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## **Estimating the Market Premium in Short Term Interest Rates**

By

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«This thesis was written as a part of the master program. Neither the institution, the advisor, nor the sensors are - through the approval of this thesis - responsible for neither the theories and methods used, nor results and conclusions drawn in this work.»

## **Abstract**

Looking at the term structure in the interest rate market one can't help notice the evident market premium above the central banks target rate. What factors might decide this premium? By using different variations of simple regression models we see that the model is constantly lagging the real time series. Acknowledging the fact that market clearings often are subject to several equations; we're better able to develop a sensible model using a simultaneous equilibrium model. The multiple equation model provides us with information about the importance of international factors as well as domestic economic variables, such as real assets and stock prices. We also find significant evidence for the simple Taylor rule using inflation deviation and GDP trend analysis. It's also worth noting that exchange rates played a less important role in deciding the market premium after Norway introduced an inflation target in its monetary policy.

## ***Preface***

Of interest, I searched for applied research explaining the market clearing for interest rates, without luck. It seemed like no one were able to give a explicit answer on what factors, above the central bank target rate that explained the risk premium in the term structure. The fact that few, if any, studies had been done in this field of interest invoked my curiosity even more. An abundance of data and isolated studies of a diversity of possible explanatory factors makes this thesis eclectic in nature.

I would like to thank Prof. Øyvind Anti Nilsen for inestimable help during the whole process. I would also like to thank Prof. Øystein Thøgersen, associate professor Stig Tenold and researcher at Norges Bank Mr. Farooq Akram for their help.

Hans Fredrik Hansen, Stavanger 23 / 8 – 2006

## *Table of Contents*

Chapter 1) Introduction.....	4
Chapter 2) Model and data.....	6
Chapter 2.1) Descriptive Analysis of Data .....	11
Chapter 3) Modelling.....	32
Chapter 3.1) The Simple Level – Level model.....	32
Chapter 3.2) Exchange Rate model .....	34
Chapter 3.3) Simultaneous regressed equations .....	38
Chapter 4) Concluding Remarks.....	42
References.....	44
Appendix One .....	48
Appendix Two .....	58
Appendix Three .....	59
Appendix Four .....	61
Appendix Five.....	64
Appendix Six .....	68
Appendix Seven.....	72

## ***Table and Figure Index***

### Tables

- Table I; Explanatory Variables
- Table II; Correlation Coefficients, Investments vs. oil and gas price
- Table III; Simple Level – Level model
- Table IV; Exchange Rate Adjusted Model
- Table V; Model Specifications
- Table VI; Simultaneous Equation Model

### Appendix; Tables

- Table A1-1; Structure in the Money Market
- Table A1-2; Correlation Coefficients; various interest rates
- Table A4-1; Auto Correlation Example; Level – Level model
- Table A4-1; Prais Winston Corrected Values
- Table A5-1; Dickey-Fuller test for unit root
- Table A5-2; First differentiated Dickey-Fuller tests.
- Table A6-1; Functional Form
- Table A6-2; Linearity Test

### Figures

- Figure I; Market Volatility
- Figure II; Main Framework
- Figure III; Norwegian Deviation from GDP potential Trend Level
- Figure IV; Norwegian Deviation from NAIRU
- Figure V; Norwegian Unemployment Gap
- Figure VI; Norwegian Budget Deficit
- Figure VII; Norwegian Credit Growth and Three Month Interest Rate
- Figure VIII; Money Growth and Inflation
- Figure IX; Norwegian Money/- and Credit Growth
- Figure X; Price Index – Norwegian Residents
- Figure XI; Norwegian Inflation
- Figure XII; OSEBX, Norwegian Three Month Rate and GDP growth
- Figure XIII; Norwegian Wage Differential and Three Month Interest Rate
- Figure XIV; Norwegian Exchange Rates and Three Month Interest Rate
- Figure XV; US and Norwegian Short Term Interest Rates
- Figure XVI; European and Norwegian Short Term Interest Rates
- Figure XVII; Model – Fit (Simple Level – Level Model)
- Figure XVIII; Model – Fit (Exchange Rate Adjusted Model)
- Figure XIX; Model – Fit (Simultaneous Equation Model)

### Appendix; Figures

- Figure A1-1; Norwegian Money Market Rates, 22<sup>nd</sup> of March
- Figure A1-2; Norwegian Forward Rates, 22<sup>nd</sup> of March
- Figure A1-3; Schedule, FRA and Money Market rates, example
- Figure A1-4; Time Structure in Money Market – Liquidity hypothesis
- Figure A1-5; Difference – Long and Short Rates
- Figure A1-6; Central Bank Interest Rates
- Figure A1-7; Norwegian Three Month Interest Rates; Real and Nominal
- Figure A3-1; Illustration of Endogeneity Problem

## Chapter 1) Introduction

This paper, focus on the evident market premium seen in interest rates. There are several reasons to study the connection between market rates and different economic factors. One is to reveal when interest rates may change and to what extent they move. As seen in figure I, interest rates tend to periodically deviate from their preceding path.

### Market Volatility

Figure depicts difference between interest rates and target rate for Norwegian data; day before and after central bank announcement. Origo represents now difference

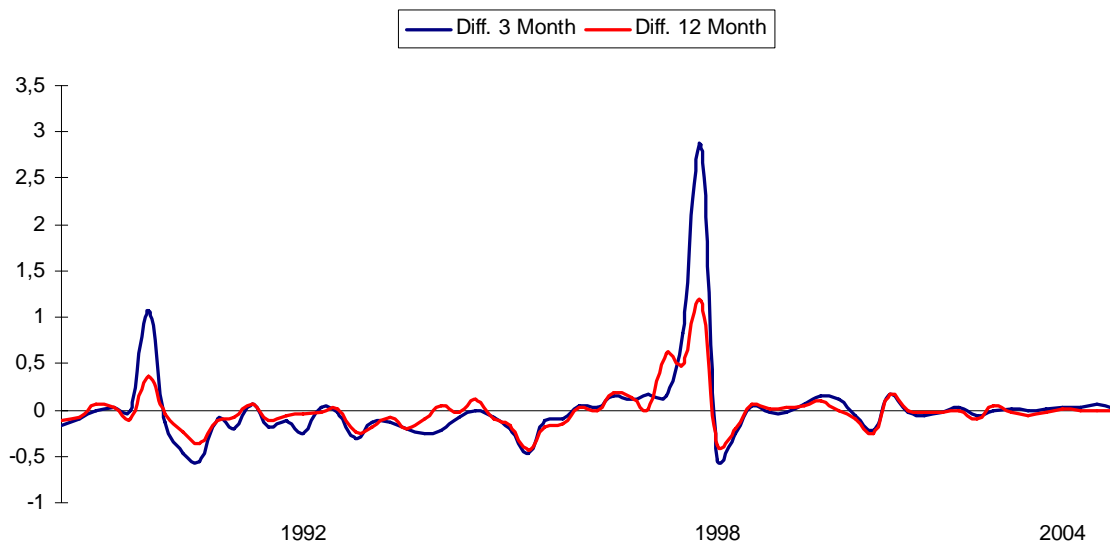


Fig I

Two, why are some shifts sudden and vehement, while others tend to be rather tranquil? Thirdly, how come interest rate volatility nearly disappears when we approach present time? Is this due to international factors, or better domestic policy rules? Answering the question; why does interest rates move as they do, are in fact the key to answer all of the queries above.

In this paper we find that the complexity and interdependence in financial markets (for an overview of financial markets; see appendix one) have to be solved by models taking into account exactly that reciprocity. Simpler models do catch direction and may give hints to important prime movers, but these are slow and constantly lag real time series. More

advanced simultaneous regressions models fit better and reveal other driving forces within the market for interest rates. Equivalently, this paper sets out to explain what factors may affect, and by what magnitude, interest rates.

## Chapter 2) Model and data

Some have proposed strict rules which aim at binding the central bank to certain pre-determined rules, both to make its predictions easily to interpret and to overcome the cognitive human restrictions of information overflow. The famous work of Kydland and Prescott (1977) were inspired by Milton Friedman (1962; 1976), and concerns the design of macroeconomic policy under inherent imperfections to credibility problems made the foundation for rules in stead of discretion. Taylor (1982, 1993, 1999) followed up and proposed a reaction function on the form

$$i_t = (\pi^* - r) + \lambda(\pi_t - \pi^*) + \gamma(y_t - y^*) \quad [1]$$

where  $i_t$  is the central bank target rate,  $\pi^*$  the announced inflation target,  $r$  neutral real rate and  $y^*$  represents potential production. The coefficients states what weight the bank puts on the different deviations<sup>1</sup>. When the economy is in equilibrium; inflation- and production gap cancel out to nil, the interest rate should be in accordance with the Fischer parity  $i = r + \pi$ . If the deviations in either of the variables are positive, the interest rate has to be set above its neutral level to reduce pressure tendencies in the economy.

In other words one could say that the interest rate formation is a simple supply and demand question. If supply exceeds demand rates fall and vice versa. This simple framework constitutes the foundation when estimating an interest rate model.

Applying the Taylor rule to our model yields

$$i_t = \underbrace{(\pi^* - r) + \lambda(\pi_t - \pi^*) + \gamma(y_t - y^*)}_{\text{Central Bank Target Rate}} + X \quad [2]$$

Where  $X$  represents the residual when regressing the target rate on the short term interest rate. Equation [3] presents the coefficients and the  $t$ -values in such a regression; a

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<sup>1</sup> Taylor proposed  $\lambda = 1,5$  and  $\gamma = 0,5$  for the US economy



positive sign on the short term rate coefficient substantiate the argument of a liquidity/- and risk premium in market rates, which accounts for about 20 % of the three month interest rate.

$$\text{Target} = 0,73 + 0,77 \text{ Short Term Rate} \quad [3]$$

$\begin{matrix} 6,11 & 43,12 \end{matrix}$

Still, the “X” factor seems large enough to continue our analysis. Svensson (1998) highlights the importance of different transmission effects; using this and building on the model as presented in the Bank of England Monetary Policy Committee (2001) one reach a framework for analyzing our unknown factor;

Main Framework for Interest Rate Model

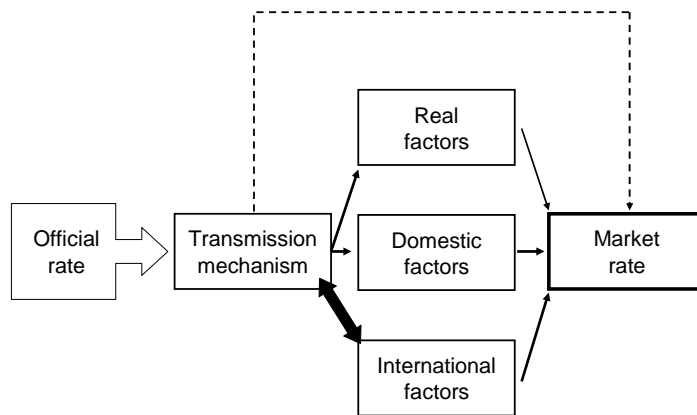


Fig II

The transmission mechanism, which is decisions about how the official interest rate affect economic activity and inflation through different channels, which are known collectively as transmission mechanism (Monetary Policy Committee 2001) is affecting the market rate both directly and indirectly as shown in the primary framework. Note how one separates between real- and domestic/international factors; implicitly meaning domestic and international nominal factors. As already mentioned in the Taylor rule; GDP gap and inflation matter when central banks decide upon their target rates. Since the relationship between the target rate and market rate are close, but not perfect, we should

test whether these variables have extra explanatory power when predicting market rates. As proxies for GDP trend gap, we could use the GDP growth gap as shown in Orphanides et al. (2000)<sup>2</sup>. A third alternative could be to use the inverse relationship between unemployment and GDP as stated in the Phillips-Curve. Naug (2003) and Bernhardsen & Bårdsen (2004) argue in favor of incorporating the oil price, since higher oil prices tend to appreciate the oil exporters currency, which then affects interest rates. In his study, Naug also uses international stock market indexes, since the stronger the stock market abroad, the more alternatives to invest in addition to Norwegian kroner. A higher stock market index tends to depreciate the local currency. Kinoshita (2006) finds that simulated and estimated interest rates effects from government debt tend to be small. However, if an increase in government debt is combined with an increase in government consumption, the effects are considerably larger. By this, we could argue that the economic impact of accumulating government debt – id est. budget deficits – cannot be ignored. When the United Kingdom and Canada undertook fiscal consolidation in the latter half of the 1990s, their interest rates fell simultaneously. On the other hand, Japanese bonds have seen limited effects of a huge accumulated governmental debt<sup>3</sup>. To isolate consumption versus investment, the model should account for national total investments. Mervyn King (2002) makes a thoroughly investigation of the impact of money on the economy. Traditionally, regression analysis does not find any influence from money on interest rates and inflation. However, these results tell us little about the significance of money within the transmission mechanism of monetary policy. King argues that the relationship is more complex, by highlighting the high correlation between inflation and money in the long run<sup>4</sup>. King stresses the fact that expectations are the key to understand the impact from money growth. Studying the transmission mechanism leads us to focus on at least two rigidities which induce time lags into the process by which changes in money lead to changes in prices and thereby interest rates. These are so called “nominal rigidities” and lags in the expectations to changes in the monetary policy regime known as “expectational rigidities.” These rigidities mean that

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<sup>2</sup> See below for a closer explanation

<sup>3</sup> The Bank of Japan did at the same time flow the market with liquidity, keeping the target rate at nil for a considerably amount of time. This fact surely affects rates in the opposite direction, making the two effects cancel.

<sup>4</sup> In a period of 30 years for various countries he finds a correlation coefficient as high as 0,99.

money affects real variables in the short run and prices in the long run. Anyway, one should not expect our model to yield a significant relation between the money growth and interest rates cause of the relatively short time span. Still, among several economist (e.g. the monetarist) “money matters.” That’s why our model contains the money growth as a control variable. Hall (2001) on the other hand finds that a readily supply of credit may affect the behavior of economic agents. Using Hall’s “credit channel” model one is able to better understand how credit growth may affect the aggregated economy. In these models borrowers are directly affected by banks credit policy. Hall concludes by stating the importance of several indicators, among them credit growth, when estimating interest rates. Financial wealth, here with focus on asset prices, is proven to be an important factor affecting both real and nominal (e.g. interest rates) aggregates (Brayton et. al 1997, Ekdahl et al. 1998 Langbraaten 2001). Investments affect the economy’s growth potential, and these are more likely to be undertaken in a “strong” stock market – Tobin’s  $q > 1$ . Increasing asset prices may also lead to increased willingness to lend with presumably better collateral. For the Norwegian economy, where 75 % of the households own their house, c.f. Andersen (2001), we would suspect that house prices (asset prices) have a significant impact in an interest rate model. Some would also argue that asset prices could provide an indicator for market expectations (Alchian & Klein 1973, Goodhart 1999 and Shiratsuka 2000). In their empirical model, Jacobsen and Naug (2004) find that interest rates and house prices are strongly interrelated. Their analysis indicates a swift and solid co-integration.

The last pillar of the model is international factors. Discussions of globalization often assert that the fortunes of small countries are driven by larger countries economies. This notion contends that small countries are highly susceptible to conditions in larger countries, and that their economies often experience volatility for reasons independent of domestic policies. Giovanni and Shambaugh (2006) finds that annual real output growth in small countries are negatively associated with interest rates in base countries, but the effect holds only for countries with pegged exchange rates. The results suggest that the primary impact of foreign interest rates is through the monetary policy channel and not as strongly through a general capital market effect. By this, one could say that foreign

interest rates will have a more direct effect on national market rates. Including both the euro and U.S. rate should yield explanatory power. Bernhardsen and Bårdsen also include the exchange rate and international capital markets to account for international factors. They use a competitive index based on trading partners exchange rates relatively to the Norwegian, the KKI index (see below for definition). One could also argue in favor of an import index, namely the I-44 index which could prove suitable.

In addition to the preceding variables elaborated on, one should stress the importance of the monetary regime (as stated by figure I). We know that the Norwegian central bank changed to a *de facto* inflation target<sup>5</sup> from an exchange rate based monetary policy with Gjedrem as new chairman of the Norwegian Central bank in 1999. As figure I clearly shows, the period before 1999 saw highly volatile market movements. The calm period after suggests that monetary regime matters. Following Hur (2005) one should expect a dummy variable (taking binary values as one from 1999 to present and nil else) to be significant and negative. Hur focuses on the path-dependency in monetary policy which induces a certain term structure of interest rates. Table I summarizes the various variables just elaborated upon.

