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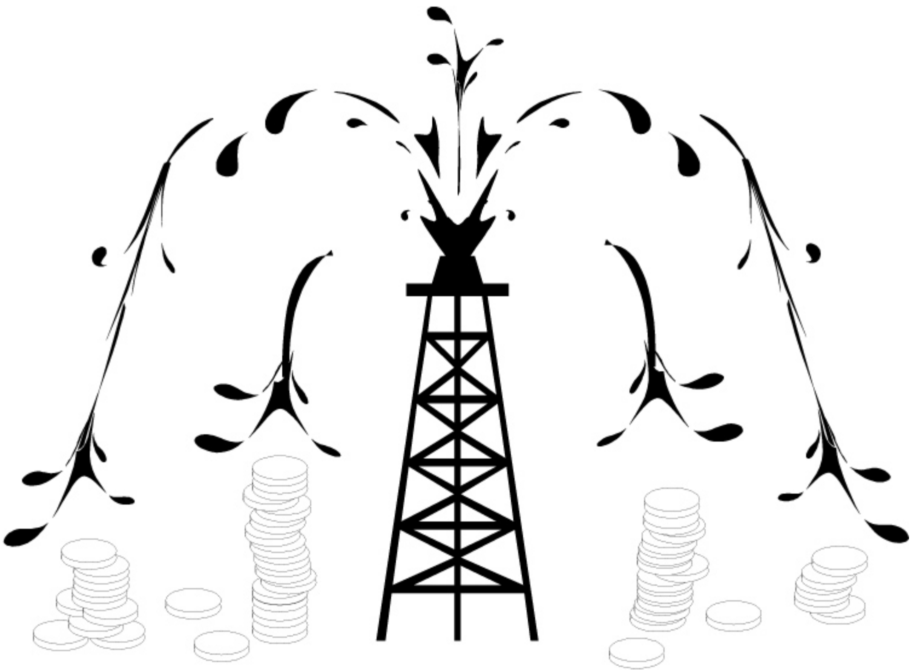
Note

Oil prices and exchange rates: A survey



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Title	**Oil prices and exchange rates: A survey**

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Abstract

Many non-US oil producers have operating revenues in US dollar and US dollar-denominated debt. If there is a negative relationship between the oil price and the US dollar the oil producers have a natural hedge. That is, if oil prices increase, so does the exchange rate and the US dollar debt, and vice versa. However, if the relationship becomes negative, an oil price increase may induce a lower US dollar debt (which is good) or, vice versa, an oil price decrease may induce a higher US dollar debt ("double trouble"). We give a survey of the literature and present a preliminary data analysis of some oil price and exchange rate data.

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Contents

1 Introduction

For an oil producer or buyer, the relationship between the oil price and currency is of vital importance. What is the relationship between the oil price (Brent quoted in USD) and the value of the US dollar or other currencies? If the US dollar strengthens towards other currencies, would this have an influence on the oil price (or vice versa)? Do other currencies influence the oil price or vice versa? If we (partly) know the answers to these questions, we can possibly avoid situations where the effect of oil price reduction is not increased due to the currency exposure policy.

Chaudhuri and Daniel (1998) and others study the relationship

$$e_t = \beta_0 + \beta_1 o_t, \tag{1.1}$$

where e_t is the (real) exchange rate and o_t is the (real) price of oil. They find that β_1 of Equation (1.1) is positive for sixteen OECD countries. Hence, "an increase in the real price of oil appreciates the real US dollar exchange rate". Many non-US oil producers have operating revenues in US dollar and US dollar-denominated debt. If there is a negative relationship between the oil price and the US dollar the oil producers have a natural hedge. That is, if oil prices increase, so does the exchange rate and the US dollar debt, and vice versa. However, if β_1 becomes negative, an oil price increase may induce a lower US dollar debt (which is good) or, vice versa, an oil price decrease may induce a higher US dollar debt ("double trouble"). In other words, if there is a possibility that β_1 could become negative, the natural hedge is a very risky choice.

An exchange rate is clearly affected by macroeconomic variables. The same certainly goes for the oil price. Using cointegration techniques on data from 1975–1998 Clostermann and Schnatz (2000) find that the EUR/USD exchange rate is driven by real interest rate increments, relative prices in the traded and non-traded goods sectors, the real oil price and the relative fiscal position. However, we are primarily interested in the relationship between oil prices and exchange rates.

This report is organised as follows. Chapter 2 is a survey of the literature. A preliminary data analysis of selected oil price and exchange rate data is presented in Chapter 3. A concluding summary is given in Chapter 4.

2 Survey

The literature on the relationship between oil prices and exchange rates is surprisingly scarce, and most of the results do not include the high oil prices (in US dollars) seen since 2004. In the following, we give an overview of the, in our view, relevant literature.

2.1 Long-run equilibriums

Chaudhuri and Daniel (1998) examine the relationship between real oil prices and real exchange rates measured with prices for 16 OECD countries, both on the log scale, mostly over the time period 1973 to 1996. Well known tests like the augmented Dickey-Fuller test and the Engel-Granger cointegration test are carried through. The Dickey-Fuller test shows that the two time series are integrated of order one. The Engel-Granger cointegration test shows evidence of the two time series being cointegrated in 13 of the 16 countries. Chaudhuri and Daniel specify an error correction model for each of the two time series as being dependent upon the other time series, and conclude that oil prices are weakly exogenous and the exchange rates are not. In other words, the causality goes from real oil prices to real exchange rates, and not the other way around. Hence, Chaudhuri and Daniel (1998) state that the non-stationarity in the US dollar real exchange rates over the years under study is due to the non-stationarity in the real oil price. Interpreting the cointegrating vector as the long-term equilibrium real exchange rate it is shown that real exchange rates display relatively long swings away from their equilibrium paths after the 1978 oil price increase, while the 1986 oil price decrease did not result in a similar misalignment. According to the authors, the latter might be a result of the world learning to adopt to a new regime of large oil shocks.

2.2 Oil prices and real exchange rates for a panel of data

Chen and Chen (2007) follow up the analysis of Chaudhuri and Daniel (1998) with a broader view and more recent data: monthly data from G7 countries from 1972 to 2005. They consider several measures of oil prices, like the world price of oil, the United Arab Emirates price of oil (Dubai), the British price of oil (Brent) and the US West Texas Intermediate price of oil. First, they examine the countries separately, and find that for only two of the countries the real oil prices and real exchange rates are cointegrated. These findings are consistent with other published findings. It is claimed that this might be due to the lack of power in the individual country-to-country tests. By pooling the countries together, Chen and Chen (2007) demonstrate, by using so-called panel cointegration techniques, that the real oil prices and real exchange rates are cointegrated. The idea is that while univariate unit-root tests have low power the panel tests considers the large number of cross-sectional units, and increase the power of the unit-root tests. The results are robust with respect to the different measures of oil prices. The robustness of the order of integration and the existence of cointegration is controlled by performing tests accounting for cross-section dependence (so called cross-sectional Dickey-Fuller tests).

The authors also examine the ability of real oil prices to forecast future real exchange returns. Both short-term (1 month) and long-term (16 and 24 months) predictions are considered. A model for the log of the real exchange rates increase k months ahead is constructed. Through bootstrapping, the authors perform tests which reject the hypothesis that real oil prices have no predictive power. The panel predictive regression estimates suggest that real oil prices have significant forecasting power. Furthermore, they perform k-step-ahead predictions by out-of-sample prediction ($k = 1$, 16 and 24 months) and compare the results with those from a random walk model. The bootstrapped p-values show that the forecasting performance is clearly better with the constructed model than with a random walk model. This holds for all the countries, except for the real exchange rate between the Canadian and the US dollar. Interestingly, the predictability turned out to be better over longer horizons for some of the countries and some of the measures of oil prices.

2.3 Cointegration of oil prices and US real exchange rates

Amano and van Norden (1998) find, based on monthly data from 1972–1993, that the US real exchange rate is cointegrated with the real price of oil, and that real oil prices may have been the dominant source of persistent real exchange rate shocks. Furthermore, (Granger-)causality runs from oil prices to the exchange rate for Germany, Japan and the United States. The authors specify and estimate an error correcting model (ECM), which has a significant out-of-sample predictive ability for the sign and changes in the real effective exchange rate. As Chaudhuri and Daniel (1998), they find that an increase in the price of oil will lead to appreciation of the US dollar in the long run.

2.4 Norwegian krone and oil prices

Norway is a major oil exporting economy. Akram (2004) explores the possible non-linear relationship between oil prices and the Norwegian exchange rate. Using daily data from 1986 to 1998, he finds a non-linear negative relationship between the value of the Norwegian krone and crude oil prices. The strength of the relationship varies with level and trend in the oil prices. The effect is stronger for oil prices below 14 USD, and negligible for oil prices above 14-15 US dollars, unless they display a downwards trend. Akram interpret the results as a an indication that Norwegian monetary authorities have defended their stable exchange rate policy with more firmness against appreciation pressure rather than against depreciation pressure.

2.5 Is China the explanation?

Was the 2002–2004 rise in oil prices permanent or not? In retrospect, it certainly seems to be permanent. Bénassy-Quéré et al. (2005) argue that one major development in both the oil market and the international monetary system since the late 1990s has been the increasing impact of China. China accounted for one third of world's increase in oil demand in 2004, and China has the second largest official reserves in foreign currencies. Bénassy-Quéré et al. use monthly data of real oil prices and US dollar real effective exchange rates from 1974–2004. First, it is established that both series are integrated of order one. Using Equation (1.1), the series are found to be cointegrated. In line with other results, they find that an increase in the price of oil will lead to appreciation of the US dollar in the long run. Using a vector error correcting model (VECM), the authors find that the exchange rate is slowly mean-reverting. Mean-reversion is not found for the oil price. Furthermore, the oil price is found to be weakly exogenous (unexplained by the model). Finally, oil prices and exchange rates are found to have Granger-causality at a 10% significance level. On the whole, the authors find that their results are in line with previous results (Amano and van Norden, 1998; Chaudhuri and Daniel, 1998), but that the cointegration analysis, relying on long time series, is unable to tell whether the 2002–2004 period is the beginning of a new, inverse regime. Based on theoretical arguments, Bénassy-Quéré et al. claim that the emergence of China could strengthen the positive causality from the oil price to the US dollar in the short, but reverse its sign in the long run.

