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by

Qaisar Farooq Akram

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When does the oil price affect the Norwegian exchange rate?

Qaisar Farooq Akram*
Research Department, Norges Bank

August 9, 2000

Abstract

Major changes in the Norwegian exchange rate have often coincided with large fluctuations in the price of crude oil. Previous empirical studies have however suggested a weak and ambiguous relation between the oil price and the exchange rate. In contrast to these studies, this paper explores the possibility of a non-linear relation between oil prices and the exchange rate. An examination of daily observations reveals a negative relation between the oil price and the nominal value of the currency. The strength of this relation depends on whether the oil price is below, inside or above the range of 14-20 US dollars a barrel. Moreover, it depends on whether the oil price is displaying a falling or rising trend. The relation is relatively strong when oil prices are below 14 dollars and are falling. These non-linear effects are tested and quantified within equilibrium correcting models of the exchange rate, derived on monthly and quarterly data to control for the influence of other macroeconomic variables. The models with non-linear oil price effects outperform similar models with linear oil price effects. The latter models grossly underestimate the exchange rate response to oil price changes in a state of low oil prices. The paper undertakes an extensive evaluation of the derived models to demonstrate the robustness of the results.

JEL Classification: *C51, E44, E52, F31.*

Key words: *Currency crises; Exchange rate; Oil price; Non-linear econometric models.*

1. Introduction

The price of crude oil is commonly believed to have a significant influence on the Norwegian exchange rate. The Norwegian currency crises in the 1990s, i.e. the appreciation pressure in 1996/97 and the depreciation pressure in 1998/1999, have been attributed to the rise and fall of oil prices, see e.g. Alexander, Green and Arnason (1997), Haldane (1997) and Norges Bank (1998) for details. Likewise, the large devaluation of the krone in 1986 is often explained with reference

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to low oil prices in 1985/86, see e.g. Norges Bank (1987, pp. 17).[1] The assumed link between the oil price and the value of the krone is based on the size of the petroleum sector relative to GDP, 10-20 % since the mid 1970s, and its relatively large share in Norway's total export of goods and services, see Aslaksen and Bjerkholt (1986) and Statistics Norway (1998). For example, in the period 1991-1997, Norway's oil production has been about 1.7 to 3 million barrels a day and oil and gas exports have made up more than 1/3 of its total export of goods and services.

A number of arguments can be put forward to explain why the nominal exchange rate of an oil producing country may appreciate when the oil price rises and depreciate when it falls. Firstly, higher oil prices increase demand of the currency of an oil exporting country and thereby raise its price relative to other currencies. Secondly, if the long run real exchange rate depends on oil prices, higher oil prices may create a wedge between the long run (equilibrium) real exchange rate and the actual real exchange rate, cf. Alexander *et al.* (1997).[2] Consequently, the nominal exchange rate may appreciate, even overshoot its equilibrium value if prices are sticky, to bring the actual real exchange rate in line with its equilibrium value, cf. Dornbusch (1976) and Mark (1990). Thirdly, if the real exchange rate is constant in the long run, as implied by the purchasing power parity (PPP) theory, higher oil prices may still bring about a short run appreciation of the real and nominal exchange rates through mechanisms that are well known from the Dutch disease literature, see e.g. Corden (1984). Accordingly, higher oil prices lead to a revaluation of petroleum wealth and increase revenues from the oil exports, see Golub (1983). This wealth and income effect can increase aggregate consumption and raise the demand of (internationally) traded and non-traded goods. As a result of higher demand of the latter goods, domestic prices may rise and place appreciation pressure on the real exchange rate, and thereby induce a transfer of resources from the sector of tradables to the sector of non-tradables.[3] Due to sticky prices, however, the nominal exchange rate may appreciate in the short run and speed up the real exchange rate appreciation to levels consistent with the temporary transfer of resources between the sectors, see Bruno and Sachs (1982). In the long run, however, the nominal exchange rate is not directly related to other variables than domestic and foreign prices. When oil prices fall, the arguments above can be reversed to explain depreciation pressure.

Empirical studies have, however, provided mixed support for the assumed covariance between the oil price and the Norwegian exchange rate, see e.g. Bjørvik, Mork and Uppstad (1998) and Akram and Holter (1996).[4] These studies find a statistically insignificant and/or numerically weak relation between the oil price and the value of the krone. Figure 1.1, which shows a cross plot between the Brent Blend oil price in US dollars and the krone/ECU exchange rate (indexed) together with the associated regression line, illustrates the existing empirical results. Contrary to the theory, the cross plot does not indicate any obvious relation between the oil price and the Norwegian exchange rate. The regression line even indicates a small positive covariance and not a negative one as expected. Such empirical findings are puzzling in the light of the theoretical

[1] In May 1986, the krone was devalued by 12 per cent relative to a trade weighted currency basket, mainly composed of (western) European currencies, see Norges Bank (1987, pp. 35-38) for details about the composition of the basket. The appreciation in 1996/97 and depreciation in 1998 were of around 10 per cent to the ECU.

[2] The real exchange rate may depend on the oil price indirectly through other variables that are affected by changes in oil prices, e.g. the stock of net foreign assets and current account.

[3] The real exchange rate is defined as $R \equiv E(P^f/P)$. E denotes the nominal exchange rate, i.e. the price of foreign currency in terms of domestic currency, while P^f and P symbolises the foreign and domestic price levels, respectively.

[4] Regretfully, there does not seem to be any study published in English on this issue.

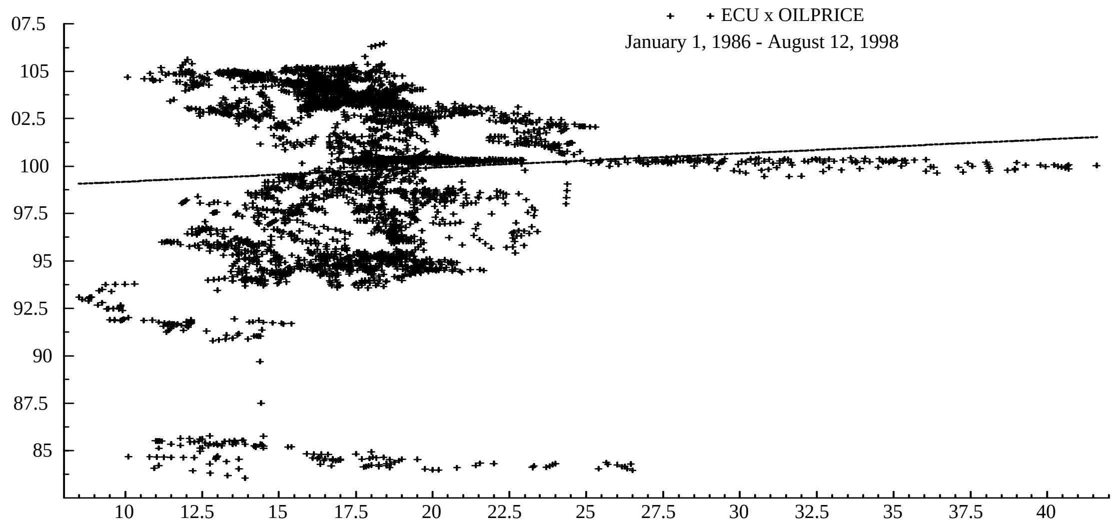


Figure 1.1: *Cross plot of the ECU index, an index for the krone/ECU exchange rate, and the price of crude oil in US dollars (horizontal axis) together with a regression line. The plot is based on 4608 daily observations over the period 1.1.1986-12.8.1998.*

literature and the widely shared belief that the oil price has been an important factor behind the major fluctuations in the value of the krone during the 1990s and the devaluation in 1986.

However, the empirical results can be interpreted in two ways. One interpretation is that the "true" relation between the oil price and the value of the Norwegian currency is weak, at best, and the empirical results are a reflection of this fact. Hence the common belief has no firm ground. Indeed, empirical studies of the oil price and exchange rates of other countries often report an unstable relation between these variables, characterised by changes in the sign and size of coefficients over different sub-samples, see e.g. Shazli (1989) and De Grauwe (1996, pp. 146-149). Furthermore, at least for the appreciation pressure in 1996/97, an alternative explanation is offered by e.g. Kvilekval and Vårdal (1997). It is argued that the appreciation pressure arose as a result of higher interest rates in Norway relative to those in the EU countries throughout 1996, cf. Figure 4.1 in the appendix of this paper.

The second interpretation is that the common belief is not baseless, but the puzzle arises from the empirical approach towards estimating the relation between oil prices and the exchange rate. The present paper tests for this second interpretation.

A common feature of most studies that measure the link between the oil price and the exchange rate, including those conducted on Norwegian data, is that they (implicitly) assume symmetric effects on the exchange rate from an increase and a decrease in the oil price. Furthermore, the oil price effects are assumed to be independent of the level of oil prices. Accordingly, (log) linear models are employed to estimate their effects on a given exchange rate. This study questions whether linear models, imposing symmetric oil price effects, tend to underestimate oil price effects on the Norwegian exchange rate and hence fail to explain major changes in the exchange rate in the face of large fluctuations in oil prices.

A non-linear relation between oil prices and the Norwegian exchange rate seems to be reasonable in the light of the Norwegian monetary policy and the role of the central bank in its conduct. Since 1972, the Norwegian monetary policy has been aimed at exchange rate stabilisation against (western) European currencies, see Alexander *et al.* (1997) and Norges Bank (1987, 1995) for details and overview. In this monetary policy framework, the nominal exchange rate will display (excessive) fluctuations, due to appreciation or depreciation pressure arising from changes in e.g. oil prices, only if the central bank is unable or unwilling to ensure stability in the exchange rate. It follows that one is more likely to observe a negative relation between oil prices and the value of the krone when the authorities abandon the practice of currency stabilisation. Studies of currency crises suggest that a central bank is often more willing to and capable of resisting pressure for currency appreciation than depreciation pressure, cf. Flood and Marion (1998) and the references therein. This asymmetry is explained by pointing to the higher costs of resisting depreciation pressure than appreciation pressure. The costs are usually measured in terms of sacrifices of objectives other than exchange rate stabilisation pursued by a central bank. These may be concerns for unemployment, competitiveness, economic growth, inflation and/or the viability of financial institutions due to its role as a lender of last resort, cf. Obstfeld (1994) and Calvo (1998).[5]

The form of a possibly non-linear relation between oil prices and the Norwegian exchange rate is not known and has to be assumed. This is however a general problem when non-linear relations between variables are considered and not specific to this case. Moreover, tests of a linear relation against a non-linear relation are often designed to have power against specific non-linear forms, see e.g. Granger, Teräsvirta and Tjøstheim (1995). To avoid making *a priori* assumptions about the form of a possibly non-linear relation between the oil price and the exchange rate, this paper starts out with an examination of the observed values of these variables using graphs and basic descriptive measures. The findings from this analysis are thereafter formalised and tested within the framework of multivariate models of the Norwegian exchange rate.

The paper proceeds as follows: The next section (2) examines daily observation of the krone/ECU exchange rate (hereafter referred to as the ECU index) and the oil price over the period January 1986-August 1998, in search for empirically stable patterns.[6] A regular pattern is likely to emerge more clearly in daily observations due to their large number than in observations collected at lower frequencies. The choice of the ECU index reflects the Norwegian policy of exchange rate stabilisation against the ECU during the 1990s. The examination turns out to reveal a non-linear, or state dependent, relation between the oil price and the ECU index. This bivariate analysis is, however, unable to control for the influence of other exchange rate determinants that might explain the apparent non-linearity.

This limitation is overcome in section 3, which tests the findings from the bivariate analysis and estimates the non-linear oil price effects using equilibrium correction models (EqCMs) of the exchange rate, see Hendry (1995). To cross-check the findings, this section models the ECU index using monthly data over the period 1990:11 to 1998:11 and the nominal effective exchange rate ($\overline{E}$) using quarterly data over the period 1972:2 to 1997:4. The quarterly data set covers almost all oil price shocks in the OPEC era and exchange rate fluctuations since the end of the Bretton Woods

[5] Generally a trade off will exist between realisation of these additional objectives where it may appear less costly for a central bank to e.g. lower interest rates in the face of appreciation pressure than raise interest rates in the face of depreciation pressure. Especially, if it is more concerned with the "side effects" on activity level than on inflation.

[6] All empirical results and graphs are obtained using PcGive 9.10 and GiveWin 1.24, see Hendry and Doornik (1996) and Doornik and Hendry (1996).

system. Thus, the model of $\overline{E}$ enables a sound assessment of the results implied by the bivariate analysis and the model of the ECU index.

In addition, both the ECU index and the $\overline{E}$ are modelled using linear and non-linear specifications of oil price effects. The models with linear oil price effects serve as our reference models and help us to judge whether a change in the representation of oil price effects leads to better model properties and different estimates of the oil price effects.

Furthermore, we undertake an extensive evaluation of the models with non-linear oil price effects to examine the robustness of the obtained results. In particular, we investigate whether our preferred model and the implied oil price effects remain invariant when exposed to additional information in the form of extra variables and observations not used in the derivation of the model. Also, we compare its merits against an alternative model with linear oil price effects, but with deterministic variables to account for the apparent non-linearity; focusing on their in-sample and out-of-sample explanatory power, in particular.

Section 4 reiterates the main findings while the appendix contains precise definitions of the variables, their sources, graphs and tables with their time series properties.

2. Empirical regularities

The analysis in this section is based on daily observations of the ECU index and the Brent Blend spot oil price in US dollars per barrel. The ECU index represents the krone/ECU exchange rate with 100 = 7.9440, which refers to the central value of the krone/ECU rate when the krone was pegged to the ECU on October 22, 1990. The sample consists of 4608 observations covering the period from January 1, 1986 to August 12, 1998.

Before embarking on the descriptive analysis, it should be kept in mind that this sample contains observations from two different exchange rate and capital mobility regimes, which are likely to affect the observed relation between the oil price and the ECU index over the sample period. On the one hand, the krone was stabilised against the trade weighted basket of currencies ($\overline{E}$) before the peg to the ECU in October 1990, which allows a possible covariation between the ECU index and the oil price to emerge more clearly than during the 1990s (when the krone was more closely linked to the ECU). But on the other hand, the Norwegian foreign exchange rate regulations were not dismantled before July 1, 1990. These limited the capital mobility between Norway and other countries and thereby the fluctuations in the exchange rate, see Olsen (1990). Thus it is not obvious whether possible covariation between the krone/ECU exchange rate and the oil price is allowed to emerge more clearly during the 1990s or during the 1980s.

Subsection 2.1 characterises the ECU index and the oil price over the sample and examines their time series properties. Subsection 2.2 reports some patterns in the bivariate relation between the oil price and the ECU index which clearly suggest a non-linear relation between the oil price and the exchange rate.

2.1. The exchange rate and the oil price

The daily observations of the ECU index and the oil price are displayed in Figure 2.1. There are relatively large swings in the index in the beginning and in the last part of the sample, especially from the end of 1996 (about observation 4000) and onwards. The early part of the sample covers

Table 2.1: Testing the presence of a unit root in the ECU index and OILPRICE, daily observations 01.01.1986-12.08.1998.

Variable	ADF(d)	$\widehat{\varrho}$	*t-value*
ECU	5	-0.0019	-2.702
ECU^{2ID}	5	-0.0020	-2.945*
OILP	5	-0.0047	-3.338*

See Table 4.1 in the appendix for details. *Indicates significance at the 5% level. The critical values at 5% and 1% are -2.863 and -3.435, respectively. ^{2ID} Indicates that 2 impulse dummies have been used to adjust for the break in the series on the 10. and 11. December 1992.

the devaluation of the krone in May 1986 while the latter part of the sample covers the appreciation of the krone in 1996/97 and the depreciation in 1998. The period of the formal peg from October 22, 1990 to December 10, 1992 (from observation 1756 to observation 2537) is distinguished by a high degree of stability. The variability in the index increases after the abandonment of the formal peg. However, it continues to be relatively small compared with the period before 1990, particularly before the autumn of 1994: the interval before observation 3168.

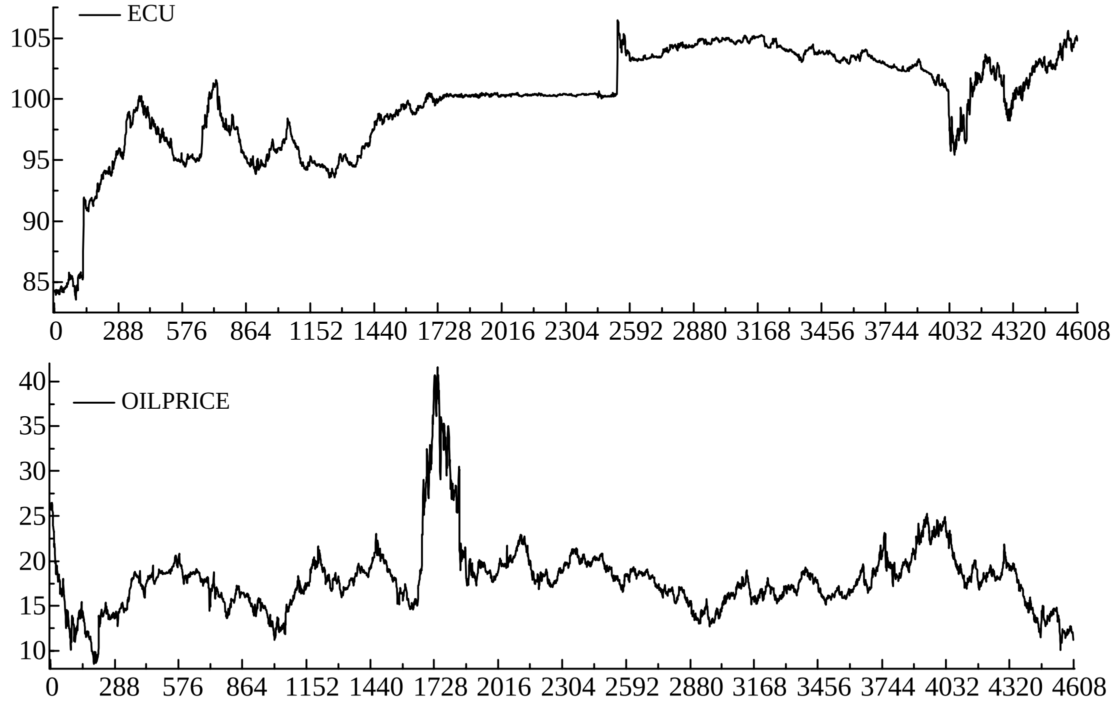
The lower part of Figure 2.1 shows that the oil price has mainly fluctuated in the range of about 14-20 dollars (per barrel), see also the histograms in Figure 2.2. Most of the prices outside this band can be confined to specific periods. Prices below 14 dollars occur mostly in 1986 and 1998. During these periods oil prices even fell below 10 dollars. Prices in excess of 20 dollars are mostly from the Gulf war period in 1990/91 and from 1996/97 when they increased up to 42 dollars and 25 dollars, respectively.