<b>Table I</b>
<b>Summary</b>
- GDP gap – Orphanides et al
- Unemployment gap - Phillips
- Oil Price – Naug and Bernhardsen & Bårdsen
- International Stock Market – Naug
- Governmental Debt – Kinoshitha
- Money Growth – King
- Credit Growth – Hall
- Asset Prices – Brayton et al., Ekdahl et al. and Langbraaten
- Foreign Interest Rates – Giovanni and Shambaugh
- Exchange Rate Indexes - Bernhardsen & Bårdsen
- Monetary Regime - Hur

<sup>5</sup> A *de jure* transition occurred March 29 2001

## Chapter 2.1) Descriptive Analysis of Data

The following sections presents the data necessary to estimate the model as presented above. If not otherwise mentioned, the data are Norwegian reported on a monthly basis to increase the number of observations (or transformed monthly).

Deviation from potential production could be defined as the gap between actual production and potential in percentage as

$$\frac{y_t - y_t^{POT}}{y_t^{POT}} \quad [4]$$

This time series consists of the aggregated GDP given by SSB<sup>6</sup>, all sectors included. Many papers seem to prefer a time series excluding the large Norwegian petroleum sector, since it's often seen as an "outlier" disturbing the data. The rationale here is simple enough, namely that the market interest rate does not discriminate between different factors which might lead to an overheated economy or vice versa. The figures used are computed from the first quarter 1978 to the third 2005, seasonally adjusted (see Appendix One for details). An economy's potential production is not known, and has to be estimated. The trend seems like a reasonable estimate in representing the potential production. I'm using a univariate method, based solely on information within the time series itself to estimate the output gap. By applying the Hodrick-Prescott filter, we minimize the following equation;

$$\min \left\{ y_t^{POT} \right\}_{t=1}^T \left\{ \sum_{t=1}^T (y_t - y_t^{POT})^2 + \lambda \sum_{t=2}^{T-1} \left[ (y_{t+1}^{POT} - y_t^{POT}) - (y_t^{POT} - y_{t-1}^{POT}) \right]^2 \right\} \quad [5]$$

Equation [5] requires an exogenous given  $\lambda$  where  $0 < \lambda < \infty$ . In their acknowledged article from 1990, Kydland and Prescott argued for  $\lambda = 1600$  when the HP-method is employed on quarterly data. NB is keeping to the same size on the lambda in computing

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<sup>6</sup> SSB – Statistisk Sentralbyrå (Statistics Norway)

Norwegian figures. Minimizing [5] using  $\lambda = 1600$  over the entire time span provides us with the deviations presented in figure III<sup>7</sup>. A transformation by the data by simple division yields monthly numbers from the quarterly SSB reports<sup>8</sup>.

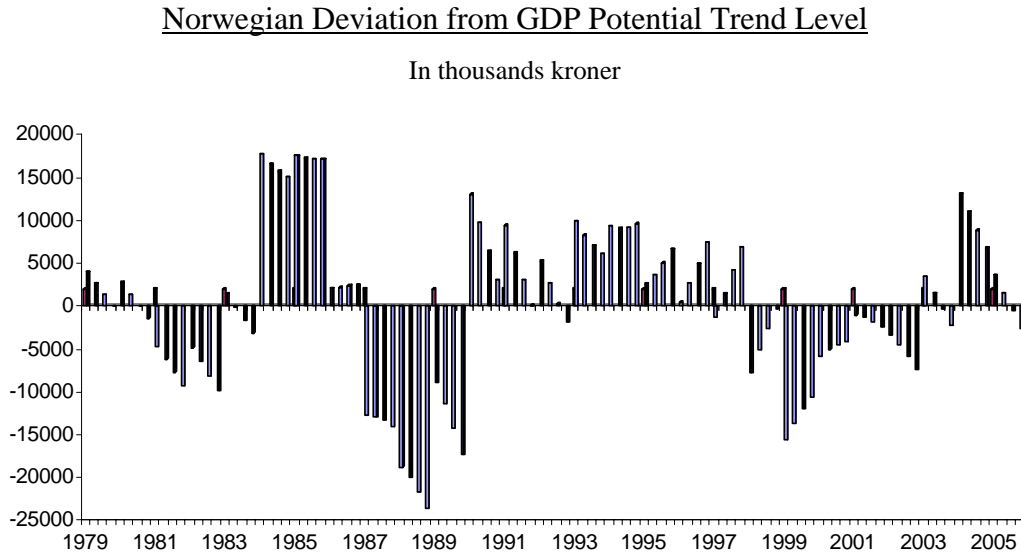


Fig III

The method described reveals non-negligible deviations from trend. For example the 150 billion positive deviations in the last quarter of 2004 computes to as much as 9 % over trend, thus leading us to suspect that it could affect the market rate since the economy periodically are either above or under its potential trend level. Assume a positive deviation caused by high private demand, which per definition leads to pressure on economic variables. The economy is producing over its potential, and has to invest to meet demand. A rise in the demand for capital will raise interest rates. On the other hand, a negative deviation leads to abundance of capital pressing rates downwards. The estimated coefficient for the GDP trend gap ought to be positive; the higher / lower the deviation the higher / lower interest rate.

<sup>7</sup> Note; some economists has argued in favour for a higher  $\lambda$  for Norwegian data, because of the relative higher volatility than other non-oil economies.

<sup>8</sup> By the following Stata command; replace  $gdp = gdp[-n-1]$  if  $Q_i == Q_i[-n-1]$

A different approach to this problem was first suggested by Orphanides et al. (2000) Instead of the more complicated output gap, one simply uses the growth gap.

$$g_t - g^{POT} \tag{6}$$

The constant  $g^{POT}$  is the arithmetic average percentual growth during the time series. In the series this computes to (3,055%  $\approx$  3%). Bernhardsen & Bårdsen (2004) finds this measurement more suitable in estimating NB's reaction function. Orphanides *et al.* argues that the uncertainty in real time GDP figures is significant, so the growth gap is a better proxy than the Taylor rule. One should expect a positive growth gap, which is growth higher than the historical average, to increase interest rates with the same rational as above.

A third variable that might be suitable in this matter could be the unemployment deviation from its potential or natural equilibrium. The Non-Accelerating Inflation Rate of Unemployment (NAIRU) could be defined in much the same way as GDP deviations from its trend. Standard macroeconomics teaches the inversely relationship between inflation and unemployment. More specifically this computes to the now famous Phillips curve, dependent on three factors

$$\frac{\pi_t - \pi_{t-1}}{\pi_{t-1}} = \pi_t^e - \beta(U_t - U_t^n) + X \tag{7}$$

Equation [7] gives useful information regarding our approach to the market interest rate clearing. Inflation growth shown in the left hand side is given by expected future inflation ( $\pi_t^e$ ), unemployment deviation from its natural rate<sup>9</sup> and a stochastic chock ( $X$ ).

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<sup>9</sup> Note how the NAIRU  $U_t^n$  is time indexed – due to the fact that the natural rate of unemployment is constantly altering.

Defining  $\frac{\pi_t - \pi_{t-1}}{\pi_{t-1}} \equiv \pi_t^s$  and rearranging gives us

$$U_t - U_t^n = \frac{1}{\beta} [\pi_t^e - \pi_t^s + X] \quad [8]$$

If one believes in relation [8], unemployment deviations explain differences in expected and actual inflation. Higher inflation does lead to higher interest rates, because market actors demand a higher premium to safeguard themselves against the “nominal tax” imposed through inflation. Then [8] is per definition a leading indicator for inflation, thus a potential efficient explanatory variable. From SSB one finds a time series presenting people out of work, monthly data stretching from 1989 to 2004. Applying the Hodrick-Prescott filter gives us the following deviations from trend<sup>10</sup>;

### Norwegian Deviation from NAIRU

In thousands

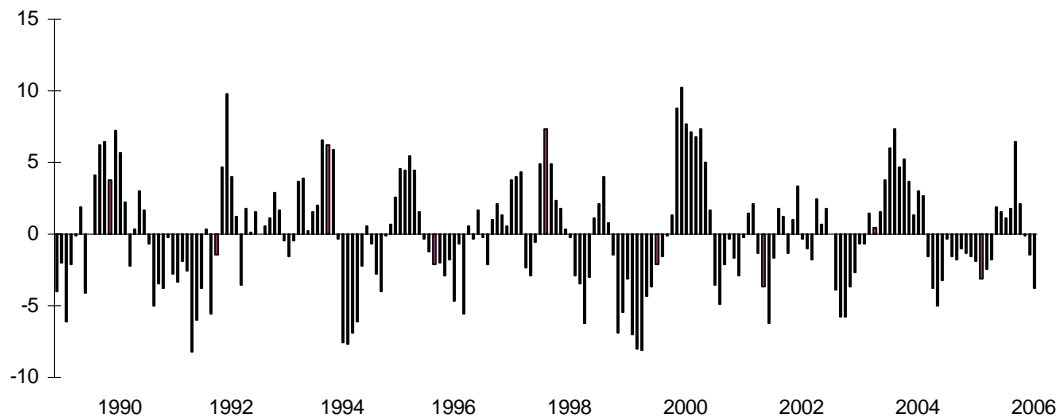


Fig IV

We should though be aware of the danger of using a trend analysis in estimating the level of NAIRU. Since the non accelerating level of inflation depends on the overall productivity in the economy, the exact NAIRU level might vary during the time series. Even so, one could reckon that the HP trend level is a reasonably proxy for the NAIRU

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<sup>10</sup> Using monthly data, one should increase  $\lambda$ . There is a consensus of  $\lambda = 14400$  for monthly data. See Raven & Uhlig (2002) or Yossin Yakhin (2003) for details.



level. Bernhardsen and Bårdsen argue in the same matter as Orphanides et al. in favor of an unemployment gap<sup>11</sup>. Using the average unemployment in the SSB's AKU numbers yields the following chart:

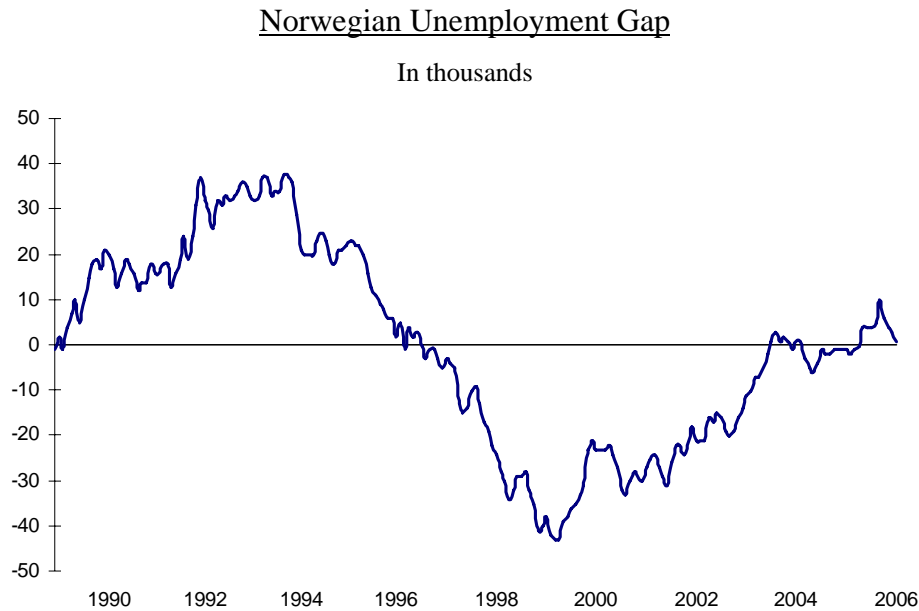


Fig V

When the gap is below zero, the economy is not producing at its potential, following the same rationale as a negative gap in the GDP figures presented above.

Since 1969 the Norwegian economy made the first step towards a petroleum economy. The last decades have transformed the economy, being more dependent on oil exports, substituting traditional manufacturing and industry for the process of extracting and selling the proceeds of our natural economic rent. This has led to an investment cycle interconnected with this industry. From Data streamer, Thompson one can gather monthly numbers for the price of Brent Blend<sup>12</sup> and natural gas, all numbers in US dollars. Table II quantifies the relationship between investments and oil- /and gas prices;

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<sup>11</sup> Average unemployment over the time series

<sup>12</sup> Note; even though the Brent Blend is solely oil from British continental shelf it's used as a reference for all other raw oil in the area. Norwegian oils are therefore closely correlated with Brent.

<b>Table II</b>					
<b>Correlation coefficients</b>					
Investments vs oil and gas price (lagged)					
	Same Period	1.lag	2.lag	3.lag	4.lag
Oil Price	0,358768 (3,21)	0,429874 (5,21)	0,629624 (5,19)	0,655731 (4,84)	0,520945 (4,32)
Gas Price	0,327282 (5,84)	0,404608 (5,15)	0,625131 (5,07)	0,748982 (5,11)	0,680825 (5,49)

The above table shows the calculated correlation coefficients ( $t$  – values in parentheses) between oil and gas prices, with investments in the industry over the period from 1986 – 2004. Same period’s price does not affect investments in any degree. While the third lag suggest that the price on petroleum products drive investments, providing correlation coefficients between investments and oil- and gas prices as high as 0,66 and 0,75, respectively. This seems plausible, since the price signal takes time to incorporate into new investments decisions. Due to this fact, both series should be taken into consideration. Since investment is used in aggregate comprising the whole economy, I use oil price as both a proxy for petroleum related investments, in fear of multicollinearity among variables and as a driving force behind currency movements. The theory suggest that higher oil prices drives investments and appreciates the national currency, leading to higher demand for capital, thus pushing up prices - *id est*. driving up interest rates. Especially lagging the variable two to periods should yield the highest positive coefficient. A third period lagged oil price will be used to incorporate the connection between interest rates and demand for funding. We expect the oil price to affect interest rates positive; higher oil- and gas price will lead to higher interest rates.

The next time series comprise total actually investments in million NOK for all sectors over the period 1989 – 2006 (quarterly data transformed to monthly by division) as presented at SSB’s web resources. The rational by using investments as an explanatory variable is to find a proxy for capital demand and to account for the amount of national

spending not due to consumption. Higher investments will then push up the price on capital. However, higher interest rate makes investments more expensive thus less profitable. The first argument should be backed by a positive correlation, but the fact computes to a negative coefficient  $(-0,38)$  thus supporting the latter statement; that the higher the investments, the lower the interest rates. We expect a negative coefficient in our model. Even so, investments ought to be a leading indicator for interest rates. Increasing outlays for investments would then indicate rising rates in the near future. Lagging the variable might prove different. We should also be aware of the possible simultaneity problem in estimating interest rates based on investments. They might be driven together, causing a “supply / demand” problem in estimating the coherence.

“Kinoshita’s” variable, the budget deficit is in the intertemporal Ricardian sense a postponed tax on the citizens, and in the present sense an indicator telling us something about public demand for services and goods. A high deficit is synonymous with high public demand, and a high postponed tax. Figure VI shows how the Norwegian budget deficit has varied in billions of kroner.

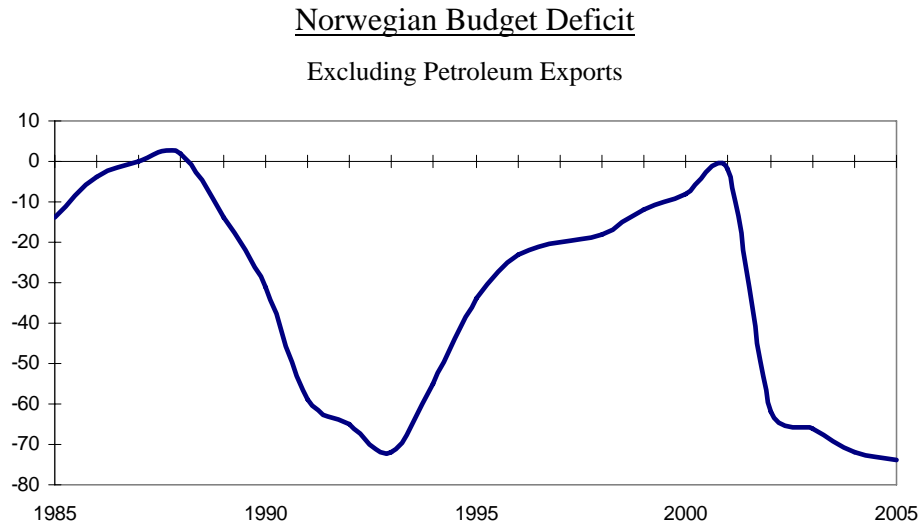


Figure VI

From this simple framework we’re able to draw some conclusions about the Norwegian fiscal situation. Oil exports bless us with a *de facto* surplus on our current account and the fiscal budget, simplifying our analysis by removing the element of intertemporal tax substitution. On the other hand it tells us that the public sectors demand is higher than

without such “windfalls.” In real sense it alters the composition from industries competing on the world market toward more service- and sheltered domestic industries (known as Dutch Disease). Shifting the composition could affect the interest rates, making our monetary policy more independent. Economists now days see this effect dominated by more mobile capital flows actually increasing our dependency on other central banks (Norman 1993, The Economist 2006). But its effect on domestic demand for goods and services are ever present. Conventional economies offset budget deficits by international loans, which are repaid with interest rates, straining future spending. In Norway this problem is easily solved by transferring resources from the oil exports to cover budget deficits. One should expect interest rates to be modestly affected by larger deficits – that is an inverse coherence between the two factors. A correlation analysis between the deficit and yearly three months interest rates and the banks target computes to 0, 33 and 0, 36 respectively. Intuitively; increasing public demand – *cet par* – crowds out private initiatives, which then start to compete on financial markets for resources. If the supply of money is constant, its price, the interest rate will raise.