2.6 Oil shocks and nonlinear effects

Hamilton (2003) discuss the nonlinear relationship between oil price changes and GDP growth. He gives a review of present literature (1999) relating the effects of oil shocks to production. Hamilton refers to many well established models, both supply- and demand-driven, implying that the log of real GDP should be linearly related to the log of the real oil price, such that falling oil prices would induce economic growth and vice versa. In all these models it is assumed that there is nothing special about oil, while Hamilton points out that clearly there is. Large disruptions in the oil supplies (and thereby prices) affect people's consumption pattern on many levels in a complicated way.

Hamilton (2003) fits a model for the GPD growth (y_t) as being linearly dependent upon GDP growth at previous time points ($y_{t-1}, \ldots$) and the percent change in the nominal price of crude petroleum, also at previous time points, ($o_{t-1}, \ldots$) for the time periods 1949 - 1980, and 1949 - 2001 (quarterly data). Hamilton demonstrates that the estimated coefficients differ considerably when considering the two periods, and some of them become less significant for the longest period compared to the shortest.

After 1980, the world has experienced several big oil price decreases. This is in contrast to the years from the Second World War to the 1980ies, where there were few periods with falling oil prices. This has encouraged researches to pose questions like "how surprising is an oil price increase based on the observed recent changes" and "is the oil price increase is big enough to reverse any decreases observed in the preceding quarters". Questions like these imply a variety of possible models. Hamilton (2003) contributes to the discussion by describing a flexible approach to nonlinear modelling. He suggests the model

$$y_t = \delta z_t + \mu(x_t) + \epsilon_t, \tag{2.1}$$

where $z_t = (y_{t-1}...)'$, $x_t = (o_{t-1}, ...)'$ and ϵ_t is an error term. By imposing a sensible covariance structure for $\mu(x_t)$ for the elements of x_t, he obtains a flexible nonlinear model. Letting $\mu(x_t) = \alpha_0 + \alpha x_t$ we have

$$\begin{aligned} y_t &= \alpha_o + \alpha x_t + \delta z_t + \lambda m(x_t) + \epsilon_t \\ &= \alpha_0 + \alpha x_t + \delta z_t + u_t, \end{aligned} \tag{2.2}$$

where $u_t = \lambda m(x_t) + \epsilon_t$.

Linearity is checked by testing the hypothesis $\lambda = 0$. Hamilton fits the model to data from 1949 to 2001, and presents various scenarios with respect to changes in x_t.

He also compares his model to other (nonlinear) models presented in the literature and discuss their behaviour. He derives a test where a stable relation is tested against the alternative that the coefficients of x_t change at a certain time point. Hamilton concludes that it is sensible to "use a nonlinear function of oil price changes if the goal is to forecast GDP growth". Furthermore, he states that for predicting GDP, oil price increases are much more important than decreases and that oil price changes provide less information with respect to forecasting GDP if they follow a period of volatile price changes.

3 Data analysis

Few of the articles discussed in Chapter 2 have investigated the recent oil price history. During the last six years, the prices have risen dramatically. In the same period, the US dollar exchange rate has weakened.

In the literature, the focus is on real prices and real exchange rates. However, an oil producer can not trade in real prices or certainly not real exchange rates. In our preliminary analysis, the focus is therefore on both nominal and real prices and exchange rates.

3.1 Data

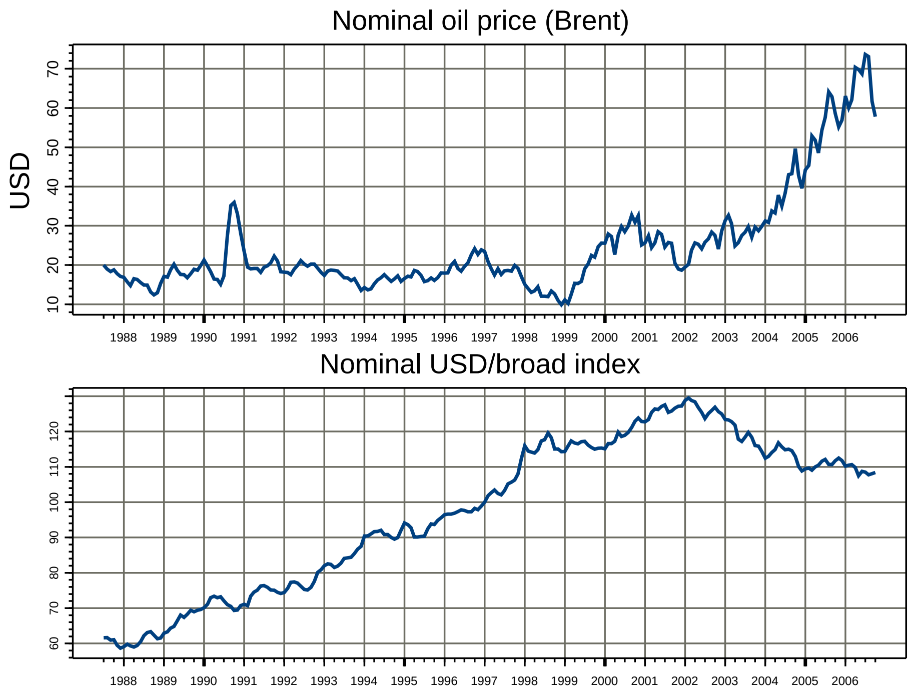

Figure 3.1. Nominal oil price (Brent) and nominal USD/broad index. USD/broad index source: `http://www.federalreserve.gov/`.

In this section we will focus on the nominal oil price (Brent) as a function of the nominal USD/broad index, presented in Figure 3.1, and the real oil price (Brent) as a function of the real effective USD, both over the period from July 1987 to June 2006, presented in Figure 3.2. We are also interested in examining if the real oil

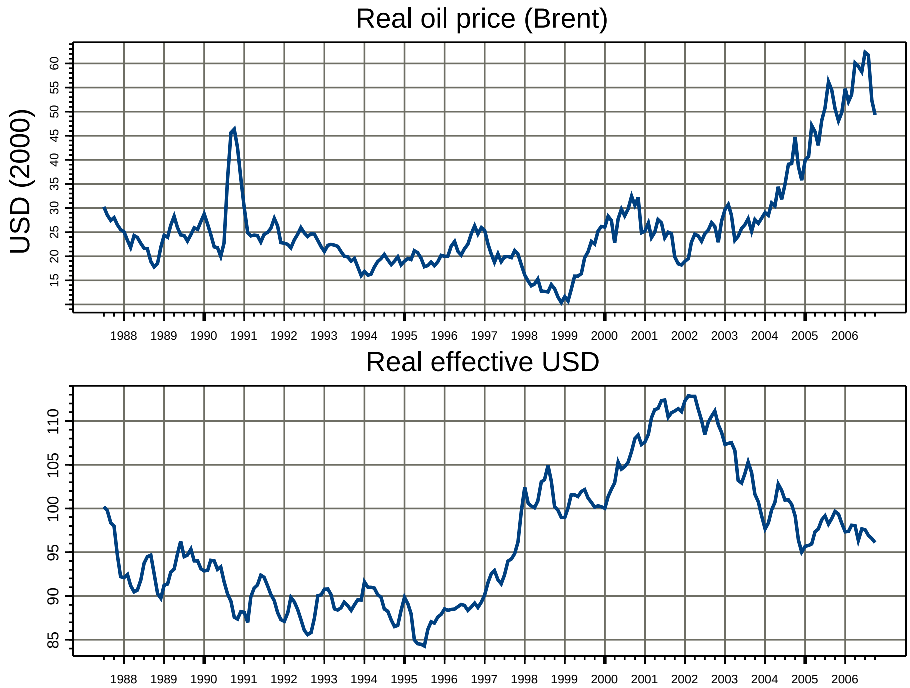

Figure 3.2. Real oil price (Brent) and real effective USD exchange rate. Source: `http://www.oecd.org/`.

price (Brent) depends on the nominal USD/broad index, presented in Figure 3.3. Figures 3.4–3.6 display the same variables as in Figures 3.1, 3.2 and 3.3, but on the logarithmic scale.

From Figures 3.1–3.3 we see how the relationship between the oil price and the exchange rate changes over time. Both the nominal and the real oil price (Brent) are fairly stable until 1987, except from a upwards jump in the last part of 1991 (the Gulf war). In the time period from 1987 until 1990, both oil prices deceased, and then further on more or less increased (with a slightly downwards jump in the last part of 2001). The two exchange rates, on the other hand, seems to behave differently. While the nominal USD/broad index increases steadily until 2002, and thereafter decreases, the real effective USD slightly decreases until the middle of 1995, thereafter increases until 2002, and then decrease. The features seen in Figures 3.1–3.3 are also seen in Figures 3.4–3.6, where the same data are presented on the logarithmic scale. From these figures we see that the relationship between the oil prices and exchange rates changes over time, and it is difficult to see any systematic pattern in this relationship.

Figure 3.7 displays the Consumer Price Index (CPI), with a base of 100 in June 2000.

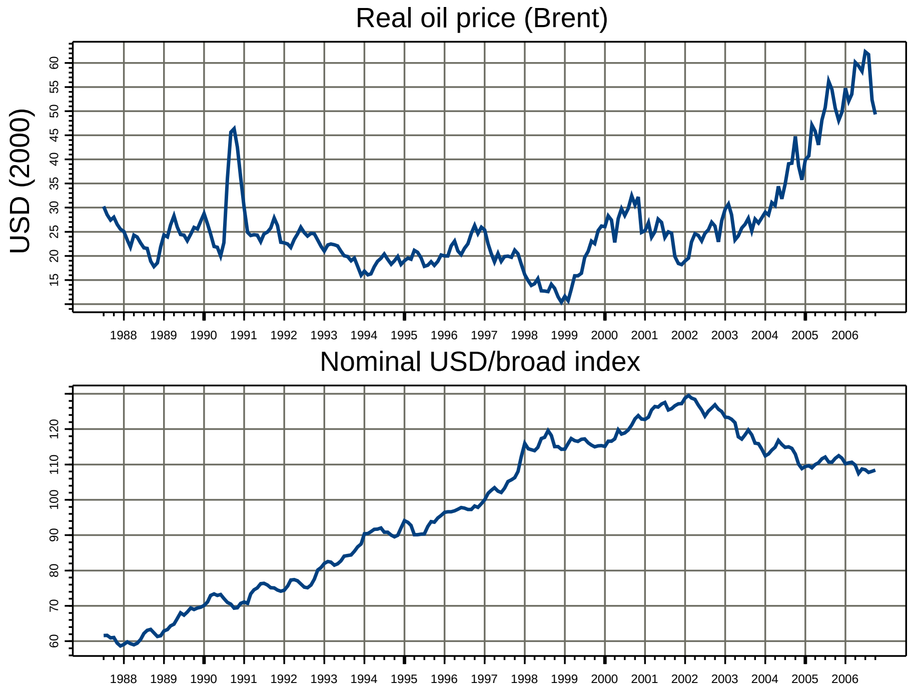

Figure 3.3. Real oil price (Brent) and nominal USD/broad index. Source: `http://www.oecd.org/`.

