econometric analysis are again; the nominal exchange rate in Norway, home and foreign prices, home and foreign interest rates and the real oil price, (see Appendix A for a further description of data and their sources).

We use monthly data, and the estimation period is from 1983M1 to 1999M12 for all countries. The start date for estimation is set to exclude the turbulence in the international interest rate markets in the early 1980s, which would necessitate a series of intervention dummies (see the discussion in MacDonald and Marsh 1999a). A few extreme observations are nevertheless remaining in the system, mainly due to changes in the exchange rate regimes not accounted for by the model (see the discussion section three), but also due to a few periods of extreme oil price fluctuations. These observations are therefore best represented with the following set of dummies:

$$D_{G,t} = \left(d84m7_t, d84m9_t, d86m5_t, d86_t, d9091_t, d9293_t, Dfloat_t, d97m1_t\right)'$$

The first three dummies pick up changes in the Norwegian exchange rate regime, in July 1984, September 1984 and May 1986 respectively. The next two dummies take care of extreme oil price fluctuations in 1986 and 1990-1991. *d9293* represents speculation against the Exchange Rate System (ERM) system in 1992-1993 (see Figure 2). *Dfloat* represents the transition to a float system in Norway in December 1992, while *d97m1* picks up the appreciation pressure in January 1997. These dummies will be general to the estimation for the trading partners, and for each of the bilateral estimations. In addition, one or two country specific dummies are included in each of the estimations. These will be discussed in their respective sections (see also Appendix A for a further description of all the dummies).

In modelling the exchange rate against Norway's trading partners, one additional dummy is included; $D_{CS,t} = dtp92_t$. This dummy controls for some of the turbulence due to the speculation against the ERM system in the second half of 1992.

In the model specification above, we assumed that all the variables are integrated of first order, I(1). To test whether the underlying processes contain a unit root, we use the augmented Dickey Fuller (ADF) test of unit root against a (trend) stationary alternative (cf. Table A-2 in Appendix A). For neither of the variables can we reject the hypothesis of I(1) in favour of the (trend) stationary alternative. However, we can reject the hypothesis that all variables are integrated of second order, I(2) (cf. Table A.3 in Appendix A).

A battery of lag reduction tests suggests a lag order of two.[13] Estimating a VAR-model with two lags, a trend and a set of dummies (including centred seasonal dummies), we cannot reject the hypothesis of absence of serial correlation at the 1 pct. level (see Table B-1 in Appendix B for diagnostic tests). However, the normality test (that is a joint test for skewness (third moment) and excess kurtosis (fourth moment)) is rejected for the whole system, essentially due to excess kurtosis. However, since the properties of the cointegration estimators are more sensitive to deviations from normality due to skewness than to excess kurtosis, we do not find the rejections of normality serious (see Juselius and MacDonald (2000)). Table B-1 also reveals some problems with the ARCH test for the exchange rate and the heteroscedasticity test for both the exchange rate and the oil price. Again cointegration test are not very sensitive to these violations, so we ignore them in the following analysis.

The cointegration tests are reported below the diagnostic tests in Table B-1. The tests indicate one cointegration vector at the 1 pct. significance level, independent of whether we look at the λ-max or the trace test. However, based on the 5 pct. level, the trace test suggests that there may be a second cointegrating vector, although adjusting for degrees of freedom, both tests (λ-max and the trace test) clearly shows that there is only one cointegrating vector.[14]

In the second half of Table B-1, different tests on the alpha and beta vectors are conducted under the restriction of one cointegration vector. We start by testing on the beta vector, that is, we test the different hypotheses reported above on the cointegration vector. First, the null restrictions on the trend and the oil price (hypotheses I and IV respectively) cannot be rejected. However, we can reject the hypothesis of pure PPP (hypothesis IIa) and interest rate differential (based on pure UIP) (hypothesis IIIa). However, neither of these two hypothesis can be rejected when the rest of the cointegrating vectors are left unrestricted (hypotheses IIb and IIIb), implying that the hypotheses of PPP and UIP should be combined. This is confirmed in hypothesis V, where a joint test of these restrictions on the cointegration vector is accepted. We therefore identify a cointegration vector with PPP augmented with the interest rate differential. This fully restricted vector has the expected signs; if the Norwegian

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[13] A lag length of two is rather small. However, increasing the lag length marginally to three or four lags, does not really change our results.

[14] Cheung and Lai (1993) suggest that the trace test is relatively more robust to excess kurtosis (and skewness) than the max test. Hence, the correct specification may involve two cointegrating vectors. On the other hand, the tabulated critical values in Osterwald-Lenum (1992) may be lower than the true critical values, since they have been derived under the condition of at most two deterministic variables (a constant and a trend). In our system we have 9 shift and impulse dummies, and most of them are non-centred. Doornik et al. (1999) suggest that shift dummies may increase the true critical values since these dummies (in contrast to the impulse dummies) do not converge quickly to zero. Hence, it seems reasonable to assume that there is only one cointegrating vector.

interest rate is high (relatively to the interest rate of Norway's trading partners), then the equilibrium real exchange rate must be low, consistent with an appreciation of the Norwegian krone.

Testing null restrictions on the alpha vector implies testing for weak exogeneity. A variable is weakly exogenous if it is not adjusting to the long run equilibrium. Table B-1 shows that that we can reject the hypothesis of weak exogeneity for the nominal exchange rate, domestic and foreign prices and the domestic interest rate at a 5 pct. level, although the hypothesis of weak exogeneity for the Norwegian interest rate is close to being accepted. The hypothesis of weak exogeneity for the foreign interest rate and oil price, are clearly not rejected.

In the last part of the table, joint tests of the alpha and beta vectors are reported. In the first reported test, the fully restricted beta vector (hypothesis V) is combined with restriction of weak exogeneity on foreign interest rate and the oil price (hypothesis G). This specification is not rejected. However, the loading coefficient for the Norwegian interest rate has a sign that is contraintuitive, as it implies that if the Norwegian interest rate is high compared to the cointegration relationship, the Norwegian interest rate will *in*crease. However, the system as a whole is stable since the exchange rate and the prices adjust faster in the correct direction. We therefore finally test whether we could restrict the Norwegian interest rate also to be weakly exogenous (hypothesis H), and this restriction cannot be rejected. The additional restriction does not change the estimated coefficients much. The estimated long run exchange rate relation is reported in equation (9), with standard error in parenthesis below.

$$v = p - p^* - \underset{(0.164)}{0.685}(i - i^*) \tag{9}$$

Equation (9) clearly implies that although PPP is not by itself a stationary process, it becomes stationary when combined with the interest rate differential. Hence, the long-run interactions between the goods and capital markets cannot be ignored. The coefficient on the interest rate differential is close to one, and implies that a one percentage point change in the interest rate differential, will lead to a one percent change in the exchange rate. Further, the fact that oil prices do not enter explicitly into the cointegrating relationship, may emphasise that any long run effect that the oil prices may have on the exchange rate, is already captured in the interest rate differential. This will be discussed further in the bilateral analysis below.

Two previous econometric studies, Jore et al. (1998) and Akram (2000a), have analysed the Norwegian exchange rate using a model set up that is related to ours, although the sample period and choice of variables varies somewhat (i.e. Jore et al. (1998) do not include the oil price and use inflation instead of prices). However, while Jore et al. (1998) reject both the PPP and the UIP condition, Akram (2000a) finds (just) support of pure form PPP, although as discussed above, it is uncertain whether he can accept this hypothesis together with the other hypothesis he also identifies.

Our study differs from both of these studies in many respects. In particular, the foreign variables in their model are weighted according to a constant weight of the trading partners as an average over the whole period. Here, we let instead the basket of trading partners change each year, according to the weight of each trading partners. This evolving weight is then used to construct the exchange rate, foreign prices and the foreign interest rate, so that these series are consistent. We believe that this is better able to capture the change in exchange rate regimes pursued, and the variables are consistent.[15]

Further, both of these studies use quarterly data, whereas we use monthly data. We believe that monthly data are better able to capture the quick adjustment in both the interest rates and the exchange rate to different shocks that usually characterise foreign capital markets.

6. Bilateral tests and sensitivity analysis

In this section we will test the robustness of the reported results, by testing the bilateral exchange rate between Norway and its four main trading partners; Germany, Sweden, UK and US. Together they account for 50 pct. of Norway's trade. Some other sensitivity results are also presented in the end.

6.1 Germany

The data for Germany looks very similar to the data for Norway's trading partners, see Figure A-1 in Appendix A, that plots the monthly nominal and real exchange rate between Norwegian kroner and German DM. This is partly due to the fact that Germany is the main trading partner of Norway, but also because many of Norway's trading partners have indirectly tried to fix their exchange rate against Germany. The correlation coefficient between nominal and real exchange rates is higher than for the trading partners; 0.8 measured against the bilateral German DM.