The next variable represents the percentual credit growth over the year in the private sector as depicted in figure VII below.

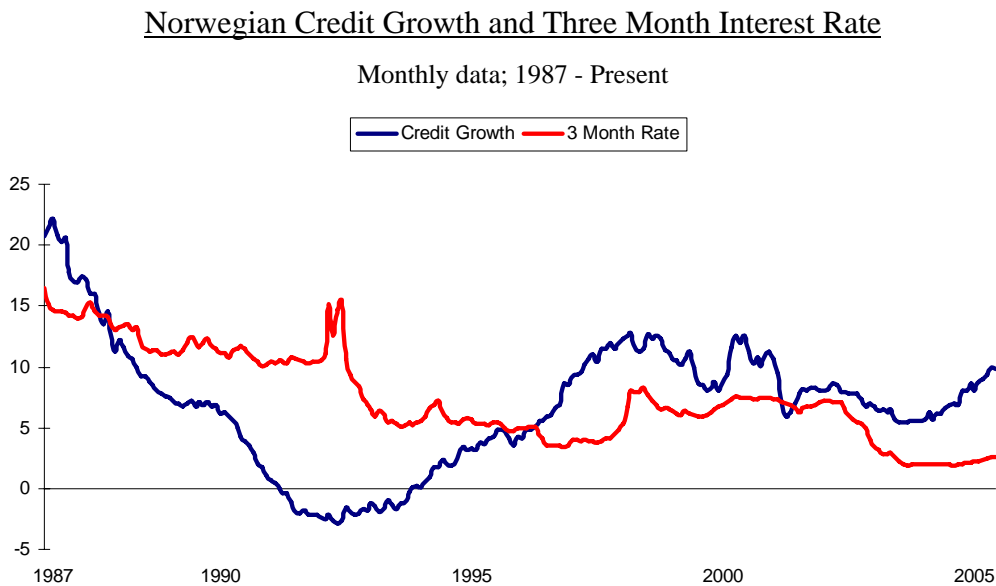


Figure VII

At first glance one may be puzzled by the apparently absent covariance between the two variables plotted in figure VII – correlating no more than 0, 19 (almost equal to the correlation between money- and credit growth, see below). Remembering Hur’s credit channel model one should expect to see a clearer picture in figure VII than actually revealed. In chapter one, we learnt how the Central Bank tries to regulate the short term rate by contracting credit from the market. A negative correlation coefficient between the two variables would then be rational. Study figure VII in more detail, such a pattern does reveal itself, still less than expected. In the model one should still expect to find an inverse relationship. Due to this pre-study the coefficient might display low  $t$ -values.

One could argue that the Norwegian Central Bank operates its monetary policy more like the US Fed – not paying much attention to money growth as opposed to the ECB explicitly targeting their rate according to inflation and money growth. If so, money growth should not affect the transmission mechanism in any degree.

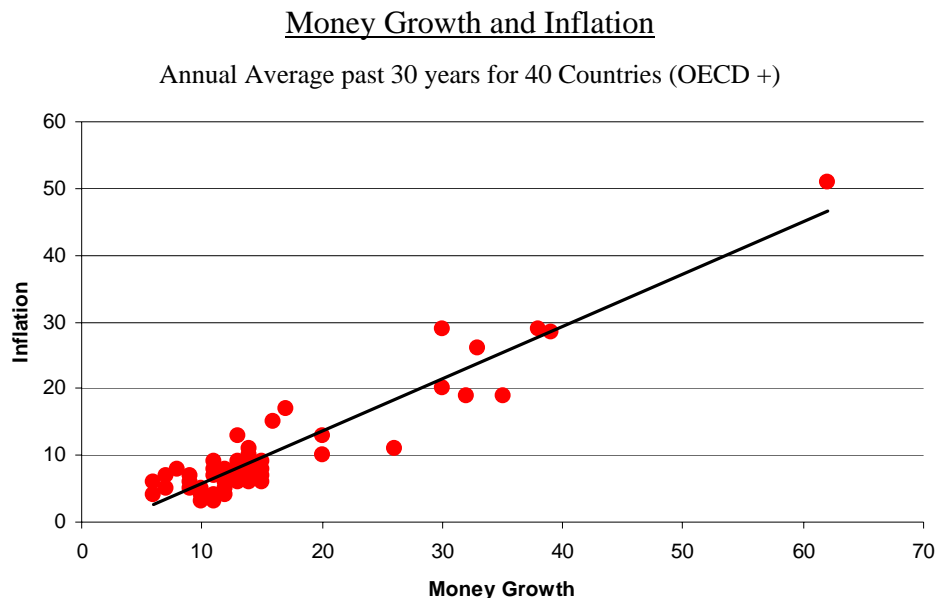


Figure VIII

Plotting the combination of inflation and money growth for OECD countries, plus some extra as in figure VIII shows a clear coherence; the horizontal axis representing the growth of money while the vertical represents inflation. The figure may be seen as a resurrection of the monetarist view; money growth leads to inflation, and in the next turn increase interest rates through a higher nominal premium. As Mervyn King clearly states, this yields true only in the long run<sup>13</sup>. But money growth might affect production in the short run. It is also possible to argue that increased money growth raises the demand for goods and services through easy access to credit. In this context one would suppose the increased money growth to sterilize some of the demand pressure on the interest rate, but the effect of increased demand for real goods to increase pressure effects in the economy. The overall effect of money growth is somewhat unclear. The time horizon might influence and central bank regime seems to be factors affecting this relationship. Figure IX shows the plotted values of the money- and credit growth in Norway from early 1990's to present.

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<sup>13</sup> King uses a large sample of 116 countries from 1968 – 98 and calculates a correlation coefficient as high as 0,99.

## Norwegian Money/- and Credit Growth

Monthly Data; 1990 – Present (red shaded area indicates new monetary regime)

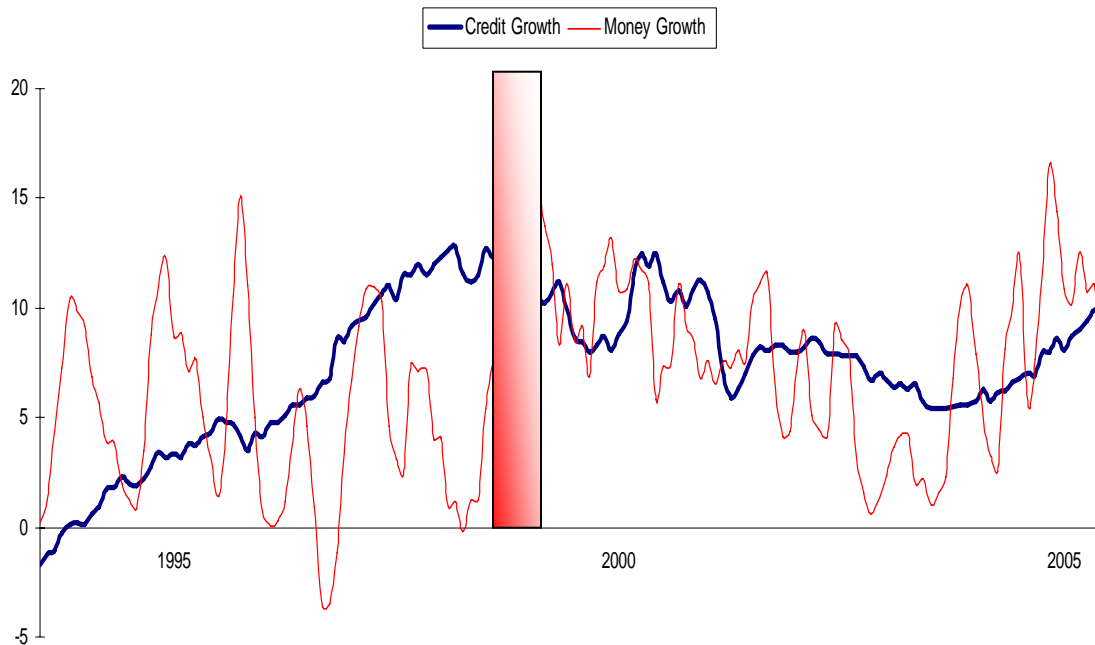


Figure IX

When the bank aimed at a fixed exchange rate regime, the money growth was highly volatile, while the inflation target after 1999 (marked by the red transparent square) narrowed the ups and downs in money growth. After 1999 the money growth also tracked the credit, as measured in percentage increase for individuals over the year, more closely. Figure IX overall correlation is only 0, 19 while the correlation jumps to 0, 46 in the period 1999 to present. A transition from inflation targeting might have strengthened the relationship between money growth and interest rate indirectly through the fact that money growth is a source to inflation. Then the transmission mechanism would affect the market rate through money growth. How this will manifest itself is not clear, but one could expect a positive covariance between money growth and interest rates. However, due to the short time span one might find insignificant coefficients.

Table A1-2 in appendix one clearly states the robust relationship between market rates and the Central Banks target rate. Since the central bank actually decides the overall level of the money market term structure one expect a clear and significant coefficient between market rates and target rates when estimating our model (as shown in equation three).

However, there is uncertainty regarding the impact market forces may have on the fluctuations around, or more precisely over the target. Since the money market is a consensus on future expectations the relation among the two are by far anticipated to be perfect. Among other factors, we saw in figure I how the rates differed before and after the central bank announced their action. A problem with multicollinearity may occur between the 10 year rate and the target rate, referring to the rational behind table A1-2. It's important to highlight that this is not a violation of the *perfect collinearity* assumption made prior to regression analysis. But it does increase the variance of the coefficient as  $\text{var}(\beta_j) \rightarrow \infty$  as  $\rho \rightarrow 1$ , where  $\rho$  represents the correlation. Using both the long term bond rates and the central bank target in the same model might derange the estimates.

As mentioned above there are possible multicollinearity problems using both the long term bond rates and the target rate cause of their high correlation. However, appendix one teaches us how different instruments in the money market are dependent on each other. We should find a positive coefficient when estimating the long term bond rates on short term rates. Even so, this is probably no more than a correlation, not causality since both money market instruments are in fact driven by the same forces.

Housing on the other hand is the most common saving instrument in a modern economy, especially the Norwegian. Latest "hot-spot" development in capital markets has been to liquidate some of this asset for immediate consumption. Studying the NAHB Housing Market Index and consumption shows a clear coherence (DN 11/8 – 06). Increasing house prices should then correlate positive with consumption, *id est*. ad to the demand for money – pushing interest rates upwards. On the other hand one could just as well argue for an inverse relationship amongst the two variables. Higher interest rates, the price of present consumption, make it more expensive to buy a home, thus reducing demand for housing which leads to lower prices. Correlation between the short term interest rate and house price index is negative and relatively large (-0, 5), supporting the latter argument. Again it's hard to separate the two effects. Consider figure X



### Price Index – Norwegian Residents

2000 = 100 (Red shaded area indicate falling residential prices)

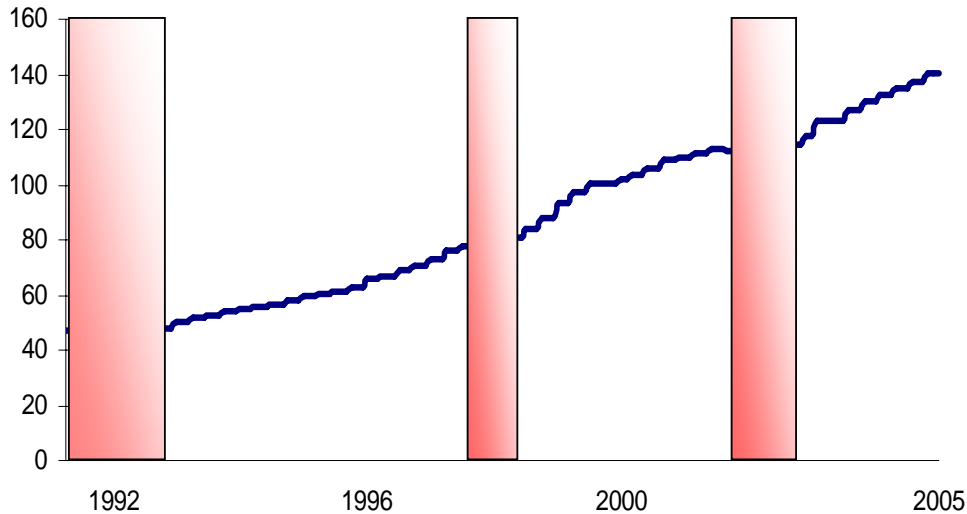


Figure X

We expect the interest rate to be higher within the transparent red squares which highlights falling house prices, than the historical average ( $\approx 3\%$ ) during these periods. Following the latter argument; higher interest rates makes it more expensive to buy a home. The average for 1991:7 to 1993:4 is 11, 6 %, for 1998:3 and 1999:2 the average interest rate was 7 %, between 2002:3 and 2003:9 it computes to 6, 2 %. This simple descriptive analysis seems to further back the notion about the inverse relationship between interest rates and house prices. We expect a negative coefficient. This argument seems to be substantiated by Jacobsen and Naug which finds a corresponding inverse relationship.

Figure X reveal a linear positive trend on the form  $y_t = \alpha_0 + \alpha_1 t$  where  $\alpha_1 > 0$ . Nothing about trending variables necessarily violates the classical linear model assumptions regarding time series analysis. However, we must be careful to allow for the fact that unobserved trending factors that affect  $y$  might also be correlated with the explanatory variables. Adding a time trend eliminates this problem!

The inflation numbers are calculated from the index published on SSB. Both monthly and over the year figures are plotted. Using the continuously month to month growth may give agents more up-to-date information. Even so, the year to year growth eases the comparison between periods.

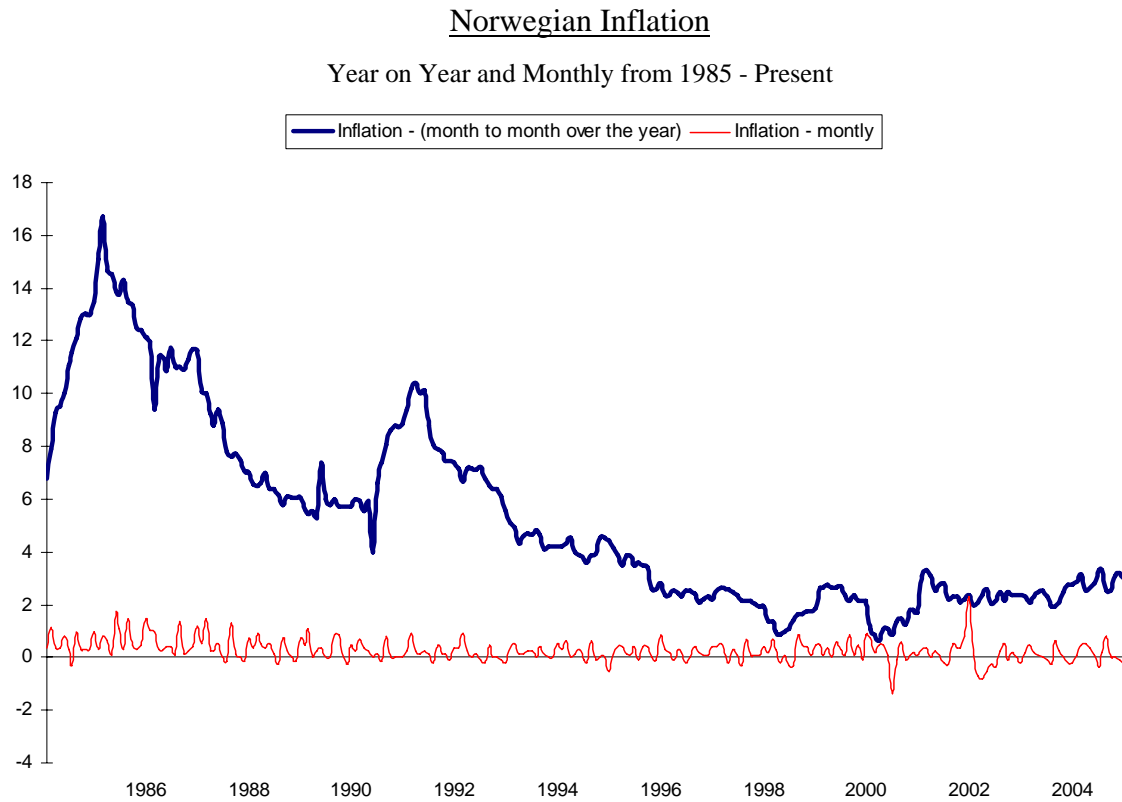


Figure XI

Figure XI show how inflation has fluctuated since 1985 to present. Economic theory treats inflation as a nominal “tax” on economic activity. The higher the inflation the higher the interest rates (nominal). Equation [9] presents this relationship, known as the nominal Fischer parity.

$$i = r + \pi \tag{9}$$

$i$  is the nominal rate,  $r$  real rates and  $\pi$  inflation; the higher the inflation, the higher the nominal rate. We expect a positive sign on the inflation as a control variable.