The overall impression is that both the ECU index and the oil price can be characterised as mean reverting processes, especially if one accounts for the break in these series. This impression is supported by the results in Table 2.1, which reports the result of augmented Dickey-Fuller (ADF) tests, see e.g. Banerjee, Dolado, Galbraith and Hendry (1993, ch. 4). The null hypotheses are of unstable (or integrated) processes for the ECU index and the oil price. The null hypothesis for the ECU index is not rejected at the strictly 5% level of significance, but is rejected when the breaks in December 1992 are accounted for.[7] The latter result is as expected in the light of the Norwegian policy of exchange rate stabilisation. It is well known that an ADF test tends to underreject the null hypothesis when there are breaks in a series, see Perron (1989).

The null hypothesis of an integrated oil price process is rejected at the 5% level of significance, even when the exceptionally high oil prices during the Gulf War are not controlled for. The result is consistent with Horsnell and Mabro (1998, pp. 186) who use about three years of daily observations, and with studies based on longer samples of data, see e.g. Perron (1989) and Green, Mork and Vaage (1996). Given the support for a mean reversion property in the oil price, the range 14-20 dollars can be interpreted as the *normal range* of the oil price in the sample period.

[7] One can argue for the use of more conservative critical values since the test is based on a model with more deterministic variables than in the standard case, cf. Banerjee *et al.* (1993, ch. 4).

Figure 2.1: *ECU index (above) and the price of crude oil. Daily observation from 01.01.1986 to 12.08.1998, 4608 observations.*



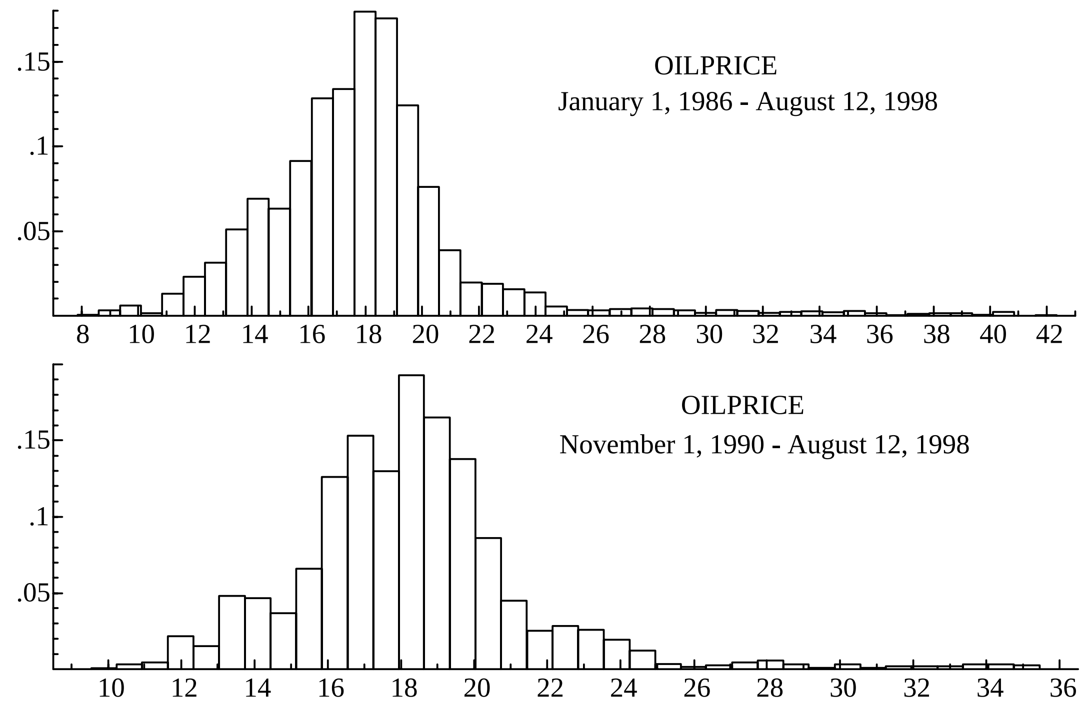


Figure 2.2: *Histograms of the daily observations of the oil price using the whole sample (above) and those from the period of peg to the ECU (bottom).*

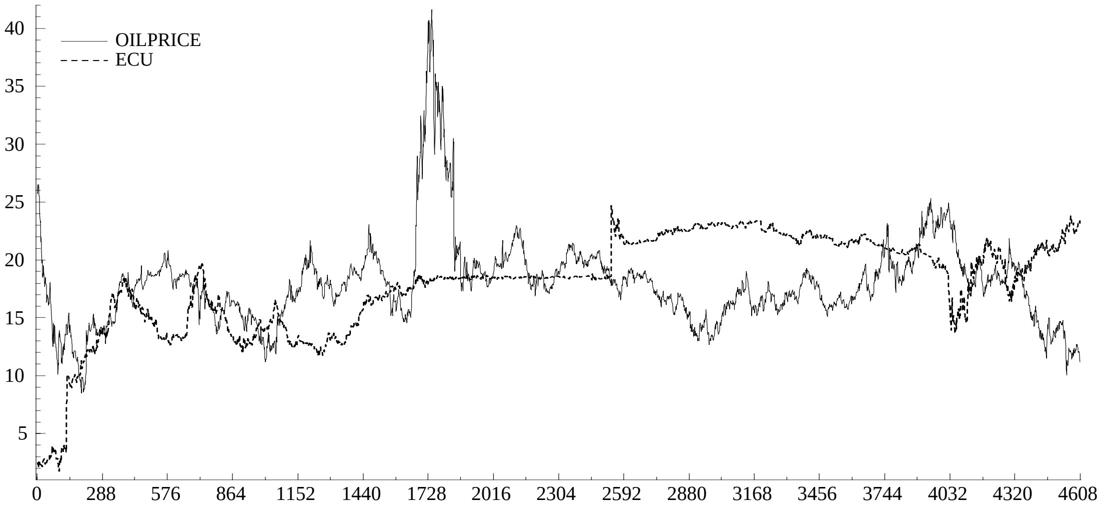


Figure 2.3: *ECU index (dashed) and the oil price from 01.01.1986 to 12.08.1998. The ECU index is mean and variance adjusted to the oil price.*

2.2. Covariance between the exchange rate and the oil price

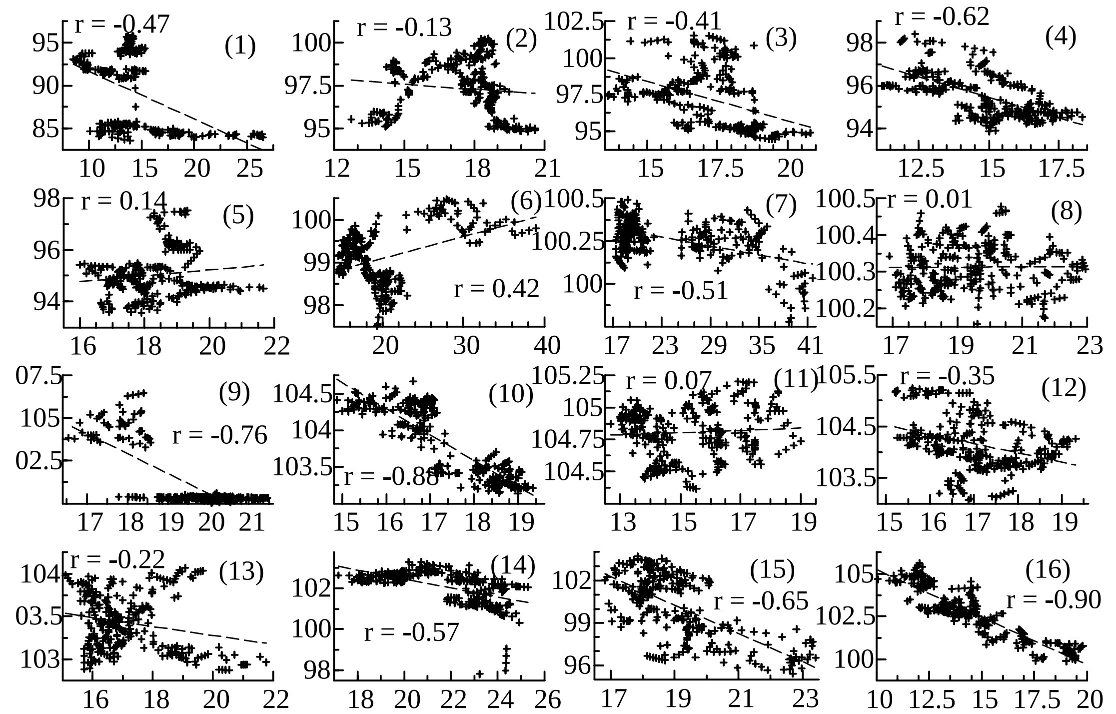
This subsection takes a closer look at the bivariate relation between the oil price and the ECU index. It points out that these variables generally display a negative covariance but the strength of this covariance depends on the level of the oil price and on whether or not the oil price is falling.

Figure 2.3 suggests that, in general, the covariance between the oil price and the ECU index is negative and relatively strong when the oil price moves outside the range of about 14-20 dollars, hereafter referred to as the normal range, but becomes negligible with a positive or negative sign when it fluctuates inside this range. As noted above, there seem to have been four (main) periods with prices outside the normal range, 1986 and 1998 with prices below 14 dollars and 1990/91 and 1996/97 with prices above 20 dollars. In three of these periods, movements in the oil price coincide with large fluctuations in the exchange rate. More specifically, both the devaluation in 1986 and the depreciation in 1998 coincide with prices below 14 dollars while the appreciation in 1996/97 coincides with prices above 20 dollars. Note also that after the appreciation pressure, the ECU index seems to crawls back to the pre-appreciation level and this appears to coincide with a return of the oil price to the normal range. However, the unprecedented high oil prices during the Gulf war in 1990/91 do not lead to any noticeable appreciation of the krone measured by the ECU index. The krone was formally pegged to the ECU in this period, but one may still wonder at the absence of any considerable appreciation pressure during this period.[8] The positive covariance or zero/negligible covariance can be clearly observed in the observations up to 1700, which corresponds to the period before January 1990.

Figure 2.4 focuses on the covariation between the ECU index and the oil price in different sub

[8] Norges Bank (1990, pp. 145) records a net purchase of foreign currency equivalent to about 6 billion NOK during August and the first half of september 1990. This in an effort to avoid the strengthening of the krone because of "the higher oil prices". During the appreciation pressure in 1996/97, however, the banks net purchase of foreign currency was equivalent to about 75 billion NOK, Norges Bank (1997).

Figure 2.4: *Cross plots of the ECU index on the oil price using non-overlapping samples of equal size. These samples are derived by splitting the 4608 daily observations from January 1, 1986 to August 12, 1998 into 16 subsamples. Each of them consists of 288 observations and covers a period of about 9 and 1/2 months.*



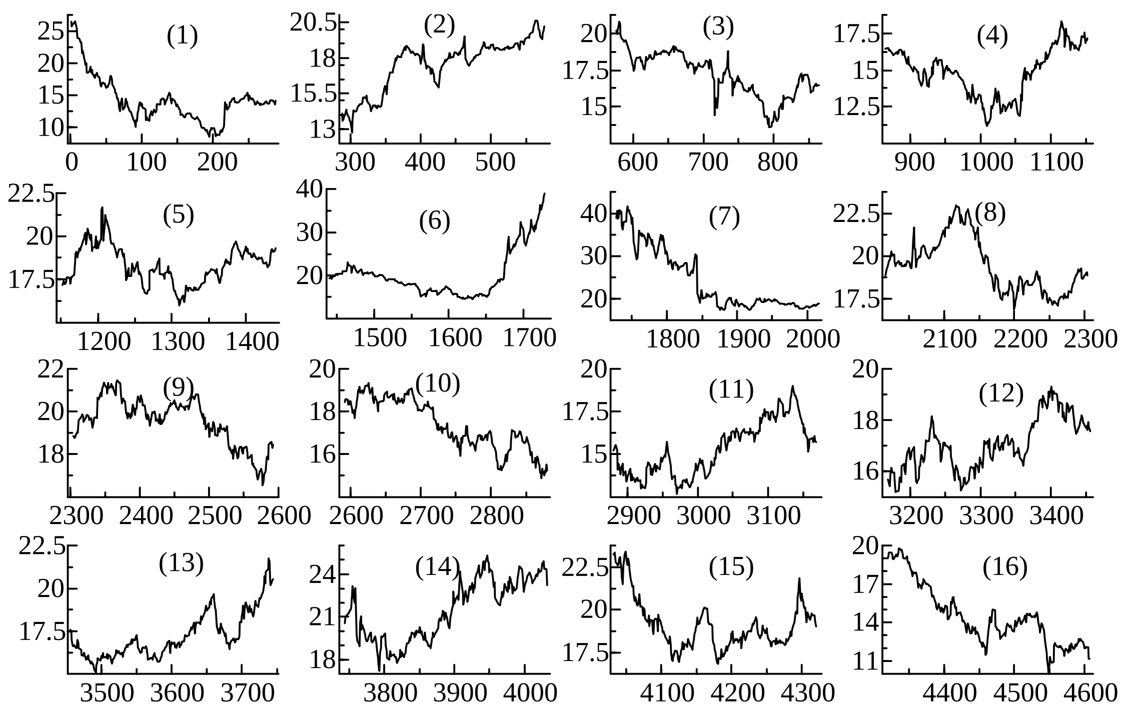


Figure 2.5: *The oil price in the 16 non-overlapping periods from January 1, 1986 to August 12, 1998, cf. figure 2.4.*

periods. It displays the covariation between these variables in 16 equally sized samples consisting of 288 (= 4608/16) observations. Each sample covers a non-overlapping period of about 9 1/2 months. For example, sample 1 consists of the first 288 observations from January 1, 1986 to October 15, 1986, while sample 2 consists of the next 288 observations from October 16 , 1986 to July 30, 1987, and so on. The degree of correlation in each sample is also reported. Figure 2.5 displays the level of the oil price in the corresponding samples. For instance, sample 1 in Figure 2.5 plots the first 288 observations of the oil price over the period January 1, 1986 to October 15, 1986, and so on.

Figure 2.4 confirms the impression from Figure 2.3 but also adds some new insight. It shows that:

- There is negative covariance in most of the samples but positive or negligible covariance in sample 5, 6, 8 and 11. In these samples the oil price is mostly inside the normal range, except in sample 6 where the positive covariance can be ascribed to the high oil prices during the Gulf War.

- The strength of the negative covariance seems to depend on whether the oil price is inside or outside the normal range. It is quite weak in sample 2, 12 and 13 but stronger in sample 1, 9, 10, 14, 15 and 16. In the former samples, the oil price is mostly inside the normal range, while the latter samples, with the exception of sample 10 and perhaps 15, contain a relatively large number of oil price observations outside the normal range. In sample 10, the observations are mostly inside the normal range.

- The negative covariance seems to be stronger when the oil price is falling compared with when it displays a rising trend. For example, samples 10 and 9 may be compared with 12 and 13, respectively. In the first pair of samples (10 and 12) and in the second pair (9 and 13), oil prices fluctuate in approximately the same price ranges, see Figure 2.4. However, as is evident from Figure 2.5, the oil price displays a falling trend in the periods covered by samples 10 and 9 and a rising trend in the periods covered by samples 12 and 13. Figure 2.4 shows that the negative correlation is stronger in samples 10 and 9 compared with the correlation in samples 12 and 13.

- The negative covariance seems to decrease with the level of the oil price. Figure 2.4 shows that the spread of observations around the regression lines is wider at higher oil prices than at lower oil prices. This is especially apparent in samples 1, 5, 9, 13 and 14, when the oil price is around 20 dollars. This pattern is more pronounced in larger samples of the data, as shown in Figure 2.6.