Two country specific dummies are included in the model for Germany in addition to the general dummies; $D_{CS,t} = \left(dger91_t, dger93_t\right)'$, to control for fluctuations in German CPI due to the (after-) effects from the reunion in 1991 and speculation against the ERM in 1993 (see Appendix A). The model diagnostics and cointegration tests are presented in Table B-2.[16] The table reveals clear

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[15] One could argue that one should use a representative interest rate instead of a basket of interest rates. However, many of the countries in the basket have interest rates that are following the German interest rate closely, since their currencies have been closely linked to German DM. By investigating the bilateral exchange rate with Germany below, we can investigate if the results reported for the basket, also holds for Germany.

[16] Unit root tests indicate that all variables are integrated of first order. Lag reduction tests suggest two lags. The diagnostic tests show some problems with non-normality in the residuals, but also now the non-normality results from excess kurtosis.

evidences of one cointegration vector. Assuming the rank to be one, we can (just) accept the hypothesis of no trend. Further, we cannot accept the hypothesis of pure PPP and stationary interest rate differential.

However, as for the case of the basket of trading partners, neither of these hypotheses can be rejected individually when the rest of the cointegrating vector is left unrestricted, implying that the hypotheses should be combined.[17] Further, the hypothesis of absence of oil cannot be accepted, when the rest of the cointegrating vector is unrestricted. In the end then, the combined hypothesis of PPP, interest rate differential and oil price cannot be rejected. We therefore identify a cointegration vector with PPP augmented for the interest rate differential and oil prices. This cointegration vector implies a negative relationship between the oil price and the (real) value of Norwegian kroner measured against German DM in the long run, so that a higher oil price appreciates the real exchange rate.

Testing for weak exogeneity shows that we can reject the null hypothesis of weak exogeneity for the exchange rate and Norwegian prices. For the other variables, the null hypothesis cannot be rejected when tested individually, although German interest rates are close to being rejected. Testing together, we can only reject that German prices, Norwegian interest rates and the real oil price are weakly exogenous. Conditioning on the cointegration vector, German prices, the Norwegian interest rate and the oil price turns out to be weakly exogenous. Equation (10) reports the estimated long run exchange rate relationship, with standard errors in parenthesis below:

$$v = p - p^* - \underset{(0.250)}{1.166}(i - i^*) - \underset{(0.015)}{0.083}\,oil \tag{10}$$

The long run exchange rate relationship reported for Germany is consistent with the results reported for the trading partners, except that now also the oil price enters significantly. The coefficient on the interest rate differential is somewhat larger than for the trading partners, but both are essentially centred around one. That the oil price turned out to be significant here but not for the trading partners, suggests that the effect is not fully reflected in the interest rate differential. The coefficient suggests that a 100 pct. change in the oil price implies a 8.3 pct. change in the exchange rate.

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[17] Note that the hypothesis of augmented PPP is only accepted when we allow for a trend. However, when all the relevant hypotheses are taken together, the hypotheses are accepted independent on the inclusion of trend or not.

6.2 Sweden

The development in both the nominal and real exchange rate against Sweden, differs remarkably from the exchange rate against Norway's trading partners. From Figure A-2 one can see that until 1992, the Swedish krone strengthen against the Norwegian krone in both nominal and real terms. At the end of 1992, Swedish kroner depreciated much more than Norwegian kroner did, after which it has continued to fluctuate. The correlation coefficient between nominal and real exchange rates is the same as for the trading partners; 0.6 measured against Swedish kroner.

One country specific dummy is included when modelling the exchange rate against Sweden; $D_{CS,t} = dswe92$. This dummy is included in order to control for the devaluation of the Swedish krone, (see Appendix A). The model diagnostics and cointegration tests are presented in Table B-3.[18] Both the max and the trace test support the existence of two cointegration vectors. In the lower part of Table B-3, tests on one of the cointegration vectors are conducted, leaving the other one unrestricted. Testing of a null-restriction for the coefficient for trend or oil price is uninteresting when tested separately, since such a test in effect does not involve any restriction at all as long as the second vector is unrestricted. The same is the case for the interest rate differential in its augmented form. However, as for the previous case studies, we can reject the hypothesis of pure PPP and pure UIP separately, but not the hypothesis of augmented PPP (when the trend is left unrestricted). Testing PPP together with the additional restriction of the interest rate differential, but leaving the trend unrestricted, can also not be rejected, even when the coefficient on the oil price is zero.

Tests on weak exogeneity indicates that Swedish prices, the Norwegian interest rate and the oil price are weakly exogenous, tested either separately or together. Combining these restrictions with the accepted restrictions on one of the cointegration vectors, we can report the following long run relationship in equation (11):

$$v = p - p^* - 3.675(i - i^*) + 0.00207t \qquad (11)$$

The cointegration vector implies that the exchange rate and Norwegian prices adjust according to a relationship between PPP, the interest rate differential and a trend. The trend implies that Norwegian kroner depreciates over time against Swedish kroner in real terms for a given interest rate differential. In addition, we have identified a second cointegration relationship, which picks up adjustments in the

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[18] Unit root tests indicate that all variables are I(1). Lag reduction tests suggest two lags. Again the diagnostic tests show some problems with non-normality in the residuals, but the non-normality results from excess kurtosis.

exchange rate and the Swedish interest rate.[19] However, it is difficult to give this vector a theoretical interpretation/justification.

6.3 United Kingdom

Figure A-3 shows that both the nominal and the real exchange rate against United Kingdom were relatively stable until 1995. In 1996 and 1997, however, the Pound appreciated, after which it has remained relatively stable. The correlation coefficient between bilateral nominal and real exchange rates is the same as for Germany, 0.8 measured against the UK pound.

One country specific dummy is included when modelling the exchange rate against UK; $D_{CS,t} = duk90_t$. The dummy picks up the high inflation rate in March 1990 (see Appendix A). The model diagnostics and cointegration tests are presented in Table B-4.[20] Only the trace test indicates one cointegration relationship at the 5 pct. level, but adjusted for degrees of freedom, there are essentially no cointegration relationships. However, since our analysis requires at least one cointegration vector, we continue the analysis under the assumption that one such vector exists. When testing the cointegration vector, we accept the hypothesis of no trend, and proceed the inference without a trend in the cointegration vector. Further, we can reject the hypothesis of pure PPP, but not augmented PPP. However both the interest rate differential and the augmented interest rate differential can be rejected, as well as the inclusion of the oil price. In the end, only the hypothesis of PPP combined with the unrestricted interest rates differential (keeping the null restrictions on the oil and the trend), is accepted. However, the coefficient for the Norwegian interest rate has the wrong sign, implying that when the Norwegian interest rate increases, the Norwegian (real) exchange rate will depreciate.

When testing for weak exogeneity separately we cannot reject that any of the variables in the system are weakly exogenous. Testing for weak exogeneity conditioned on the cointegration vector identified above, weak exogeneity is rejected for domestic prices and interest rates. However, the loading coefficient for domestic prices has the wrong sign; implying that prices adjust away from long run equilibrium instead of back to the long run equilibrium. As it is also difficult to give the cointegration vector a meaningful interpretation, we therefore conclude that we cannot find a reliable long run exchange rate equation between Norway and the UK.

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[19] The second cointegrating vector is $v = -0.097p + 0.553p^* + 1.141i - 3.074i^* - 0.015oil - 0.001702t$.

[20] Unit root tests indicate that all variables are I(1). The lag reduction test reveals 4 lags. Again the diagnostic tests show some problems with non-normality in the residuals, but also now it seams as the non-normality results from excess kurtosis.

6.4 United States

Figure A-4 shows that for the United States, the bilateral nominal and real exchange rate against US dollar have followed each other closely, with the correlation coefficient being as high as 0.95.

Under the estimation, two additional impulse dummies are included; $D_{CS,t} = \left(dus84_t, dus86_t\right)'$. The former picks up fluctuations in the US interest rate, the latter fluctuations in US CPI (see Appendix A). The model diagnostics and cointegration tests are presented in Table B-5.[21] The cointegration max and trace tests support one cointegration vector (at the 5 pct. and the 1 pct. significance level respectively), though their adjusted versions indicate no cointegration relationships. However, assuming that there is one cointegration vector, we can reject the hypothesis of no trend, and continue the remaining tests including the trend. As in the other cases, pure PPP and stationary interest rate differential are rejected separately, but now the hypothesis of augmented PPP is also rejected. Even PPP in its weak symmetric form can be rejected.[22] The augmented interest rate differential is on the other hand accepted, and also the zero restriction on oil prices.

We can reject the null hypothesis of weak exogeneity for all the variables except the oil price when tested separately, although only barely for the US interest rate. However, taken together, we cannot reject that both the oil price and the US interest rate are weakly exogenous. As our main interest is in testing the hypothesis of PPP, we test the hypothesis of augmented PPP (leaving the other variables unrestricted) together with the weak exogeneity assumptions of the oil price and US interest rate. In this case we can only barely reject the hypothesis of augmented PPP. However, as was the case for UK, the coefficient for the Norwegian interest rate has the wrong sign, implying that when the Norwegian interest rate increases, the Norwegian (real) exchange rate will depreciate. We therefore conclude that we cannot find a reliable long run exchange rate equation between Norway and the US.