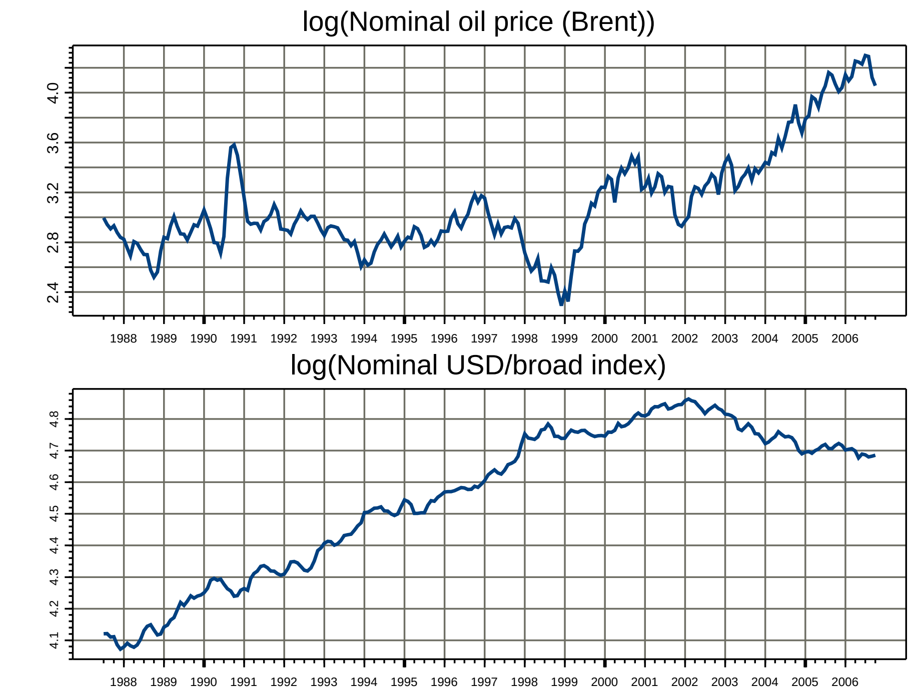

Figure 3.4. Logarithms of nominal oil price (Brent) and nominal USD/broad index.

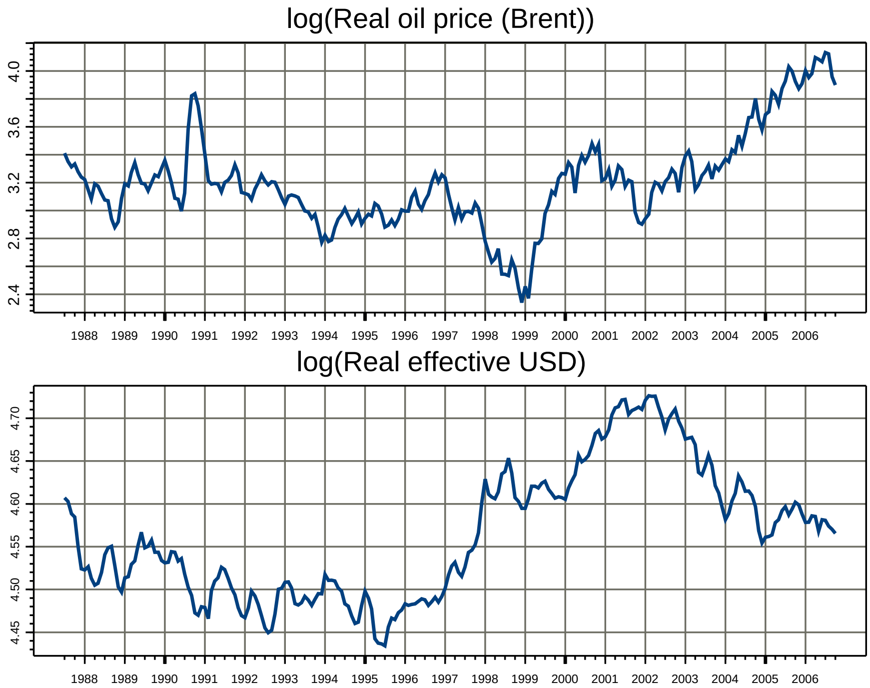

Figure 3.5. Logarithms of real oil price (Brent) and real effective USD exchange rate.

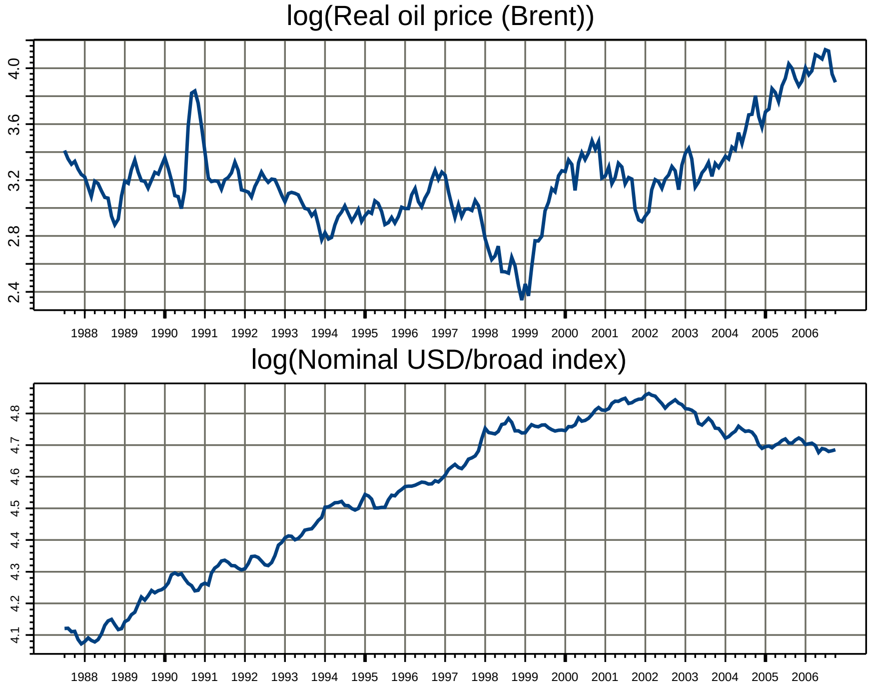

Figure 3.6. Logarithms of real oil price (Brent) and nominal USD/broad index.

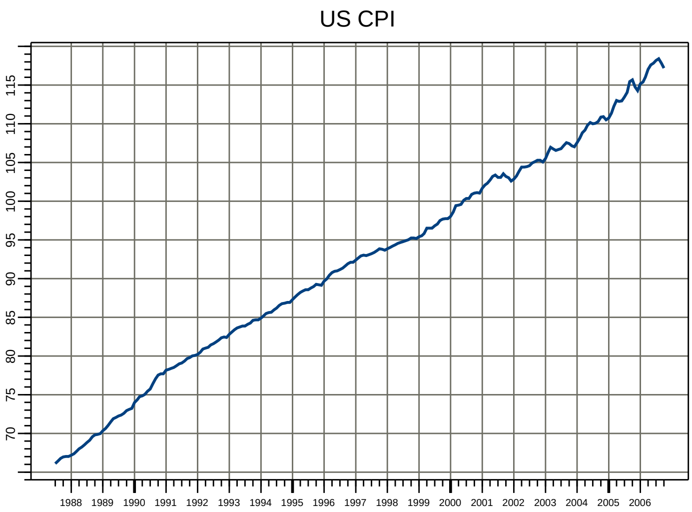

Figure 3.7. US CPI. Source: Source: `http://www.oecd.org/`.

3.2 Regression analysis

Figure 3.8 displays scatterplots of the various relationships we are interested in exploring, on the logarithmic scale. There is no apparent systematic relationship between the variables in any of the plots.

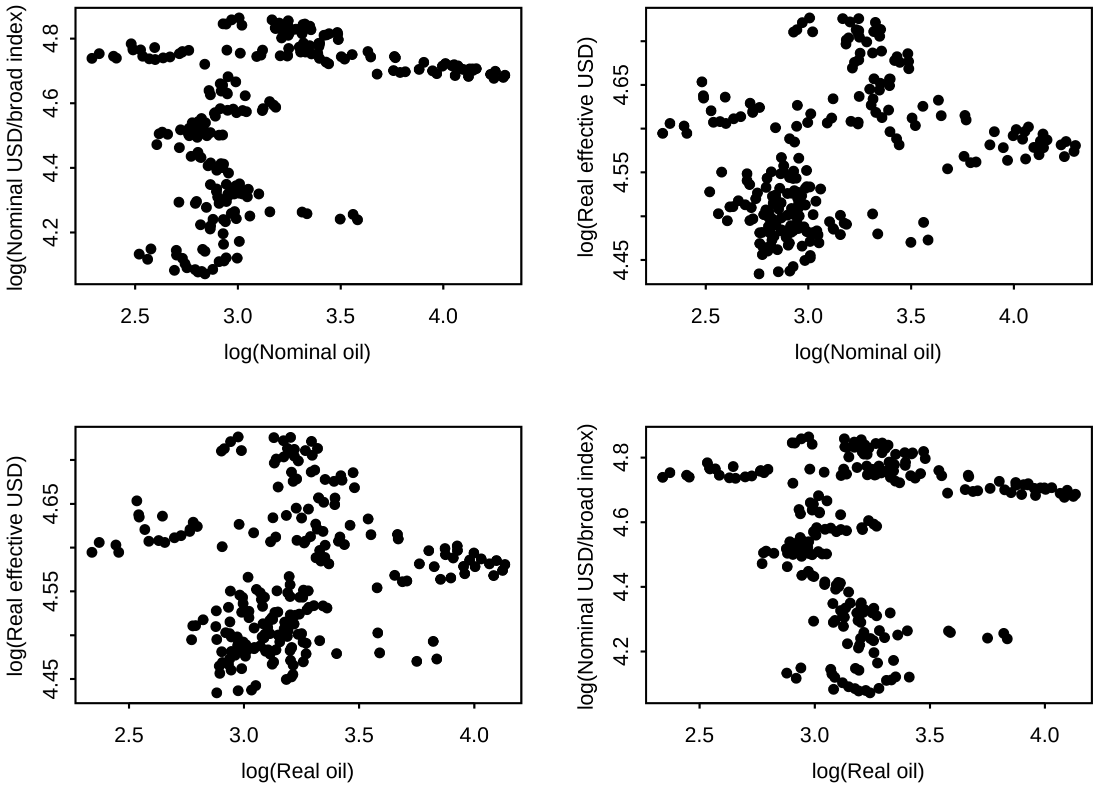

Figure 3.8. Scatterplot of data.