As shown in Dørum and Lund (1986) the stock market is seen as a leading indicator, at least in the US. They also highlight how the three month interest rate would lead the business cycle, especially in Great Britain. If the same proved true in Norway, the stock market would automatically follow the interest rate.

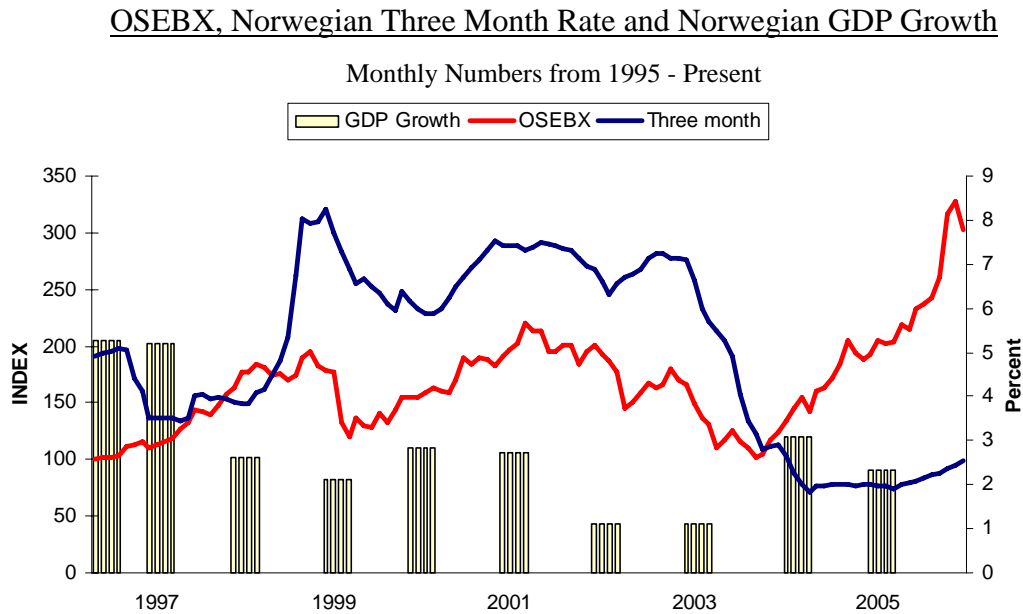


Figure XII<sup>14</sup>

Figure XII does provide some backing for the leading indicator hypothesis. Both interest rates and the stock market index are turning at the end of the 2001 recession. But the signals are more blur for other shifts. Could this be useful in our analysis? Studying figure XII in more detail seems to reveal a pattern, where the stock market is leading the interest rate. Using the highly informative market for stocks as an explanatory variable could be constructive. Incorporating a leading variable predicting future interest movements tell us something about market expectations.

We've seen how inflation might affect interest rates. What might drive inflation then? Wages are a naturally candidate. In the NB inflation report 2004/2 one predicts the Norwegian equilibrium wage growth (a wage growth compatible with 2, 5 % inflation) to

<sup>14</sup> The columns and the three month interest rate (represented by the blue line) follow the left hand y-axis, and are read in percentage growth. The OSEBX variation is read on the right hand y-axis as an index value.

be 4, 75 %. Figure XIII depicts the gap between actually and equilibrium growth. A positive gap will then indicate increased inflation.

### Norwegian Wage Differential vs. Three Month Interest Rate

Wage differential indicates deviation from NB's estimate on non-inflationary wage growth (4, 75%)

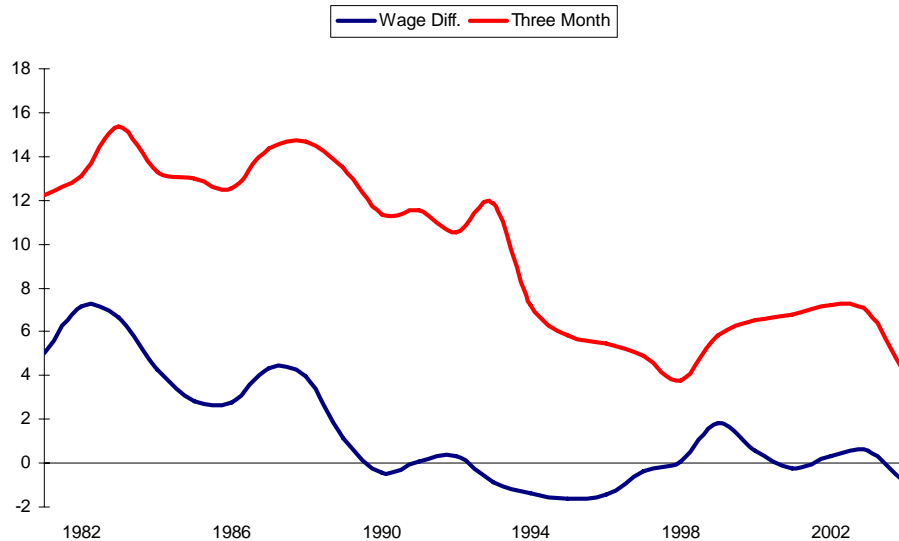


Figure XIII

Not surprisingly, the two variables track each other closely. Since a positive wage gap has to be met with tighter monetary policy which affect canals in the transmission mechanism. The correlation coefficient computes to a high as 0, 72. One should expect to find a positive coefficient for the wage differential.

Globalized capital markets with ever increasing cross-border capital, goods and service flows affects national interest rates. The days of sovereign monetary policy is definitively over. Making a model that predicts interest rates need to pay attention to factors outside our national sphere. A small open economy does not affect the international market rates; models see the interest rates as an exogenously parameter.

One distinguishing mark with the overall framework is the reciprocal effect between international factors and the transmission mechanism, complicating the estimating procedure.

We know that exchange rates affect domestic target rates, and through different channels the market rate. Simultaneously interest rates influence exchange rates. Enhancing the now infamous “simultaneous estimating” problem. In a simple one-equation model the interest rate will dominant the effect on exchange rates (Bernhardsen and Bårdsen). Increased interest rates – *cet par* – strengthen the national currency. On the other hand, a stronger exchange rate dampens inflation, *id est*. reducing the nominal premium reducing interest rates. These effects have to be separated by estimating two models simultaneously, as shown in equation [10] and [11] (for details, see appendix three)

$$\Delta i = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n + \beta \Delta KKI + \varepsilon \quad [10]$$

$$\Delta KKI = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n + \beta \Delta i + \varepsilon \quad [11]$$

Alternatively we could substitute the KKI for an I-44 import index. The I-44 exchange rate index is a nominal exchange rate based on the foundation of 44 exchange rates against the Norwegian currency (geometrical average weighed with the amount of import from our most important trade partners) A rise in the index is synonymous with a depreciating Norwegian currency (imports more expensive).

Laspeyres’<sup>15</sup> index formula is the basis behind the I-44. The formula is written;

$$V_t \equiv \sum_{i=1}^N \left( \frac{v_t^i}{v_0^i} \right)^{\alpha_0^i} \quad \forall t \quad [12]$$

Where  $v_0^i$  represents the base rate for currency  $i$ , while  $v_t^i$  is currency  $i$  level at time  $t$ , and lastly  $\alpha_0^i$  which is the given currency’ weight according to its import share.

---

<sup>15</sup> Laspeyres, Etienne (1834 – 1913) published an article in 1871 contemplating on the use of indexes. He presented the use of a weighted index. Formally he showed how an index changed when variables in the index changed;  $\frac{P_2}{P_1} = \sum \frac{p_2 x_1}{p_1 x_1}$  summed over prices  $n = 1$  to  $N$  where the  $x$ ’s are the period 1 quantity vector for goods 1 through  $N$ .

KKI<sup>16</sup>  $x_{13}$  is a nominal index based in real exchange rates computed on the basis of Norwegian NOK against the currencies to Norway's major trading partners. Until 1<sup>st</sup> of February it consisted of 18 countries, but since then it has been enlarged, and now comprise 25 of our most important trading partners. It's also based on Laspeyres' index formula, with a similar interpretation; a rise in the index is equivalent to a fall in the value of the Norwegian currency.

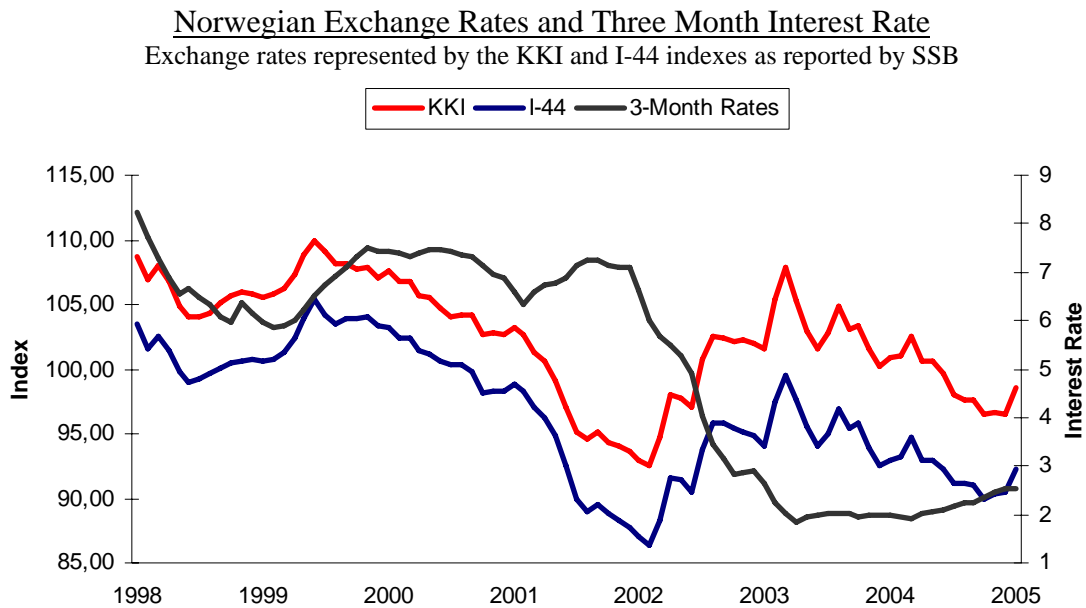


Figure XIV

Figure XIV depicts the movements in the Norwegian exchange rates from 1998 – 2005 (1997 = 100) along with the three month interest rate (right axis). Inverse scaling, where falling curves means a stronger NOK. A stronger currency seems to be leading a fall in the interest rates. If that's the case, we would expect a positive sign on the exchange rate index; a stronger NOK will lead to falling rates. But it's hard to conclude, since the interest could in fact lead the exchange rate turning the argumentation upside-down. Then we're back to the simultaneity model presented above. Bernhardsen and Bårdsen use foreign short term interest rates as a proxy for exchange rate movements. Both procedures will be explored in chapter three.

<sup>16</sup> Konkurranskursindex – Index for competitiveness

As mentioned above, we expect international interest rates for big economies to lead Norwegian rates. Figure XV plot US and Norwegian short term interest rates for the period 1995 to present. They correlate by no more than 0, 305. It could in fact be explained by the peculiar effects Norway has had since it's transformation to a petroleum economy. More likely, as figure XV suggest, that the US rate tends to lead the Norwegian to much for the correlation coefficient to catch the covariance between the two rates. Market analyst tracking interest movements in Norway does in fact talk about a decoupling of U.S. and Norwegian rates.

US and Norwegian Short Term Interest Rates

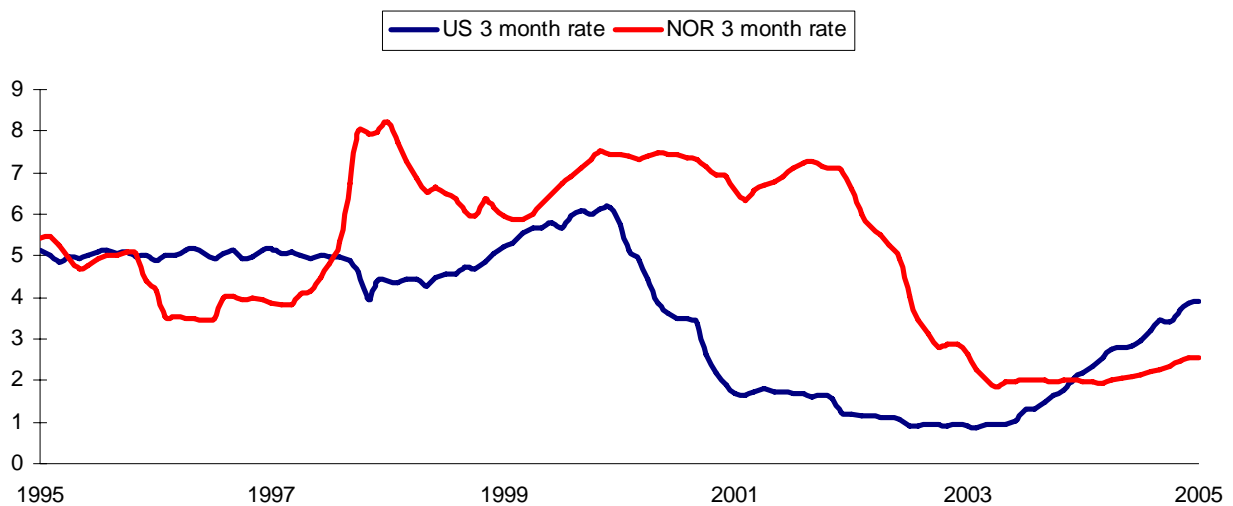


Figure XV

However, the two descriptive analyses do not yield a clear answer. Intuitively, one should expect US monetary policy to have a major effect on the global economy including the Norwegian. Assuming a positive coefficient in our estimates seems reasonable. We could also use the foreign interest (or the difference between equilibrium rates<sup>17</sup>) as an instrument for exchange rates, avoiding the simultaneous estimating problem mentioned above.

<sup>17</sup> Equilibrium rates might be calculated as an arithmetic average over the time series.

Using the same argumentation as above, it seems reasonable to include the European money market. In the period before the common EURO currency one could use the German rates as a proxy for Europe as a unity. Taken into consideration the relatively closeness and tight economic relationship with Europe one should expect to find somewhat higher correlation between Norwegian and European rates than for US rates. Computing the numbers gives us a surprisingly high correlation compared with the US 0,305 against 0,75 for Europe. Figure XVI seems to back this notion; rates following each other closely with an exception for the distinctive Norwegian increase seen in 1998 – 1999<sup>18</sup>.