6.5 Some sensitivity analysis

In this section we perform some alternative specifications of the model, to check the robustness of our reported results. In particular, we check the robustness of using another price index, a different model for oil prices, and the importance of excluded variables.

Prices

Testing of PPP is normality conducted using consumer prices. However, whole sale prices (WPI) and producer prices (PPI) are also commonly used, as well as unit labour costs. The advantage of using

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[21] Unit root tests indicate that all variables are I(1). The lag reduction test indicates 4 lags. The diagnostic tests show that we have a problem with non-normality in the residuals, but again this results from excess kurtosis.

[22] That is, we only restrict the coefficients for domestic and foreign prices to be equal, but with different signs. The rest of the vector is unrestricted.

CPI is that it is considered to be a broad measure of prices. Hence it is a good measure of prices if the basket of goods does not differ very much from a country to another. The drawback with CPI is that it includes taxes on goods (such as VAT) and non-tradable goods that are hard to compare between different countries. On the other hand, the basket of goods in PPI and WPI may differ substantially between the countries, and they are often calculated differently in the various countries.

Nevertheless, to investigate the implications of using another price index, we used the PPI instead of CPI in our analysis. The index is constructed in the same way as we constructed CPI for the trading partners. Lag reduction test yields that 5 lags are necessary in the VAR. With 5 lags, the cointegration tests clearly support one cointegration vector. Imposing restrictions on this vector, we can still reject pure PPP. However, in contrast to our previous results, now also augmented PPP is rejected. Only the hypothesis of weak form PPP (with symmetry) in combination with restriction of interest rate differential is accepted. The interest rate differential has the right signs. Hence, using another price index essentially confirms our results, although a more general definition of PPP has to be used.

Oil price

Above we have assumed there are symmetric and linear effects of the oil price on the exchange rate (or between any of the variables). However, Mork et al. (1994) have shown that there are important asymmetries between the effects of oil price increases and decreases on the US economy. More recently, Hooker (1996) has argued that the relationship between oil and the macroeconomy has decreased dramatically in the US since 1973. However, contrary to the results obtained by Mork et al. (1994), Hooker finds that re-specifying the VAR according to asymmetry theories does not restore the oil macroeconomic relationship.

Hamilton (1996), on the other hand, argues that as most of the increases in the price of oil since 1986 have followed immediately after even larger decreases, they are corrections to the previous decline rather than increases from a stable environment. To correctly measure the effect of oil price increases on the macroeconomy, he suggests that one should compare the price of oil with where it has been over the previous year, rather than with where it was the previous quarter (or month) alone. By constructing what he refers to as the net oil price (the a maximum value of the oil price observed during the preceding year), Hamilton (1996) shows that the historical correlation between oil price shocks and the macroeconomy remains.

Using a methodology similar to that described in Hamilton (1996), does not really change our results. In particular, replacing the oil price with a net oil price in the model for the trading partners, we still identify a cointegrating vector between the real exchange rate and the interest rate differential. There are, however, some more evidence of a second cointegrating vector, and restricting on both, we can identify a long run relationship between the exchange rate and the oil price (and a trend), in addition to our originally identified vector (the oil price does not enter significantly there). However, the effect of the oil price is small, but it enters with the right sign and similar in magnitude to that identified for Germany. Overall then, it seems to be little evidence that the oil price will affect the nominal exchange rate in the long run, although allowing for a non-linear relationship, a (weak) long run link between the oil price and the exchange rate may be present (see also Akram (2000b) for a non-linear analysis of the effects of the oil price).

7. Conclusions

Our analysis indicates that PPP holds against a basket of Norway's trading partners only when we incorporate the interest rate differential. However, pure PPP is rejected. This implies that although PPP is not by itself a stationary process, it becomes stationary when it is combined with the interest rate differential. Hence, the long-run interactions between the goods and capital markets are too important to be ignored by simply investigating PPP in a three dimensional system consisting of the exchange rate, domestic prices and foreign prices.

However, although the evidence for the basket of trading partners is robust, evidences for bilateral PPP are more mixed. We do find some evidence of PPP combined with interest rate differential when the Norwegian krone is measured against Germany DM and Swedish kroner, although for the case of Germany we need to include the oil price, and a trend is included in the case of Sweden. For United Kingdom and United States we do not find any reliable relationship involving PPP. We argue that rejection of bilateral PPP may result from different kinds of shocks in the foreign countries. These shocks may be negligible when modelling against a basket of currencies. Hence, caution should be made when modelling bilateral exchange rates, in particular if the country under investigation has many trading partners.

Having tested the parity conditions bilaterally between Norway and the individual trading partners, also imply that we indirectly have tested if the parity conditions hold between the trading partners themselves. In particular, since we could not reject the hypothesis of augmented PPP between Norway and Germany, but rejected it between Norway and the UK and Norway and the US, it implies that augmented PPP may be rejected between Germany and UK and Germany and the US. The literature has led to mixed conclusions regarding this hypothesis, and we therefore lend support to models that reject (augmented) PPP between these countries, see among others Nessen (1996) and Jacobsen and Nessen (1998).

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The data set

Data sources

All the data series, except the oil price and German CPI, are taken from the International Financial Statistics (IFS) from International Monetary Fund (IMF). The nominal oil price is taken from the data bank at Norges Bank (the central bank of Norway) and German CPI is taken from OECD**.** Below we specify the different data series and the impulse and shift dummies more thoroughly.

Table A-1: IMF weights from 1982 to 1999.

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993-1999^{I}
Austria	1.50	1.50	1.50	1.50	1.60	1.60	1.60	1.60	1.60	1.70	1.70	1.70
Belgium	3.40	3.40	3.30	3.40	3.50	3.50	3.50	3.40	3.00	3.00	3.00	3.10
Canada	1.40	2.80	1.70	1.40	1.40	1.60	1.70	1.60	1.50	1.40	1.30	1.40
Denmark	5.40	5.00	5.20	5.40	5.60	5.60	5.50	5.00	4.50	5.30	5.60	4.80
Spain	0.90	0.90	1.00	1.30	1.10	1.30	1.20	2.00	1.90	2.00	2.20	2.50
Finland	5.00	4.50	4.70	4.20	4.20	4.70	4.30	4.30	4.30	4.30	4.10	3.50
France	6.60	6.60	7.10	6.60	6.80	6.60	6.90	7.40	7.50	7.50	7.50	7.40
Germany	15.50	14.80	15.30	15.70	16.30	14.80	14.30	14.60	14.90	14.60	14.80	14.10
Ireland	0.80	0.50	0.60	0.40	0.80	0.90	1.10	0.60	0.60	0.60	0.60	0.70
Italy	4.00	4.30	4.10	4.60	4.90	5.40	5.30	5.00	5.50	5.10	5.30	5.30
Japan	9.10	8.70	8.90	9.60	9.80	8.70	8.50	8.30	8.60	8.60	9.60	10.80
Netherlands	5.30	5.10	5.60	5.80	5.70	5.90	5.60	5.50	5.90	6.90	5.80	6.20
Sweden	16.00	16.10	15.30	14.90	15.40	15.90	15.90	15.80	15.10	14.60	14.20	12.70
Switzerland	2.00	2.40	2.10	2.20	2.20	2.30	2.20	2.10	2.10	1.80	1.80	1.80
UK	13.10	12.20	11.60	11.90	10.90	11.30	11.50	11.60	12.00	11.90	11.80	13.10
US	10.00	11.20	12.00	11.10	9.80	9.90	10.90	11.20	11.00	10.70	10.70	10.90

I) For the period 1994 - 1999 the weights from 1993 are used. Source: Norges Bank/IMF.

Exchange rates

The exchange rate is taken from line *rf* in IFS from IMF. This line reports the average amount of home currency per dollar in the respective month. For Germany, the exchange rate for West Germany is used before the reunification. Based on these data, Norwegian kroner per foreign currency is calculated. For the exchange rate against Norway's trading partners (TP), the reciprocal of the nominal effective exchange rate *neu* is used, with the weights given by Table A-1 above.

Interest rates

The interest rates are the money market interest rate (line 60b). This is the day monthly average of the day-to-day interbank rate (the federal funds rate for United States). Due to huge fluctuation in this rate for Norway, we have used the three-month interbank rate instead (line 60zb). The interest rate for Norway's trading partners is calculated by a weighted arimetic average, using the weights reported in Table A-1. The interest rate for Sweden shows huge fluctuations in September 1992, due to a currency crisis. To correct for this outlier, we adjusted the interest rate down by 62 pct. points, from about 82 pct. to about 20 pct. The observation is still extreme both compared to the interest rates in the months before and after as well as to the Norwegian interest rate. The fluctuations in the interest rate for Sweden is also reflected in the interest rate for the trading partners, and based on Sweden weights in the basket of trading partners, we adjust the interest rate for the trading partners down by 8 pct. points in September 1992. The data is divided by 100, so an annual interest rate of 10% is written as 0.10.