For a linear regression model we might use a so called rolling regression analysis in order to assess the stability of the model parameters over time. For a window of length $n < T$, a rolling linear regression model can be written as

$$\boldsymbol{y}_t(n) = \boldsymbol{X}_t(n)\boldsymbol{\beta}_t(n) + \boldsymbol{\epsilon}_t(n), t = n, \ldots, T,$$

where $\boldsymbol{y}_t(n)$ is a vector of responses, $\boldsymbol{X}_t(n)$ a vector of explanatory variables, $\boldsymbol{\beta}_t(n)$ a vector of regression parameters and $\boldsymbol{\epsilon}_t(n)$ a vector of error terms.

We fit such a model (Equation (1.1)) for the three relationships stated in Section 3.1. Applying a window of 10 years gives the rolling regression estimates displayed in Figures 3.9–3.11. Apparently, the linear regression coefficient β_1 is significantly positive in some periods and negative in others. However, we should be cautious interpreting the results, since our assumption of independent and identically distributed error terms generally do not hold here. Hence, the confidence bands should not be trusted blindly.

Instead of a linear regression model, we may consider a non-linear model. In a generalized additive model (GAM; Hastie and Tibshirani (1990)), we replace the linear term $\boldsymbol{X\beta}$ with a non-linear function of $\boldsymbol{X}$. Figures 3.12–3.14 display the fitted generalized additive models for the three time series relationships stated in Section 3.1. Generally, the relationship seems to be non-linear. Figures 3.15–3.17 show the results when fitting generalized additive models where also a non-linear term of time is included. In Figures 3.18–3.20, the non-linear term of time in Figures 3.15–3.17 is replaced with a linear term. When we include a term of time, the non-linear relationship becomes considerable more linear. In other words, the time-term seems to explain much of the non-linearity. However, again we should be careful interpreting the results, since the assumptions of independent and identically distributed error terms generally do not hold here. Since GAM is a non-linear technique, this could influence both the confidence bands and the regression coefficients themselves.

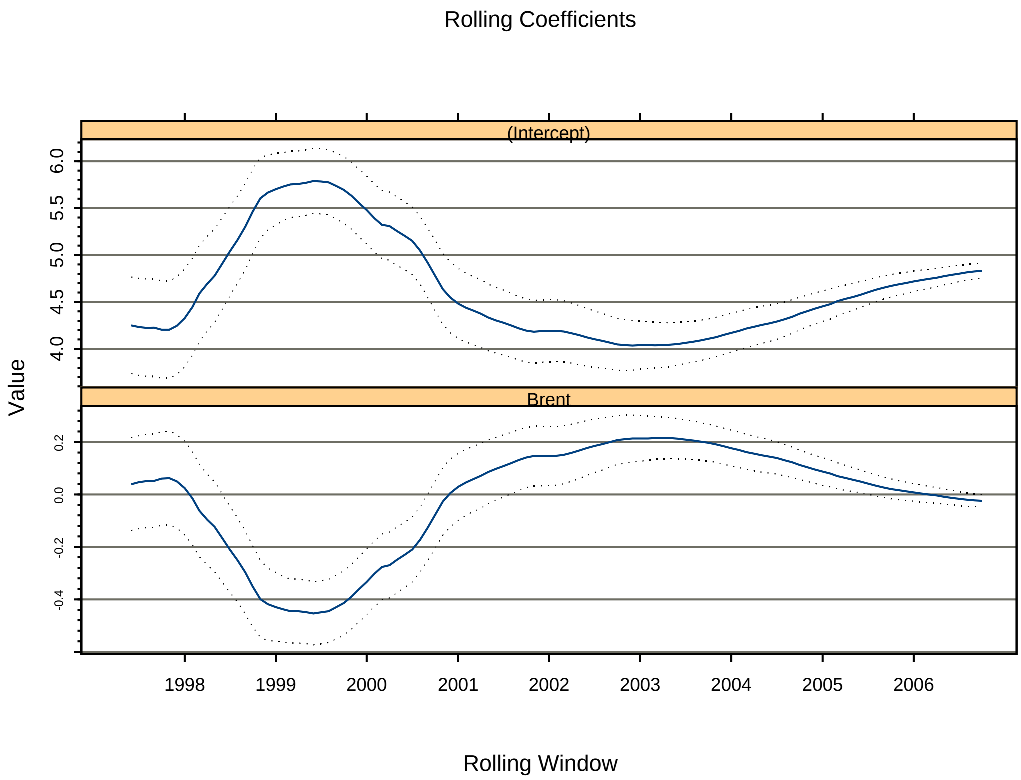

Figure 3.9. Rolling regression estimates (ten years) for nominal USD/broad index as dependent upon the nominal oil price (logarithmic prices).

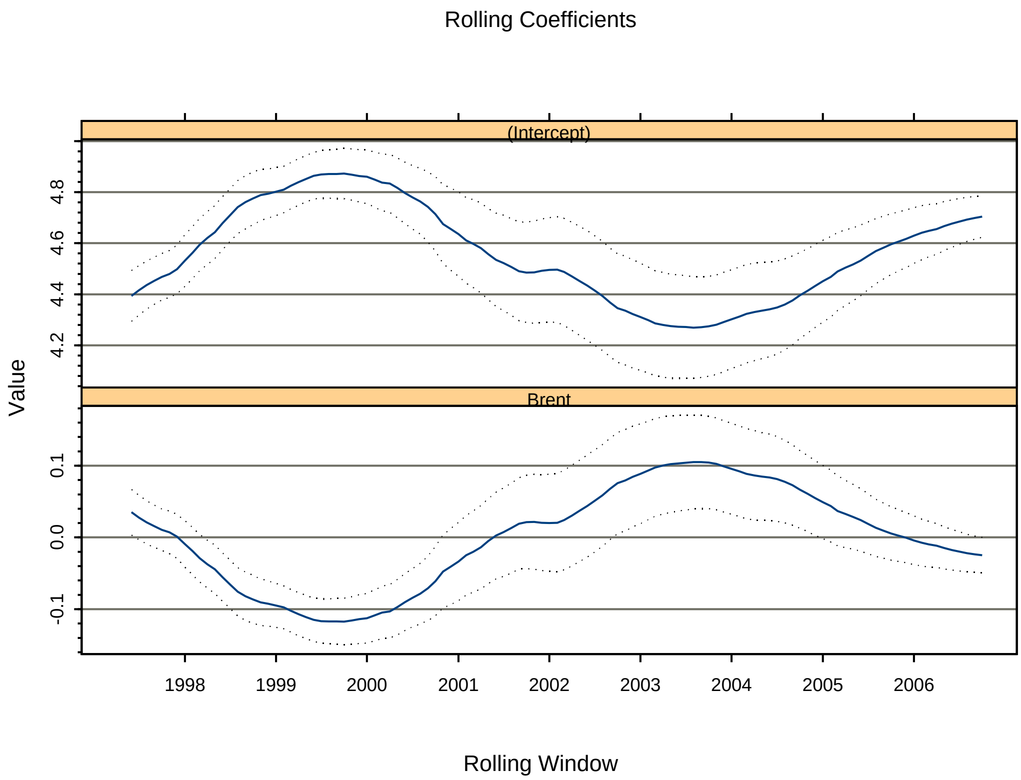

Figure 3.10. Rolling regression estimates (ten years) for real USD as dependent upon the real oil price (logarithmic prices).

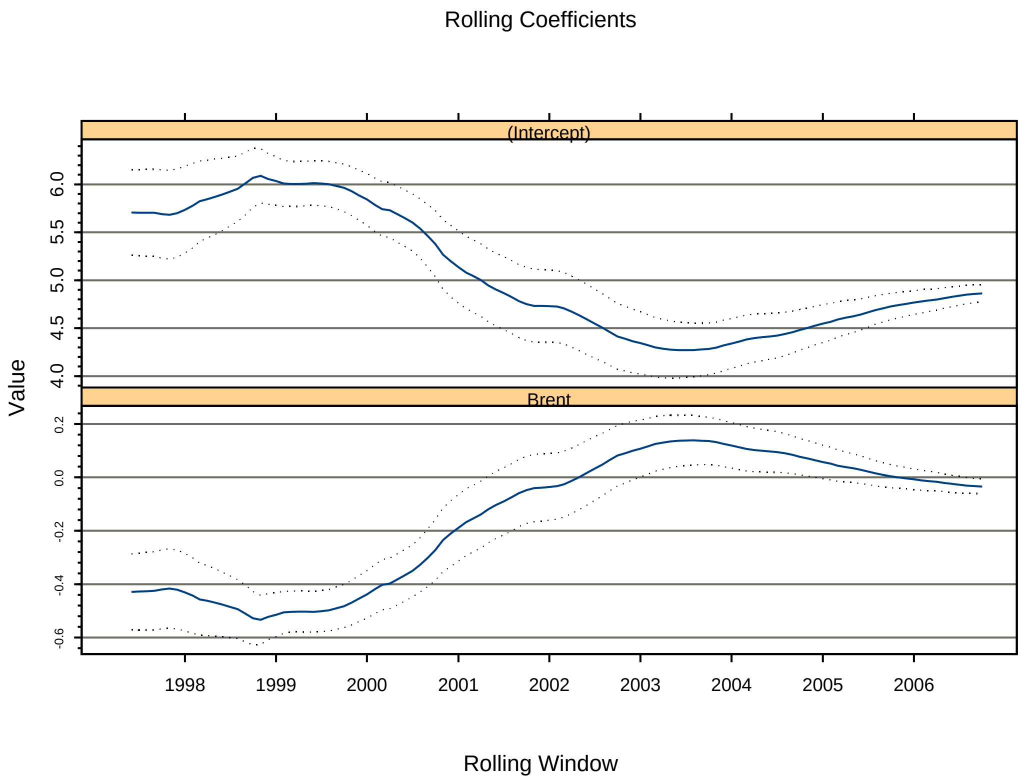

Figure 3.11. Rolling regression estimates (ten years) for nominal USD/broad index as dependent upon the real oil price (logarithmic prices).