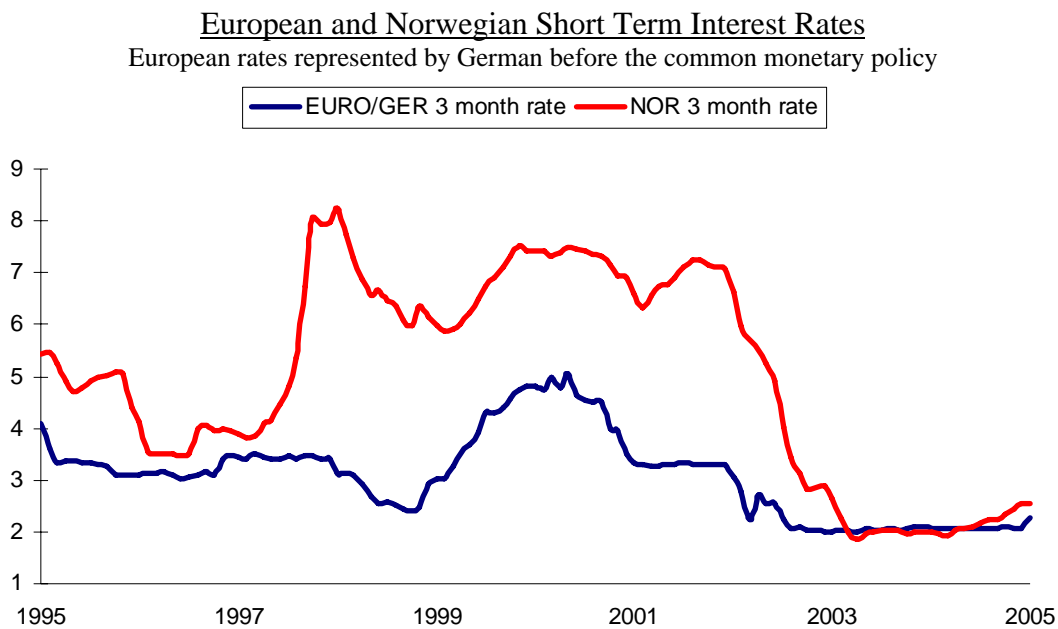


Figure XVI

Following Naug and Bernhardsen & Bårdsen one could use the S&P 500 as a proxy for international capital markets to estimate the simultaneous model as described above.

<sup>18</sup> Economic analyses have criticized the Central Bank for "out of phase" interest rate increases in this period, causing major loss of competitiveness'. On the other hand, this "punishment" for reckless wage increases has proved effective in the after match.



Extending the above discussion, it could also provide useful information about expectation for foreign interest rate movements, in particular the US rate.

The data material presented above may contain some weaknesses that violate the assumptions made prior to a time series regression analysis. First of all we assume that the model is linear in its parameters. Secondly, the expected value of the error  $u_t$ , given the explanatory variables for all time periods is zero, formally:  $E(u_t | X) = 0, t = 1, 2, \dots, n$ . Third, we assume no perfect collinearity, meaning that no independent variable is constant, or a perfect linear combination of the others. The fourth assumption regards homoskedasticity which requires the unobservable affecting interest rates have a constant variance over time. And last, there are made assumptions about no serial correlation (or autocorrelation) in the error term. Appendix three and four treat problems regarding autocorrelation and stationarity more thoroughly using different tests on susceptible time series, and shows how to correct.

### Chapter 3) Modelling

With reference to chapter two we should now be able to make an estimate on the model answering the poser presented in the introductory chapter; “what factors, and by what magnitude, affect the short term market interest?” Starting out with a simple level – level OLS analysis; hoping to keep the model as simple as possible.

#### Chapter 3.1) The Simple Level – Level model

The level – level model is on first difference to correct for non stationary time series (see appendix five for a more thorough discussion and testing). After a tedious process of testing different combinations of our model we report table III. Other specifications have also been tried out. The results of these exercises varied slightly, but the model seen in table III came out most plausible, based on sign, former studies as referred to in chapter two and significance. Others tested combinations did not yield economic or statistical significance. Based on our earlier discussion on fit and significance we report the results shown in table III.

**Table III; Simple Level – Level Model**

Interest Rate (First Difference)	Coefficient	Standard Error	t - value	P - value
Target Rate (First Difference)	0,63	0,11	6,12	0,000
Euro Rate (First Difference)	0,47	0,25	1,87	0,063
Budget Deficit	-0,003	0,0014	-2,10	0,037
Long Term Bond Rate	0,16	0,045	3,54	0,001
Investments (First Difference)	0,00005	0,000015	3,28	0,001
GDP – HP trend	0,00012	0,000022	5,61	0,000
House Prices	0,011	0,0025	4,13	0,000
Constant	-2,00	0,49	-4,09	0,000

The Huber – method shows no signs of non – ideal data, reporting the probability of  $F > 0$  in the range of 0 0002 with only four iterations. But it reports somewhat higher value to the target rate as an explanatory variable, increasing both the coefficient and  $t$ -value. A quantile method confirms the robustness of the model. Extending the quantile method with bootstrapping does not alter the conclusion (see appendix seven for details on robust regressions). Still, some changes to coefficients and  $t$ -value occur. All but the Euro rate are significant at the five percent level, yielding  $t$  values above the heuristic of  $>1,8$ . The model is also satisfactorily corrected for serial correlation, with a  $DW$  statistics well above 2. The complete model yields signs according to expectations. Somewhat surprising, house prices squared and cubed came out insignificant. When interpreting the results, one has to be aware of the first differentiated variables. If the target rate increases by a quarter from 2 % to 2, 25 % the model predict an increase in the three month rate *cet par* of 0, 1575 % (0, 63 × 0, 25). The model explain slightly more than 35 % of the variation in the time series according to an  $R_{adj}^2 = 0,3520$ . The figure below plots the model against the real time interest rate.

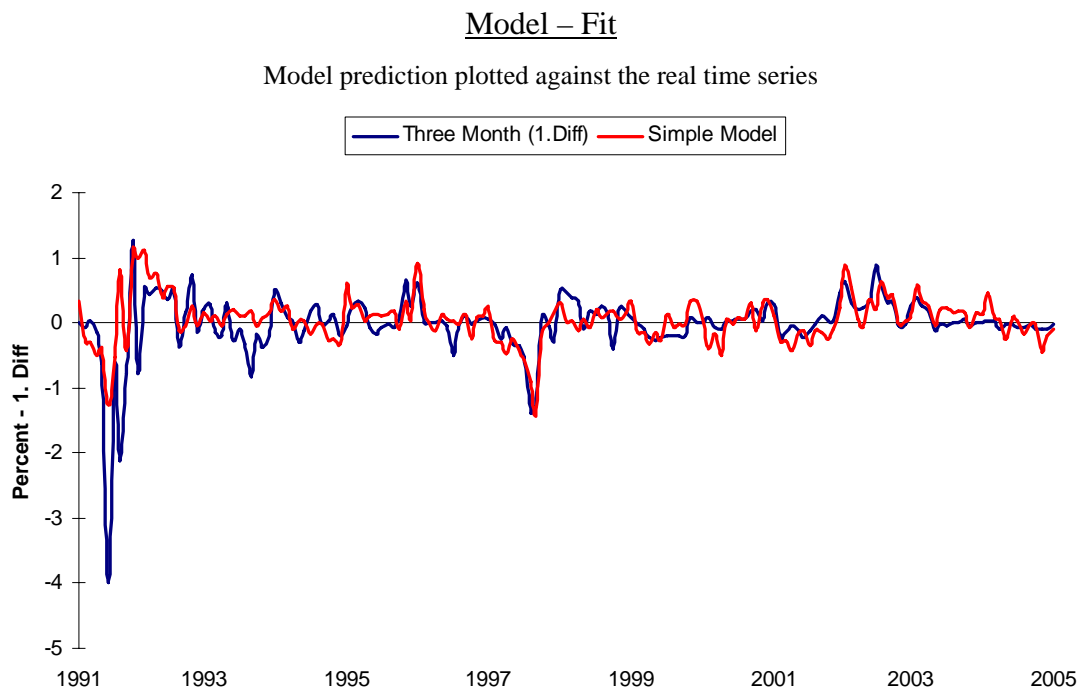


Figure XVII

The results from the model are somewhat hard to interpret. No systematic deviation seems to appear. However, the model tends to lag the real data. History may teach us why the model act as it does. The turbulence in the beginning of the nineties was mainly driven by (ir)rational speculation with the now infamous investor George Soros in the lead role; actually driving the whole exchange rate regime from a pegged ECU cooperation to a floating exchange rate regime. While the “Asia crisis” in 1997 / 1998 on the other hand affected the Norwegian economy through real factors more than the nominal,<sup>19</sup> and the model correctly predict lower rates. The period before 1999 was also a period where exchange rate volatility affected domestic target rates more profoundly than after, since the exchange rate value appeared directly in Norges Banks object function. This should affect market rates in the same direction. In the above model exchange rate movements are captured by the euro interest rate. This relationship is by no means perfect<sup>20</sup>, but a simple way to avoid some of the simultaneous problems elaborated upon in the preceding chapters. If the volatility from the ECU collapse in 1992 was caused mainly by speculation in exchange rates, a more explicit exchange rate model may do better in capturing nominal chocks.

### Chapter 3.2) Exchange Rate model

As stated in the previous chapter, a model leaving out the currency or nominal volatility is just capable of explaining “real” chocks. By expanding the model as presented in table III one could aim at a better fit, especially in the early period of the time series. Following a two-step procedure, we first, estimate the simple level – level model, with an index for the Norwegian exchange value as the right hand side as presented in Bernhardsen & Bårdsen<sup>21</sup>;

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<sup>19</sup> While the 1992 crisis was a speculative ”attack” on different currencies within the ECU co-operation, the Asia Crisis affected Norway mainly by hurting the export sector.

<sup>20</sup> Also note that the euro right hand side variable is not significant at the five percent level, as opposed to all the others.

<sup>21</sup> A comprehensive process of testing different combinations of variables gives [13] as the best fit, with a  $R_{adj}^2 = 0,2876$  and strong  $t$ - values: Note that this model is identical to the model as seen in both Bernhardsen & Bårdsen and Naug.

$$\log kki = \beta_0 + \beta_1 \text{oilprice} + \beta_2 \text{oilprice}(2.\text{lag}) + \beta_3 \text{SP-500} \quad [13]$$

The rationale is that the oil price will affect the Norwegian Krone while SP – 500 is a proxy for international stock markets (represented by the Standard and Poor 500 index). Predicting the model, and using the predicted values as a right-hand side in the original model from the above chapter yields;

$$Dy_t = \beta_0 + \beta_1 \text{tar} + \beta_2 \text{eur} + \beta_3 \text{Bud.Def} + \beta_4 10y + \beta_5 \text{Inv.} + \beta_6 \text{HP-GDP} + \beta_7 + \text{House} + \beta_8 \log(kki)^{\text{Pred}} \quad [14]$$

The new model as seen in [14] does (in a kind) adjust for exchange rate movements as a function of oil price and international stock markets. Still, it's a static model which doesn't account for the simultaneous interaction between the two variables. By doing this, one is aiming at a model as simple as possible without complicating unnecessarily.

The procedure success is measured in the difference between the new  $R_{\text{adj}}^2$  and the one from the simple model. One should expect the new model to be a closer fit especially in the 1991 / 1992 market volatility. Table IV summaries:

**Table IV; Exchange Rate Adjusted Model**

<b>Interest Rate (First Difference)</b>	<b>Coefficient</b>	<b>Standard Error</b>	<b>t - value</b>	<b>P - value</b>
<b>Target Rate (First Difference)</b>	0,699	0,114	6,14	0,000
<b>Euro Rate (First Difference)</b>	0,490	0,252	1,95	0,053
<b>Budget Deficit</b>	-0,0045	0,0021	-2,13	0,035
<b>Long Term Bond Rate</b>	0,179	0,048	3,68	0,000
<b>Investments (First Difference)</b>	0,000046	0,000015	3,10	0,002
<b>GDP – HP trend</b>	0,00013	0,000022	5,69	0,000
<b>House Prices</b>	0,011	0,0026	4,23	0,000
<b>Log kki (predicted)]</b>	3,50	3,39	1,03	0,304
<b>Constant</b>	-18,47	-15,97	-1,16	0,249

The entire robustness tests used here (Huber, Iteration and Iteration with bootstrapping) concludes that the OLS is in fact BLUE<sup>22</sup>. However, target rate and investments increases in importance as these robustness tests are done. All methods yield approximately same conclusions. Robustness models set aside; the new model has a slightly higher  $R_{adj}^2$  0,3542 – 0,3520 = 0,0022, and is satisfactorily corrected for auto correlation. But the bootstrapping reports a lower  $R_{adj}^2$  which might indicate some non-idealness in the data material. Still, a study of figure XVIII below reveals that the new model actually predicts the chock of 1991 / 1992 marginally better<sup>23</sup>. Even so, the results are disappointing in the

<sup>22</sup> With a slightly weaker (but not significant different from the “ideal” data) iteration robustness than the previous level – level model.

<sup>23</sup> To get a clearer picture one has to make a descriptive analysis of the raw data behind figure XXVI

sense that it does not provide us with a fundamentally better model. The model even seems to lag “real” shocks even more than the pure level – level model.

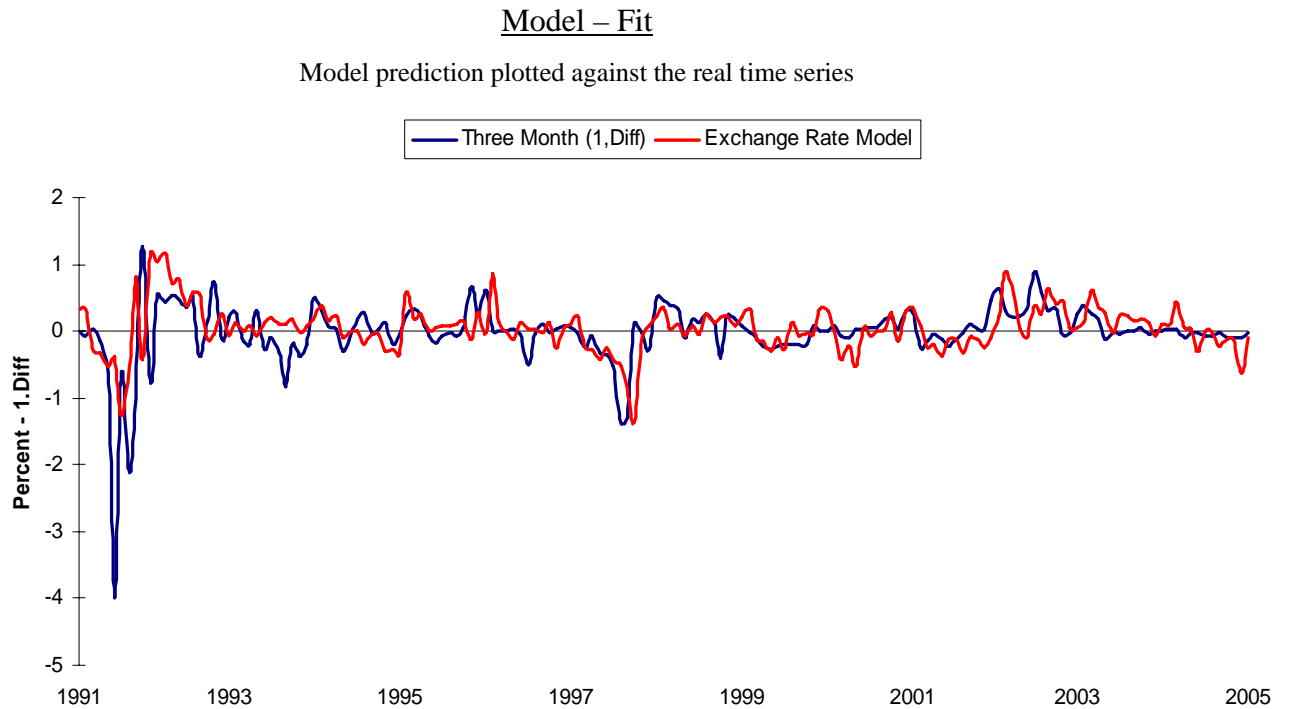


Figure XVIII

Remember how the data descriptive revealed several “demand / supply” relations. Various advanced econometrics textbooks (e.g. Gujarati, Wooldridge, Hamilton etc.) teaches us the heritage from Frisch on how to solve the simultaneous problem as elaborated upon in chapter 2.1 and appendix three. Expanding the model even further, taking into account the fact that these variables move together may yield a better fit.