Prices

The consumer price indices are taken from line 64, except for the German consumer price index that is taken from OECD (CPALLTO1.IXOB.M). The consumer and producer price indices for Norway's trading partners are calculated as a weighed geometric average (weights reported in Table A-1).

In the estimation above, the real oil price in Norwegian kroner is used. The real oil price in Norwegian kroner is calculated by multiplying the nominal oil price in dollar with the krone-dollar exchange rate and then dividing by the Norwegian consumer price index. The source of the nominal oil price in dollar is Norges Bank (line M2001712), and it is the monthly average of daily oil prices.

Dummies

We use 8 different general dummies, i.e. dummies used in all of the models.

- d84m7, d84m9 and d86m5 are impulse dummies that are unity in one month and null otherwise, e.g. d84m7 is unity in July 1984 and null otherwise. These dummies are included to take account for different changes in the Norwegian exchange rate regime. In July 1984, the basket of currencies that Norway was holding the krone fixed against changed, from being calculated as a arimetic average to a geometric average. In practice this involved a devaluation of 2 pct. In September 1984 it was decided to temporary hold the exchange rate index 2 pct. higher than the centre of the exchange band, and in practice this involved a devaluation of 2 pct.. In May 1986 the value of the Norwegian krone was depreciated with about 10 pct., due to the fall in the oil price and increased labour cost in production.

- d86 equals 1 from December 1985 to April 1986, and picks up the decrease in the oil price during this period.
- d9091 equals 1 in August 1990 and -1 in January and February 1991. This dummy captures the fluctuations in the oil price due to the Golf war.
- d9293 equals 1 in September and November 1992, -1 in October 1992 and January and February 1993, and null otherwise. This dummy controls for the speculations against the ERM system in the second half of 1992.
- Dfloat is a step dummy that equals 1 from December 1992, null otherwise. It picks up the change to a floating exchange rate regime.
- d97m1 controls for the appreciation pressure against the Norwegian krone in January 1997. This dummy equals unity in January 1997 and zero otherwise.

In addition we have included different country specific dummies.

- When modelling the exchange rate against Norway's trading partners, the dummy dtp92 is included. This dummy equals 1 in August and September 1992, -1 in October and November 1992 and null otherwise. This dummy is included to control for speculations against the ERM system.
- For Germany, the dummies dger91 and dger93 are included. The dummy dger91 equals 1 in July and October 1991, and controls for fluctuations in the German CPI and interest rate. (Probably repercussions of the reunion in 1990.) The dummy dger93 equals 1 in January 1993, and null otherwise, and is probably picking up after-effects of the speculations against ERM in the second half of 1992.
- For Sweden, the dummy dswe92 is included. This dummy is 1 in September 1992, -1 in November 1992 and null otherwise. This dummy takes care of the speculation against the Swedish exchange rate.
- For United Kingdom, the dummy duk90 is used. This dummy equals unity in Mars 1990, and null otherwise, and picks up high inflationary pressure, which the model is not able to explain.
- For United States, two additional dummies are included; dus84 and dus86. The former is unity in the tree last months of 1984 and controls for fluctuations in the interest rate. The latter is unity from February to May 1986, and controls for fluctuations in the US consumer price index.

Unit root tests

A variable is called (covariance) stationary if its first and second order (unconditional) moments are independent of time. If the variable is stationary after removing a deterministic trend, the variable is called trend stationary.

A variable is called integrated of order *i*, I(i), if it must be differentiated *i* times in order to be stationary (alternatively trend stationary). Economic variables are normally integrated of order zero or one. However, some economic variables are (or at least behaves as) integrated of order two.

To test whether a variable *x* is I(0) or I(1) we make use of a test as in Equation (A-1). We include two lags of the variable as explanatory variables, i.e. an AR(2) model, since we are using two lags in most of our models. (NB: The test results are robust to other lag lengths, ie. 4 lags). The null hypothesis $\gamma=0$ implies that the variable is non-stationary, whereas the alternative hypothesis $\gamma<0$ implies that the variable is stationary.[23]

$$\Delta x_t = \mu + \gamma x_{t-1} + \varphi \Delta x_{t-1} + \xi \cdot t + \psi S_t + \varepsilon_t \tag{A-1}$$

Table A-2: Unit root tests

	NOR	TP	GER	SWE	UK	US
		Without trend, i.e. ξ=0. Critical values: 5%=2.88, 1%=3.46.				
v		1.84	1.71	1.96	1.84	2.13
r		2.39	1.27	2.56	1.19	1.70
i	1.07	0.23	0.55	1.72	1.03	1.52
i-i*		1.87	1.30	3.02*	2.26	1.44
		With trend. Critical vales: 5%=3.43, 1%=4.01				
p	1.93	0.06	0.89	0.41	0.01	0.12
oil	2.22					

TP: Trading partners.

In Table A-2, test statistics for unit roots are reported. The reported variable is the (absolute) t-value of γ. One asterisks (*) indicates that the null hypothesis (of non-stationary) is rejected at a 5 pct. level.

In the first part of the table we have tested variables that do not trend. We have therefore not included the trend in the unit root test, i.e. $\xi=0$. In the first row, we report the unit root tests of the nominal exchange rate between Norway and the trading partners (TP), Norway and Germany (GER), Norway

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[23] More precisely the alternative hypothesis is $|\gamma + 1| < 1$.

and Sweden (SWE), Norway and United Kingdom (UK) and Norway and the United States (US). The row below reports the unit root tests of the real exchanger rate for these countries. Thereafter, the unit root tests for the nominal interest rate for all countries are reported, and below that, the interest rate differential between Norway and each of the group of foreign countries. The lower part of Table A-2, report the unit root test of prices and the oil price. Since these variables are trending variables, we have included the trend to allow for trending behaviour also under the alternative hypothesis.

According to the reported tests, both the nominal and the real exchange rate are non-stationary. Furthermore, the individual interest rates, the interest rate differential, prices and the real oil price are non-stationary.

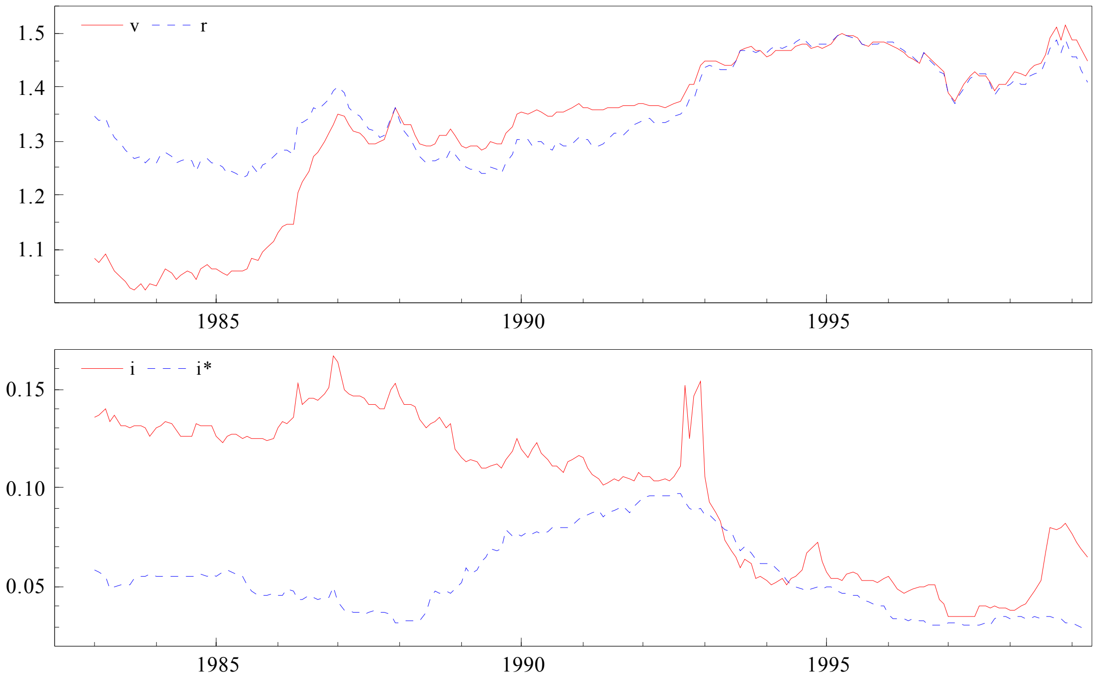
To test whether a variable *x* is I(1) or I(2) corresponds to test whether D*x* is I(0) or I(1). This is done in Table A-3, where two asterisks (**) indicates rejection of non-stationarity of *x* is rejected at the 5 pct. level. We therefore conclude that all variables seems to be I(1).