To summarise, the graphical analysis suggests both *level* and *trend* dependent oil price effects on the exchange rate. In general, there is a negative covariance between the oil price and the exchange rate. The degree of covariance, however, is stronger when the oil price is outside the normal range of about 14-20 dollars than when it is inside this range, which appears as the normal range of oil prices in this sample. The covariance also shows a tendency to decrease with the level of the oil price, which also implies that the oil price effect is stronger when oil prices are below the normal range compared with when they are above this range. In addition to the level effects, the covariance seems to become stronger when the oil price is on a downward trend rather than

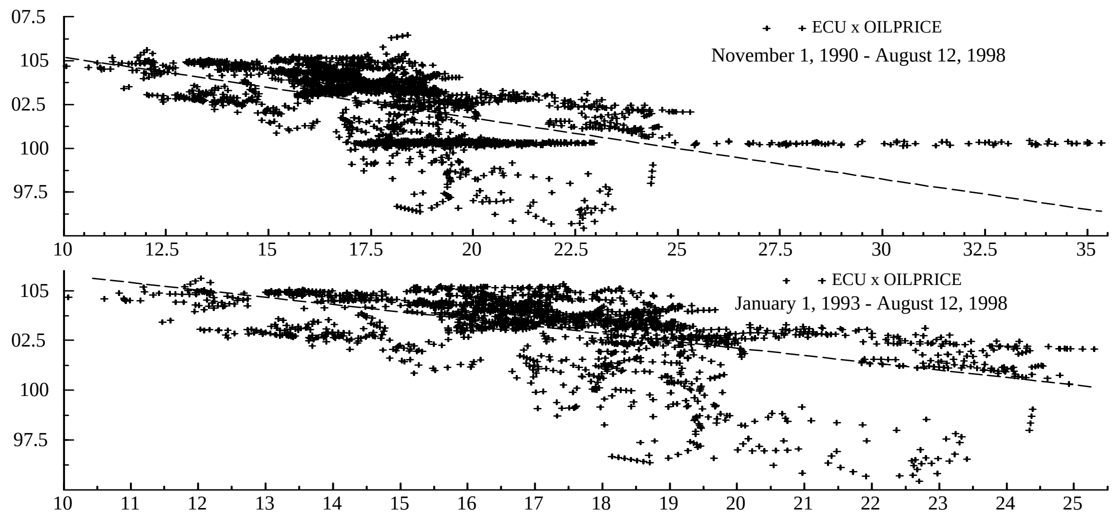


Figure 2.6: *Cross plots of the ECU index on the oil price using daily observations. The straight lines are the corresponding regression lines.*

on an upward trend. Thus, the covariance appears to be negligible when the oil price is inside the normal range, unless it displays a falling trend.

The bivariate analysis of this subsection, however, does not control for the possible influence of other exchange rate determinants. Hence it offers a potentially biased impression of the relations between the oil price and the exchange rate. The next section makes attempts to correct for this.

3. Multivariate exchange rate models

It is well documented that fluctuations in oil prices lead to considerable changes in macroeconomic variables, see e.g. Hamilton (1983) and Mork, Olsen and Mysen (1994). Some of these variables, such as the current account, interest rates, level of economic activity and inflation are also regarded as important determinants of nominal exchange rates, see e.g. Frankel and Rose (1995). Because of the correlation between macroeconomic variables and oil prices, partial effects of the oil price on the Norwegian nominal exchange rate may be quite different from those indicated by the bivariate analysis. Moreover, the non-linear effects of the oil price might have emerged due to our failure to control for the influence of these variables in the preceding analysis. It cannot be precluded that once they are accounted for, the effects of oil prices, if any, are linear and independent of the level and the trend in the oil price.

The purpose of this section is to control for the influence of potentially relevant variables and factors when testing: (a) whether oil prices have non-linear effects on the Norwegian nominal exchange rate, (b) whether the effects are *level* and *trend* dependent, as suggested by the bivariate analysis, and (c) whether a linear representation of oil price effects leads to underestimation of oil price effects on the exchange rate.

To this end, we derive single equation multivariate models of the exchange rate; specifically, equilibrium correcting models (EqCMs) of the Norwegian nominal exchange rate. These models are not derived from a particular exchange rate theory but from quite general models containing variables that are interpretable within different exchange rate theories. The general models are thereafter simplified by following a "general to specific" modelling strategy in which parsimony is sought through data based coefficient restrictions, see Hendry (1995). The exchange rate literature is quite pessimistic with regard to the ability of macroeconomic variables to explain exchange rate movements, see e.g. Frankel and Rose (1995). However, most empirical studies confine their attention to variables and parameter values implied by a preferred exchange rate theory. Relatively general models without a priori coefficient restrictions seem to be better equipped to explain exchange rate movements and to serve their purpose in the present context.

Secondly, to convince ourselves that the obtained results are not an artefact of a given data sample, a model or are regime specific, this section models relative changes in both the ECU and the trade weighted nominal exchange rate ($\overline{E}$). The ECU index is modelled on a monthly data set that covers the period 1990:11 to 1998:11, while the $\overline{E}$ (also indexed) is modelled on a quarterly data set covering the period 1972:2-1997:4. The monthly data set is from the period with peg to the ECU while the quarterly data set covers almost the whole history of the Norwegian exchange rate since the end of Bretton Woods system, and all the major oil price shocks in the OPEC era. The data sets also differs with regard to capital mobility regimes. In contrast to the quarterly data set, the monthly data set only covers the period with unregulated capital mobility. The Norwegian foreign exchange regulations were gradually removed in the second half of 1980s and were fully dismantled by July 1990, see Olsen (1990).

Thirdly, we attempt to isolate the contribution of non-linearisation on the estimates of oil price effects and models' properties by deriving models with linear and non-linear oil price effects for both the exchange rate indices. The two models of a given exchange rate index are similar to each other but for the representation of oil price effects. The differences in the estimates of oil price effects and in the properties of models across a given pair of models may therefore be ascribed to differences in the representation of oil price effects; despite potential shortcomings with a given pair of models such as possible bias owing to our use of single equation models and due to neglect of potentially relevant explanatory variables. Note that the focus on single equation models implicitly assumes that the conditioning variables are weakly exogenous for the parameters of interest, in this case the coefficients of oil prices, see Engle, Hendry and Richard (1983). A violation of this assumption can lead to inconsistent and inefficient estimates of the parameters of interest. A test of this assumption however requires models of all the conditioning variables, which are beyond the scope of the present paper. Though we cannot claim that our estimators of the oil price effects provide consistent and efficient estimates of the *partial effects* of oil prices on the exchange rate, or of any other variable, possible differences in the oil price effects across the pairs of models still enable us to address the issues that are the focus of this study: (a), (b) and (c) noted above.

Finally, to further substantiate the results, we undertake an extensive evaluation of the models with non-linear oil price effects. Specifically, they are exposed to a battery of tests aimed at testing whether they are well specified and especially whether the oil price effects are adequately characterised. Also, their explanatory power is measured against the models with linear oil price effects. In addition, we consider whether the quarterly model (with non-linear oil price effects) remains intact when we include variables that are neglected during its derivation, and whether it remains stable when reestimated on an extended data set. The latter data set contains new observations for 7 quarters over the period 1998:1-1999:3, a period in which oil prices and the Norwegian exchange rate have displayed excessive fluctuations. Furthermore, the properties of the quarterly model are compared against a model with linear oil price effects but with deterministic variables to account for the apparent non-linearity. Properties that are focused upon are: the in-sample and out-of-sample explanatory power.

The remainder of this section is organised as follows: The general model is formulated in subsection (3.1), which also motivates the choice of variables. Subsection (3.2) considers the models with linear oil price effects and formally tests the appropriateness of a linear representation of oil price effects, in particular. Subsection (3.3) formulates and derives the models with non-linear oil price effects while subsection (3.4) undertakes the evaluation.

3.1. A general EqCM of the exchange rates

Equation (3.1) presents a general EqCM of the nominal exchange rate e_t, where $e = ecu$, $\overline{e}$.

$$\begin{aligned}\Delta e_t &= \alpha_0 - \phi[e - (cpi - cpi^f)]_{t-1-j} + \beta_1 \left[R - R^f\right]_{t-j} + \\ &\sum_{j=0}^{p}[\alpha_i \Delta e_{t-1-j} + \pi_{1j}\Delta cpi_{t-j} - \pi_{2j}\Delta cpi^f_{t-j} - \beta_{2j}\Delta R_{t-j} \\ &+\beta_{3j}\Delta R^f_{t-j} + \mu_j \Delta FI.Y_{t-j} + \Gamma_j \mathbf{Z}_{t-j}] + \Psi \mathbf{B}_t \\ &+ f_t(\sum_{j=0}^{p}\Omega_{1j} oilp_{t-j},\ \sum_{j=0}^{p}\Omega_{2j}\Delta oilp_{t-j}) + v_t. \end{aligned} \tag{3.1}$$

Variables in small letters indicate that they are natural logs of the original variables, e.g. *ecu* is the natural log of the ECU index. Δ denotes a change over one month or a quarter while p indicates the number of lags. These will be determined during the estimation of the models' parameters represented by the Greek letters and supposed to be positive and constant over time. The appendix provides precise definitions of the variables, their graphs and reports their time series properties, i.e. whether a given variable is stationary or non-stationary in unit root sense. As evident from the tables in the appendix, the general model appears to be balanced, since the left hand side variables and the right hand side variables and terms can be characterised as stationary processes, see Banerjee *et al.* (1993, ch. 3). Finally, v_t is the residual assumed to be independently, identically and normally distributed with zero mean and variance σ^2, i.e. IIDN(0, σ^2).

The term $[e - (cpi - cpi^f)]$, possibly in addition to the constant term α_0, represents a deviation from the equilibrium level of the nominal exchange rate under the PPP hypothesis. Accordingly, the nominal exchange rate reflects the ratio between domestic and foreign prices in the long run. In general, the empirical evidence in favour of this assertion is mixed, see e.g. Rogoff (1996) for a survey of the literature. However, it has not been rejected when tested for between Norway and its trading partners, see Edison and Klovland (1987) and Akram (2000).[9]

[9] Klovland and Edison (1987) use annual data from 1874 to 1971 to model the Norwegian prices. They do not reject the PPP-hypothesis between Norway and UK when using a model that controls for the excessive exchange rate volatility in the period 1914 and 1928.

Akram (2000) tests for PPP between Norway and its trading partners using the same quarterly data set as employed in the present study. It is shown that the proportonality between the exchange rate and the relative

Short run fluctuations in the exchange rate can be attributed to variables that affect the demand of domestic assets relative to foreign assets, cf. portfolio balance models of exchange rates, see e.g. Hallwood and MacDonald (1994, pp. 186-205). The exchange rate tends to appreciate when the demand of domestic assets increases relative to the demand of foreign assets, i.e. assets denominated in domestic and foreign currencies, respectively. This is likely to take place when the opportunity costs of holding foreign assets increase or are expected to increase. The opportunity costs of holding domestic assets increase due to expected depreciation of the domestic currency, a rise in foreign interest rates and/or due to a fall in domestic interest rates.

The model allows for short run effects of domestic and foreign prices, represented by the inflation rates Δcpi and Δcpi^f. If PPP holds, the difference between Δcpi and Δcpi^f can be interpreted as expected depreciation. Expected depreciation may also be proxied by the spread between domestic and foreign interest rates. According to the *uncovered interest rate parity (UIP)* hypothesis, the interest rate differential is equal to expected depreciation.[10]

Changes in domestic and foreign interest rates, ΔR and ΔR^f, are supposed to capture changes in the opportunity cost of holding domestic assets rather than foreign assets. When modelling *ecu* on monthly data from the 1990s, we employ three month Norwegian and European money market rates: $R = R3$ and $R^f = R3^f$. However, when modelling $\overline{e}$ on quarterly data since the early 1970s, we employ the Norwegian government bond rate and the trade weighted government bond rate: $R = RB$ and $R^f = RB^f$. The domestic bond rate was chosen in preference to the money market rates as the latter displays a quite erratic behaviour until the end of the 1970s, probably because of a thin domestic money market and regulations of international capital flows, see Figure 4.2 in the appendix. The use of the government bond rate in trading countries is motivated by the policy of exchange rate stabilisation against the currencies of a majority of these countries. This policy is expected to entail a close link between the domestic and the foreign interest rates. However, the spread between these interest rates was relatively large in the 1970s and 1980s, see Figure 4.2. These can be partly ascribed to the Norwegian capital regulations which were not fully dismantled before 1990 and were relatively tight during the 1970s, but may also reflect devaluation expectations and risk premia due to the frequent devaluations in this period, see Alexander *et al.* (1997).

In the model, $\Delta FI.Y$ is foreign net financial investment in Norway relative to the Norwegian GDP (Y). Financial investment abroad tend to place upward pressure on the value of the domestic currency. Hence a rise in $\Delta FI.Y$ is expected to bring about exchange rate depreciation.

The vector $\mathbf{Z}$ represent variables such as changes in the activity level and productivity growth at home and abroad; and different measures of government expenditure at home. Higher activity level and productivity growth at home relative to abroad are often believed to raise the value of the domestic currency, while a rise in domestic government expenditures is believed to have the opposite effect, cf. Balassa (1964), Samuelson (1964) and Gibson (1996).

The content of vector $\mathbf{Z}$ is sample dependent, due to the availability of data. On the monthly data set we are only able to consider the effects of the differences in the activity level and of changes in government expenditure. Here, the differences in the activity level are measured by

consumer price indices between Norway and its trading partners is not rejected, either in a univariate or in a system framework.

[10] If UIP does not hold, the spread may reflect risk premia in addition to expected depreciation, see e.g. Gibson (1996) and Hallwood and MacDonald (1994).

changes in the registered rate of unemployment at home and abroad, Δu and Δu^f, while changes in government expenditures relative to GDP are taken into account by the government budget surplus, *Fisc.Y.* When employing the quarterly data set, however, we also consider growth in GDP (Δy) to represent changes in the activity level at home, as an alternative to Δu. In addition, we are able to allow for productivity growth at home and abroad. Productivity at home and abroad is measured by q and q^f, respectively, which are defined as natural logs of the inverse of unit labour costs in Norway (ULC) and in its trading partners (ULC^f): $q = ln(1/ULC)$ while $q^f = ln(1/ULC^f)$. The inverse of unit labour costs can be interpreted as value added per unit labour cost. Changes in government expenditures relative to GDP are taken into account by Δg where g is defined as the sum of government consumption (C_G) and gross real investment (J_G), relative to GDP (Y): $g = (C_G + J_G)/Y$. We also allow C_G/Y and J_G/Y to enter separately in the model, i.e. without the homogeneity restriction.

The variables represented by the vector **Z** have, however, received mixed support in exchange rate models, see e.g. Frankel and Rose (1995). They are therefore not included in the general models of ecu and $\bar{e}$ at the outset, in order to avoid over-parameterisation relative to the number of observations, which is likely to be a problem if several lags of a given variable are included in the general models. However, we test for their significance upon reaching parsimonious versions of each model. This allows us to examine whether a preferred specification of a model is invariant to inclusion of additional variables.

Vector **B** contains a number of dummy variables to account for outliers and other extreme observations that remain unexplained by the variables explicitly included in the model and thereby reduce the potential omitted-variable bias in parameter estimates. They are also intended to ensure the validity of the residual assumptions.

Finally, the model allows the oil price to affect the exchange rate in both the short run and the long run, since both the relative changes in the oil price ($\Delta oilp$) and the log level of the oil price ($oilp$) are present. In the latter case, oil prices are allowed to create a wedge between the nominal exchange rate and the relative price ($cpi - cpi^f$) in the long run. Accordingly, the long run real exchange rate depends on the oil price in contrast to the PPP theory. Both the short run and long run oil price effects are included in an unspecified form. The analysis in the following subsections is essentially aimed at finding the appropriate specification of the oil price effects.

3.2. Models with symmetric oil price effects

Models with symmetric oil price effects, hereafter *linear models,* were formulated by inserting the following specification of $f_t(.)$ into model (3.1):

$$f_t(\sum_{j=0}^{p} \Omega_{1j} oilp_{t-j}, \ \sum_{j=0}^{p} \Omega_{2j} \Delta oilp_{t-j}) = \sum_{j=0}^{p} [\Omega_{1j} oilp_{t-j} + \Omega_{2j} \Delta oilp_{t-j}]. \qquad (3.2)$$

The (general) models of Δecu_t and $\Delta \bar{e}_t$ were then estimated by OLS for a common lag length of 2 ($= p$). To allow for a linear approximation of possible non-linear oil price effects, greater numbers of lags for $oilp_t$ and $\Delta oilp_t$ were also considered. Following a "general to specific" modelling strategy, variables that appeared to have numerically small and statistically insignificant coefficients were excluded from the models, in most cases, for the sake of parsimony. But some were also retained in the models to ease comparison with the non-linear models to be derived later. In addition to the exclusion restrictions, parsimony was also sought through symmetry restrictions on coefficients that had almost the same estimates but opposite signs. For example, coefficients of changes in the domestic interest rates and the inflation rate are restricted to make them interpretable as changes in the domestic "real interest rate".