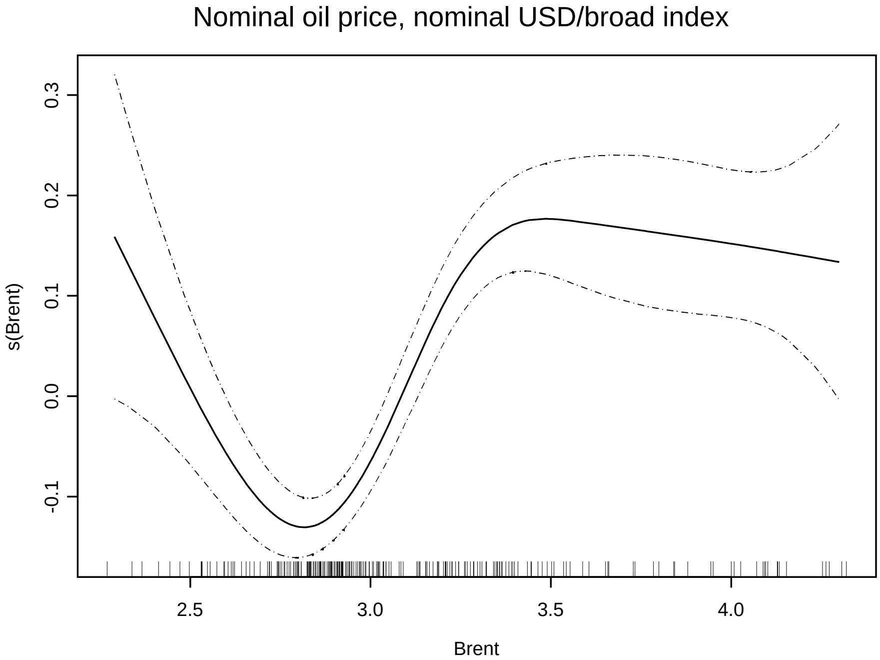

Figure 3.12. GAM fit of nominal USD/broad index as a function of the nominal oil price (logarithmic prices).

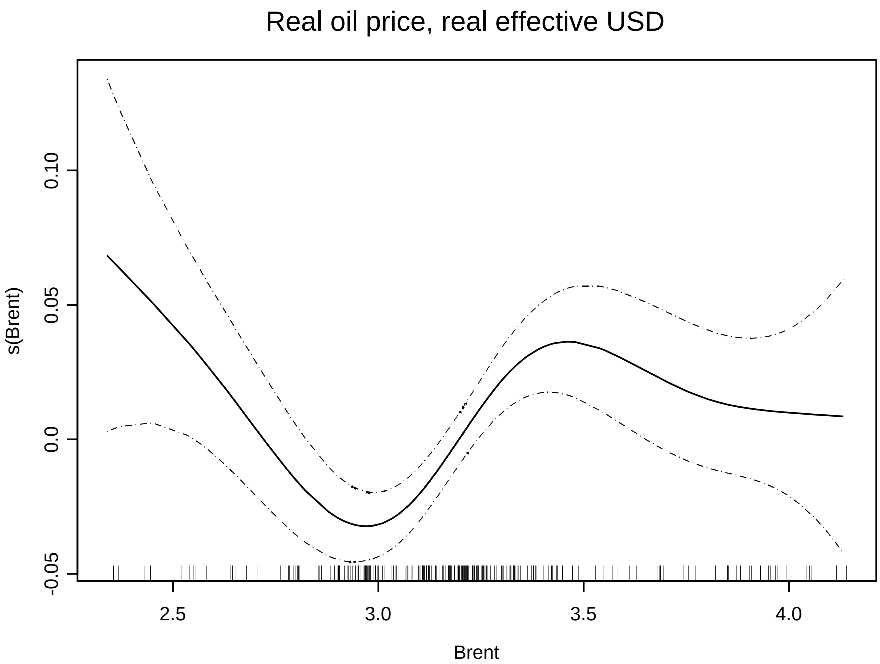

Figure 3.13. GAM fit of real effective USD as a function of the real oil price (logarithmic prices).

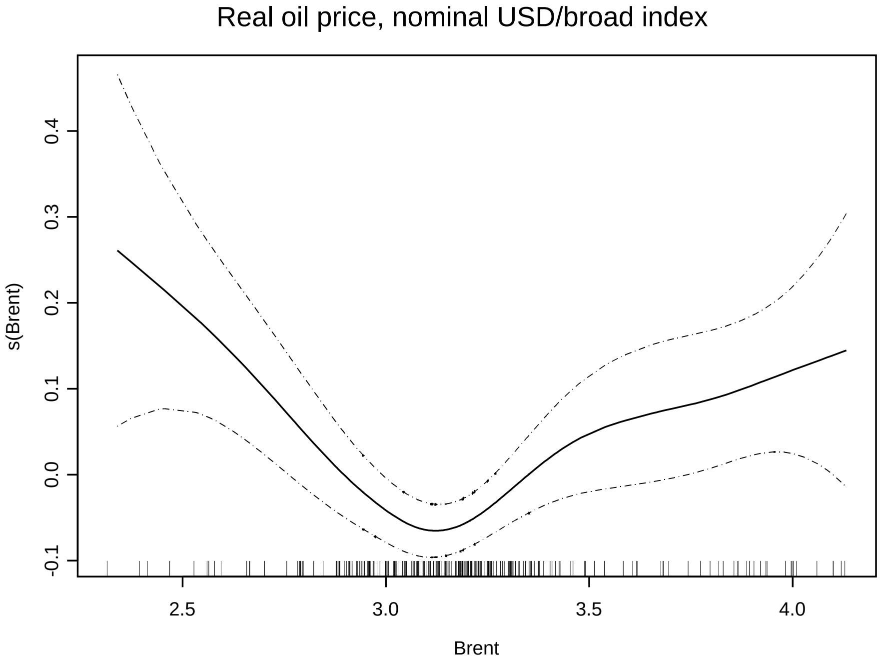

Figure 3.14. GAM fit of real effective USD as a function of the real oil price (logarithmic prices).

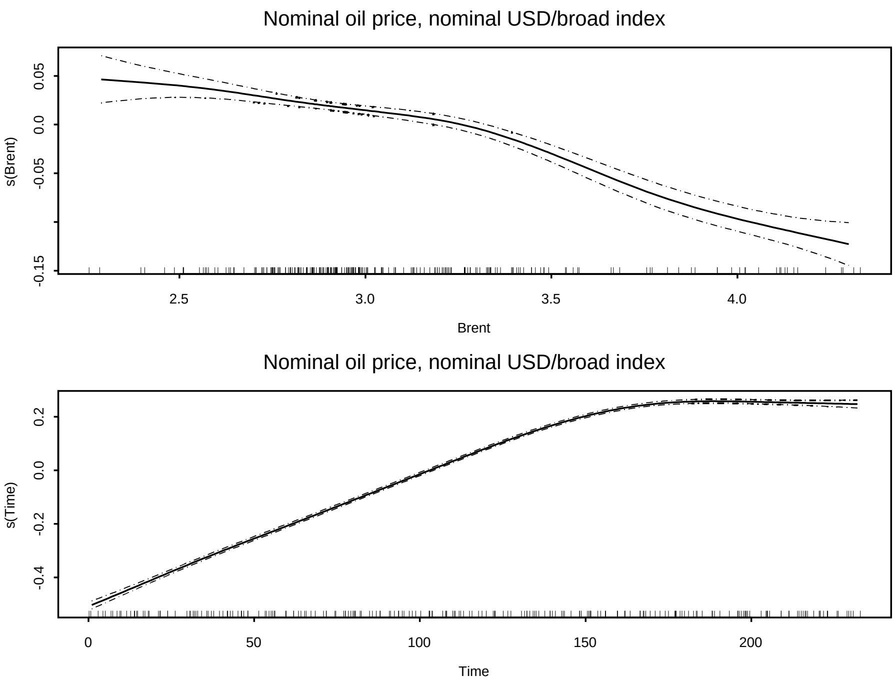

Figure 3.15. GAM fit of nominal USD/broad index as a function of the nominal oil price (logarithmic prices) and time.

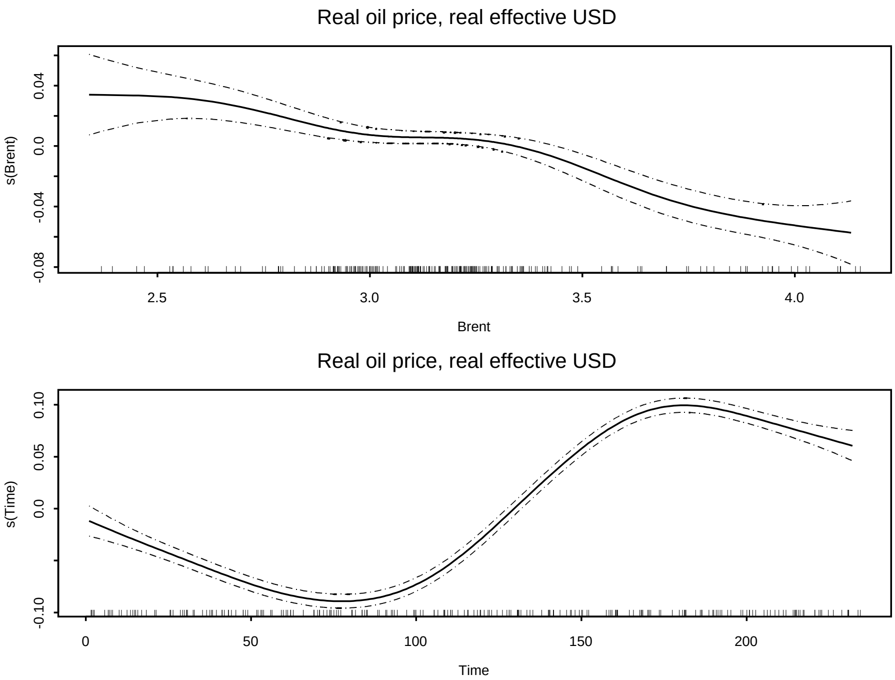

Figure 3.16. GAM fit of real effective USD as a function of the real oil price (logarithmic prices) and time.