Table A-3: Unit root tests

	NOR	TP	GER	SWE	UK	US
		Without trend, i.e. ξ=0. Critical values: 5%=2.88, 1%=3.46.				
Dv		8.29**	7.26**	8.34**	10.2**	8.79**
Dr		8.93**	7.80**	8.69**	9.90**	8.74**
Di	10.4**	9.66**	8.53**	11.9**	10.6**	6.98**
D(i-i*)		10.6**	9,97**	12.4**	10.7**	8.95**
Dp	5.82**	5.59**	7.99**	6.95**	6.70**	7.37**
Doil	9.04**					

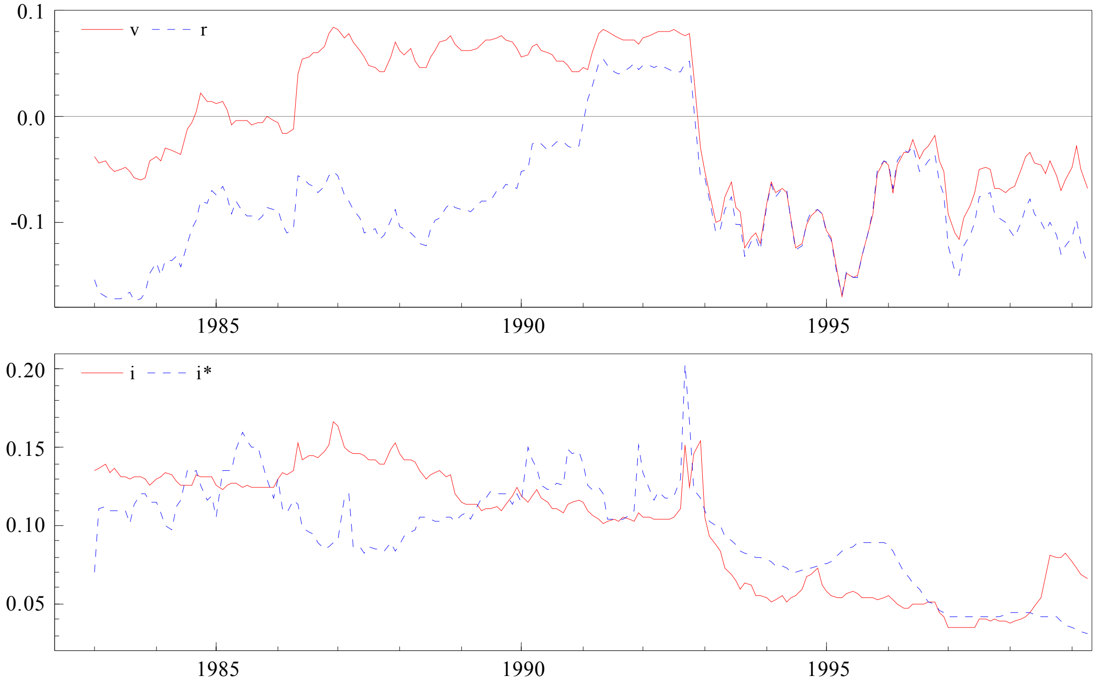
Figures

Figure A-1: Germany[1]



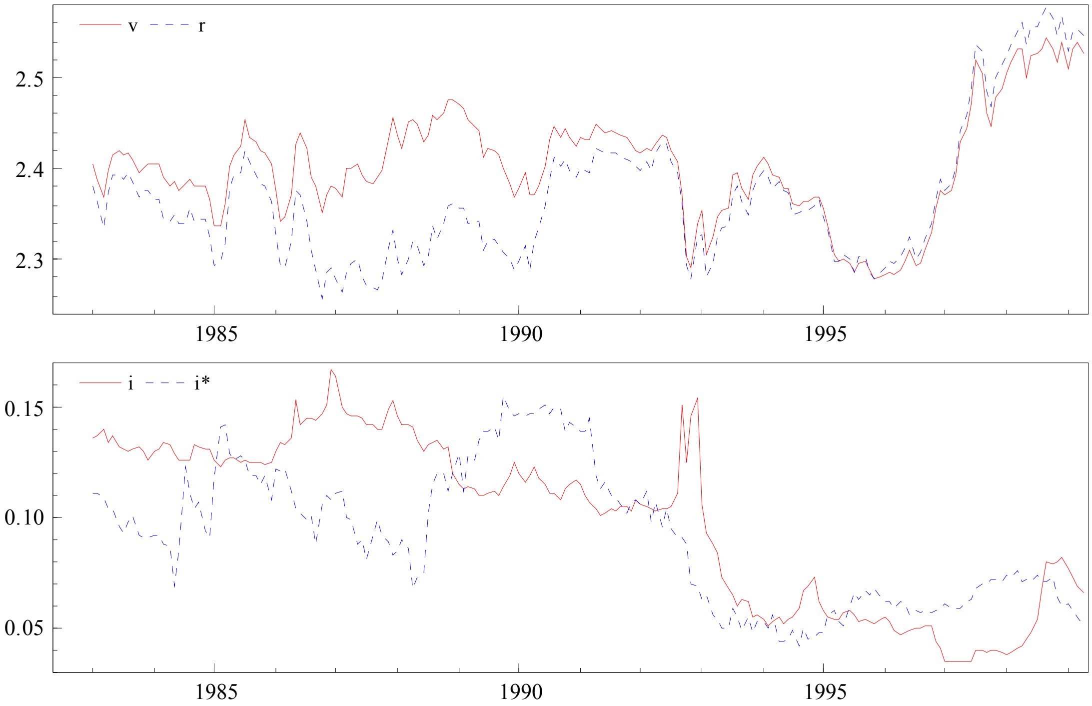
1) Nominal exchange rates (v), real exchange rates (r), Norwegian interest rate (i) and German interest rate (i*).

Figure A-2: Sweden[1]



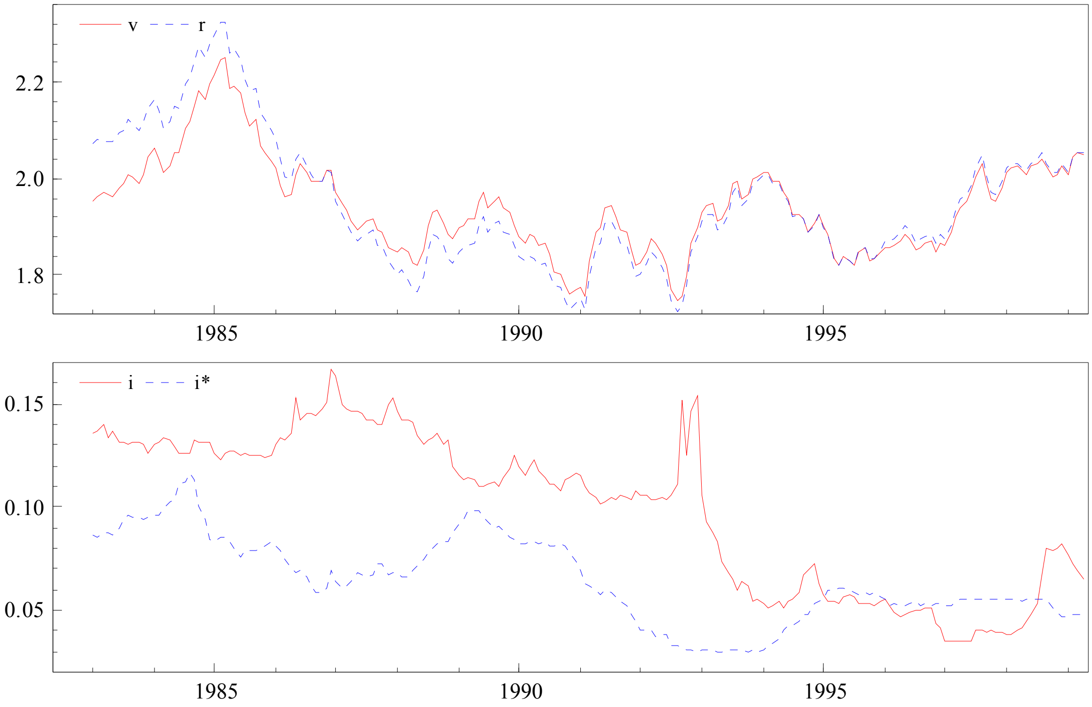
1) Nominal exchange rates (v), real exchange rates (r), Norwegian interest rate (i) and Swedish interest rate (i*).

Figure A-3: United Kingdom[1]



1) Nominal exchange rates (v), real exchange rates (r), Norwegian interest rate (i) and UK interest rate (i*).

Figure A-4: United States[1]



1) Nominal exchange rates (v), real exchange rates (r), Norwegian interest rate (i) and US interest rate (i*).