Table 3.1: An EqCM of the ECU rate with linear oil price effects.

$$
\begin{aligned}
\widehat{Decu}_t = & \underset{(1.757)}{0.178} - \underset{(-1.336)}{0.033} [ecu - (cpi - cpi^f)]_{t-2} + \underset{(4.092)}{0.183} [R3 - R3^f]_t \\
& + \underset{(23.891)}{1.384} Decu_{t-1} - \underset{(-9.307)}{0.520} Decu_{t-2} - \underset{(-4.673)}{0.274} \Delta[R3_{t-2} - Dcpi_{t-1}] \\
& - \underset{(-2.905)}{0.858} Dcpi^f_{t-1} + \underset{(2.158)}{0.008} DFI.Y_t \\
& - \underset{(-5.160)}{0.028} i93p12 - \underset{(-4.978)}{0.026} i97p1 + \underset{(3.892)}{0.021} i97p11 + \underset{(6.300)}{0.034} i98p1 \\
& - \underset{(-4.348)}{0.024} i98p3 - \underset{(-0.115)}{0.001} i98p6 + \underset{(4.605)}{0.026} i98p9 - \underset{(-7.815)}{0.049} i98p11 \\
& - \underset{(-3.942)}{0.017} oilp_{t-1} - \underset{(-3.313)}{0.031} \Delta oilp_t
\end{aligned}
$$

Sample: 1990:11-1998:11 , $T = 97$, $k = 18$. *Method: OLS*

Diagnostics

$\hat{\sigma}_L$	=	0.511%
Log lik	=	473.323
AR $1-6$ $F(6,73)$	=	1.242[0.295]
$ARCH(6)$ $F(6,67)$	=	1.075[0.386]
$Het.\ Xi^2$ $F(26,52)$	=	0.640[0.891]
Normality $\chi^2(2)$	=	0.632[0.729]
RESET F(1, 78)	=	4.386[0.040]*
TT_L $F(6,73)$	=	2.650[0.027]*

The t-values are in brackets (.) below the estimates and p-values are in large brackets [.] beside the test statistics. AR 1-6 F(df1, df2) tests for autocorrelation in the residuals up to 6 lags. df1 and df2 denote degrees of freedom. ARCH(6) F(df1, df2) tests for autoregressive conditional heteroscedasticity (ARCH) up to order 6, see Engle (1982). Het. Xi^2 F(df1, df2) tests for heteroscedasticity by using squares of regressors , see White (1980). The normality test with chi-square distribution is that by Jarque and Bera (1980). RESET F(df1, df2) is a regression specification test. It tests the null hypothesis of correct model specification against the alternative of misspecification, indicated by the significance of $\widehat{y}^2$, i.e. the square of the fitted value, in the model, see Ramsey (1969). TT_L F(df1, df2) is defined in the main text. Here and elsewhere in this study, a raised star *indicates rejection of the null hypothesis at the 5% level of significance, while two stars** indicate rejection at the 1% level.

Monthly changes in the ecu_t (Δecu_t) turned out to be difficult to model satisfactorily with a limited number of lags on the stochastic variables and relatively few deterministic regressors. In comparison, annual changes in the ecu_t ($Decu_t \equiv ecu_t - ecu_{t-12}$) could be characterised parsimoniously using e.g. annualised domestic and foreign inflation rates and foreign net financial investment in Norway, $Dcpi$, $Dcpi^f$ and $DFI.Y_t$, respectively. Still a number of deterministic regressors were needed to capture large fluctuations in the exchange rate, especially during the years 1997 and 1998. In contrast, quarterly changes in the trade weighted exchange rate $\overline{e}$ ($\Delta\overline{e}$) were straightforward to model, only requiring a (centered) dummy with 1 in 1997:1 and -1 in 1997:2 to capture the appreciation and the subsequent depreciation during the first half of 1997.

Table 3.2: An EqCM of the effective exchange rate with linear oil price effects.

$$
\begin{aligned}
\Delta\widehat{\overline{e}}_t = &- \underset{(-3.350)}{0.110} \; [\overline{e} - (cpi - cpi^f)]_{t-1} + \underset{(2.918)}{0.246} \; \Delta\overline{e}_{t-1} \\
&- \underset{(-2.712)}{0.324} \; \Delta(RB_{t-1} - \Delta cpi_{t-2}) - \underset{(-2.094)}{0.227} \; \Delta cpi^f{}_t \\
&+ \underset{(2.216)}{0.699} \; \Delta^2 RB^f{}_{t-1} + \underset{(2.311)}{0.147} \; \Delta_4 FI.Y_t - \underset{(-3.952)}{0.035} \; id97q1 \\
&- \underset{(-0.659)}{0.005} \; \Delta oilp_t - \underset{(-2.073)}{0.015} \; \Delta oilp_{t-1} + \underset{(0.208)}{0.002} \; \Delta oilp_{t-2}
\end{aligned}
$$

Sample: 1972:2-1997:4 , $T = 103$, $k = 10$. *Method: OLS*

Diagnostics

$\hat{\sigma}_L$	=	1.2%
Log lik	=	408.901
R^2	=	0.46
$AR\ 1-5\ F(5,88)$	=	0.532[0.752]
$ARCH\ (4)\ F(4,85)$	=	0.596[0.666]
$Het.Xi^2\ F(20,72)$	=	0.835[0.665]
$Het.XiX_j\ F(56,36)$	=	0.638[0.936]
Normality $\chi^2(2)$	=	1.260[0.533]
$RESET\ F(1,92)$	=	4.407[0.039]*
$TT_L F(9,84)$	=	2.227[0.028]*

Tests for omitted variables

			Δcpi_t	ΔRB_t	ΔRB_t^f	$(RB - RB^f)_{t-1}$	$FI.Y_{t-1}$
Coeff.	*estimate*		0.060	0.049	−0.598	0.002	0.036
Single:	$F(1,\ 88)$		[0.752]	[0.882]	[0.172]	[0.975]	[0.620]
Joint:	$F(5,\ 88)$	[0.806]					

Note: Brackets below the estimates contain t-values while square brackets contain p-values. The value of R^2 is almost the same if a constant term is included. Tests are explained in Table 3.1. Tests for omitted variables impose zero restrictions, individually and jointly, on the coefficients of the indicated variables when included in the presented model.

Table 3.1 and 3.2 present the relatively parsimonious versions of the models of $Decu_t$ and $\Delta\overline{e}_t$, respectively, and the associated model diagnostics. Table 3.2 also reports the outcome of variable omission tests and the coefficient estimates of a number of variables when added (jointly) to the quarterly model.

In both models, positive changes in domestic "real interest rates", $\Delta[R3_{t-2} - Dcpi_{t-1}]$ and $\Delta(RB_{t-1} - \Delta cpi_{t-2})$, and foreign inflation place appreciation pressure on the exchange rates. A reduction in foreigners' financial investment in Norway, or equivalently increased Norwegian financial investment abroad, also implies exchange rate appreciation. The equilibrium correction terms have the expected signs in both models, but the equilibrium correction term in the monthly model appears statistically insignificant at the standard levels of significance. In the quarterly model, however, it is statistically significant at the 1% level, even if it is considered as non-stationary (integrated) under the null hypothesis and the critical values are found by the response function of MacKinnon (1991). In which case, the appropriate critical t-value at the 1% level is

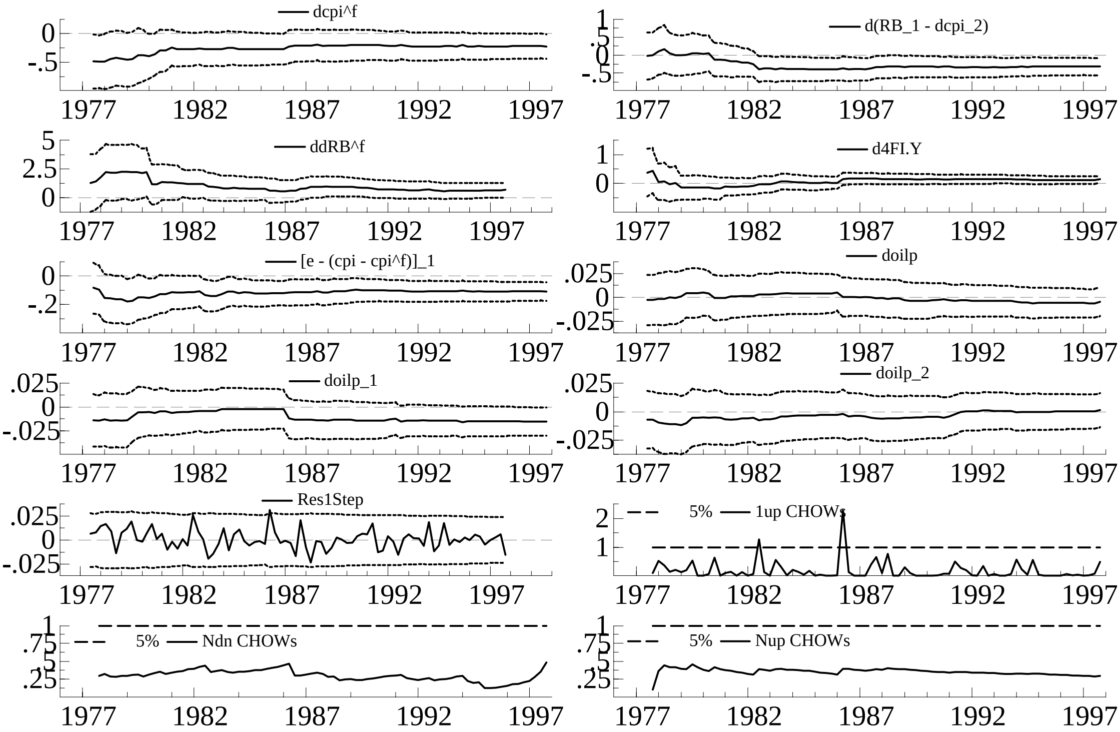


Figure 3.1: *Constancy statistics for the model of $\Delta\bar{e}$ with linear oil price effects, see Table 3.2. Initial estimation period is 1972:2-1976:4. Prefix "d" denotes the first difference Δ. The graph show the recursive coefficient estimates $\pm 2SE_t$ for the indicated regressors, One-step ahead residuals $\pm 2SE_t$ and Chow statistics for the model. The latter are scaled by their critical values at the 5% level.*

-2.585.[11]

The spread between the domestic and foreign interest, proxying depreciation expectations, is significant in the monthly model only. In the quarterly model, there was neither a contemporaneous nor a lagged effect from the spread between domestic and foreign bond rates, see e.g. the outcome of variable omission tests in Table 3.2. The effects of changes in foreign interest rate were found to be weak and largely insignificant in the monthly model. In the quarterly model, however, acceleration in foreign bond rates contributes to depreciation pressure in a statistically significant way. One possible explanation for their insignificance in the monthly model can be the high degree of correlation between domestic and foreign interest rates in the sample. The sample covers a period of deregulated capital markets in which the Norwegian government has pursued a stable exchange rate policy. Consequently, the Norwegian interest rates have by and large followed European interest rates for the sake of exchange rate stability. The collinearity between these interest rates may have contributed to the uncertainty in the estimated effects of foreign interest rates and thereby to their insignificance.

[11] The 1% critical value for the case when there is no constant term, no trend and one non-stationary variable under the null hypothesis can be calculated as: -2.5658 -1.960/103 - 10.04/(103)^2 ≈ -2.585, see MacKinnon (1991).

The policy of exchange rate stabilisation may also explain the persistence in the rate of depreciation in both models. Especially in the monthly model where the sum of the autoregressive coefficients is above 0.80, which implies long periods of depreciation or appreciation even in the absence of input from other variables. This points to *bandwagon effects* in the foreign exchange market, but may largely reflect the stable exchange rate policy pursued by the Norwegian government in this period.

The effects of oil prices seem to be mixed. In the monthly model, both the contemporaneous change and the lagged level of *oilp* appear statistically significant at the standard levels with negative coefficient estimates. Hence, oil prices have appreciations effects both in the short run and long run. In the quarterly model, however, positive changes in the oil price place appreciation pressure on the exchange rate, but their effects are not significantly different from zero, perhaps with the exception of $\Delta oilp_{t-1}$. Its full sample estimate is barely significant at the 5% level, but its coefficient estimates on less than the full sample are not, see the recursive estimates in Figure 3.1. The figure also shows that the recursive estimates of the coefficients of $\Delta oilp_t$ and $\Delta oilp_{t-2}$ are quite close to zero in the period 1977:1-1997:4. Actually, there do not seem to be any effects of oil prices at all before 1986. On the basis of these findings one could conclude that oil prices do not have significant effects on the nominal exchange rate, even in the short run. This contrasts with the quite common belief that fluctuations in the oil price tend to have a strong impact on the Norwegian krone, but is nevertheless consistent with earlier empirical findings using linear models, see e.g. Bjørvik *et al.* (1998) and the references therein.

The diagnostic tests suggest that the residuals from each of the models satisfy the standard assumptions, that is, they appear as IIDN(,) as assumed. However, the regression specification test (RESET) rejects both model formulations at the 5% level. To test whether the rejection is due to possible misrepresentation of oil price effects, we apply the test for non-linearity suggested by e.g. Teräsvirta (1998). This test, denoted as TT_L, is performed on the residuals from each of the models to test the null hypotheses of linear oil price effects against the alternative hypothesis of non-linear oil price effects, with the oil price (*OILP)* as the transition variable. Although the null hypothesis is tested against the alternative hypothesis of neglected non-linearity of smooth transition type, the test also has power against the alternative of abrupt transitions. Table 3.1 and 3.2 show that the null hypotheses of linear oil price effects are rejected at the 5% level.

3.3. Models with asymmetric oil price effects

The non-linear oil price effects suggested by the graphical analysis in section 2 can be characterised by the following specification of $f_t(.)$ with $c_1 = 14$ and $c_2 = 20$.

$$\begin{aligned} f_t(.) &= [\sum_{i=0}^{L}(\phi_i oilp_{t-i} + \widetilde{\phi}_i \Delta oilp_{t-i})]\text{x}F_{t,\ Low} \\ + \quad & [\sum_{i=0}^{H}(\theta_i oilp_{t-i} + \widetilde{\theta}_i \Delta oilp_{t-i})]\text{x}F_{t,\ High} \\ + \quad & [\sum_{i=0}^{D}(\psi_i oilp_{t-i} + \widetilde{\psi_i} \Delta oilp_{t-i})]\text{x}F_{t,\ Diff},\ \text{where} \end{aligned} \tag{3.3}$$

$$F_{t,\ Low} = [1+\exp\{\lambda_1(OILP_t - c_1)\}]^{-1}, \qquad \lambda_1 > 0 \tag{3.4}$$
$$F_{t,\ High} = [1+\exp\{-\lambda_2(OILP_t - c_2)\}]^{-1}, \qquad \lambda_2 > 0 \tag{3.5}$$
$$F_{t,\ Diff} = [1+\exp\{\delta(OILP_t - OILP_{t-d})\}]^{-1}, \ \delta > 0. \tag{3.6}$$

The logistic functions $F_{t,\ Low}$, $F_{t,\ High}$ and $F_{t,\ Diff}$ are assumed to reflect the state of the oil price, i.e. whether it is below c_1 US dollar, above c_2 US dollars or below/above the price in period $t-d$, respectively. In addition to the Greek letters in (3.3)-(3.6), c_1 and c_2 are constant parameters while L, H and D denote number of lags in the different states. For (finite) values of λ_1, λ_2 and δ

$$\begin{aligned}
F_{t,\ Low} &\longrightarrow 1 \text{ when } OILP \ll c_1 \text{ USD} \\
F_{t,\ Low} &\longrightarrow 0 \text{ when } OILP \gg c_1 \text{ USD} \\
F_{t,\ High} &\longrightarrow 1 \text{ when } OILP \gg c_2 \text{ USD} \\
F_{t,\ High} &\longrightarrow 0 \text{ when } OILP \ll c_2 \text{ USD} \\
F_{t,\ Diff} &\longrightarrow 1 \text{ when } \{OILP_t - OILP_{t-d}\} \ll 0 \\
F_{t,\ Diff} &\longrightarrow 0 \text{ when } \{OILP_t - OILP_{t-d}\} \gg 0.
\end{aligned}$$

Note also that for sufficiently large values of λ_1 and λ_2

$$F_{t,\ Low} \longrightarrow 0 \text{ and } F_{t,\ High} \longrightarrow 0 \text{ for } c_1 < OILP < c_2.$$

This provides a mechanism to represent the state of the oil price when it is fluctuating in the range c_1-c_2 dollars.

Empirical specification of the logistic function requires estimates of the transition parameters λ_1, λ_2 and δ, the threshold values c_1 and c_2 and of the delay parameter d. The estimates of the transition parameters and the threshold values can be obtained by estimating model (3.1) with the non-linear specification of $f_t(.)$, using non-linear least square (NLS) or maximum likelihood (ML), in principle. The estimation requires plausible starting values for these parameters, however. The bivariate analysis in subsection 2.2 provides plausible starting values for c_1 and c_2 by suggesting that they should be close to 14 and 20 US dollars, respectively. It seems reasonable that the transition parameters λ_1, λ_2 and δ are rather large, though it is difficult to decide upon exact values. Large values of these parameters lead to abrupt transition between 0 and 1 when $OILP_t$ deviates from c_1, c_2 or $OILP_{t-d}$, while small values of these bring about smooth transition between 0 and 1. The intuition for large values of these parameters is based on the observations that the major fluctuations in the Norwegian exchange rate have often coincided with fluctuations in the oil prices and that both oil prices and exchange rates often display abrupt transition from one level to another, in contrast to real economic variables. During estimation, however, we experiment with both low and high values of these parameters. The value of d can be chosen by comparing the explanatory power of the model estimated with different values of d, conditional on values of the transition and threshold parameters. The preferred estimates of these parameters and of the delay parameter can be selected after an iteration process: estimating λ_1, λ_2, δ, c_1 and c_2 conditional on a chosen d, which is thereafter revised conditional on the estimates of λ_1, λ_2, δ, c_1 and c_2, and so on.

Details of how the models with non-linear oil price effects were specified and estimated are provided below.