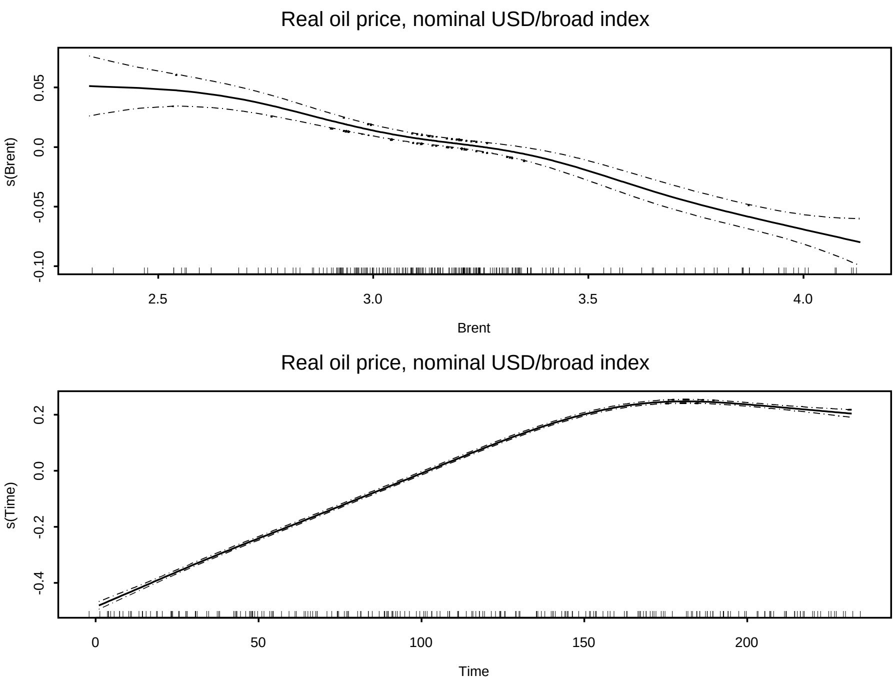

Figure 3.17. GAM fit of real effective USD as a function of the real oil price (logarithmic prices) and time.

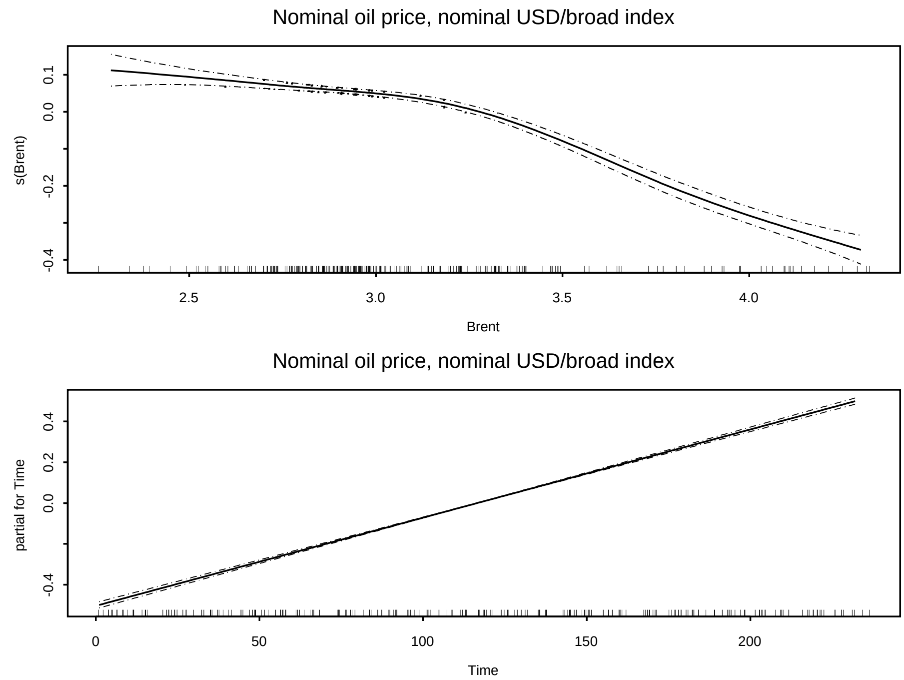

Figure 3.18. GAM fit of nominal USD/broad index as a function of the nominal oil price (logarithmic prices) plus a linear term of time.

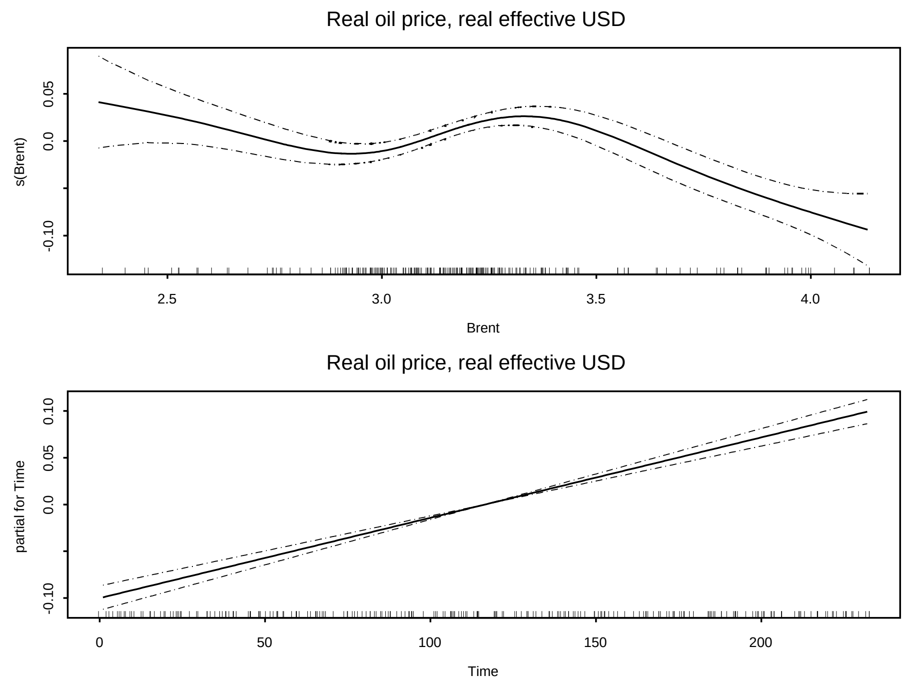

Figure 3.19. GAM fit of real effective USD as a function of the real oil price (logarithmic prices) plus a linear term of time.

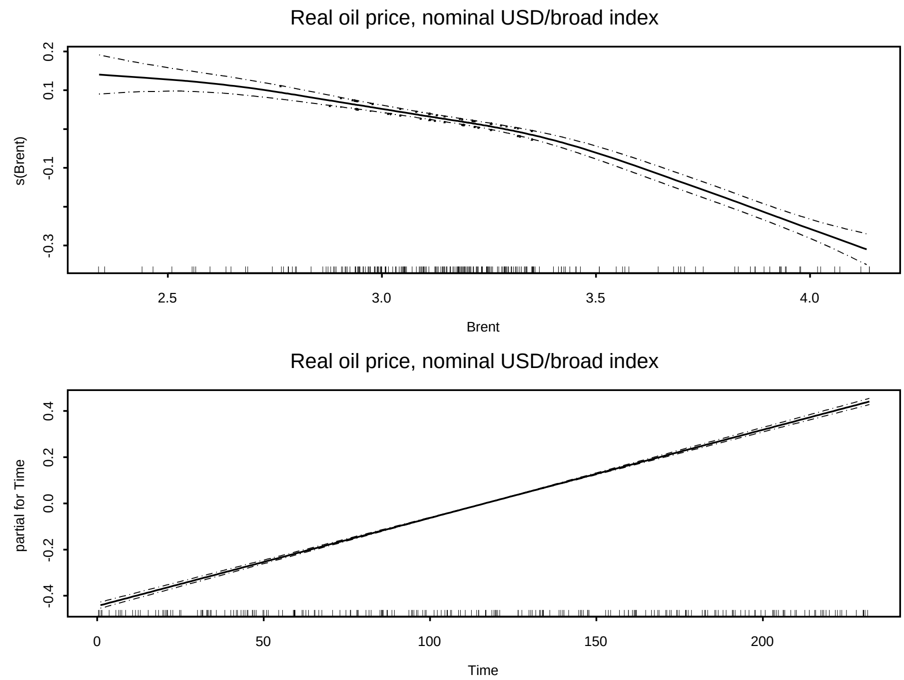

Figure 3.20. GAM fit of real effective USD as a function of the real oil price (logarithmic prices) plus a linear term of time.

3.3 Change-points

We test for structural changes in the linear relationship in Equation (1.1). Such tests may be performed by testing the hypothesis that the regression coefficients remain constant against the alternative that at least one coefficient varies over time (Zeileis et al., 2003). Even though we believe that the relationship (1.1) holds locally, this test is not perfectly satisfactory, since we are more interested in β_1 than β_0, while both are tested for changes. In the test of Zeileis et al. (2003), the maximum number of allowed breakpoints has to be specified. In Figures 3.21–3.23, 9, 7, 6 and 7 breakpoints was found, respectively. Even through the estimated number of change points is somewhat high, the results seem sensible.