Appendix B

Estimation results

Table B-1: Trading partners[a]

Diagnostic tests[b]

		vTP	pNOR	pTP	iNOR	iTP	oil
AR 1-7	F(7,163)	1.24 [0.28]	0.93 [0.48]	0.59 [0.77]	0.41 [0.89]	0.89 [0.51]	0.48 [0.48]
Norm	X2(2)	20.8 [0.00]**	24.2 [0.00]**	36.9 [0.00]**	46.9 [0.00]**	16.0 [0.00]**	33.8 [0.00]**
Skewness		0.18	0.07	0.21	0.74	0.26	0.46
Exc. kurt.		1.70	1.83	2.49	3.94	1.46	2.64
ARCH 7	F(7,156)	5.57 [0.00]**	0.54 [0.80]	0.21 [0.98]	2.00 [0.06]	2.11 [0.05]*	1.32 [0.24]
Het	F(26,143)	2.87 [0.00]**	1.17 [0.32]	0.95 [0.54]	1.95 [0.01]**	1.78 [0.02]*	2.12 [0.00]**
System:	AR 1-7 F(252,740)=1.04 [0.34]		Norm X2(12)=185.34 [0.00]**		Het F(546,2102)=1.31 [0.00]**		

Cointegrating rank tests

H0:rank=p	eigenvalue λ_i	λ-max[c]	λ-max adj.	95%	λ-trace[d]	λ-trace adj.	95%
p=0	0.308	75.25**	70.82**	44.0	165.6**	155.9**	114.9
p≤1	0.164	36.58	34.43	37.5	90.36*	85.05	87.3
p≤2	0.140	30.79	28.98	31.5	53.78	50.62	63.0
p≤3	0.058	12.09	11.38	25.5	23.00	21.64	42.2
p≤4	0.040	8.36	7.87	19.0	10.91	10.27	25.3
p≤5	0.012	2.55	2.40	12.3	2.55	2.40	12.3

Unrestricted alpha and beta

	vTP	pNOR	pTP	iNOR	iTP	oil	Trend[e]
alpha	-0.055	0.016	-0.016	0.022	0.003	0.337	---
beta	1	-1.232	1.408	0.489	-1.487	-0.028	0.412

Cointegrating vectors

Number	Name	Beta restrictions	Estimated beta	LR prob
I	No trend	(1, *,*,*, *,*,0)	(1,-1.212,1.221,0.405,-1.158,-0.030, 0)	0.46 [0.50]
IIa	Pure PPP	(1,-1,1,0,0,0,0)	(1,-1 ,1 ,0 ,0 , 0 , 0)	15.5 [0.02]**
IIb	Augm. PPP, no trend	(1,-1,1,*, *,*,0)	(1,-1 ,1 ,0.364,-1.023,-0.007, 0)	1.90 [0.59]
IIIa	Interest rate differential	(0, 0,0,1,-1,0,0)	(0, 0 ,0 ,1 ,-1 , 0 , 0)	40.7 [0.00]**
IIIb	Augm. UIP, no trend	(1, *,*,a,-a,*,0)	(1,-1.236,1.281,0.683,-0.683,-0.028, 0)	4.38 [0.11]
IV	No oil/trend	(1, *,*,*, *,0,0)	(1,-0.992,0.988,0.384,-1.039, 0 , 0)	2.42 [0.30]
V	PPP, UIP, no oil/trend	(1,-1,1,a,-a,0,0)	(1,-1 ,1 ,0.572,-0.572, 0 , 0)	6.26 [0.28]

Weak exogenity

Number	Variable	Alpha restrictions	LR prob
A	vTP	(0,*,*,*,*,*)	8.70 [0.00]**
B	pNOR	(*,0,*,*,*,*)	4.63 [0.03]*
C	pTP	(*,*,0,*,*,*)	16.0 [0.00]**
D	iNOR	(*,*,*,0,*,*)	4.29 [0.04]*
E	iTP	(*,*,*,*,0,*)	0.26 [0.61]
F	oil	(*,*,*,*,*,0)	3.53 [0.06]
G=E+F	iTP and oil	(*,*,*,*,0,0)	3.68 [0.16]
H=D+E+F	iNOR, iTP, oil	(*,*,*,0,0,0)	7.99 [0.05]*

Joint tests of alpha and beta

Comb.	Estimated alpha	Estimated beta	LR prob
V+G	(-0.083,0.022,-0.020,0.024,0,0)	(1,-1 ,1 ,0.565,-0.565, 0 , 0)	10.0 [0.19]
V+H	(-0.086,0.024,-0.018,0 ,0,0)	(1,-1 ,1 ,0.685,-0.685, 0 , 0)	13.4 [0.10]

a) Trading partners: p=2 (2 lags), $D_{CS,t}$=$dtp92_t$, $D_{G,t}$ is defined in the text. b) AR 1-7 is Harvey's (1981) test of 7th order residual autocorrelation; NORM is the normality test described in Doornik and Hansen (1994); ARCH is the Engle (1982) test for 7th order autoregressive conditional heteroscedasticity in the residuals; and Het is a test for residual heteroscedasticity due to White (1980). c) The λ-max test the null hypothesis of r cointegrating vectors against the alternative r+1, r=0,1,2,..,n-1, where n is the Numberer of variables in the model, see Johansen (1988). In the adjusted version of the test, the number of observations T is replaced by T-nk, where k is the number of lags, see Reimers (1992). d) The λ-trace test for r=0,1,2,..,n-1. Also here we report the adjusted version (see Reimers, 1992). e) The estimated coefficient for the trend is multiplied by 1000. Critical values are taken from Osterwald-Lenum, (1992), and (*) denotes rejection at the 5 percent significance level while (**) indicates rejection at the 1 percent level.

Table B-2: Germany[a)]

Diagnostic tests[b)]

		vGER	pNOR	pGER	iNOR	iGER	oil
AR 1-7	F(7,162)	1.31 [0.25]	1.68 [0.12]	1.70 [0.11]	0.939 [48]	1.34 [0.23]	0.53 [0.81]
Norm	X2(2)	22.1 [0.00]**	34.0 [0.00]**	18.1 [0.00]**	30.7 [0.00]**	24.8 [0.00]**	36.4 [0.00]**
Skewness		0.23	0.01	0.44	0.75	0.23	0.32
Exc. kurt.		1.78	2.28	1.72	3.02	1.93	1.93
ARCH 7	F(7,155)	1.67 [0.12]	0.27 [0.96]	1.46 [0.19]	0.72 [0.66]	2.37 [0.02]*	1.67 [0.12]
Het	F(26,142)	2.11 [0.00]**	1.17 [0.28]	1.11 [0.34]	1.40 [0.11]	1.02 [0.44]	2.39 [0.00]**
System:	AR 1-7 F(252,734)=1.36 [0.00]**		Norm X2(12)=162.5 [0.00]**,		Het F(546,2085)=1.121 [0.04]*		

Cointegrating rank tests

H0:rank=p	eigenvalue λ_i	λ-max[c)]	λ-max adj.	95%	λ-trace[d)]	λ-trace adj.	95%
p=0	0.308	75.11**	70.69**	44.0	158.1**	148.8**	114.9
p≤1	0.171	38.23*	35.98	37.5	83.02	78.14	87.3
p≤2	0.133	29.04	27.33	31.5	44.79	42.15	63.0
p≤3	0.045	9.30	8.75	25.5	15.75	14.82	42.4
p≤4	0.022	4.55	4.28	19.0	6.49	6.07	25.3
p≤5	0.009	1.90	1.79	12.3	1.90	1.79	12.3

Unrestricted alpha and beta

	vGER	pNOR	pGER	iNOR	iGER	oil	Trend[e)]
alpha	-0.046	0.019	-0.005	0.004	-0.008	0.117	---
beta	1	-1.341	0.540	1.069	-1.032	0.072	2.326

Cointegrating vectors

Number	Name	Beta restrictions	Estimated beta	LR prob
I	No trend	(1, *,*,*, *,*,0)	(1,-1.049,1.498,1.648,-1.944,0.090,0)	3.39 [0.07]
IIa	Pure PPP	(1,-1,1,0,0,0,0)	(1,-1 ,1 ,0 , 0 ,0 ,0)	54.6 [0.00]**
IIb	Augm. PPP, no trend	(1,-1,1,*, *,*,0)	(1,-1 ,1 ,1.154,-1,685,0,074,0)	8.85 [0.03]*
IIc	Augmented PPP	(1,-1,1,*, *,*,*)	(1,-1. ,1 ,1.315,-1.596,0.105,0.717)	2.48 [0.29]
IIIa	Interest rate differential	(0, 0,0,1,-1,0,0)	(0, 0 , 0 ,0 , 1 ,-1 ,0)	28.6 [0.00]**
IIIb	Augm. UIP, no trend	(1, *,*,a,-a,*,0)	(1,-1.064,1.534,1.833,-1.833,0.091,0)	3.55 [0.17]
IIIc	Augmented UIP	(1, *,*,a,-a,*,*)	(1,-1.337,0.544,1.052,-1.052,0.072,2.306)	0.00 [0.95]
IVa	No oil/trend	(1, *,*,*, *,0,0)	(1,-1.509,2.124,2.316,-2.655,0 ,0)	7.74 [0.02]*
IVb	No oil	(1, *,*,*, *,0,*)	(1,-1.792,0.585,1.282,-1.135,0.000,3.296)	3.82 [0.05]
V	PPP, UIP	(1,-1,1,a,-a,*,*)	(1,-1 ,1 ,1.470,-1.470,0.109,0.739)	2.68 [0.44]
VI	PPP, UIP, no trend	(1,-1,1,a,-a,*,0)	(1,-1 ,1 ,1.435,-1.435,0.079,0)	9.33 [0.05]
VII	PPP, UIP, no oil	(1,-1,1,a,-a,0,*)	(1,-1 ,1 ,3.511,-3.511,0 ,0.311)	22.4 [0.00]**
VIII	PPP, UIP, no oil/trend	(1,-1,1,a,-a,0,0)	(1,-1 ,1 ,3.918,-3.918,0 ,0)	22.7 [0.00]**