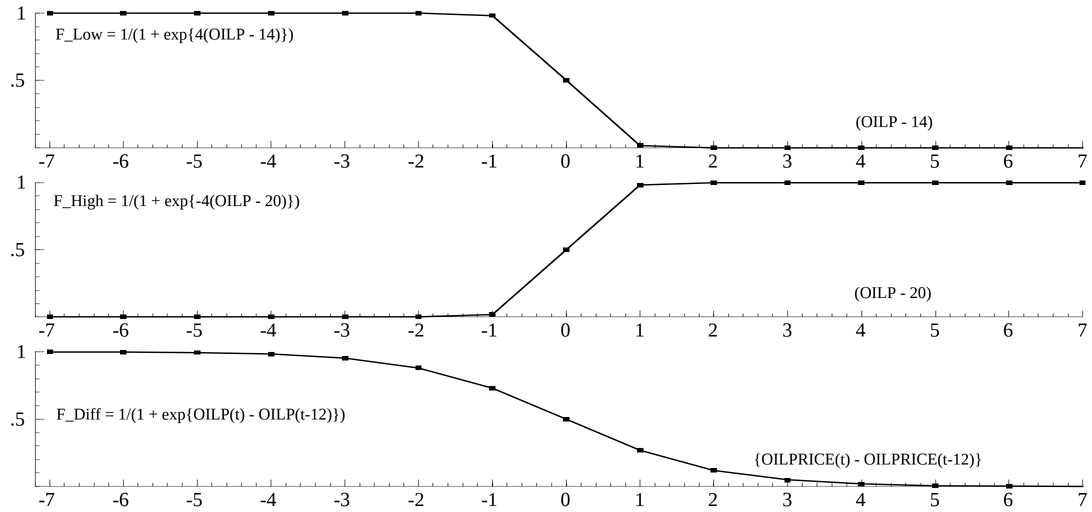


Figure 3.2: *The upper figure describes the value of F_{Low} for deviations of the oil price from 14 dollars. The figure in the middle shows the value of F_{High} for deviations of the oil price from 20 dollars. The figure at the bottom describes the value of F_{Diff} for deviations of the oil price from its value a year ago.*

Estimation: The models with non-linear oil price effects were derived in two steps to ease the estimation of λ_1, λ_2, δ, c_1 and c_2. In the first step, the parsimonious models of $Decu_t$ and $\Delta\overline{e}_t$ in Table 3.1 and 3.2 were reformulated with the function $f_t(.)$ specified in (3.3)-(3.6), replacing the linear oil price effects. A common value of 2 for L, H, and D was chosen while the values of d were varied in the interval 1-12 and 1-4 in the case of the model on monthly and quarterly data, respectively. However, the obtained maximum likelihood estimates of λ_1, λ_2, δ, c_1 and c_2 were generally quite uncertain, even when the models were sequentially reduced (and degrees of freedom increased) by excluding oil price terms with numerically insignificant effects. One explanation could be that the uncertainty associated with these parameters reflects the difficulty in distinguishing between the shapes of a transition function, e.g. $F_{t,Low}$, at large values of the transition parameter, cf. Granger and Teräsvirta (1993) and Teräsvirta (1998). To accomplish this, a large number of observations around the threshold value, e.g. $c_1 = 14$, is required. For example, it is quite difficult to distinguish between the shapes of $F_{t,Low}$ for $\lambda_1 = 4$ and $\lambda_1 = 5$.

The high degree of uncertainty associated with the estimates of the transition and threshold parameters led us to assess their values conditional on each other. Conditional on $c_1 = 14$ and $c_2 = 20$, values of λ_1, λ_2 and δ equal to 4, 4 and 1, respectively, increased the explanatory power of the models compared with a number of other sets of values (for these parameters). For the monthly model, a value of $d = 12$ provided a slightly better fit than any other value in the interval 1-12, while a value of $d = 1$ provided the best fit on the quarterly data. Attempts were also made to estimate the threshold parameters c_1 and c_2 conditional on the proposed values of λ_1, λ_2, δ and d. Still the estimates on the monthly data turned out to be quite uncertain.

Table 3.3: An EqCM of the ECU rate with non-linear oil price effects.

$$\widehat{Decu_t} = \underset{(2.851)}{0.268} - \underset{(-2.436)}{0.056} [ecu - (cpi - cpi^f)]_{t-2} + \underset{(3.668)}{0.152} [R3\text{-}R3^f]_t$$
$$\underset{(18.627)}{1.227} Decu_{t-1} - \underset{(-5.720)}{0.372} Decu_{t-2} - \underset{(-5.070)}{0.266} \Delta[R3_{t-2} - Dcpi_{t-1}]$$
$$- \underset{(-2.385)}{0.649} Dcpi^f_{t-1} + \underset{(2.493)}{0.008} DFI.Y_t$$
$$- \underset{(-6.428)}{0.055} i93p12 - \underset{(-5.782)}{0.027} i97p1 + \underset{(3.752)}{0.018} i97p11 + \underset{(6.617)}{0.032} i98p1$$
$$- \underset{(-6.125)}{0.042} i98p3 - \underset{(-3.627)}{0.055} i98p6 + \underset{(5.663)}{0.064} i98p9 - \underset{(-8.190)}{0.080} i98p11$$
$$- \underset{(-3.656)}{0.0175} oilp_{t-1}$$
$$- \underset{(-3.575)}{0.2881} \Delta oilp_t \text{ x}[1 + \exp\{4(OILP_t - 14)\}]^{-1}$$
$$- \underset{(-1.423)}{0.0223} \Delta oilp_t \text{ x}[1 + \exp\{-4(OILP_t - 20)\}]^{-1}$$
$$- \underset{(-3.152)}{0.0428} \Delta oilp_t \text{ x}[1 + \exp\{(OILP_t - OILP_{t-12})\}]^{-1}$$

Sample: 1990:11-1998:11 , $T = 97$, $k = 20$. *Method: OLS*

Diagnostics

$\hat{\sigma}_{NL}$	=	0.455%
Log lik	=	*485.703*
LR-Test: $\chi^2(2)$	=	24.761[0.000]**
$AR\ 1-6\ F(6,71)$	=	0.704[0.647]
$ARCH(6)\ F(6,65)$	=	0.718[0.637]
$Het.\ Xi^2\ F(30,46)$	=	0.851[0.676]
Normality $\chi^2(2)$	=	0.281[0.869]
RESET F(1, 76)	=	0.239[0.626]
$TT_{NL}F(21,56)$	=	1.006[0.472]

Note: t-values (ordinary) in brackets (.) below the estimates and p-values in large brackets [.] beside the test statistics. TT_{NL} F(df1, df2) is defined in the main text.

See Table 3.1 for details about the other tests.

On the quarterly data, however, quite precise estimates of c_1 and c_2 at around 14 and 20 were obtained, especially when oil price terms that appeared redundant were excluded from the model. In particular, the level of oil price ($oilp$) had a relatively weak non-linear effect on the exchange rate. Also, the terms representing the oil price effects when *OILP* is above c_2 dollars had relatively weak effects. The estimate of c_1 was found to be fairly invariant to starting values when the oil price terms that appeared redundant were excluded. For example, it exhibited fast convergence to about 14.2, with a standard error estimate of around 0.37, when its starting value was varied in the range 12-18. A likely reason for the ability to derive relatively precise estimates of c_1 and c_2 at least, is that the quarterly data set contains more observations of $OILP$ around 14 and 20 USD than the monthly data set, see Figure 3.3.

Given the evidence from the bivariate analysis in section 2 and the estimates of c_1 and c_2 on quarterly data, we proceeded with the modelling of $Decu_t$ on monthly data with c_1 and c_2 fixed

Table 3.4: An EqCM of the effective exchange rate with non-linear oil price effects.

$$
\begin{aligned}
\Delta\widehat{\overline{e}}_t = & - \underset{(-3.608)}{0.100} \; [\overline{e} - (cpi - cpi^f)]_{t-1} + \underset{(2.678)}{0.190} \; \Delta\overline{e}_{t-1} \\
& - \underset{(-3.352)}{0.346} \; \Delta(RB_{t-1} - \Delta cpi_{t-2}) - \underset{(-2.348)}{0.204} \; \Delta cpi^f{}_t \\
& + \underset{(3.050)}{0.821} \; \Delta^2 RB^f{}_{t-1} + \underset{(1.799)}{0.099} \; \Delta_4 FI.Y_t - \underset{(-4.211)}{0.032} \; id97q1 \\
& [- \underset{(-3.950)}{0.103} \; \Delta oilp_t - \underset{(-2.724)}{0.023} \; \Delta oilp_{t-2}] \text{x} [1 + \exp\{4(OILP_t - \underset{(37.711)}{14.197})\}]^{-1} \\
& - \underset{(-3.635)}{0.030} \; \Delta oilp_{t-1} \text{x} [1 + \exp\{OILP_t - OILP_{t-1}\})]^{-1}
\end{aligned}
$$

Sample: 1972:2-1997:4 , $T = 103$, $k = 10$. *Method: MLE*

Diagnostics

$\hat{\sigma}_{NL}$	=	1.00%
Log lik	=	418.852
R^2	=	0.56
AR $1-5$ $F(5,88)$	=	0.410[0.841]
$ARCH$ (4) $F(4,85)$	=	0.478[0.752]
$Het.Xi^2$ $F(20,72)$	=	0.495[0.960]
$Het.Xi$ Xj $F(56,36)$	=	1.265[0.228]
Normality $\chi^2(2)$	=	1.707[0.426]
$RESET$ $F(1,92)$	=	0.461[0.499]
TT_{NL} $F(22,64)$	=	0.889[0.665]

Note: Brackets below the estimates contain (ordinary) t-values while square brackets contain p-values. R^2 was obtained by OLS with c_1 fixed at 14.197. The value of R^2 is almost the same if a constant term is included in the model. Het. Xi^2 F(df1, df2) tests for heteroscedasticity by using cross products of regressors , see White (1980). TT_{NL} F(df1, df2) is defined in the main text. The other tests are explained in Table 3.1

at 14 and 20.

Table 3.3 and 3.4 present parsimonious versions of the two models and the associated diagnostics. In contrast to the model of $\Delta\overline{e}_t$, the model of $Decu_t$ is estimated by OLS since it is linear in parameters for fixed values of the transition and threshold parameters. A re-estimation by OLS of generalised versions of both models with L, H, D and p set to 2 and $f(,)$ defined by the reported values of λ_1, λ_2, δ, d, c_1 and c_2, also led to the same specific versions as shown in Table 3.3 and 3.4, when statistically insignificant variables and terms were excluded for the sake of parsimony.

Except for the non-linear oil price terms, both models contain the same regressors as the models with linear oil price effects presented in Table 3.1 and 3.2. Note also that the equilibrium correction term $[ecu$ - $(cpi$-$cpi^f)]_{t-2}$ in the monthly model has become significant at the 5% level when using the t-distribution, which is not inappropriate given the evidence for stationarity of this term, see Table 4.1 in the appendix. Now both models suggest that the Norwegian nominal exchange rate responds to differences in domestic and foreign prices in the short and long run.

However, the models have different long run solutions. The log level of oil price, $oilp_{t-1}$, appears in a linear way in the model of *Decu* (and even with the same coefficient estimate as in the linear model of *Decu),* see Table 3.1 and 3.3. The implication is that higher oil prices lead to an appreciation of the long run real exchange rate (ecu-cpi-cpi^f), in contrast to the PPP theory. On the quarterly data set, however, (log) level of oil prices were not found to have linear or non-linear

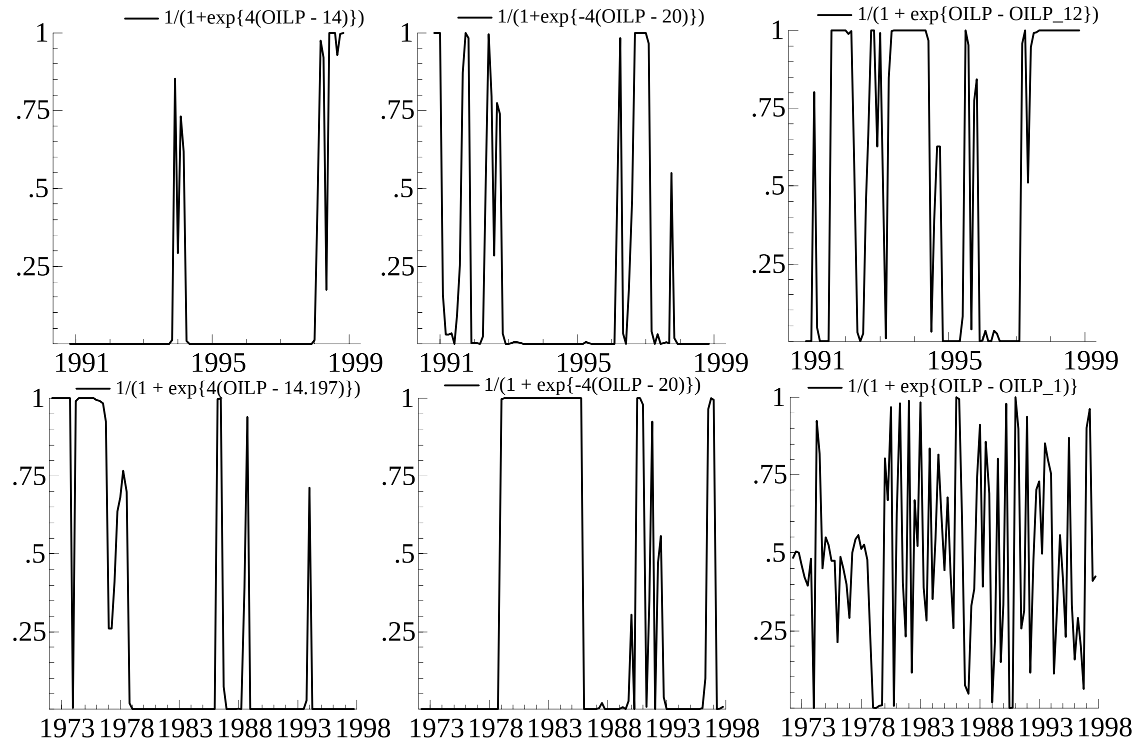


Figure 3.3: *First row: Values of the logistic functions over the period 1990:11-1998:11, monthly data. Second row: Values of the logistic functions over the period 1972:2-1997:4, quarterly data.*

effects on $\Delta\bar{e}_t$. For example, an F-test accepted zero restrictions on $oilp_t$, $oilp_{t-1}$ and $oilp_{t-2}$ with a p-value of about 90% when they were added to the model in Table 3.4. Thus the long run real exchange rate ($\bar{e}$-cpi-cpi^f) equals a constant, zero, in strict accordance with the PPP theory.

Short run oil price effects: Table 3.3 and 3.4 show that oil prices have statistically significant non-linear effects in the short run. The non-linear effects are essentially the same in both models suggesting that changes in oil prices have relatively strong effects when oil prices are below 14 USD and are displaying a falling trend. At levels around or above 20 dollars, oil prices were found to have statistically insignificant effects when judged at the 5% level. As noted above, such terms have been left out from the model of $\Delta\bar{e}$ altogether since their coefficients were also numerically small. The model of *Decu* however contains such a term, though it is only statistically significant at the 10% level. More observations at higher levels of oil prices may provide more firm evidence on its relevance.

Numerically, the effects of oil prices when below 14 dollars are almost 10 times the size of the effects suggested by the corresponding linear models. In a state of falling oil prices, the effects are also relatively stronger at levels of oil prices higher than 14 dollars. It is apparent that a linear representation of oil price effects tends to bring about underestimation of the exchange rate response to fluctuations in oil prices.

The non-linear oil price effects implied by both models are consistent with the level and trend

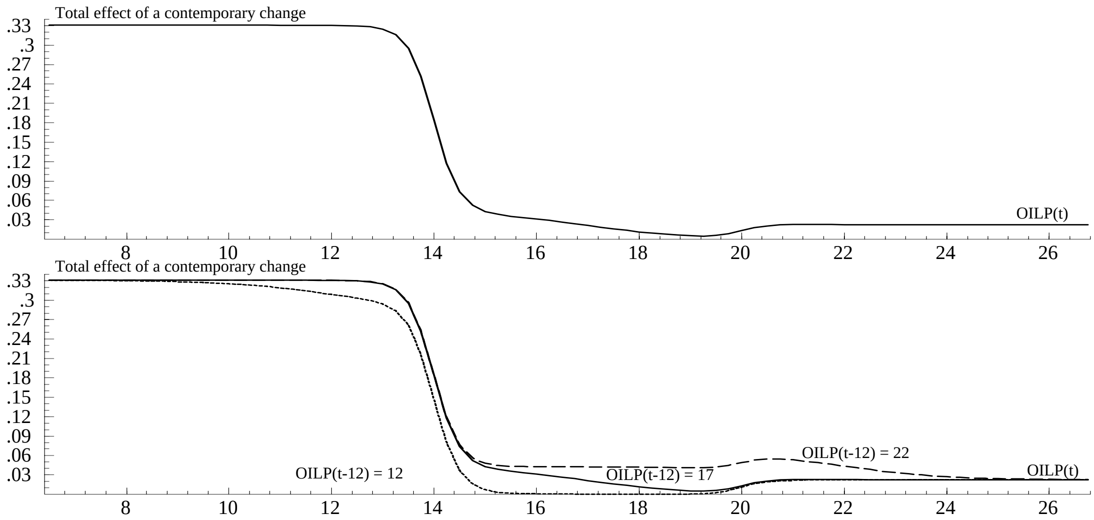


Figure 3.4: *Top: The total contemporary effect* $(=[0.288F_{Low}+0.022F_{High}+0.043F_{Diff}]x\Delta oilp_t)$, *in absolute value, of a change in the oil price (vertical axis) at different levels of the current oil price (OILP(t)).* F_{Diff} *is defined by OILP(t-12) = 17. Bottom: The total contemporary effect of a fall in the oil price if the oil price was 12 (dotted line), 17 (solid line) and 22 (dashed line) dollars a years ago, i.e. at* $t-12$. *Horizontal axis: current level of oil price in dollars (OILP(t)).*

effects suggested by the bivariate analysis in section 2, apart from the statistical insignificance of oil price effects at oil prices around and above 20 dollars.