### Chapter 3.3) Simultaneous regressed equations

Creating a four equation model yields;

Equation	Obs.	"R-sq"	chi2	P
Market Rate (1.Diff)	113	0,6664	228,49	0,0000
Target Rate	113	0,2618	52,31	0,0000
KKI (log)	113	0,5561	142,57	0,0000
House Price (index)	113	0,5640	151,15	0,0000

All equations are significant at the fourth decimal and yielding high  $R^2$  with an exception for the Taylor Rule which explains no more than 26 % of the variation in the data material. Several studies have expanded the Taylor Rule to better fit the actual central bank reaction function (see for example Fahre & Reme and Bernhardsen & Bårdsen).



**Table VI: Simultaneous Equation Model**

Three Month (1. Diff.)	Coeff.	Std.Err	Z	P > Z
Target Rate (1.Diff)	0,7753	0,0536	14,47	0,000
Euro Rate (1.Diff)	0,2129	0,1022	2,08	0,037
Constant	0,0017	0,0161	0,11	0,912
<b>Target Rate</b>				
Inflation Deviation	1,0218	0,1507	6,78	0,000
GDP – HP trend	-0,00027	0,000072	-3,74	0,000
Constant	5,25	0,1747	30,04	0,000
<b>KKI (log)</b>				
Dummy	-0,0173	0,0059	-2,91	0,004
Oilprice	-0,0003	0,0001	-3,19	0,000
S&P 500	0,0001	0,0000	11,34	0,000
Constant	4,4827	0,0139	321,69	0,000
<b>House Price (index)</b>				
Credit growth	-4,8063	0,6466	-7,43	0,000
Market Rate (1.diff)	15,0307	6,1454	2,45	0,014
OBX	0,4028	0,0357	11,25	0,000
Constant	73,9900	7,0093	10,56	0,000

Not surprisingly the model finds a significant relationship between the target rate and the three month market rate. The euro rate is also a significant explanatory variable. The U.S. rate did not yield any extra explanatory power to the model. This is consistent with the market view that the Norwegian short term rate is supposed to be decoupled from the U.S. rate (DN 22 / 9 – 06). At first glance, it could seem like a puzzle that the dummy did not yield significant results in the first equation. Earlier studies (e.g. Fahre & Reme) did not find support for the simple Taylor rule at all when explaining the central banks target rate. The simultaneous equation model on the contrary comes up with highly

significant coefficients. The reason may be that Fahre and Reme does not account for the simultaneous equilibrium in such markets. However, there is still a lot of unexplained variation in this equation. International factors represented by the KKI index made a huge contribution to the overall explanatory power of the model. Here the dummy comes out significant, predicting less coherence between exchange rates and interest rates in the period after Gjedrem took office. Implicating that the Central Bank monetary reign affect market rates through its object function. Oil prices and international capital markets affect interest rates through the exchange rate as Naug and Bernhardsen & Bårdsen predicted; both with the right sign. Investments surprised by not contribute to the model, but house prices made an important impact. The signs on the explanatory variables in the house index equation may seem peculiar at first glance. But they actually tell us something about the cycle house prices are at. When credit growth slows down, house prices are at its peak. When the interest rate difference is positive, that is this periods rate are higher than last period, meaning inclining rates, house prices are again at its peak. The OBX index tells us something about the “Animal Spirits” in the economy. As expected, the more positive, that is a higher OBX index, the higher house prices. Figure XIX depicts the simultaneous equation model and the actual three month rate at first difference.

## Model – Fit

Model prediction plotted against the real time series

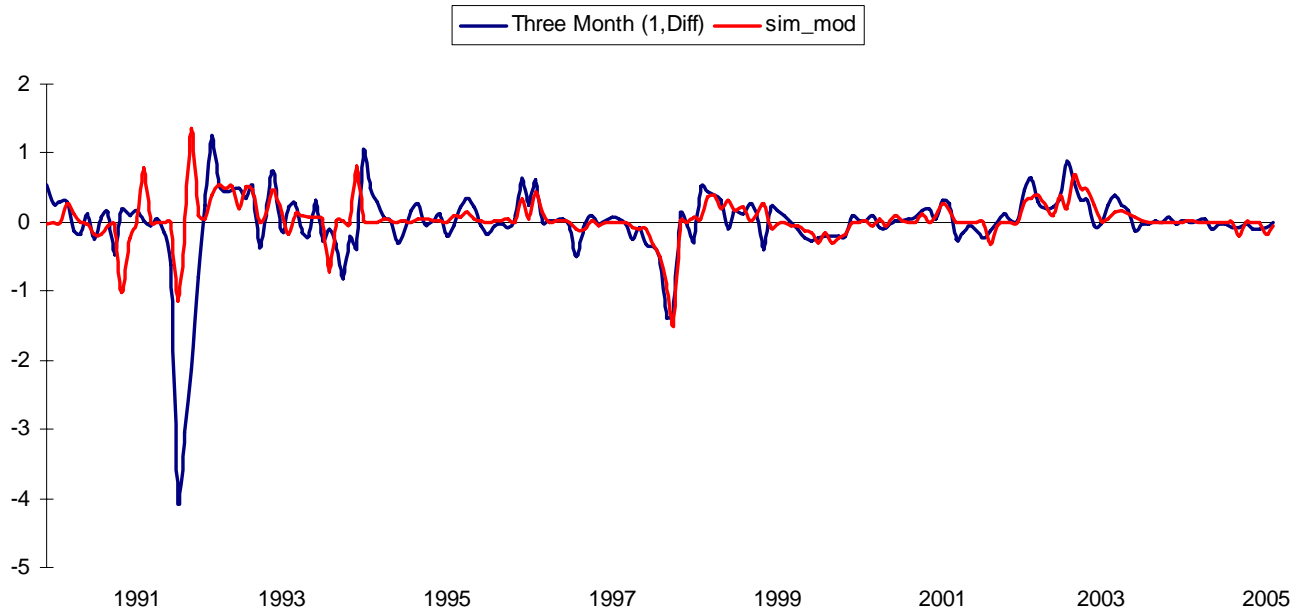


Figure XIX

A study of the predicted model reveal a far better fit than the two preceding ones. But the market volatility in the early 1990s is still not captured. However, if pressure had accumulated during a non sustainable pegged European exchange rate cooperation which suddenly “exploded” in 1992; it would be hard, if not impossible to find a model to actually predict such violent shifts. The market was also marginalized during the fixed exchange regime. Concentrating at the time series in later periods should yield more fertile information. Common features in the two previous models were their innate and notoriously late predictions. The predicted value always lagged the actual results. The simultaneous equation model is far better at synchronous predictions. However, it misses some of the volatility during the 1990s and never reaches the peaks and bottoms (with an exception for the real chock of 1997). This might be to the fact that market tend to “overshoot” its reactions in the exchange rate and interest rate market (see e.g. Burda & Wyplosz 2001 and Dedekam Jr. 1999)

## **Chapter 4) Concluding Remarks**

This paper addressed the apparent risk premium which is consisted with the normally upward sloping term structure in the market for interest rates. The question posed was; “which factors, and by what magnitude could explain this divergence between target rates and market rates?” The literature poses different qualified guesses and some isolated studies, but none to my knowledge have tried to estimate the overall premium. A descriptive and two quantitative models highlighted the importance of the simultaneous interaction among the different explanatory variables. Taking the step towards a full blown simultaneous equation model seems to have mended, at least some, of the problems faced with the “supply / demand” problem.

The simultaneous equation model gives us a better understanding of the interaction among economic aggregates and helps explain why market rates diverge from the target rate to the extent that they do. Most of all, the model teaches us how globalized capital markets are a major force in deciding domestic rates. As opposed to what e.g. Hur finds in his study<sup>24</sup>. The “collapse” of the simultaneous equation model when leaving out international factors is proof of its importance. But this is not to say that international factors are the sole explanatory variable. A significant dummy variable taken together with figure I tell us that the monetary regime is important. However the dummy did not yield a significant coefficient before it was incorporated into the KKI equation; further substantiating the importance of international factors. In all other combinations it proved insignificant; suggesting that our monetary policy have to follow trading partners’ monetary reign. Even so, the house price index (which might be interpreted as a proxy for overall domestic economic conditions) does create a space for sole home market considerations. Taking Great Britain as a similar example might support this view. In the early period of this millennium they aggressively raised interest rates to puncture a domestic housing bubble where market rates followed promptly. In this period they were far out of phase with important trading partners (EU and US). Still they felt obliged to increase rates to avoid a wider economic recession from financial turbulence. The short story is thus; international factors drive the national interest rates, but exceptional

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<sup>24</sup> Hur finds that globalized capital and interest rate markets only affect countries with pegged currencies.

conditions may temporarily allow for domestic independence. By this I hope to have paved the road towards more research on interest rates.

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## **Appendix One**

### Role of the financial system and interest rates

Interest rates are defined within a financial system, which are no more than a market place for agents with different needs. To understand interest rates, one should know something about this marketplace. A more formal definition of a financial system provided by Bain & Howells (2005)

*“a financial system is a set of markets for financial instruments, and the individuals and institutions who trade in those markets with the regulators and supervisors of the system”*

The users of the system are people, firms and other organizations who wish to make use of the facilities offered by a financial system. The facilities offered may be summarized as;

- Intermediation between surplus and deficit units
- Financial services as insurance and pensions
- A payments mechanism
- Portfolio adjustments facilities

Even though different branches of the industry specialize in one or more of the above mentioned functions, they have one thing in common. All have the effect of channeling funds from those who have a surplus to those who have a deficit. In developed economies end users can be facilitated by intermediate *market makers* to smooth capital flows. Developed capital markets are characterized by high income pr. capita<sup>25</sup>, often higher than required for current consumption. The difference between income and consumption is called saving. In these economies aggregate saving is positive. A further characteristic for these economies is the level of capital intensity. A capital intensive economy requires borrowing to finance present disbursement in real capital, a transition referred to as investments. However, many people will be saving at a level which exceeds their real

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<sup>25</sup> Relatively to world average.

investment spending. Indeed this is generally true for households whose needs and opportunities for real investments are limited. Thus, many household saves without undertaking any real investment. The difference between saving and real investment is their financial surplus. This surplus is available for lending and gives rise to net acquisition of financial assets (NAFA). The distinction between saving and lending affects available capital, thus the price of capital – the interest rate. Equation [1] sums up;

$$(Y - C) - I = NAFA \quad [A1-1]$$

$Y$  represents income,  $C$  current consumption and  $I$  investments in physical capital which equalize the net acquisition of financial assets.

What conditions has to be met for those with a surplus to be willing to lend to those with a deficit? As a general principle we might say that lenders target maximum return for minimum risk. Further, we assume that lenders have a positive attitude towards liquidity. Return on financial assets may take one or a number of forms. As a general rule, all returns are risk adjusted prices for delayed consumption. As [1] states,  $Y > C$  means literally saving, or delayed consumption. Risk on the other hand is deviations from the expected future outcome. Last, *cet par*, lenders prefer the opportunities which offer the greatest liquidity.

Contra entries are those who need to borrow, whose income are not sufficient to meet current spending plans. Usually company's planning to invest in real capital, but also agents borrow to increase their risk profile. In the aggregate borrowing and lending must sum to zero.

The role of the financial system is to provide a market place where economic agents with different saving and investment needs meet. As these markets have developed through time, diversity and complexity of products has increased. As we shall see, for a simple concept as interest rates there exists a great many different variations.

Most commonly known rates for everyone are commercial banks funding- and interest rates. The difference between these is called the interest margin, which covers expenses and provide yields to banks shareholders. Secondly, the differential reflects some of the risk the bank imposes by engaging itself in the business of lending. Some contracts are more risky than others, and it should not be surprising that interest rates vary; the higher the risk, the higher the interest rate. The low end benchmark in this market is governmental loan. Lenders ability to write new taxes makes these less volatile than its counterparts. Lending is also made for shorter and longer periods. Longer maturity loan separates into fixed and floating interest rates. Bank deposits are used to lending, but a bank cannot expect balance between deposits and loan and has to turn to the money market to cover eventual imbalances. The interest margin in this market is referred to as the “bid-ask-spread.” Activity in the money market has to be in the same currency, so there is a money market for each currency. Money market for the Norwegian Kroner is named Norwegian Interbank Offer Rate, or just NIBOR. The money market for each currency is divided into several maturities, known as terms. A typical structure is as seen in table A1-1 below;

<b>Table A1-1</b>		
<b>Time structure in the money market</b>		
• <b>Over Night</b>	- (abbreviation; <b>O/N</b> )	• <b>2 Month</b>
• <b>TOM/Next</b>	- (abbreviation; <b>T/N</b> )	• <b>3 Month</b>
• <b>1 Week</b>		• <b>6 Month</b>
• <b>2 Week</b>		• <b>9 Month</b>
• <b>1 Month</b>		• <b>12 Month</b>

One does not pay principal in the money market, but both interest rates and the face value is repaid when the contract expires. Interest rates are agreed on up front. The most commonly used rate for this purpose is the three month, and are representative for the short term interest rates in most money markets, including the Norwegian.

### Norwegian Money Market Rates

As announced 22.march 2006

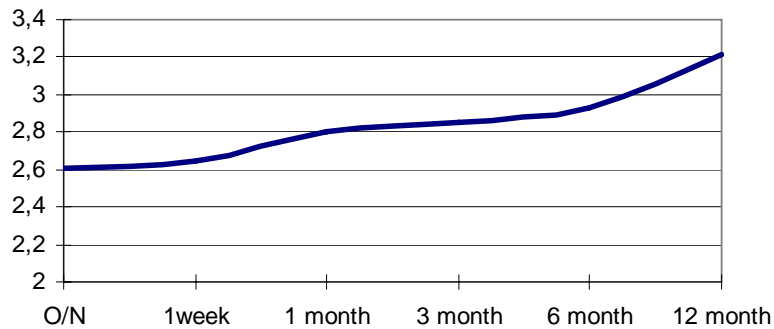


Figure A1-1

Plotting the different short term interest rates gives an indication of the markets future expectation. As figure A1-1 clearly states, the market expect future interest rates to rise. Why is this? To give an explanation we have to incorporate a closely related market, namely the Forward Rate Agreement (FRA-market). Together with the money market there is a market for interest rate derivatives, which is different contracts regulating risk concerning future volatility. A FRA-contract obliges the buyer to enter into the FRA-contract in the future. Seller is bound to render. FRA-contracts transfers risk from those who do not want to be exposed, to more risk willing agents.

## Norwegian Forward Rates

As announced 22.march 2006

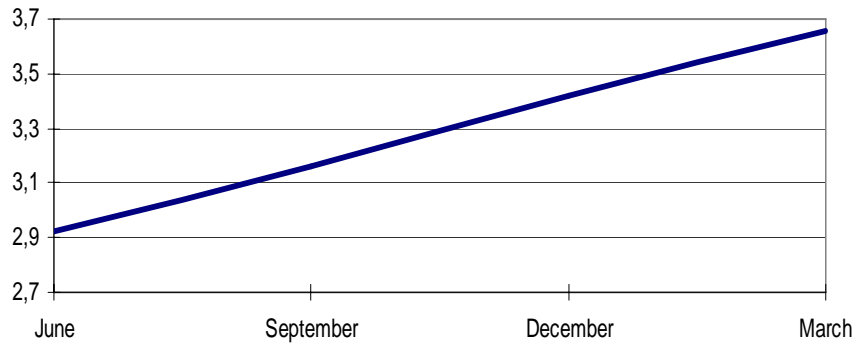


Figure A2-2

Contracts in the FRA-market are traded in three, six or twelve month contracts respectively; three months having the highest turn-over. Figure III depicts the FRA-market at the same day as the money market. Both the money- and the FRA-market are highly competitive, which makes them similar in structure. Assume that a bank needs a nine month funding in the money market. Further, the bank does not want any interest rate volatility during the specified period. An obvious candidate for this investment is to engage into a nine-month money market loan  $f_n$ . An alternative would be to buy a six month money market loan  $y_{n-1}$  and at the same time enter into a three month FRA running in six months  $y_n$ .