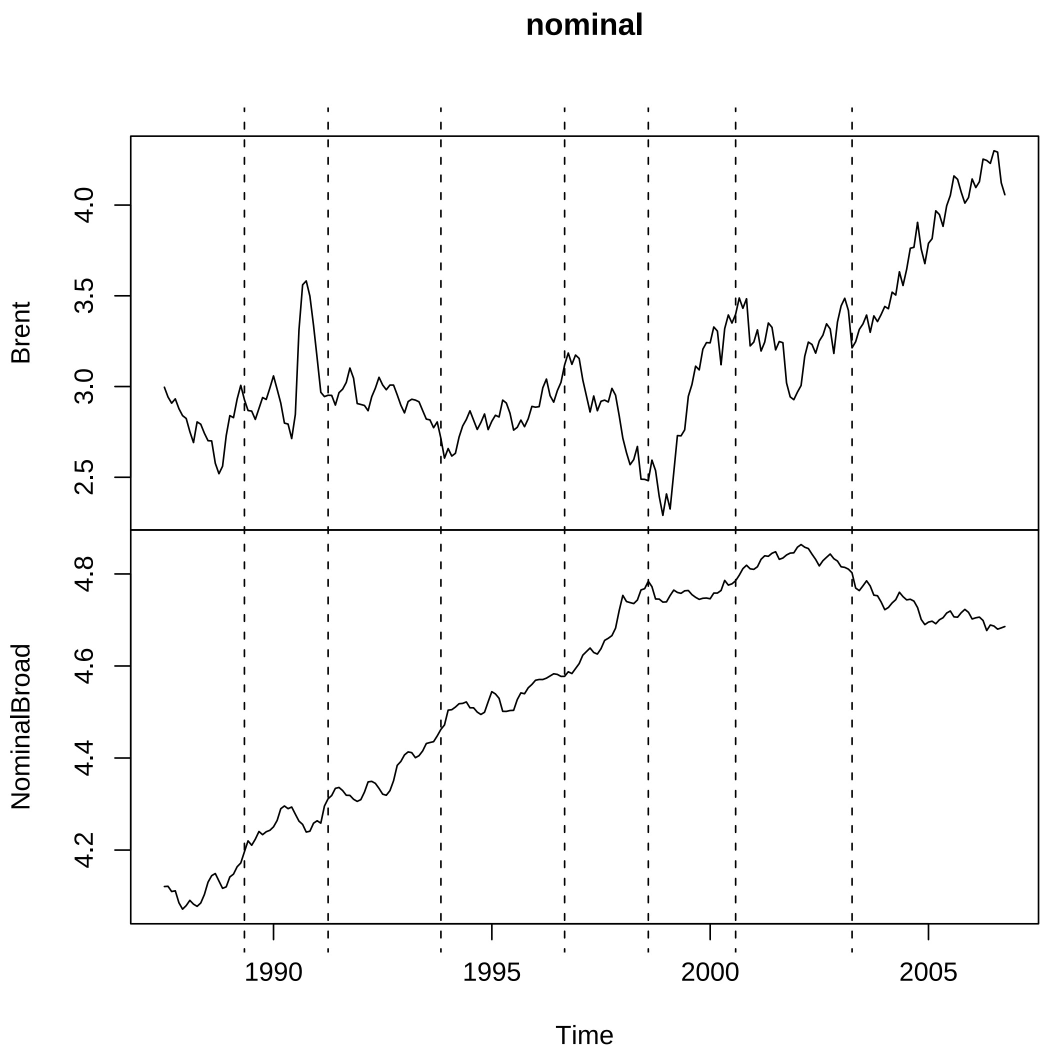

Figure 3.21. Breakpoints for regression (1.1) for nominal USD/broad index as dependent upon the nominal oil price (logarithmic prices).

Figure 3.22. Breakpoints for regression (1.1) for real USD as dependent upon the real oil price (logarithmic prices).

We may also ask the following question: *If we allow and find just one breakpoint, when does it occur?* The results of an analysis allowing for maximum one breakpoint are given in Figures 3.24–3.26, and the breakpoints found are October 1993, November 1997 and November 1995, respectively.

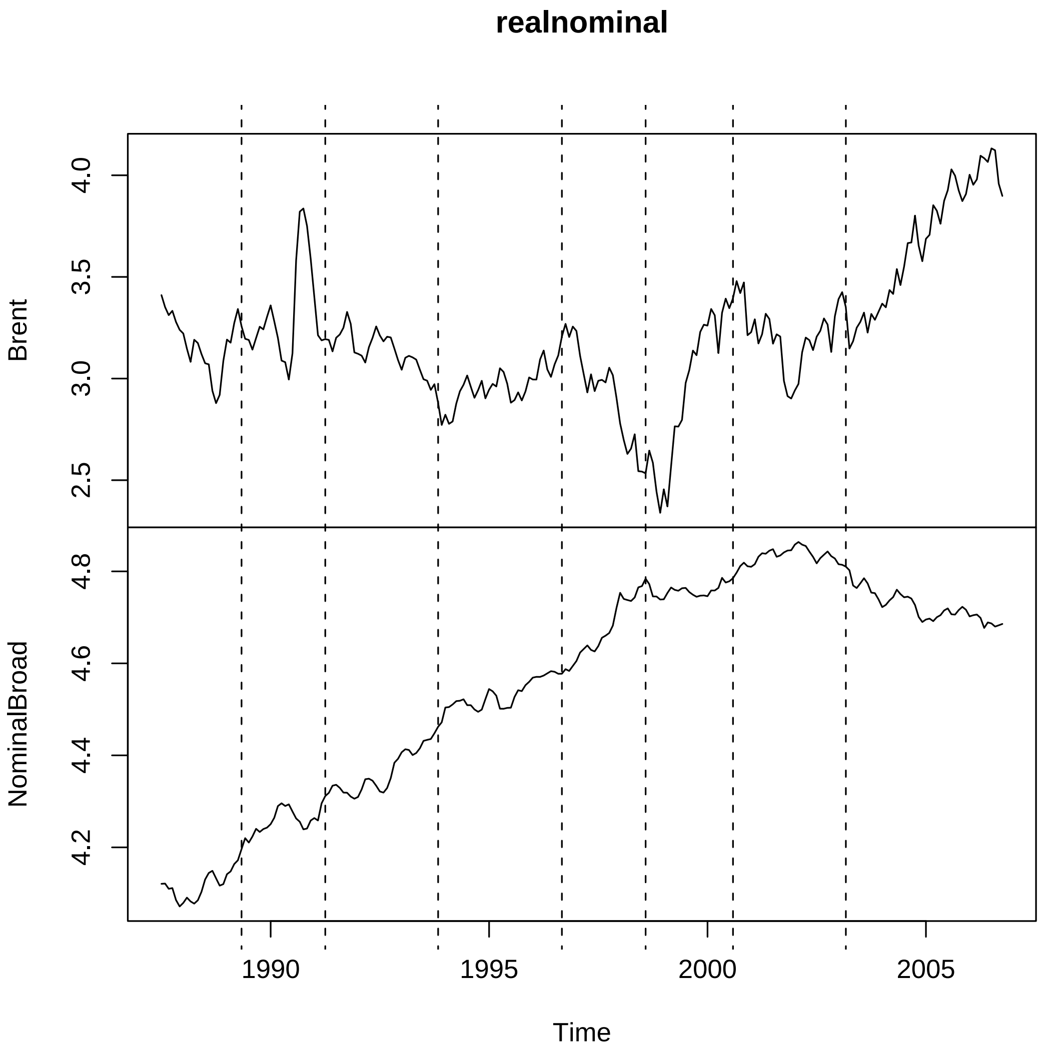

Figure 3.23. Breakpoints for regression (1.1) for nominal USD/broad index as dependent upon the real oil price (logarithmic prices).

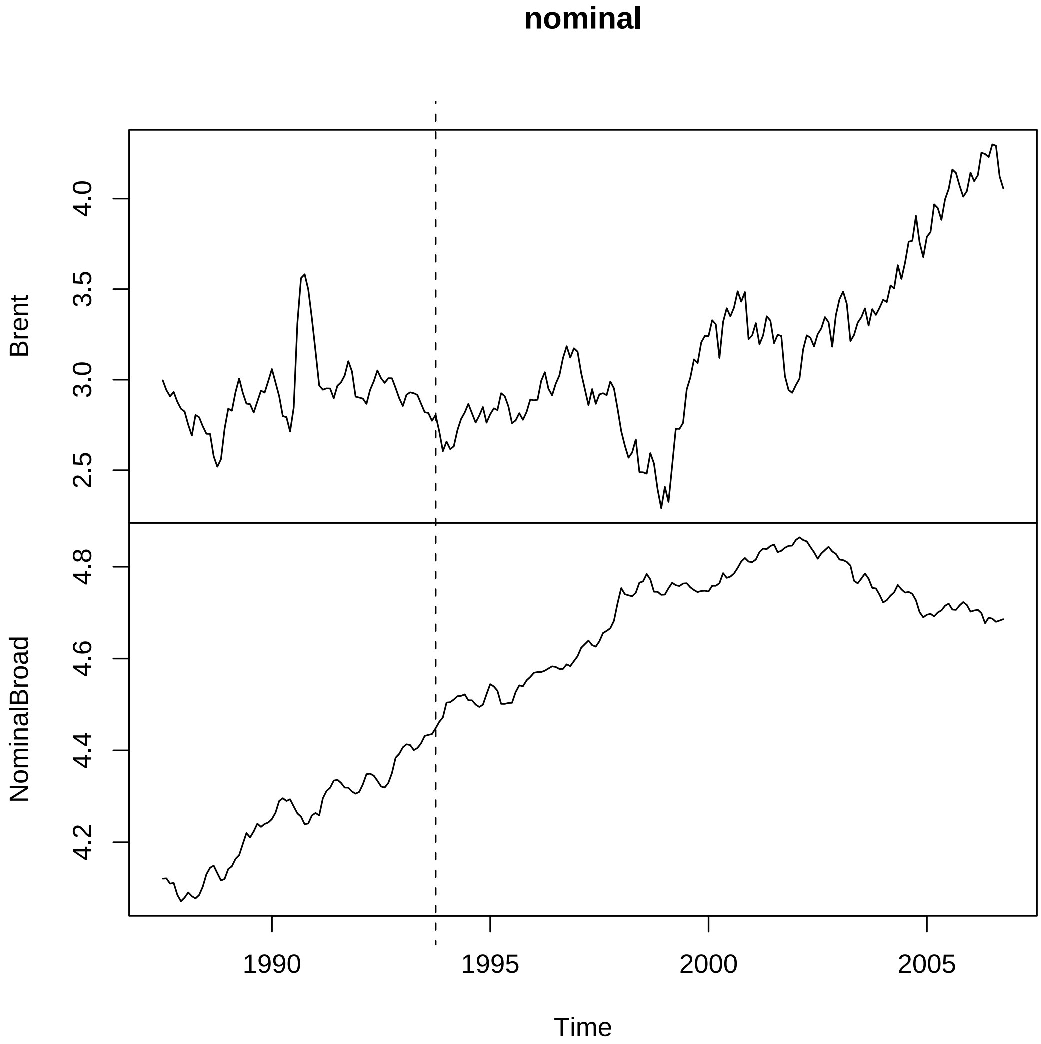

Figure 3.24. Breakpoint for regression (1.1) for nominal USD/broad index as dependent upon the nominal oil price (logarithmic prices).