Figure 3.4 lays out the level and trend effects of oil prices on the exchange rate implied by the model of *Decu*. As noted above, both models imply essentially the same short run effects of oil prices. For the purpose of illustration, however, we focus on the effects suggested by the model of *Decu* since it also seems to capture the findings based on the bivariate analysis.

The graph at the top in Figure 3.4 illustrates how the strength of short run oil price effects depends on the level of the oil price in dollars, *OILP*. It sketches the total contemporaneous effect (in absolute value) on the exchange rate from $\Delta oilp_t$ at different levels of *OILP* under the assumption that $OILP_{t-12}$ is 17 dollars. The relation between the effect on the exchange rate and the oil price in dollars appears convex. The effect is strongest when the oil price is below 13 dollars. This because $F_{t,Low}$ and $F_{t,Diff}$ are fully active since their values are close to 1 at such price levels, see Figure 3.2. As the oil price rises above 14 dollars, the partial effect declines sharply but thereafter at a slower pace as it rises above 15 dollars. The reason is that $F_{t,Low}$ converges to zero as the oil price rises above 15 dollars, see Figure 3.2.

The effect of the trend term, $\Delta oilp$ x F_{Diff}, also declines as the difference between the current price and past price (17 dollars) is reduced, and disappears altogether at 19 dollars, that is, when the oil price has risen by 2 dollars relative to the past, see Figure 3.2. In the range of 15-19 dollars, the contemporaneous effect on the exchange rate is entirely determined by the relative decline or rise in the oil price, cf. Figure 3.2. When the oil price rises above 19 dollars, the effect tends to increase because $F_{t,High}$ starts rising to 1. The effect at high levels of the oil price is however remarkably weak compared with the effect at low levels of the oil price.

The graph at the bottom in Figure 3.4 illustrates the trend effect more clearly. It shows that the strength of short run oil price effects also depends on whether the oil price is displaying a rising or falling trend. For instance, if the oil price was 22 dollars or higher a year ago, the effect of a decrease or increase, $\Delta oilp_t \gtrless 0$, is higher if the current price $(OILP_t)$ is below its level of the previous year. The trend effect becomes negligible and vanishes when the current price exceeds past levels.

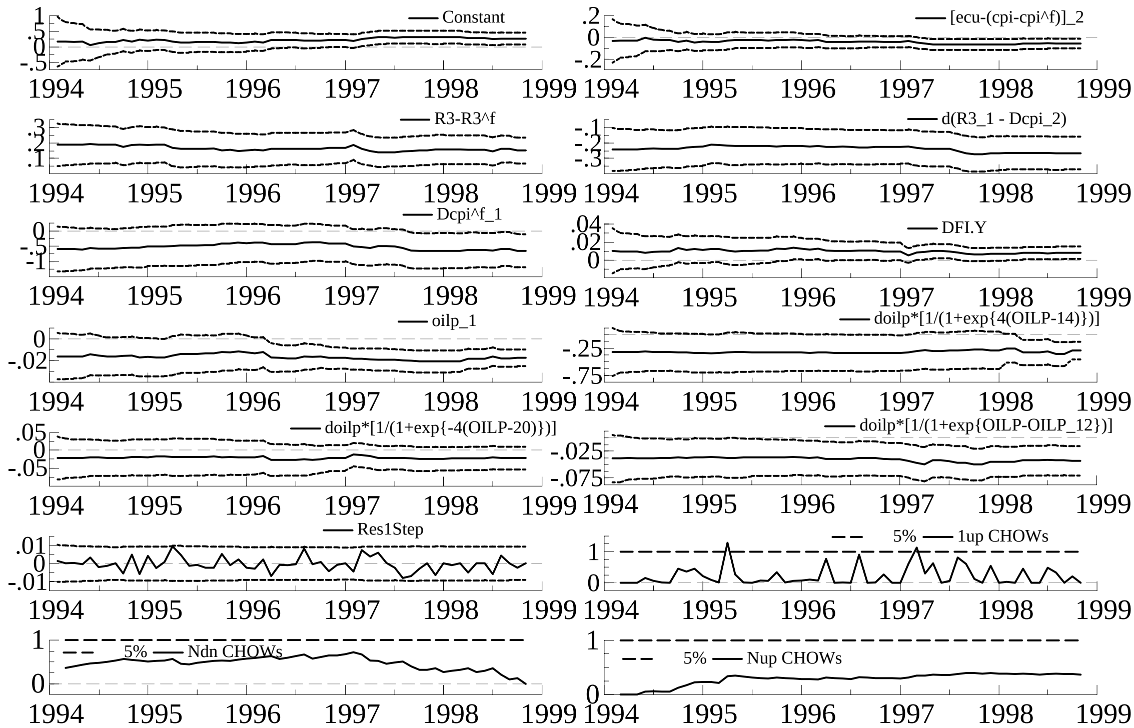


Figure 3.5: Model: *The EqCM of Decu with non-linear oil price effects. Recursive OLS estimates* $\pm 2SE$ *of the coefficients in the non-linear model. Thereafter: 1-Step ahead residuals* $\pm 2SE$*, 1-step ahead Chow tests, break point (Ndn) and forecast Chow tests scaled by their 5% critical values. The initial estimates are based on 40 observations, i.e. on the period 1990:11-1994:2. Prefix "d" denotes the 1. difference, while "D" denotes 12. difference (e.g. Dcpi =* cpi_t*-*cpi_{t-12}*).*

3.4. Model evaluation

The diagnostics in Table 3.3 and 3.4 show that the regression specification test (RESET) does not reject the functional forms at standard levels of significance any more. The test for no neglected non-linear effects of a specified variable suggested by e.g. Teräsvirta (1998) is also performed on the residuals from both models to asses whether non-linear effects of oil prices have been adequately characterised. The test is denoted as TT_{NL} and is performed using *OILP* as the transition variable. The tables shows that the null hypotheses of no-neglected non-linear oil price effects are not rejected at the standard levels of significance, in both cases. Also, the standard assumptions about the residuals are not rejected, as in the case of the linear models. The dummy variables are still needed however to ensure adherence to these assumptions in both models.

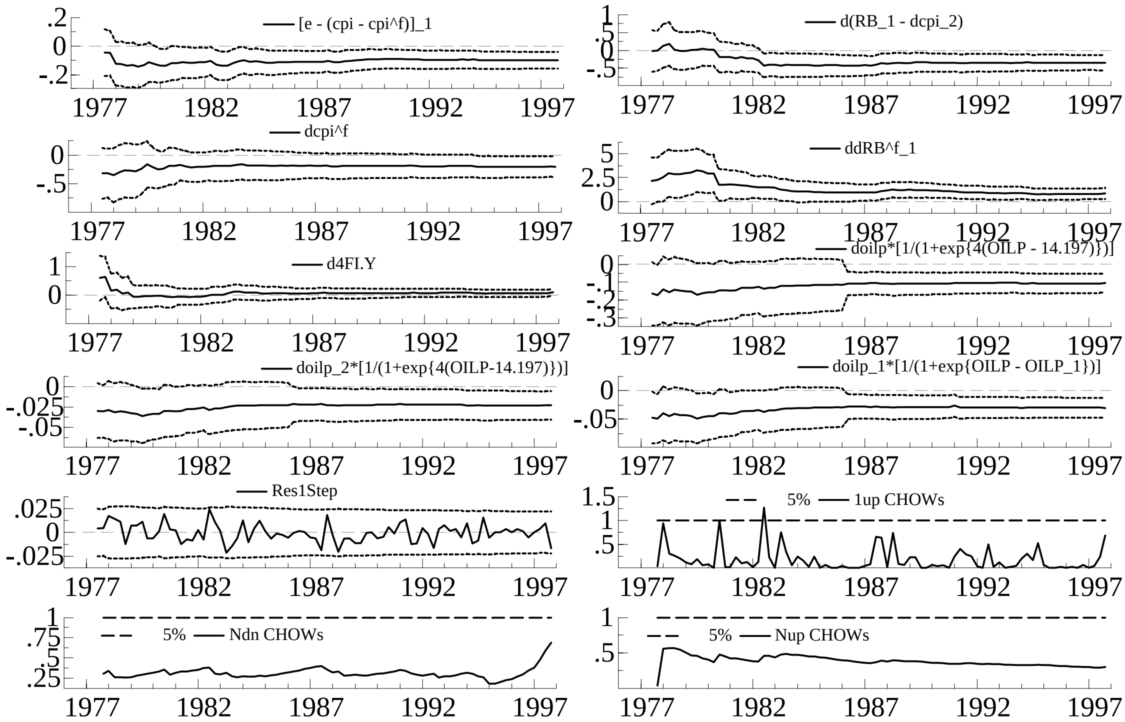


Figure 3.6: *Model: The EqCM of $\Delta\overline{e}$ with non-linear oil price effects. Constancy statistics for the EqCM with non-linear oil price effects. Initial estimation period is 1972:2-1976:4. These have been obtained by fixing c_1 at 14.197 and estimating the model recursively by OLS. Prefix "d" denotes the first difference Δ. The graphs show the recursive coefficient estimates $\pm 2SE_t$ of the indicated regressors, One-step ahead residuals $\pm 2SE_t$ and Chow statistics for the model. The latter are scaled by their critical values at the 5% level of significance.*

The tests for parameter stability over time do not indicate non-constancy in the parameters of both models at the 5% level, see Figure 3.5 and 3.6. In particular, the recursive OLS estimates of the non-linear oil price effects are remarkably stable over time. It is worth noticing that the standard deviations of the oil price effects when oil prices are below 14 dollars decrease relatively fast as more observations below this level come along, but without affecting the coefficient estimates of the oil prices, see e.g. Figure 3.5 in the beginning of 1998 and Figure 3.6 in 1985/1986.

The non-linear models are clearly preferred over the linear models in terms of explanatory power. Table 3.1 and 3.2 show that the linear models have lower explanatory power than the non-linear models. In the case of the models of $Decu_t$, an LR test can be performed. Its outcome, reported in Table 3.3, indicates that the linear model of $Decu_t$ is strongly rejected against its non-linear version.

The higher explanatory power of the non-linear models relative to the linear models is clearly demonstrated in Figure 3.7. For the linear and non-linear models, it displays the residuals, 1-step ahead residuals ± 2 times recursively estimated standard errors ($\widehat{\sigma}$), SE_t, and 1-step ahead Chow

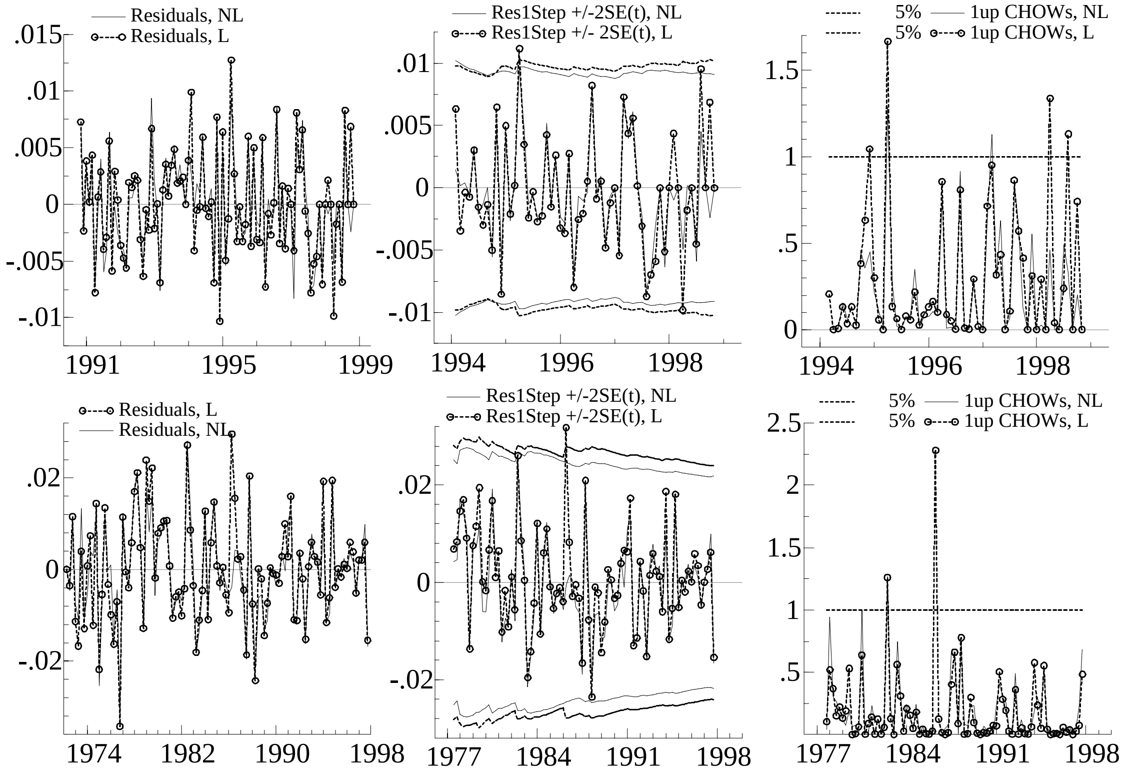


Figure 3.7: *Upper row: Residuals, 1-step ahead residuals $\pm 2SE_t$, 1-Step ahead Chow statistics and the 5% critical values based on the linear (L) and non-linear (NL) EqCMs of Decu estimated on the monthly data set. Lower row: Residuals, 1-step ahead residuals $\pm 2SE_t$, 1-Step ahead Chow statistics and the 5% critical values based on the linear (L) and non-linear (NL) EqCMs of $\Delta\bar{e}$ estimated on the quarterly data set. Everywhere, solid lines denote values based on the corresponding non-linear models denoted by NL.*

test statistics, scaled by the (same) one off critical value at the 5% level. The non-linear oil price effects appear important in explaining the large fluctuations in the exchange rates which lead to lower standard errors of the residuals in the non-linear models than in the linear models. They also lead to more stable parameter estimates particularly in the face of oil price falls, as indicated by the Chow statistics.

For example, Figure 3.7 shows that there are fewer spikes in the residuals from the non-linear model of $Decu_t$ than in the residuals from its linear model, especially around 1994 and in 1998. Figure 3.3 suggests that the non-linear effects of low and declining oil prices are active in these periods and eliminate the spikes. However, Figure 3.7 indicates relatively smaller difference between the explanatory power of the two models in 1996/97, i.e. during the large appreciation pressure. Thus the appreciation pressure seems to have arisen mainly due to other factors than the relatively high oil prices in this period, as suggested by e.g. Kvilekval and Vårdal (1997).

The lower row of Figure 3.7 gives the impression that the non-linear model of $\bar{e}$ mainly owes its superior performance to the coincidence between low oil prices and the devaluation in 1986. There is thus a need to investigate whether low oil prices can explain other incidents of fall in the value of the krone. We turn to this issue later.

Extension of the information set with additional variables: Table 3.5 demonstrates that the model of $\Delta\bar{e}$ with non-linear oil price effects is quite robust to extensions of the information set. The information set has been extended by vector $\mathbf{Z}$; specifically, by productivity growth at home and abroad, Δq and Δq^f, growth in government expenditures (Δg) and growth in domestic GDP (Δy) or changes in unemployment rate Δu. The additional variables were included with up to three lags. Table 3.5 presents the model and the outcome of variable omission tests when Δq, Δq^f and Δg are included with up to three lags.

Table 3.5: The EqCM of the effective exchange rate with additional variables.

$$
\begin{aligned}
\Delta\widehat{\bar{e}}_t = &- \underset{(-3.223)}{0.097}\ [\bar{e} - (cpi - cpi^f)]_{t-1} + \underset{(2.606)}{0.205}\ \Delta\bar{e}_{t-1} \\
&- \underset{(-2.232)}{0.279}\ \Delta(RB_{t-1} - \Delta cpi_{t-2}) - \underset{(-1.966)}{0.257}\ \Delta cpi^f{}_t \\
&+ \underset{(2.538)}{0.765}\ \Delta^2 RB^f{}_{t-1} + \underset{(1.428)}{0.086}\ \Delta_4 FI.Y_t - \underset{(-3.575)}{0.029}\ id97q1 \\
&[- \underset{(-3.564)}{0.103}\ \Delta oilp_t - \underset{(-2.347)}{0.023}\ \Delta oilp_{t-2}]\mathrm{x}[1 + \exp\{4(OILP_t - 14.197)\}]^{-1} \\
&- \underset{(-3.758)}{0.034}\ \Delta oilp_{t-1}\mathrm{x}[1 + \exp\{OILP_t - OILP_{t-1}\})]^{-1} \\
&- \underset{(-1.702)}{0.059}\ \Delta q^f_t - \underset{(-0.765)}{0.026}\ \Delta q^f_{t-1} + \underset{(0.270)}{0.009}\ \Delta q^f_{t-2} + \underset{(0.342)}{0.011}\ \Delta q^f_{t-3} \\
&- \underset{(-0.739)}{0.022}\ \Delta q_t - \underset{(-0.519)}{0.016}\ \Delta q_{t-1} + \underset{(0.409)}{0.013}\ \Delta q_{t-2} - \underset{(-0.495)}{0.015}\ \Delta q_{t-3} \\
&- \underset{(-1.316)}{0.235}\ \Delta g_t - \underset{(-0.544)}{0.111}\ \Delta g_{t-1} + \underset{(0.209)}{0.043}\ \Delta g_{t-2} - \underset{(-1.850)}{0.353}\ \Delta g_{t-3}
\end{aligned}
$$

Sample: 1972:2-1997:4 , $T = 103$, $k = 22$, *Method: OLS*

Tests for omission of variables

			Δq^f	Δq	Δg	Δy	Δu
Joint[a]	$F(4,\ 81)$	:	[0.484]	[0.611]	[0.111]		
Separate[b]	$F(4,\ 89)$	:	[0.349]	[0.773]	[0.139]	[0.311]	[0.805]

Note: Brackets below the estimates contain (ordinary) t-values while square brackets contain p-values. Model estimated by OLS with c_1 fixed at 14.197.
[a]The F-tests were performed by placing zero restrictions on the contemporary and lagged values of the indicated variable while retaining the additional variables.
[b]The F-test were performed by excluding all additional variables except the contemporary and lagged values of the indicated variable.