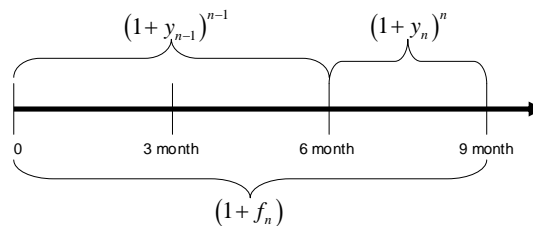


Figure A1-3

Figure A1-3 schedules the two alternatives. Since all agents in the same situation would choose the most propitious solution, market forces would eliminate arbitrage, leading to<sup>26</sup>;

<sup>26</sup> Note; eq. 2 is somewhat simple. First, one has not taken into consideration compounded interest. Secondly one should also make corrections for “bid-ask-spread” in this market.

$$(1 + y_n)^n = (1 + y_{n-1})^{n-1} (1 + f_n) \quad [\text{A1-2}]$$

As already mentioned, we could interpret the money- and the FRA-markets as a collective guess on future interest rates. Assume today's expectations are higher than future rates; agents could then make money by enter into contracts, and lending out on future rates today making money. Since arbitrage is not possible in a perfect market the forward rate equals the market consensus expectation of future short term interest rate; in other words  $f_n = E(r_n)$  and liquidity premiums is zero. Because  $f_n = E(r_n)$  we may relate yields on long term bonds to expectations of future interest rates. In addition, we can use the forward rates derived from the yield curve to infer market expectations of future rates<sup>27</sup>. For example; from eq. [A1-2] we may also write  $(1 + y_n)^n = (1 + y_{n-1})^{n-1} (1 + E[r_n])$  if the expectation hypothesis is correct. An upward sloping curve would be clear evidence that investors anticipate increases in interest rates.

Defenders of the liquidity premium hypothesis would say that there are scarcity on long-term bonds unless the forward rate exceeds short interest rate,  $f_2 > E[r_2]$ , whereas long-term investors will be unwilling to hold short bond unless  $E[r_2] > f_2$ . In other words, both groups of investors require a premium to induce them to hold bonds with maturities different from their investment horizon. Advocates of the liquidity preference theory assume that short-term investors dominate the market, generally speaking, the forward rate exceed the expected short rate. The excess of  $f_2$  over  $E[r_2]$ , the liquidity premium, is predicted to be positive. This implies that both curves slopes are steeper than the pure expectation hypothesis suggests.

Institutional factors in the bond market, as regulations and behavioral restrictions induce the borrowers and lenders to operate within certain intervals of possible maturities,

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<sup>27</sup> By a procedure known as Bootstrapping. See Bodie et al. (2003) for a more thoroughly explanation of Bootstrapping

creating market rates in each of these restricted segments. The interest rates are thus decided upon market clearing in different segments. A change in the relative supply in certain intervals will affect the rate structure.

### Time Structure in the Money Market

Liquidity Preference Hypothesis

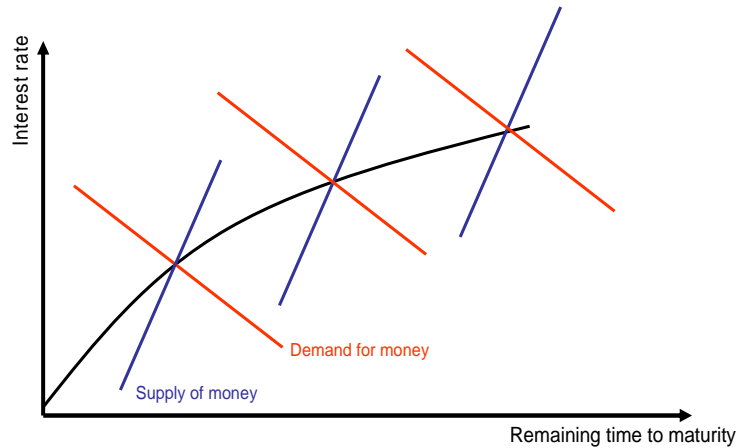


Figure A1-4

The expectation hypothesis stated that today's rates in the money- and FRA-market are the collective anticipation of future rates. While the liquidity preference theory highlighted the fact that a falling FRA-rate would surely indicate lower future interest rates. Figure A1-5 shows the calculated difference between the long term rate (yield on the ten-year governmental bond) and short term rates (three month effective rate in the money market). The transparent red-colored squares emphasize falling GDP in the Norwegian mainland economy.



## Difference Between Long and Short Interest rates

Positive numbers indicates backwardation, while negative numbers contango

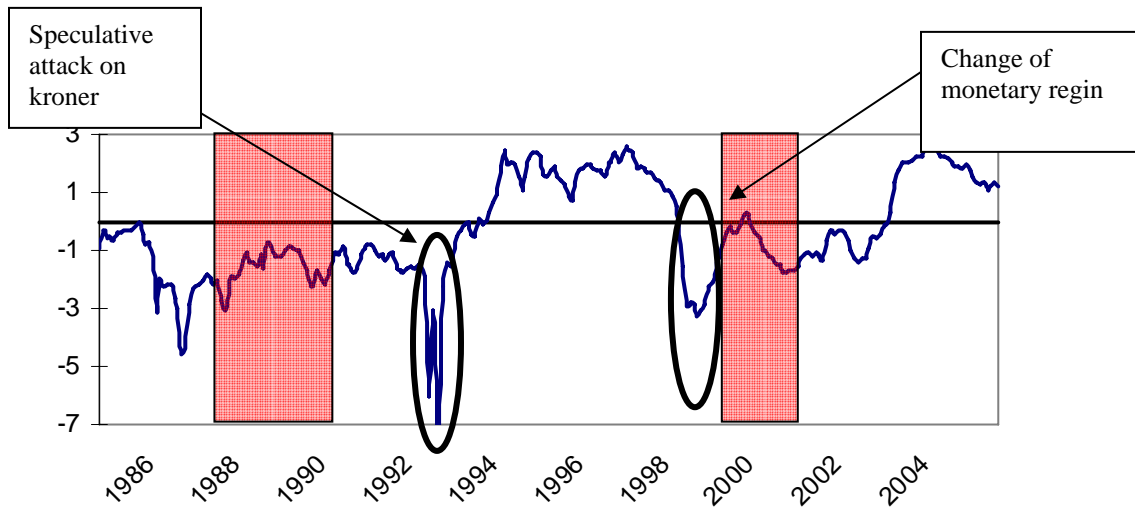


Figure A1-5

If long term rates are less than short term, that is a negative difference in figure A1-5, one should expect future rates to fall. No agent would enter into short and uncertain contracts if cheap safe long were available. Falling rates indicates an economy in decline. Figure A1-5 support the notion that contango<sup>28</sup> is a leading indicator of GDP numbers; anticipating the bank-crisis in the late eighties and the dot.com bubble. However, the speculative attack in 1992 stands out as a unique occurrence with no obvious economic character. Still, interest rates are important for the real economy. Basic Keynesian economics teaches us how interest rates affect economic behavior; figure A1-5 seems to substantiate the argument.

### Role of the Central Bank

Combination of risk premiums, expectations and institutional segmentation shapes the money market curve. So far, so good; but what determine the level of the curve? The Central Bank can, through market operations, decide one point on the curve, but are in no position to decide upon the general interest rate level as some may think. The Norwegian

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<sup>28</sup> Long rates lower than short rates

Central Bank, as most others<sup>29</sup>, is targeting the shortest rate in the market, namely the overnight-rate. Market rates would then track above the overnight-rate. Regulating the interest paid in the NIBOR market, commercial banks can place their surplus liquidity at interest bearing rates determined by the Central Bank. Since no bank would place money at lower rates, the *folio* (deposit rate) form the floor, while its *dagslånsrente* (overnight) the roof. The difference between these two is 200<sup>30</sup> basis points. At the same time, the bank regulates the liquidity to hold the overnight rate as close to the folio as possible. Figure A1-6 illustrates;

### Norwegian Central Bank Interest Rates

Floor and roof in the money market is decided by the central bank. Money market operations is done b y regulating the overnight interbank rate.

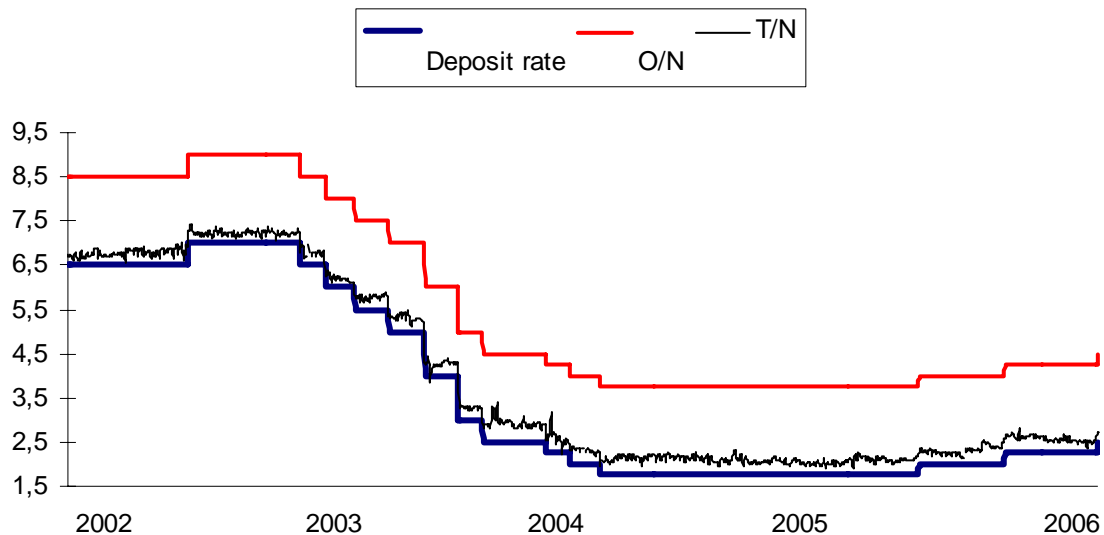


Figure A1-6

Regulating the lower bound in the NIBOR market is not the only effect the central bank has on money market rates. Signaling its future moves has a more indirect effect, which stems from the markets ability to foresee how the central bank interprets its target function. In an ideal market, there should be no market stir after the bank announces a change in the target rate. As the introduction stated, this is not the case in real life.

<sup>29</sup> Except the Swiss Central Bank, which aim at the three-month rate

<sup>30</sup> Two percent

However, plotting the nominal and real rate from 1979 to present shows how yield requirements (id.est the compensation investors demand to invest in various projects) have been falling as the nominal “tax” has been reduced.

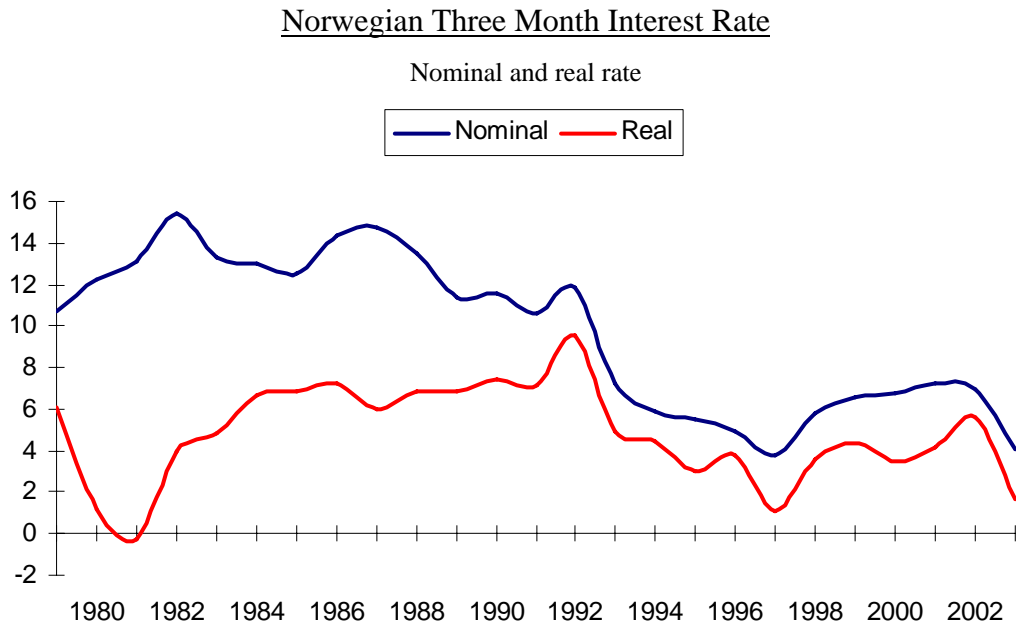


Figure A1-7

As argued, the central bank is an important actor in the financial market, deciding the level, affecting the expectations and influence premiums investors demand in the money market. Could we measure this importance? Table II gives an impression of how closely different instruments in the money market follows each other.

<b>Table A1-2</b>				
<b>Correlation coefficients</b>				
	<b>Target Rate</b>	<b>O/N</b>	<b>3 Month</b>	<b>12 Month</b>
<b>Target Rate</b>	<b>1</b>			
<b>O/N</b>	<b>0,804219</b> (60,3)	<b>1</b>		
<b>3 Month</b>	<b>0,933561</b> (43,11)	<b>0,870408</b> (52,95)	<b>1</b>	
<b>12 Month</b>	<b>0,936647</b> (36,60)	<b>0,804074</b> (51,0)	<b>0,97384</b> (116,94)	<b>1</b>

Correlation coefficients in the area of 0,9 are extremely high, but correlation, of course is not causation. Even so, the close relationship should not come as a surprise if we believe in equation [A1-2]. As we stated in the beginning, the money market (and the FRA-market) are highly co-integrated. We also saw how the central banks target determined the level; with respect to table A1-2 one could argue that the risk premium has been fairly constant, tracking the target closely.

## ***Appendix Two***

### Seasonally Adjusting Time Series

Quarterly time series of this type should be seasonally adjusted. From the fact that a series consist of a trend ( $L$ ), a seasonally- ( $S$ ), a cyclical- ( $C$ ) and an irregular component ( $I$ ) we're able to isolate both  $I$  and  $S$ . (Pindyck & Rubinfeld 2001) The first step in this procedure is to calculate a moving average ( $MA$ ) of fourth grade<sup>31</sup>;

$$y_t^{MA} = \frac{1}{4}(y_{t-2} + y_{t-1} + y_t + y_{t+1})$$

Isolating  $L$  and  $C$

$$\frac{y_t}{y_t^{MA}} = \frac{(L \times S \times C \times I)}{(L \times C)} = S \times I \equiv z_t$$

By taking the average of every identical quarter we obtain

$$\begin{aligned} z_{1\text{quarter}} &= (\text{Year}_{t-n} : \text{Q1} + \text{Year}_t : \text{Q1} + \dots + \text{Year}_n : \text{Q1}) \\ &= \frac{1}{n}(z_{t-n} + \dots + z_t + \dots + z_n) \\ z_Q &= \frac{1}{n}(z_t + z_{t+3} + z_{t+7} + \dots) \end{aligned} \quad [\text{A2-1}]$$

The expression in [A2-1] represents the quarterly factor which is used in adjusting every observation for its seasonally distinctive characteristic. Doing this procedure on the data for seasonally adjusted GDP figures gives factors all close to one<sup>32</sup>. On the other hand, unadjusted investments figures have larger factors which state the importance of seasonally adjusting figures before use in econometric models.

## **Appendix Three**

### Simultaneity

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<sup>31</sup> Because we're working with quarterly data

<sup>32</sup> The factors are; 1) 1,05 2) 1,03, 3) 0,99 and 4) 1,01

As stated in the introduction and highlighted in the data discussion; we're facing a common supply – demand relationship between several of the variables in question. Using an ordinary least square method could then lead to biased and inconsistent results. In this context it's useful to incorporate some new terminology. Consider the following three-equation supply-demand model;

$$\text{Supply:} \quad \hat{y}^S = \alpha_1 + \alpha_2 X_t + \alpha_3 X_{t-1} + \varepsilon_t \quad [\text{A3-1}]$$

$$\text{Demand:} \quad \hat{y}^D = \beta_1 + \beta_2 X_t + \beta_3 Q_t + u_t \quad [\text{A3-2}]$$

$$\text{Eq.:} \quad \hat{y}^S = \hat{y}^D \quad [\text{A3-3}]$$

In the model, we're referring to  $\hat{y}^S$ ,  $\hat{y}^D$  and  $X_t$  as endogenous variables, determined within the system of equations. The model also contains two variables that are not determined directly within the system. These so-called predetermined variables help cause the movement of the endogenous variables within the system.  $X_{t-1}$  and  $Q_t$  are both predetermined variables in the model. However, there are big differences between the two predetermined variables. The first variable  $X_{t-1}$  is in fact determined within the system – by past values of the variables. Thus, lagged endogenous variables are predetermined variables. Finally, the variable  $Q_t$  is determined completely outside the model system and is called an exogenous variable. Graphically we could illustrate the endogeneity as;

### Illustration of endogeneity problem

Supply and demand is interdependent. The shape of the supply curve could be drawn from different demand equations and vice versa

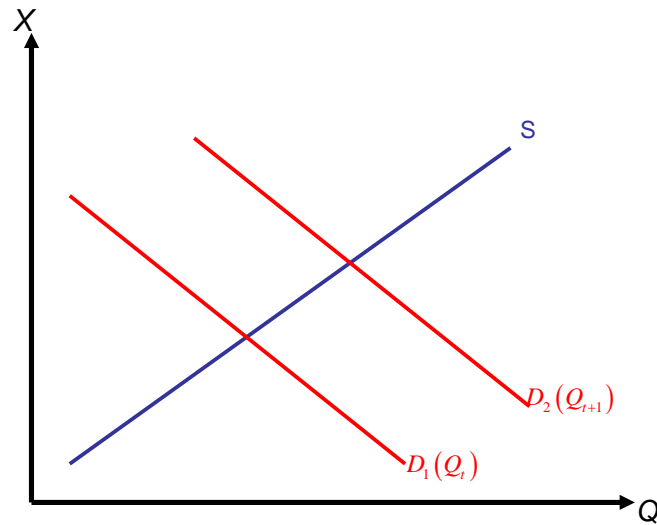


Figure A3-I

In time period  $t$  we have an equilibrium at the intersection between  $S$  and  $D_1(Q_t)$ . Assume now that  $Q_{t+1} > Q_t$  which implies a shift in the demand curve. Since both  $X$  and  $Q$  are endogenous, applying ordinary least square will generate biased and inconsistent estimators. See Gujarati (2003) for a more thoroughly discussion.