Weak exogenity

Number	Variable	Alpha restrictions	LR prob
A	vGER	(0,*,*,*,*,*)	6.08 [0.01]*
B	pNOR	(*,0,*,*,*,*)	21.0 [0.00]**
C	pGER	(*,*,0,*,*,*)	2.94 [0.09]
D	iNOR	(*,*,*,0,*,*)	0.41 [0.52]
E	iGER	(*,*,*,*,0,*)	3.75 [0.05]
F	oil	(*,*,*,*,*,0)	0.89 [0.34]
G=D+F	iNOR and oil	(*,*,*,0,*,0)	1.39 [0.50]
H=C+D+F	pGER, iNOR and oil	(*,*,0,0,*,0)	5.14 [0.16]
J=D+E+F	iNOR, iGER and oil	(*,*,*,0,0,0)	5.38 [0.15]
K=C+D+E+F	pGER,iNOR,iGER,oil	(*,*,0,0,0,0)	13.3 [0.01]*

Joint tests of alpha and beta

Comb.	Estimated alpha	Estimated beta	LR prob
VI+H	(-0.032,0.019, 0 ,0,-0.012,0)	(1,-1 ,1 ,1.166,-1.166,0.083,0)	11.6 [0.11]
VI+J	(-0.021,0.014,-0.005,0, 0 ,0)	(1,-1 ,1 ,2.469,-2.469,0.073,0)	19.0 [0.01]**

a) Germany: p=2, $D_{CS,t}=(dger91_t$, dger93 $_t)'$, $D_{G,t}$ is defined in the text. b)-e) See Table B-1.

Table B-3: Sweden[a)]

Diagnostic tests[b)]

		vSWE	pNOR	pSWE	iNOR	iSWE	oil
AR 1-7	F(7,163)	0.34 [0.93]	1.12 [0.35]	2.43 [0.02]	0.56 [0.79]	0.83 [0.56]	0.52 [0.82]
Norm	X2(2)	27.1 [0.00]**	27.7 [0.00]**	46.4 [0.00]**	52.3 [0.00]**	91.5 [0.00]**	38.6 [0.00]**
Skewness		-0.01	0.13	1.40	0.58	0.49	0.35
Exc. kurt.		1.96	2.02	6.06	3.78	5.19	2.72
ARCH 7	F(7,156)	3.18 [0.00]**	0.46 [0.86]	3.09 [0.01]**	2.16 [0.04]*	0.39 [0.91]	2.14 [0.04]
Het	F(26,143)	2.01 [0.01]**	1.58 [0.05]*	1.18 [0.26]	2.53 [0.00]**	2.00 [0.01]**	1.83 [0.01]*
System:	AR 1-7 F(252,740)=0.94 [0.71]		Norm X2(12)=277 [0.00]**			Het F(546,2102)=1.29 [0.00]**	

Cointegrating rank tests

H0:rank=p	eigenvalue λ_i	λ-max[c)]	λ-max adj.	95%	λ-trace[d)]	λ-trace adj.	95%
p=0	0.237	55.27**	52.02**	44.0	163.0**	153.4**	114.9
p≤1	0.215	49.38**	46.47**	37.5	107.7**	101.4**	87.3
p≤2	0.141	31.03	29.20	31.5	58.34	54.91	63.0
p≤3	0.095	20.44	19.23	25.5	27.32	25.71	42.4
p≤4	0.025	5.22	4.91	19.0	6.88	6.48	25.3
p≤5	0.008	1.66	1.56	12.3	1.66	1.56	12.3

Unrestricted alpha and beta

	vSWE	pNOR	pSWE	iNOR	iSWE	oil	Trend[e)]
alpha	-0.120	0.018	-0.012	0.002	-0.028	0.373	---
	-0.043	-0.012	-0.002	0.004	-0.028	-0.091	---
beta	1	-0.821	0.266	0.809	-0.096	-0.029	0.876
	1	0.552	-0.698	-1.613	3.45	0.039	0.866

Cointegrating vectors

Number	Name	Beta restrictions[f)]	Estimatet beta	LR prob
I	No trend	(1, *,*,*, *,*,0)	does not involve any restriction on coint. space	NA
IIa	Pure PPP	(1,-1,1,0, 0,0,0)	(1,-1,1,0, 0,0,0)	18.8 [0.00]**
IIb	Augmented PPP	(1,-1,1,*, *,*,*)	beta is not uniquely identified	2.47 [0.12]
III	Interest rate differential	(0, 0,0,1,-1,0,0)	(0, 0,0,1,-1,0,0)	12.9 [0.02]*
IVa	No oil	(1, *,*,*, *,*,0)	does not involve any restriction on coint. space	NA
IVb	No oil/trend	(1, *,*,*, *,0,0)	beta is not uniquely identified	0.94 [0.33]
V	PPP, no oil/trend	(1,-1,1,*, *,0,0)	beta is not uniquely identified	11.9 [0.01]**
VI	PPP, UIP	(1,-1,1,a,-a,*,*)	beta is not uniquely identified	2.47 [0.29]
VII	PPP, UIP, no oil	(1,-1,1,a,-a,0,*)	beta is not uniquely identified	3.26 [0.35]
VIII	PPP, UIP, no trend	(1,-1,1,a,-a,*,0)	beta is not uniquely identified	8.60 [0.04]*

Weak exogenity

Number	Variable	Alpha restrictions[g)]	LR prob
A	vSWE	(0,*,*,*,*,*)	18.2 [0.00]**
B	pNOR	(*,0,*,*,*,*)	16.8 [0.00]**
C	pSWE	(*,*,0,*,*,*)	0.98 [0.61]
D	iNOR	(*,*,*,0,*,*)	0.44 [0.80]
E	iSWE	(*,*,*,*,0,*)	9.11 [0.01]*
F	oil	(*,*,*,*,*,0)	5.00 [0.08]
G=C+D+F	pSWE, iNOR and oil	(*,*,0,0,*,0)	6.49 [0.37]

Joint tests of alpha and beta

Comb.	Estimated alpha	Estimated beta	LR prob
VII+G	(-0.111,0.009,0,0,-0.030,0)	beta is not uniquely identified	8.78 [0.46]

a) Sweden: p=2, $D_{CS,t}=dswe92_t$, $D_{G,t}$ is defined in the text. b)-e) See Table B-1. f) The second cointegration vector is unrestricted. g) Restrictions imposed on both alpha columns.

Table B-4: United Kingdom[a)]

Diagnostic tests[b)]

		vUK	pNOR	pUK	iNOR	iUK	oil
AR 1-7	F(7,151)	0.53 [0.81]	1.01 [0.43]	0.87 [0.53]	1.50 [0.17]	0.97 [0.45]	1.21 [0.30]
Norm	X2(2)	4.07 [0.13]	24.7 [0.00]**	100 [0.00]**	25.1 [0.00]**	35.9 [0.00]**	7.29 [0.00]**
Skewness		-0.28	-0.11	0.74	0.75	0.20	0.14
Exc. kurt.		0.47	1.86	6.34	2.60	2.44	0.84
ARCH 7	F(7,144)	1.24 [0.28]	0.42 [0.89]	0.21 [0.98]	1.08 [0.38]	2.27 [0.03]*	1.23 [0.29]
Het	F(50,107)	0.80 [0.81]	0.65 [0.95]	0.57 [0.99]	0.85 [0.74]	0.80 [0.80]	1.22 [0.20]
System:	AR 1-7 F(252,669)=1.19 [0.04]*		Norm X2(12)=211 [0.00]**		Het F(150,1820)=0.73 [1.00]		

Cointegrating rank tests

H0:rank=p	eigenvalue λ_i	λ-max[c)]	λ-max adj.	95%	λ-trace[d)]	λ-trace adj.	95%
p=0	0.170	37.97	33.50	44.0	117.5*	103.6	114.9
p≤1	0.163	36.34	32.06	37.5	69.49	70.14	87.3
p≤2	0.098	21.01	18.55	31.5	43.16	38.08	63.0
p≤3	0.071	15.06	13.29	25.5	22.14	19.53	42.4
p≤4	0.025	5.19	4.58	19.0	7.07	6.24	25.3
p≤5	0.009	1.89	1.66	12.3	1.89	1.66	12.3