None of these variables turns out to have statistically significant effects at the 5% level. The fiscal policy variables have relatively large coefficients that indicate appreciation pressure on the nominal exchange rate when government spendings increase. The effects are however insignificant at the 5% level, even if other clearly insignificant terms are omitted from the model. The variable omission tests indicate that none of the added variables have significant effects and can be omitted from the model altogether. This was also the case when the insignificant variables were sequentially omitted from the model, with one exception. The contemporaneous effect of productivity changes in the trading countries (Δq^f_t) was found to be significant at the strictly 5% level when all the other additional variables were excluded from the model, but with the "wrong" sign, i.e. negative. Government expenditures on consumption and real investment were also entered separately, i.e. as

$\Delta(C_G/Y)$ and $\Delta(J_G/Y)$ with up to three lags, but neither of them were found to have significant effects.

Growth in GDP (Δy) was also included in the model with up to three lags, both when the additional variables were present and when they were left out, but no significant effects were found and there no noteworthy change was detected in the coefficient estimates of the initial variables. Changes in GDP, as well in the rate of unemployment (Δu), are likely to reflect the influence of different variables that affect the Norwegian economy. Including Δy, or Δu, in the model may to some extent, mop up the effects of variables which are not explicitly included in the model. The variable omission tests, however, show that neither Δy nor Δu has statistically significant effects on the nominal exchange rate.

Similar results were obtained in the case of the monthly model with non-linear oil price effects. For example, an *F-test* accepted zero restrictions on the associated $\mathbf{Z}$ vector when included with two lags in the model. The $F(9, 68)$ statistics was 0.999 with a p-value of 0.45. As noted earlier, vector $\mathbf{Z}$ vector includes $Fisc.Y$, Δu and Δu^f in the case of the monthly model.

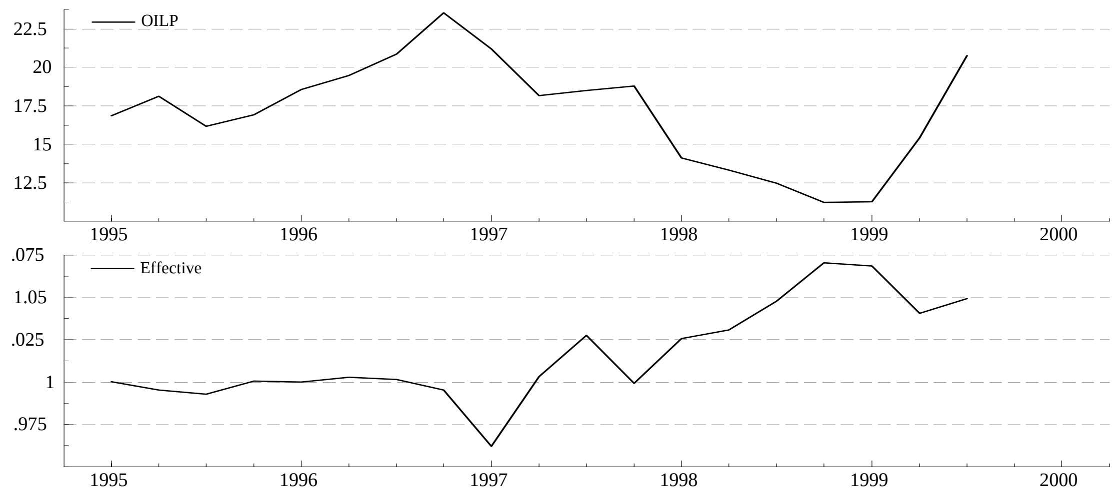


Figure 3.8: *Oilprice in US dollars (OILP) and the effective nominal exchange rate* $(\overline{E})$ *over the period 1995:1-1999:3.*

Post sample evaluation In the following, we undertake a post-sample evaluation of the model of $\Delta\overline{e}$. We are able to extend the quarterly data set by 7 quarters for all the variables in the model except $FI.Y$ for which we lack the data for the year 1999. $\Delta_4 FI.Y$ is anyway statistically insignificant at the 5% level so we do not expect that it will induce considerable omitted variable bias in other parameter estimates if the model is estimated without it.

The new observations cover the period 1998:1-1999:3 in which oil prices have fluctuated across a relatively wide range of levels and displayed both a downward and upward trend, see Figure 3.8. The figure also shows a relatively large depreciation in the value of the nominal effective exchange rate ($\overline{E}$) during 1998 followed by a marked appreciation in 1999. The new observations are therefore quite informative for the purpose of assessing the stability of the model, and of the

Table 3.6: The EqCM of the effective exchange rate estimated on data extended by 7 quarters.

$$\Delta\widehat{\overline{e}}_t = - \underset{(-3.988)}{0.110} [\overline{e} - (cpi - cpi^f)]_{t-1} + \underset{(2.053)}{0.149} \Delta\overline{e}_{t-1}$$
$$- \underset{(-2.942)}{0.318} \Delta(RB_{t-1} - \Delta cpi_{t-2}) - \underset{(-2.900)}{0.277} \Delta cpi^f{}_t$$
$$+ \underset{(2.887)}{0.818} \Delta^2 RB^f{}_{t-1} + 0\ \Delta_4 FI.Y_t - \underset{(-3.765)}{0.031} id97q1$$
$$[- \underset{(-5.243)}{0.123} \Delta oilp_t - \underset{(-2.959)}{0.025} \Delta oilp_{t-2}]\text{x}[1 + \exp\{4(OILP_t - 14.197)\}]^{-1}$$
$$- \underset{(-3.577)}{0.031} \Delta oilp_{t-1}\text{x}[1 + \exp\{OILP_t - OILP_{t-1}\})]^{-1}$$

Sample: 1972:2-1999:3 , $T = 110$, $k = 9$. *Method: OLS*

Diagnostics

$\hat{\sigma}$	=	0.011
R^2	=	0.54
DW	=	1.99
AR 1 − 5 $F(5, 96)$	=	0.376[0.864]
$ARCH$ (4) $F(4, 93)$	=	0.198[0.939]
$Het.Xi^2$ $F(18, 82)$	=	0.580[0.904]
$Het.Xi\ Xj$ $F(46, 54)$	=	0.697[0.894]
$Normality$ $\chi^2(2)$	=	1.376[0.503]
$RESET$ $F(1, 100)$	=	0.289[0.592]

Note: Brackets below the estimates contain (ordinary) t-values while square brackets contain p-values. c_1 fixed at 14.197 while $\Delta_4 FI.Y_t$ was left out from the model. The value of R^2 is almost the same if a constant term is included in the model. Tests are explained in Table 3.1.

non-linear oil price effects, in particular.

Table 3.6 presents the model of $\Delta\overline{e}$, reestimated by OLS on the extended data set with c_1 fixed at 14.197, and the associated diagnostics. The table shows that the model is intact; particularly the oil price effects, whose statistical significance has increased. Beside that, the t-value of the equilibrium correction term has become almost -4 which lends strength to the hypothesis of purchasing power parity in the long run. Furthermore, the model diagnostics have improved.

The model with linear oil price effects in Table 3.2 was also reestimated on the extended data set. However, the oil price effects remained almost as in Table 3.2. Moreover, zero restrictions on $\Delta oilp_t$, $\Delta oilp_{t-1}$ and $\Delta oilp_{t-2}$ were accepted by an F-test with a p-value of 6%. In addition, the RESET test still suggested a functional form misspecification at the 5% level.

A model with deterministic account of non-linearity: Figure 3.7 seemed to suggest that the higher explanatory power of the non-linear model of $\overline{e}$ stems from a proper representation of the devaluation in 1986, which coincided with the oil price fall in 1985/1986. One may suspect that a model with linear oil price effects but with dummy variables for the abrupt changes in the exchange rate can lead to a comparable improvement in the linear model and make the non-linear representation of oil price effects redundant. Moreover, oil prices may not even have linear effects on the exchange rate once the devaluation is controlled for by dummy variables, cf. Bjørvik *et al.* (1998).

Table 3.7: Models of the effective exchange rate with dummy variables to represent the non-linearity.

$$\Delta\widehat{\overline{e}}_t = -\underset{(-3.420)}{0.107}[\overline{e}-(cpi-cpi^f)]_{t-1} + \underset{(2.802)}{0.233}\Delta\overline{e}_{t-1} - \underset{(-2.949)}{0.340}\Delta(RB_{t-1}-\Delta cpi_{t-2}) - \underset{(-2.488)}{0.258}\Delta cpi^f{}_t + \underset{(2.637)}{0.798}\Delta^2 RB^f{}_{t-1} + \underset{(1.432)}{0.091}\Delta_4 FI.Y_t - \underset{(-4.115)}{0.035} id97q1 - \underset{(-0.228)}{0.002}\Delta oilp_t - \underset{(-1.239)}{0.009}\Delta oilp_{t-1} + \underset{(0.592)}{0.004}\Delta oilp_{t-2} + \underset{(2.975)}{0.038} id86q2 + \underset{(1.684)}{0.021} id86q3$$

Sample: 1972:2-1997:4 , $T = 103$, $k = 12$. *Method: OLS*
$R^2 = 0.52$, $\hat{\sigma} = 0.0115$, *RESET* $F(1, 90) = 1.608$ [0.208]

$$\Delta\widehat{\overline{e}}_t = -\underset{(-3.498)}{0.105}[\overline{e}-(cpi-cpi^f)]_{t-1} + \underset{(2.623)}{0.213}\Delta\overline{e}_{t-1} - \underset{(-3.261)}{0.358}\Delta(RB_{t-1}-\Delta cpi_{t-2}) - \underset{(-2.269)}{0.227}\Delta cpi^f{}_t + \underset{(3.301)}{0.974}\Delta^2 RB^f{}_{t-1} + \underset{(1.782)}{0.108}\Delta_4 FI.Y_t - \underset{(-3.822)}{0.031} id97q1 - \underset{(-0.091)}{0.001}\Delta oilp_t + \underset{(0.237)}{0.003}\Delta oilp_{t-1} + \underset{(1.971)}{0.020}\Delta oilp_{t-2} - \underset{(-0.536)}{0.012} id86q2 + \underset{(0.118)}{0.002} id86q3$$
$$[-\underset{(-2.478)}{0.122}\Delta oilp_t - \underset{(-3.050)}{0.044}\Delta oilp_{t-2}]\text{x}[1+\exp\{4(OILP_t - 14.197)\}]^{-1} - \underset{(-1.981)}{0.037}\Delta oilp_{t-1}\text{x}[1+\exp\{OILP_t - OILP_{t-1}\})]^{-1}$$

Sample: 1972:2-1997:4 , $T = 103$, $k = 15$. *Method: OLS*
$R^2 = 0.58$, $\hat{\sigma} = 0.0109$, *RESET* $F(1, 87) = 0.453$ [0.503]

Note: Brackets below the estimates contain (ordinary) t-values while square brackets contain p-values. Both models were estimated by OLS with c_1 fixed at 14.197. The value of R^2 is almost the same if a constant term is included.

A model with dummy variables would be preferable if the co-movement in the oil price and the exchange rate in 1985/86 was a unique event and not a stable feature; since otherwise, a model with non-linear oil price effects is likely to over-predict the exchange rate depreciation in a state of low and falling oil prices. In the following we test for: (a) whether oil prices have significant effects once the devaluation is controlled for, and in particular, whether use of dummy variables can make the non-linear representation of oil price effects redundant, and (b) whether the incident of low oil prices and a fall in the value of the currency in 1986 was just a unique event and unlikely to be repeated in the future.

The upper panel of Table 3.7 presents a model with dummy variables to account for the events in 1986, which seems to be the main cause of the observed non-linearity. Two impulse dummies that takes on a value of 1 in 1986:2 and in 1986:3, respectively, appeared sufficient to capture the fall in the value of the exchange rate, see Figure 3.9. Consequently, there is an increase in the explanatory power of the model relative to the linear model in Table 3.2, measured by R^2 and $\widehat{\sigma}$,

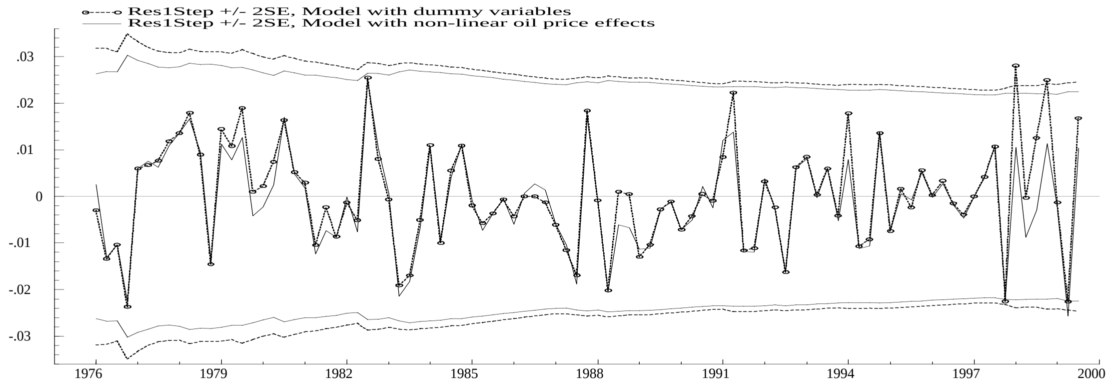


Figure 3.9: *Dashed lines:1-step ahead residuals* $\pm 2SE$ *of the model with dummy variables in the upper panel of Table 3.7, but recursively estimated on data over the period 1972:2-1999:3. Solid lines: depict 1-step ahead residuals* $\pm 2SE$ *based on the model with non-linear oil price effects of Table 3.7, but also recursively estimated on data covering the period 1972:2-1999:3. Initial estimation period 1972:2-1975:4, in both cases.*

and the RESET test does not reject the functional form at the 5% level.

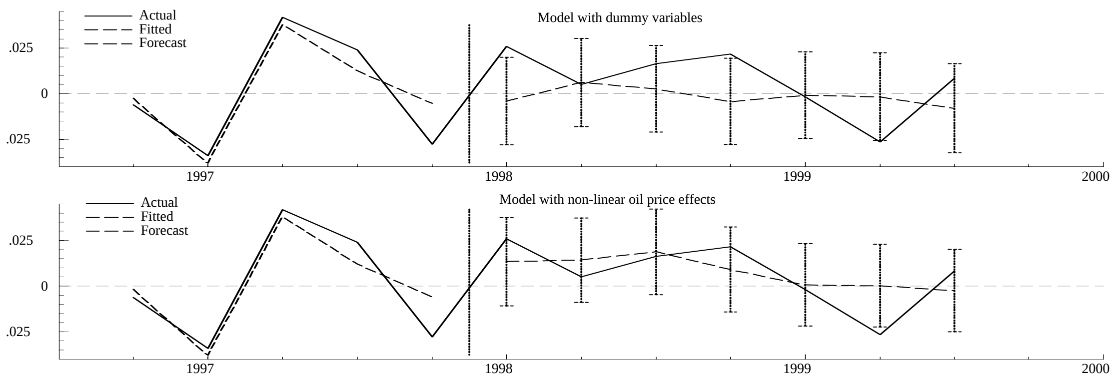


Figure 3.10: *Top: Actual, fitted and forecasted values (1-step ahead) of* $\Delta\bar{e}$ *based on the model with dummy variables, cf. the upper panel of Table 3.7. The dotted bars are 95% prediction intervals. 1-step ahead forecasts are for the period 1998:1-1999:3. Bottom: As above but based on the model with the non-linear oil price effects, Table 3.4.*

In this model, the oil price effects are even weaker than in the linear model, numerically and statistically. Hence one could omit them altogether from the model for the sake of parsimony, and claim that the common perception of significant oil price effects on the Norwegian exchange rate just owes to the coincidence of devaluation and low oil prices in 1986. However, this would be a fallacy as shown below.

The lower panel of the table adds the non-linear oil price terms to the above model, with c_1 fixed at 14.197. The inclusion demonstrates that linear oil price terms and the oil price-fall dummy variables become redundant while non-linear oil price terms are significant at the 5% level.

This exercise supplements the evidence in favour of the model with non-linear oil price effects, which also outperforms the model with the dummy variables in terms of explanatory power. The latter property is obvious in Figure 3.9, which shows that the estimated standard errors of the residuals of the model with non-linear oil price effects is lower than that of the model with the dummy variables, not only in the sample used to derive the models but also when the sample is extended by 7 quarters to 1999:3.

Figure 3.10 shows that the model with non-linear oil price effects is able to account for falls in the value of the krone beyond the devaluation in 1986. The figure depicts the 1-step ahead forecasts for $\Delta\overline{e}$ over the period 1998:1- 1999:3 based on the model with dummy variables and the models with non-linear oil price effects, as presented in the upper panel of Table 3.7 and Table 3.4. It appears that the model with dummy variables significantly under-predicts the depreciation of the exchange rate during 1998 while the model with non-linear oil price effects does not. Both models under-predict the appreciation of the exchange rate in 1999:2, however, which coincides with rising oil prices, see Figure 3.10. This points to oil price effects in the direction of those suggested by the bivariate analysis and the monthly model with non-linear oil price effects. As noted earlier, such effect were found statistically insignificant on the quarterly data, possibly due to the scarcity of such co-movements in oil prices and the exchange rate in the quarterly data sample ending in 1997:4. However, it remains to be investigated whether $\Delta_4 FI.Y$ can account for the poor forecasts for 1999:2.