## **Appendix Four**

### Serial Correlation

Running a regression analysis on time series we assume that the dependent variable is not serial correlated. Formally, we may write this assumption as;

$$\text{corr}(u_t, u_{t-1}) = 0 \quad \forall t \quad [\text{A4-1}]$$

This means that, if interest rates are unexpectedly high for a specified period, they are likely to be above average also for the next period. Importantly, [A4-1] says nothing about the dependent variables. For example; inflation is almost certainly correlated across time, but this does not violate the assumptions elaborated on above.

Since the Gauss-Markov Theorem<sup>33</sup> requires both homoskedasticity and serially uncorrelated errors, the ordinary least square is no longer the best linear unbiased estimates<sup>34</sup> if autocorrelation is present. Testing for AR (1) autocorrelation using the Durbin Watson test.

We have;

$$DW = \frac{\sum_{t=2}^n (\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^n \hat{u}_t^2} \quad [\text{A4-2}]$$

Simple algebra<sup>35</sup> yields

$$DW \approx 2(1 - \rho) \quad [\text{A4-3}]$$

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<sup>33</sup> See Wooldridge 10.4 for details.

<sup>34</sup> We say; OLS is not BLUE – Ordinary Least Square is not the Best Linear Unbiased Estimate.

<sup>35</sup>  $DW = \frac{\sum (\hat{u}_t - \hat{u}_{t-1})^2}{\sum \hat{u}_t^2} = \frac{\sum \hat{u}_t^2 + \sum \hat{u}_{t-1}^2 - 2 \sum \hat{u}_t \times \hat{u}_{t-1}}{\sum \hat{u}_t^2}$ , defining  $\frac{\sum \hat{u}_{t-1}^2}{\sum \hat{u}_t^2} \approx \frac{\sum \hat{u}_t^2}{\sum \hat{u}_t^2} \cong 1$  and

$\frac{\sum \hat{u}_t \times \hat{u}_{t-1}}{\sum \hat{u}_t^2} \equiv \rho$  yields  $DW = d = 1 + 1 - 2\rho \Rightarrow 2(1 - \rho)$ . Defining  $(1 - \rho) \equiv \theta$



We're testing

$$H_A : \rho > 0 \quad [A4-4]$$

From the approximation in [A4-3],  $\hat{\rho} \approx 0$  implies that  $DW \approx 2$  and  $\hat{\rho} > 0$  implies that  $DW < 2$ . Note how we must compare the  $DW$  with two sets of critical values,  $d_u$  (for upper) and  $d_l$  (for lower). If  $d_l \leq DW \leq d_u$  the test is inconclusive. STATA report these boundaries automatically when performing a Durbin Watson test.

The DW statistic for an example regression with dependent variable three month interest rate against the target rate, oil price lagged three periods, euro rates and investment yields<sup>36</sup>;

<b>Table A4-1</b>		
Dependent variable; Three month interest rate at a level – level analysis		
Var.	Coefficient Estimate	t-values
Target Rate	0,857	39,10
Oil Price (L.3)	-0,003	-4,81
Euro Rate	0,409	8,30
Investments	0,000014	1,76

Table A4 - 1 report:  $R^2_{ADJ} = 0,9926$  and a Durbin-Watson statistic  $(5, 73) = 0,774$ . As a rule of thumb, we say that a DW statistics lower than two implies positive serial correlation. Interest rates are therefore highly serial correlated. We're correcting for this

<sup>36</sup> Note; Investments are statistically significant when the model is regressed on same period oil price.

using either the Cochrane-Orcutt method<sup>37</sup> or the Prais-Winston to correct. Table A4 - 2 reports the Prais-Winston results;

<b>Table A4-2</b>		
<b>Dependent variable; Three month interest rate with an <i>prais</i> analysis</b>		
<b>Var.</b>	<b>Coefficient Estimate</b>	<b>t-values</b>
<b>Target Rate</b>	<b>0,853</b>	<b>18,78</b>
<b>Oil Price (L.3)</b>	<b>-0,0005</b>	<b>-0,76</b>
<b>Euro Rate</b>	<b>0,334</b>	<b>3,76</b>
<b>Investments</b>	<b>0,000014</b>	<b>2,10</b>

Table A4-2 report  $R_{ADJ}^2 = 0,916$  and a DW-statistics  $I, 93$  still not within the conclusive range but far better than the results seen in table V. All variables are less significant than table A4-1, note especially that oil price are no longer significant while investment now are. The models explanatory power is also reduced. This example highlights the importance of correcting for autocorrelation.

Suspecting autocorrelation of higher order we're correcting following the procedure of Wooldridge.

## ***Appendix Five***

### Stationarity

<sup>37</sup> See Wooldridge page 404 →

A stationary time series process is one whose probability distributions are stable over time in the following sense: if we take any collection of random variables in the sequence and then shift that sequence ahead  $h$  time periods, the joint probability distribution must remain unchanged<sup>38</sup>. An example would be a process as written in [A5-1]

$$y_t = \alpha + \rho_1 y_{t-1} + e_t \quad , \quad t = 1, 2, \dots \quad \text{[A5-1]}$$

The crucial assumption for weak dependence of an AR (1) process is the stability condition  $|\rho_1| < 1$ . Then we say that  $y_t$  is a stable process. Unfortunately, many economic time series are thought to have  $\rho_1 = 1$ , saying it's strongly dependent. Such a process is called a random walk. If  $\alpha > 0$  we say that the time series has drift. A series generally thought to be well-characterized by a random walk without drift is in fact the three month interest rate. Taking the first difference, by subtracting  $y_{t-1}$  on both sides and defining  $\theta = 1 - \rho$  gives [A5-2]. This usually sorts out the problem, with non stationary time series, avoiding the regression results becoming spurious.

$$\Delta y_t = \alpha + \theta y_{t-1} + e_t \quad \text{[A5-2]}$$

Then we're testing  $H_1 : \theta = 0$  against  $H_A : \theta < 0$ . The problem is that standard normal distribution does not apply. Using critical values as formulated by Dickey and Fuller<sup>39</sup> (1979) is necessary. Testing for unit root in the susceptible time series, using the Dickey Fuller test yields;

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<sup>38</sup> Formally; The stochastic process  $(x_t : t = 1, 2, \dots)$  is stationary if for every collection of time indices

$1 \leq t_1 \leq t_2 \leq \dots \leq t_m$ , the joint distribution of  $(x_{t_1}, x_{t_2}, \dots, x_{t_m})$  is the same distribution of

$(x_{t_1+h}, x_{t_2+h}, \dots, x_{t_m+h})$  for all integers  $h \geq 1$

<sup>39</sup> Critical value for different significance levels varies according to the specific time series.

**Table A5-1**  
**Dickey-Fuller test for unit root**

Var.	Number of observations	Test Statistic	Coeff. Estimate	5% Critical Value	MacKinnon approximate p-value
Short Term Interest Rate	328	-2.617	-0,05	-3.427	0.2723
Investments	192	-6.867	-0.39	-3.438	0.0000
Oil Price	72	-2.227	-0,17	-3.478	0.4748
Money Growth	143	-4,095	-0,22	-3,444	0,0064
Credit Growth	227	1,139	0,01	-3,433	1,0000
Inflation, monthly	251	-14,034	-0,884	-3,430	0,0000
Inflation, yearly	311	-2,475	-0,04	-3,428	0,3403

Table A5-1 clarifies the suspicion that was raised during the descriptive plot analysis. Investments, money growth and monthly inflation do not follow a unit root while the rest are. Taking the first difference on the rest of the time series might help alleviate the problem. The same results yields for the natural logarithm to the short term interest rate. As table A5-2 depicts, the procedure has made all non-stationary series stationary.

**Table A5-2**  
**Dickey-Fuller test for unit root (first difference)**

Var.	Number of observations	Test Statistic	Coeff. Estimate	5% Critical Value	MacKinnon approximate p-value
Short Term Interest Rate	327	-16,53	-0,92	-3,427	0,0000
Oil Price	71	-16,536	-0,11	-3,479	0,0000
Credit Growth	226	-12,997	0,07	-3,433	0,0000
Inflation, yearly	310	-17,035	-0,98	-3,428	0,0000

With regard to above discussion one should proceed with the series from table A5-2 in the estimation procedure.

## Appendix Six

### Estimating

Using the knowledge from the variables and the interest market clearing as theory predicts we now need to choose an appropriate model specification. The ordinary level-level model seen in table III and IV assumed a linear relationship between the dependent and independent variable. More realistically, interest rates affect economic variables different dependent on the absolute size of the variables. Consider an interest rate increase from two to four percent, a 100% increase while the difference between 10 to 12 percent just computes to a 20% increase. It seems reasonable that such changes may affect other variables in a non-linear matter. Fortunately, it's rather easy to incorporate many non-linearities into simple regression analysis by appropriately defining the dependent and independent variables. A model that gives approximately a constant percentage effect is;

$$\log(y) = \alpha + \beta_n \log(x_n) + u \quad [\text{A6-1}]$$

By taking logs on both sides of [A6-1] we obtain the constant elasticity model. Testing for linearity or to capture a decreasing / increasing marginal effect one have to use a model of higher orders as shown in [A6-2]<sup>40</sup>

$$\hat{y} = \alpha + \beta_1 x_1 + \beta_2 x_1^2 + \beta_3 x_1^3 + u \quad [\text{A6-2}]$$

These transformations do not alter the assumption regarding linearity in the parameters. The key is that the equation is still linear in the parameters  $\beta_1$  and  $\beta_2$ . There are no restrictions on how  $y$  and  $x$  relates to the original and explanatory variables of interest. We're just altering the variables according to a supposedly more correct model

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<sup>40</sup> Note that a *cet par* analysis does not make sense in [24]. We may write  $\frac{\Delta y}{\Delta x} \approx \beta_1 + 2\beta_2 x$  (from the first order condition). This says that the slope of the relationship between  $x$  and  $y$  depends on the value of  $x$ ; the estimated slope is  $\beta_1 + 2\beta_2 x$

specification. Table A6-1 summarizes the different models that might be appropriate in the following section.

Table A6 – 1; Functional Form

Model	Dependent variable	Independent variable	Interpretation of $\beta_1$
level-level	$y$	$x$	$\Delta y = \beta_1 \Delta x$
level-log	$y$	$\log(x)$	$\Delta y = (\beta_1 / 100\%) \Delta x$
log-level	$\log(y)$	$x$	$\% \Delta y = (100\beta_1) \Delta x$
log-log	$\log(y)$	$\log(x)$	$\% \Delta y = \beta_1 \% \Delta x$

Faced with the different functional forms elucidated on above and the descriptive analysis from chapter two we should be able to make some qualified guessing regarding the right model specification.

### Functional Form

As seen in the model / data chapter, some of the series where non-stationary. To correct for this we estimate on first difference. Not correcting for this would surely result in spurious regression analysis. Further, to account for the fact that interest rates might take some time to adjust to markets changes, one could also estimate on the form  $y_t = \beta_0 + \beta_1 x_t + \beta_n y_{t-1} + \varepsilon_y$ . Note that if  $\text{corr}(y_t, y_{t-1}) > 0$  and / or  $\text{corr}(\varepsilon_y, \varepsilon_{y-1}) > 0$  we might expect the model to actually be estimated on the form  $y_t = \beta_0 + \beta(\approx y_t)$  again causing spurious results. A simple regression substantiate the suspicion by yielding extremely high explanatory power and are further strengthened by a correlation coefficient as high as 0, 98. The same could be said about the variable displaying the difference between short and long interest rates as presented in chapter 1. Regressing the

model  $y_t = \beta_0 + \beta_1 (y_t - y^{long})$  which could in fact be written  $y_t = \beta_0 + \beta_1 (y_t) - \beta_1 (y^{long})$ .

This simple transformation reveals that the interest rate is regressed against a perfect match of itself<sup>41</sup>; using any of these as control variables requires great precaution when interpreting the results.

Using equation [A6-2] we may compute simple tests to see if variables are in fact linear related.

**Table A6 - 2; Testing for linearity**

Interest Rate (First Difference)	Coefficient	Standard Error	t - value	P - value
Oilprice	-0,012	0.016	-0,73	0,467
Oilprice (Squared)	0.000043	0.0000574	0,75	0,453
GDP – HP Trend	0.00013	0.000029	4,22	0,000
GDP – HP Trend (Squared)	8,36 – 09	8,52 – 09	0,98	0,328
Investments	4,38 – 06	0.00011	0,04	0,969
Investments (Squared)	3,58 – 10	3,33 – 09	-0,06	0,954
House Prices	-0.27	0.080	-3,37	0,001
House Prices (Squared)	0.00303	0.00093	3,26	0,001
House Prices (Cubed)	-0,00001	3,45 - 06	3,01	0,003
NAIRU	0.0006	0,015	0,04	0,967
NAIRU (Squared)	0.00093	0.003	0,32	0,749
Constant	7,36	2,25	3,27	0,001

As table A6-2 reveals; house prices and interest rates are not linearly related. The effect is represented by the significant coefficient on the quadratic variable. Even the third order comes out significant. This implies that interest rates affect house prices the most within

<sup>41</sup> Note that there still is a restriction on the variable  $y_t$  given by  $\beta_1 y_t = -\beta_1 y^{long}$  dividing with  $\beta$  on both sides; we may write  $y_t = -y^{long}$  which actually make  $y_t$  a proxy for the market liquidity premium.



a certain interval. Low rates have an increasing effect, while high rates have a decreasing but positive effect; intuitively reasonably. This is substantiated by the positive  $\beta_2$  coefficient and negative  $\beta_3$ .

## ***Appendix Seven***

### Robust Regression

Basic regressions perform ordinary least squares (OLS) regressions. OLS then assumes “ideal” data; if errors are normally, independently and identically distributed then OLS is more efficient than any other unbiased estimator. The flip side to this statement often get overlooked: if errors are not normal distributed then other unbiased estimators might outperform OLS. In fact, the efficiency of OLS degrades quickly in the face of heavy-tailed (outlier – prone) error distributions (Hamilton 2004). This because OLS tends to track outliers, fitting them at the expense of the rest of the sample. Over the long run, this leads to greater sample – to – sample variation or inefficiency when samples often contain outliers. More observations may even exaggerate the problem. Robust regressions methods aim to achieve almost efficiency of OLS with the ideal data and substantially better than OLS in non-ideal data. Robust regressions encompass a variety of different techniques, each with advantages and drawbacks for dealing with problematic data. In this paper we have used two different methods for robustness testing; both having in common their ability to pass outliers creating an “ideal” data set. The Huber - method performs robust regressions of  $y$  on its predictors, using iteratively reweighted least squares with bi-weight functions tuned for 95 % Gaussian efficiency (Hamilton 2004). By using a Huber function, the method downweights observations with larger residuals. After several Huber iterations, it shifts to a Tukey biweight (as suggested by Li 1985) tunes for 95 % Gaussian efficiency. The regression results estimates standard errors and tests hypothesis using pseudovalues method that does not assume normality. While the quantile regression, also known as least absolute value (LAV) or minimum L1-norm regressions. By default this method (at least in STATA) models  $y$  conditional on 0, 5 quantile (approximate median) as a linear function of the predictor variables, and thus provides median regressions (Gujarati 2003).