Unrestricted alpha and beta

	vUK	pNOR	pUK	iNOR	iUK	oil	Trend[e)]
alpha	-0.019	-0.003	0.001	0.007	0.008	-0.002	---
beta	1	1.064	-0.076	-12.364	-1.406	-0.159	-6.389

Cointegrating vectors

Number	Name	Beta restrictions	Estimated beta	LR prob
I	No trend	(1, *,*,*, *,*,0)	(1, 0.881,-2.587,-19.064,-2.528,-0.464, 0)	0.24 [0.63]
IIa	Pure PPP	(1,-1,1,0, 0,0,0)	(1,-1 , 1 , 0 , 0 , 0 , 0)	29.9 [0.00]**
IIb	Augm. PPP, no trend	(1,-1,1,*, *,*,0)	(1,-1 , 1 ,-61.476,-5.253,-0.821, 0)	3.64 [0.30]
IIIa	Interest rate differential	(0, 0,0,1,-1,0,0)	(0, 0 , 0 , 1 , 1 , 0 , 0)	13.5 [0.04]*
IIIb	Augm. UIP, no trend	(1, *,*,a,-a,*,0)	(1,-1.212,-4.791, 19.658,-19.658,-0.800,0)	9.11 [0.01]*
IV	No oil/trend	(1, *,*,*, *,0,0)	(1, 4.652,-5.065,-23.505,-3.203, 0 , 0)	1.70 [0.43]
V	PPP, no oil/trend	(1,-1,1,*,*,0,0)	(1,-1 , 1 ,-127.96, -7.922, 0 , 0)	7.23 [0.12]
VI	PPP, UIP, no oil/trend	(1,-1,1,a,-a,0,0)	(1,-1 , 1 ,-27.492,27.492, 0 , 0)	13.2 [0.02]*

Weak exogenity

Number	Variable	Alpha restriction	LR prob
A	vUK	(0,*,*,*,*,*)	1.45 [0.23]
B	pNOR	(*,0,*,*,*,*)	0.80 [0.37]
C	pUK	(*,*,0,*,*,*)	0.39 [0.53]
D	iNOR	(*,*,*,0,*,*)	1.63 [0.20]
E	iUK	(*,*,*,*,0,*)	0.39 [0.53]
F	oil	(*,*,*,*,*,0)	0.00 [0.98]
G=A+C+E+F	vUK, pUK, iUK and oil	(0,*,0,*,0,0)	4.97 [0.29]
H=B+C+F	pNOR, pUK and oil	(*,0,0,*,*,0)	3.86 [0.28]

Joint tests of alpha and beta

Comb.	Estimated alpha	Estimated beta	LR prob
V+A	(0 ,-5e-5,1e-5, 1e-4, 5e-5, -5e-5)	(1,-1 , 1 ,-741.36, 100.03,0 , 0)	9.44 [0.09]
V+B	(-5e-4 ,0 ,8e-6, 1e-4, 3e-4, -4e-4)	(1,-1 , 1 ,-341.40,-250.91,0 , 0)	16.5 [0.01]**
V+C	(-0.002,5e-4,0 ,0.001, 8e-4, -9e-4)	(1,-1 , 1 ,-73.632, -7.465, 0 , 0)	7.74 [0.17]
V+D	(0.003,4e-4,2e-5 , 0 ,-0.003,0.002)	(1,-1 , 1 , 38.122, 33.961, 0 , 0)	17.4 [0.00]**
V+E	(-0.002,-7e-4,1e-4,0.001,0 ,05e-4)	(1,-1 , 1 ,-51.300, 9.685, 0 , 0)	8.74 [0.12]
V+F	(-0.001,-3e-4,8e-5, 6e-4, 5e-4, 0)	(1,-1 , 1 ,-124.14,- 7.494, 0 , 0)	7.23 [0.20]
V+G	(0 ,-7e-4,0 ,0.001, 0 , 0)	(1,-1 , 1 ,-56.020, 13.370, 0 , 0)	10.6 [0.23]

a) United Kingdom: p=4, $D_{CS,t}=duk90_t$,, $D_{G,t}$ is defined in the text. b)-e) See Table B-1.

Table B-5: United States[a)]

Diagnostic tests[b)]

		vUS	pNOR	pUS	iNOR	iUS	oil
AR 1-7	F(7,150)	0.62 [0.74]	1.50 [0.17]	2.06 [0.05]	1.78 [0.10]	0.69 [0.68]	1.06 [0.39]
Norm	X2(2)	1.21 [0.55]	23.8 [0.00]**	2.84 [0.24]	27.1 [0.00]**	14.3 [0.00]**	7.27 [0.03]*
Skewness		0.18	0.08	0.20	0.83	0.00	0.20
Exc. kurt.		0.06	1.81	0.38	2.88	1.23	0.84
ARCH 7	F(7,143)	0.23 [0.98]	0.33 [0.94]	1.13 [0.35]	0.61 [0.75]	1.71 [0.11]	1.46 [0.19]
Het	F(50,106)	0.73 [0.90]	0.79 [0.82]	0.67 [0.94]	0.99 [0.50]	1.01 [0.47]	1.03 [0.44]
System:	AR 1-7 F(252,663)=1.15 [0.08]		Norm X2(12)=76.6 [0.00]**		Het F(150,1801)=0.72 [1.00]		

Cointegrating rank tests

H0:rank=p	eigenvalue λ_i	λ-max[c)]	λ-max adj.	95%	λ-trace[d)]	λ-trace adj.	95%
p=0	0.212	48.48*	42.77	44.0	126.2**	111.4	114.9
p≤1	0.161	35.79	31.58	37.5	77.73	68.59	87.3
p≤2	0.100	21.55	19.01	31.5	41.95	37.01	63.0
p≤3	0.066	13.82	12.2	25.5	20.40	18.00	42.4
p≤4	0.029	5.91	5.21	19.0	6.58	5.81	25.3
p≤5	0.003	0.67	0.59	12.3	0.67	0.59	12.3

Unrestricted alpha and beta

	vUS	pNOR	pUS	iNOR	iUS	oil	Trend[e)]
alpha	-0.036	-0.005	-0.002	0.007	-0.004	0.003	---
beta	1	-2.313	9.485	-1.930	-0.554	-0.248	-15.55

Cointegrating vectors

Number	Name	beta-restr	Estimated beta	LR prob
I	No trend	(1, *,*,*, *,*,0)	(1,-3.890, 4.821,-7.707,-6.310,-0.472, 0)	6.52 [0.01]*
IIa	Pure PPP	(1,-1,1,0, 0,0,0)	(1,-1 ,1 , 0 , 0 , 0 , 0)	32.5 [0.00]**
IIb	Augmented PPP	(1,-1,1,*, *,*,*)	(1,-1 ,1 ,-8.712,-6.210,-0.219, 0.489)	9.18 [0.01]*
IIc	Augm. PPP, weak form	(1,-a,a,*, *,*,*)	(1,-3.649, 3.649,-7.857,-6.051,-0.518, 0.706)	7.25 [0.01]**
IIIa	Interest rate differential	(0, 0,0,1,-1,0,0)	(0, 0 , 0 , 1 , 1 , 0 , 0)	42.0 [0.00]**
IIIb	Augmented UIP	(1, *,*,a,-a,*,*)	(1,-2.250,10.429,-0.641, 0.641,-0.225,-17.654)	0.34 [0.56]
IV	No oil	(1, *,*,*, *,0,*)	(1,-1.034,10.538,-1.628,-0.297, 0 ,-19.892)	1.27 [0.26]
V	PPP, UIP	(1,-1,1,a,-a,*,*)	(1,-1 , 1 ,-0.540, 0.540,-0.351, -3.105)	19.9 [0.00]**

Weak exogenity

Number	Variable	Alpha restriction	LR prob
A	vUS	(0,*,*,*,*,*)	6.04 [0.01]*
B	pNOR	(*,0,*,*,*,*)	10.3 [0.00]**
C	pUS	(*,*,0,*,*,*)	5.00 [0.03]*
D	iNOR	(*,*,*,0,*,*)	4.53 [0.03]*
E	iUS	(*,*,*,*,0,*)	4.01 [0.05]*
F	oil	(*,*,*,*,*,0)	0.00 [0.96]
G=E+F	iUS and oil	(*,*,*,*,0,0)	4.96 [0.08]

Joint tests of alpha and beta

Comb.	Estimated alpha	Estimated beta	LR prob
IIb+F	(-0.028,-0.003,-0.002,0.008,-0.001,0)	(1,-1 ,1 ,-9.020,-6.469,-0.213, 0.516)	9.21 [0.03]*
IIb+G	(-0.035,-0.003,-0.002,0.010, 0 ,0)	(1,-1 ,1 ,-7.919,-5.540,-0.235,-0.217)	9.56 [0.05]*

a) United States: p=4, $D_{CS,t}$=(*dus84*$_t$, dus86$_t$)', $D_{G,t}$ is defined in the text. b)-e) See Table B-1.