Nevertheless, Figure 3.10 suggests that a fall in the value of the exchange rate in the face of low and falling oil prices is not a coincidental feature of the model. Hence, a model with dummy variables for the in-sample falls in the value of the exchange rate is likely to under-predict the exchange rate response in states of low and falling oil prices.

4. Conclusions

This paper has investigated whether imposition of a linear relation between oil prices and the Norwegian exchange rate leads to an underestimation of oil price effects and hence a failure to explain major changes in the exchange rate in the face of large fluctuations in oil prices. This is believed to be a feature of earlier work on this subject.

The paper has utilised samples of daily, monthly and quarterly observations of different lengths and a variety of techniques and models to investigate whether oil prices have non-linear or state dependent effects on the value of the Norwegian exchange rate. In particular, it has derived data consistent and interpretable equilibrium correcting models of both the krone/ECU exchange rate and the nominal effective exchange rate. Moreover, it has undertaken an extensive evaluation of the derived models to demonstrate the robustness of the obtained results, which have appeared fairly unanimous across the data samples and the different models. These results are:

There is a negative relation between the oil price and the Norwegian exchange rate: a rise in oil prices tends to raise the value of the krone while a fall tends to reduce the value of the krone.

The negative relation is however non-linear since the strength of this relation varies with the level and the trend in oil prices. A change in oil prices has a stronger impact on the exchange rate when the level of the oil price is below 14 US dollars than at higher levels. It also appears that the impact of a change in oil prices tends to increase at levels of oil prices around and above 20 US dollars, but this result has been found to be statistically insignificant at the 5 % level. A change in the oil price has numerically and statistically insignificant effects when oil prices fluctuate within their normal range, which has appeared to be the levels between 14 and 20 US dollars in the data samples at hand. The effect of a change in oil prices on the exchange rate has also been found to depend on whether oil prices display a falling or rising trend. In the former case, the effect is quite strong while a change in oil prices does not have any significant effect on the exchange rate if oil prices are on a rising trend. Accordingly, changes in oil prices have negligible effects, if any, on the exchange rate if oil prices are at normal levels, unless they exhibit a falling tendency.

The effects of a change in oil prices on the exchange rate has been found to be much stronger in models with the non-linear representation of oil price effects than in models with a linear representation of oil price effects. For instance, at low levels of oil prices, the effect of a change in oil prices is about 10 times stronger than in the models with linear oil price effects. There is ample evidence to suggest that imposition of linear oil price effects tends to bring about a gross underestimation of the exchange rate response to a change in oil prices, especially, when oil prices are at low levels and are falling.

The models with non-linear oil price effects outperform the models with linear oil price effects in terms of explanatory power, especially during the major falls in the value of the krone. Moreover, the former models appear to be data consistent in contrast to the latter models, which are found to be misspecified. Furthermore, a model with the non-linear representation of oil price effects successfully predicts the out-of-sample depreciation of the Norwegian exchange rate in 1998. This is in contrast to a similar model but with dummy variables to account for in-sample excessive fluctuations in the exchange rate. Thus, the observed non-linearity seems to reflect a stable feature of the underlying relation between the oil price and the exchange rate rather than a coincidental or an unique in-sample event.

The reported non-linear oil price effects are only significant in the short run. In the long run, oil prices are found to have linear effects on the krone/ECU exchange rate but no effects on the nominal effective exchange rate. The model of the krone/ECU exchange rate, which is based on monthly data from the 1990s, implies that the Norwegian real exchange rate depends on the oil price. Accordingly, high levels of oil prices lead to a real exchange rate appreciation. However, the model of the nominal effective exchange rate, based on quarterly data over the period 1972-1997, implies that the nominal exchange rate only reflects the ratio between domestic and foreign prices, in strict accordance with the purchasing power parity (PPP) hypothesis. Accordingly, the Norwegian real exchange rate is constant and independent of oil prices in the long run. Thus the empirical evidence in this paper provides mixed support for the PPP hypothesis. However, given the long span of data used in deriving the model of the nominal effective exchange rate, we are inclined to attach more weight to the implications of this model than to those of the model of the krone/ECU exchange rate.

The absence of non-linear oil price effects in the long run and the strong support for the non-linear oil price effects in the short run is consistent with the view that non-linearities may arise due to institutional behaviour. That is, the findings are consistent with the view that a central bank is often less keen on stabilising the exchange rate when faced with depreciation pressure compared with appreciation pressure, especially when the exchange rate target is in conflict with other concerns such as unemployment, financial stability and competitiveness. Such an asymmetric response can itself lead to stronger pressure for depreciation than for appreciation and thereby make the depreciation self-fulfilling. The empirical evidence in this paper indicates that a change in the oil price is likely to trigger larger capital movements and hence larger exchange rate fluctuations when the oil prices are below their normal range and are falling. Low and falling oil prices, due to their adverse effects on e.g. the activity level, may intensify the tension between a stable exchange rate policy and other objectives pursued by the monetary authorities and thus, increase the uncertainty associated with their commitment to the exchange rate policy.

Finally, we note that this paper has presented well specified multivariate exchange rate models with remarkably stable parameter estimates and fairly high explanatory power, which is encouraging. This is against the background of widespread pessimism in the literature regarding the possibility of deriving such exchange rate models, with or without non-linear effects of macroeconomic variables, see e.g. Meese and Rose (1991), Meese (1990) and Frankel and Rose (1995). Therefore, the paper not only suggests that one takes a new look at studies that have reported unstable oil price effects on exchange rates, but also offers results that can be utilised in further theoretical and empirical research on exchange rates.

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Appendix A.1: Monthly data

Small letters indicate the natural logarithm of the variables listed below, e.g. $x = ln(X)$. Unless otherwise stated, the source is Norges Bank's database TROLL8.

The variables and some of their transformations are graphed in Figure 4.1 below. The unit root tests are reported in Table 4.1.

CPI: Consumer price index. Series no. M1600012.

CPI^f: Consumer price in Norway's trading partners. Series no. M4690512.

ECU: Index for NOK/ECU. Central value: 7.9940 =100. Series no. M9302432 for monthly and D9302432 for daily observations.

Fisc.Y: Public sector's net savings relative to the gross national product (Y).

i93p12: Impulse dummy that takes on a value 1 in 1993:12 and zero elsewhere. The other impulse dummies are constructed in a similar way.

Dcpi : Consumer price inflation in Norway. $Dcpi_t = cpi_t - cpi_{t-12}$

$Dcpi^f$: Consumer price inflation in Norway's trading partners, mainly western European countries. Calculated as *Dcpi*.

Decu: $= ecu_t - ecu_{t-12}$.

$\Delta R3$: $= R3^f_t - R3^f_{t-1}$.

$\Delta R3N$: $= R3_t - R3_{t-1}$.

FI.Y: Foreign net financial assets in Norway relative to GDP. FI.Y = *(B70NOSS-BNO70SS)/Y.* Source: database TROLLBAL, Norges Bank.

OILP: Spot price of Brent Blend crude oil in US dollars. Series no. M2001712 for monthly and D2001712 for daily observations.

$R3^f$: Effective per annum eurorent on ECU denominated assets, maturity three month. Series no. M865135C.

R3: Effective per annum eurorent on NOK denominated assets, maturity three month. Series no. M901605C.

U: Registered (or open) unemployment rate, seasonally unadjusted. Series no. M0102322.

U^f : Registered unemployment in EU countries, seasonally adjusted. Series no. M4746023.

Y: Gross national product of Norway. The monthly series is calculated by even distribution of the quarterly series on each of the month (in the quarter). Source. Quarterly National Accounts, Statistics Norway.

Table 4.1: Unit root tests, monthly observations 1989:7-1998:11.

Variable	d	$\widehat{\varrho}$	*t-adf(d)*
OILP	1	-0.160	-4.263**
oilp	1	-0.123	-3.083*
R3	3	-0.043	-1.808
$R3^f$	1	-0.003	-0.350
$\Delta R3$	1	-0.797	-4.709**
$\Delta R3^f$	2	-0.536	-4.548**
$[R3\text{-}R3^f]$	3	-0.247	-3.595**
$[cpi - cpi^f]$	2	-0.046	-3.603**
ecu	2	-0.059	-2.364
ecu^D	2	-0.061	-2.964*
$[ecu\text{-}(cpi\text{-}cpi^f)]$	5	-0.050	-2.873*
$[ecu\text{-}(cpi\text{-}cpi^f)]^D$	5	-0.053	-3.749**
DFI.Y	5	-0.118	-3.796**

The following model is estimated to test the H_0: $\rho = 0$: $\Delta y_t = \mu + \varrho y_{t-1} + \sum_{i=0}^{d} \phi_i \Delta y_{t-1-i} + \delta D + \varepsilon_t$,. The augmented Dickey-Fuller model: $\delta = 0$. * and ** indicate significance at 5% and are 1%, respectively. The respective critical values -2.863 and -3.435. ^{D} Indicates that an impulse dummy has been used to adjust for the break in the series in December 1992.

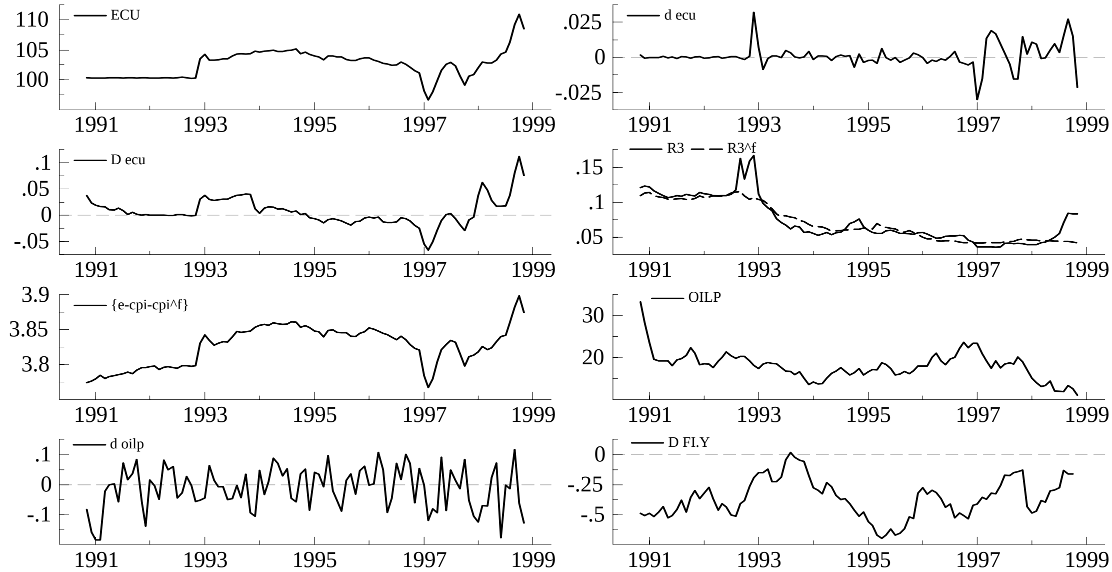

Figure 4.1: *Monthly observations of selected variables over the period 1990:11-98:11.* $d = \Delta$ while $\mathrm{D} = \Delta_{12}$.

A.2 Quarterly data

Unless stated otherwise, the variables listed below are taken from the data base for RIMINI, the quarterly macroeconometric model used in Norges Bank. The main sources for RIMINI's data base are Quarterly National Accounts, FINDATR, TROLL8 , OECD_MEI and IFS. These data bases are maintained by Statistics Norway, Norges Bank, Norges Bank, OECD and IMF, respectively. The RIMINI names of the variables are indicated in square brackets []. Note that this paper employs seasonally unadjusted quarterly data. Some of the variables are graphed in Figure 4.2 while the unit root tests are reported in Table 4.2.

CPI : Consumer price index for Norway, 1991 = 1. [CPI].

CPI^f: Trade weighted average of consumer price indices for Norway's trading partners. Measured in foreign currency, 1991 = 1. [PCKONK].

C_G : Public consumption expenditures, fixed 1995 prices, Mill. Norwegian krone (NOK). [CO].

CS : Centered seasonal dummy variable (mean zero) for the first quarter in each year. It is 0.75 in the first quarter and -0.25 in each of the three other quarters, for every year.

E : Trade weighted nominal value of NOK, 1991 = 1. [PBVAL].

$FI.Y$: A measure of foreigners (all), net financial investment in Norway, fixed 1991 prices, Mill. NOK. Constructed by taking the first difference of net foreign debts share of GDP, [LZ.Y], i.e. $FI.Y = \Delta \mathrm{LZ.Y}$.

g : Public expenditures' share of GDP, i.e. $g = (C_G + J_G)/Y$.

id97q1 : Impulse dummy related to the oil price hike in 1996/97. It has a value of 1 in 1997:1, -1 in 1997:2 and zero elsewhere.

J_G : Public expenditures for gross real investment, fixed 1995 prices, Mill. NOK. [JO].

OILP : Price per barrel of Brent Blend crude oil in US dollars. Source TROLL8, series no. Q2001712.

Q : Value added per unit labour cost in Norway. The inverse of value added based unit labour costs. 1/[LPE.Y].

Q^f: Value added per unit labour cost in trading partners. The inverse of trade weighted average of value added based unit labour costs. 1/[M.LPE].

R : Trade weighted real exchange rate, defined as R = $(E \text{ x } CPI^f)/CPI$. [RPBVAL].

RB : Yield on 6 years Norwegian government bonds, quarterly average. [R.BS].

RB^f : NOK basket-weighted average of interest rates on long term foreign bonds. [R.BKUR].

RS : *3* month Euro krone interest rate. [RS].

U : Total unemployment rate, fraction of labour force exclusive self employed and those on labour market programs. [UTOT].

Y : Gross domestic product for Norway. Mill. NOK, fixed 1995 prices. [Y].

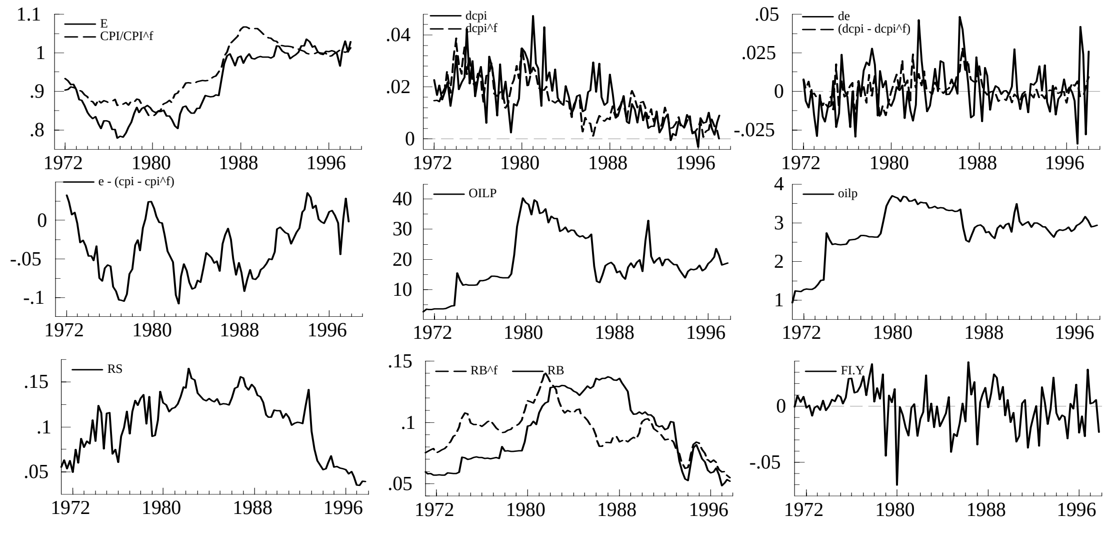

Figure 4.2: *Quarterly observations of selected variables over the period 1972:1-97:4. Prefix* $d = \Delta$. $E \equiv \overline{E}$ and $e \equiv \overline{e}$.

Table 4.2: ADF tests for unit root, constant and trend included.

Variables	$1-\widehat{\varrho}$	t-ADF	ADF(p)	k
e	-0.094	-3.169	1	4
Δe	-0.815	-8.128**	0	3
cpi	-0.001	-0.111	5	7
Δcpi	-0.521	-4.775**	4	5
cpi^f	-0.006	-1.371	8	11
Δcpi^f	-0.351	-3.864*	7	9
$\overline{e}$-cpi-cpi^f	-0.167	-3.945*	7	7
RB	-0.018	-1.151	8	7
ΔRB	-0.724	-6.573**	6	6
RB^f	-0.057	-2.623	3	6
ΔRB^f	-0.686	-6.748**	3	5
$FI.Y$	-0.619	-5.133**	7	7
$oilp$	-0.079	-2.424	5	5
$oilp^a$	-0.170	-3.850*	5	5
$OILP$	-0.059	-1.733	5	6
$OILP^a$	-0.085	-2.195	5	6

Note: Dickey -Fuller critical values: 5% = -3.457, 1% = -4.057. Constant and trend included. Sample 1972:2-1997:4. ^{a} When using sample 1974:1-1997:4. p denotes the largest significant lag and k denotes the number of regressors.

Qaisar Farooq Akram: When does the oil price affect the Norwegian exchange rate

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