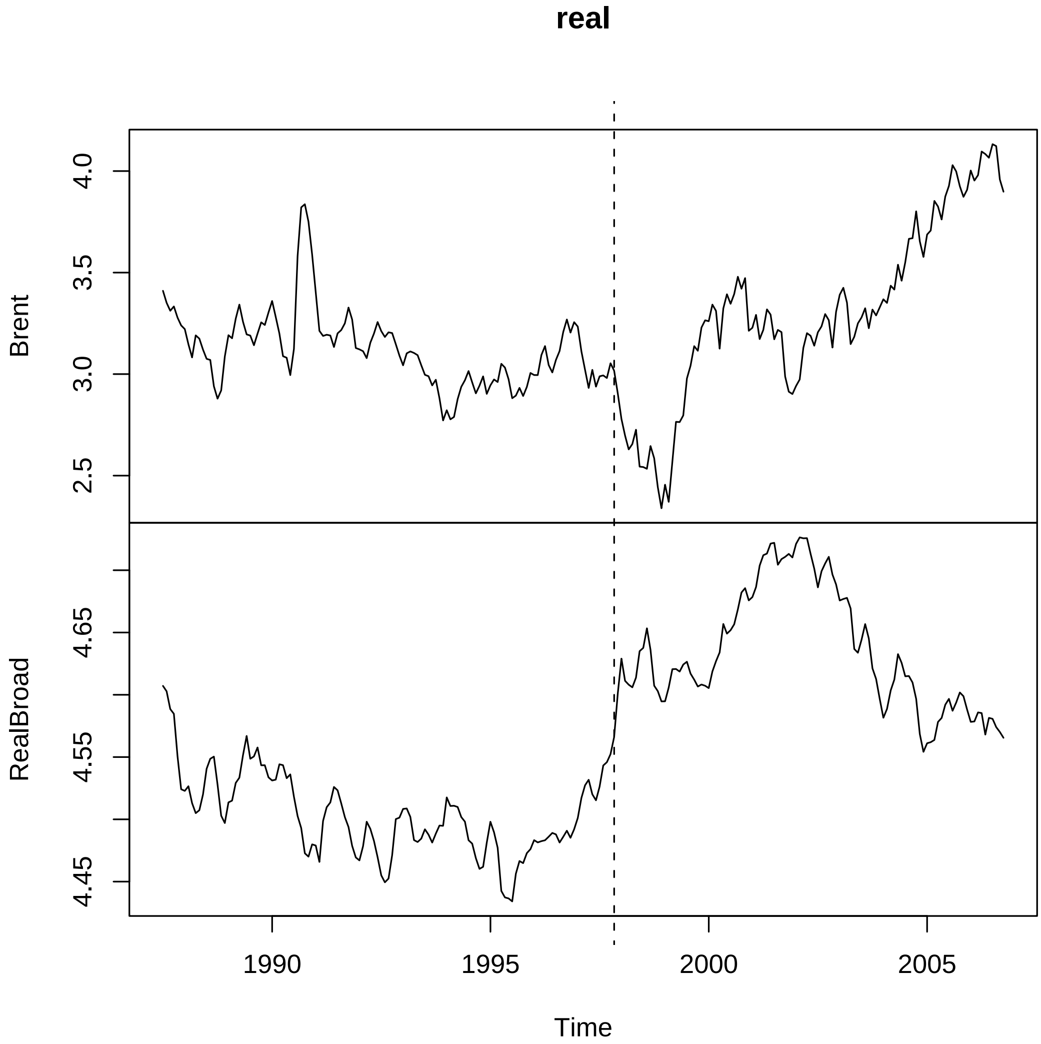

Figure 3.25. Breakpoint for regression (1.1) for real USD as dependent upon the real oil price (logarithmic prices).

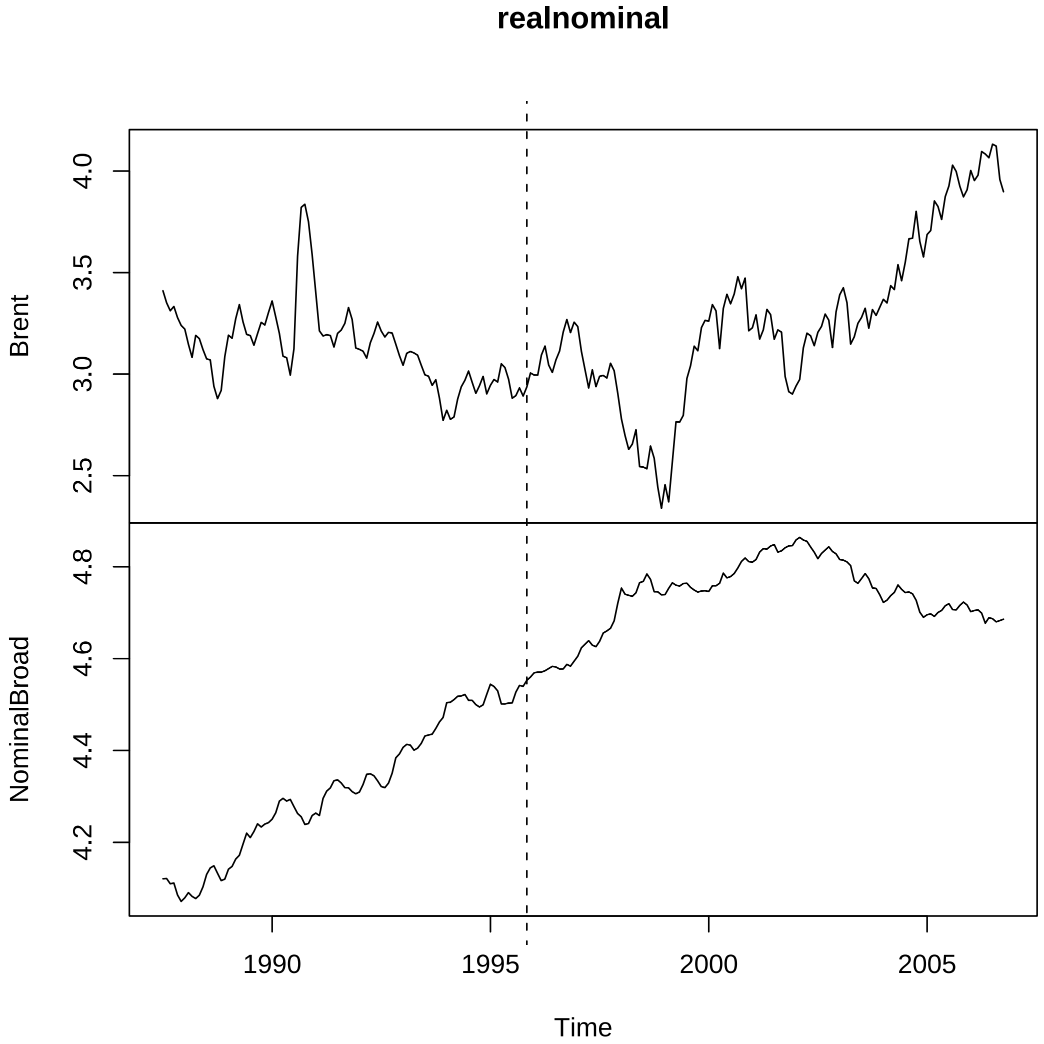

Figure 3.26. Breakpoint for regression (1.1) for nominal USD/broad index as dependent upon the real oil price (logarithmic prices).

4 Summary

Based on the relatively few number of relevant papers found when conducting the literature survey (presented in Chapter 2) it seems that the questions posed in Chapter 1:

- What is the relationship between the oil price (Brent quoted in USD) and the value of the US dollar or other currencies?
- If the US dollar strengthened towards other currencies, would it influence the oil price (or vice versa)?
- Do other currencies influence the oil price (or vice versa)?

might not have been as frequently posed as first believed. Also, from the papers presented in Chapter 2 and the analysis conducted in Chapter 3 we may conclude that there is no simple, unambiguous answer to the questions posed in Chapter 1.

All the papers presented in Chapter 2 claim to have found some sort of relationship between oil prices and exchange rates. How strong this relationship is and how it is specified varies quite a lot between the papers. This might not be so surprising, since the findings are based on different time series covering different time periods. Chaudhuri and Daniel (1998) demonstrate a linear, positive relationship between the (real) exchange rate and the (real) price of oil. Amano and van Norden (1998) find the same relationship. This is also the case for Bénassy-Quéré et al. (2005), but the authors focus on the role of China as a factor that changes the causality from positive in the short run to negative in the long run (that is, from the oil price to the US dollar in the short run to causality from US dollar to oil in the long run). Akram (2004), on the other hand, finds a non-linear negative relationship between the value of the Norwegian krone and crude oil prices. Hamilton (2003) demonstrates that the degree of relationship between oil price changes and GDP growth differ according to the time period under consideration, and that a linear relationship might only be valid for a short period of time. Interestingly, he also claims that when predicting GDP oil price increases are much more important than decreases. This may rule out a simple, linear relationship between oil prices and exchange rates.

All in all, there seems to be a general consensus that there is a relationship between the oil price and the value of the US dollar or other currencies in the literature survey in Chapter 2. How strong this relationship is varies according to which measures of the oil price, which other currencies and which time periods are being studied. In some studies the relationship is weak, in other studies it is not even present at all. Our conclusion, based on the literature survey presented in Chapter 2 and the analysis conducted in Chapter 3, is that there is a relationship between the oil price and the value of the US dollar or other currencies, and that this relationship must generally be described as weak. Traditionally this weak relationship has been positive, but during the later years this is not necessarily so. See Hamilton (2003), Section 2.6, for a discussion on this. In explaining the development of both the oil price and the value of the US dollar or other currencies many macroeconomic variables might be relevant. These might be other time-series describing features of a country's economy, sudden events in the oil industry (e.g. new findings of oil, accidents), national or international political decisions, wars, etc. Some of these variables might again be co-founded with other variables, and so on. Also, some of these other time-series might in certain time periods have a large influence on the oil price and/or the value of the US dollar or other currencies and not at all in other time periods. Just finding the relevant factors that should go into a model is a complicated task. Also, being able to take into account the possibly very time-variating correlation between these factors themselves, to the oil price and the value of the US dollar or other currencies, makes this an extremely difficult, maybe even impossible, problem. A purely statistical time series analysis might therefore be of limited value. We feel that in order to shed light on the questions posed in Chapter 1, it might be just as valuable with an analysis based more on economical arguments.

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