Thesis for the *Master of Economic Theory and Econometrics* degree

Norwegian Inflation

An Empirical Study – 1667-2004

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Abstract

This thesis contains an empirical investigation of several models of Norwegian inflation estimated on annual observations from 1667 to 2004. The approach taken is simple one equation models estimated by OLS or IV. The focus has been on presenting a variety of models instead of an in depth analysis of anyone particular model.

The analysis starts out with the sub sample covering the years prior to 1830 using the death/birth-ratio and temperatures as proxies for supply shocks. In addition we include English inflation, paper money and war dummies as explanatory variables. We find a very strong relationship between Norwegian and English inflation. One possible interpretation is that Norway can be viewed as a small open economy even prior to 1830. The death/birth-ratio is an indicator of the demographic conditions in the society, but is treated as a proxy for supply shocks in this thesis. This interpretation may sometimes be problematic, but arguments are given for its validity. This thesis shows that wars did not contribute to inflation until the mid 18th century and that the introduction of paper money did affect prices, especially during the Napoleonic War when the monetary regime collapsed.

The period post 1830 are covered by three types of models; the inverted money demand function, the P*-model and the Phillips Curve model. The period is divided into two sub samples, one prior to 1914 and one post 1914.

The inverted money demand function shows reasonable properties in both samples. We identify a positive effect of money growth, a negative effect of output growth, a positive effect of interest rates and a positive effect of imported inflation. The main difference between the two sample periods is that the effect of lagged inflation is increasing, the effect of money growth is decreasing and the effect of import prices is increasing. The direction of causality is discussed, and we find some evidence that indicates that it has changed. In the 19th century money affected prices, but in the 20th century the direction of causality seems to be from prices to money.

The P*-model views inflation as a function of lagged inflation and lagged deviation from the equilibrium price level. We find that the model fits data well on the 19th century sample, but estimated on the 20th century sample the model shows signs of misspecification.

The final model is the Phillips Curve. The main focus is on the so called hybrid version of the (Neo-Keynesian) Phillips Curve, including both lagged inflation and expected inflation next period in addition to the output gap which is an indicator of the activity level of the economy. We are not able to detect significant effects of the output gap. More favorable results are provided by using the unemployment rate as the indicator of economic activity. We show that the model can be improved even more by introducing the yield spread as a proxy for inflation expectations.

Contents

Preface

This master thesis was written while I had a student internship in the Research Department at Norges Bank[1] (the Central Bank of Norway). I would like to express my gratitude to Norges Bank for providing me with economic funding and inspiring working conditions during this period, and above all for allowing me to write my master thesis on a topic that I found very interesting.

The work on this thesis can be split into two major parts. The first is the collection of data and the second is the analysis of these data. It has not been easy to find long time series of good quality covering the years of interest. Without the help of the library staffs at Norges Bank, Statistics Norway and the University of Oslo, this process would have been much more time consuming.

A number of individuals have contributed by giving advices on data, discussing problems related to this thesis or by reading and commenting some earlier drafts of the thesis. Among them are Jan F. Qvigstad, Jan Tore Klovland, Farooq Akram, Roger Hammersland, Helge Brunborg and Linda Margrethe Taje.

I would in particular like to thank my advisors professor Ragnar Nymoen at the University of Oslo and Øyvind Eitrheim, Director of Research at Norges Bank. They have both contributed by reading numerous of drafts, correcting many errors and suggesting solutions to problems that I met. All remaining errors and weaknesses are of course my own responsibility.

[1] The views expressed are those of the author, and do not necessarily represent those of Norges Bank.

1. Introduction

The subject of this master thesis is empirical modelling of Norwegian inflation from 1667 to 2004. This modelling process is impossible without a consistent and high-quality time series of Norwegian prices. In section 1.1 we will present the construction of the main data series of our analysis, the annual consumer price index (CPI) from 1667 to 2004. Section 1.2 will give a quick overview of the Norwegian price history from 1516 based on this CPI. We will identify some major changes in the general price level and some trends. In section 1.3 we will present a simple framework for analysing changes in the price level. This baseline model can be used to explain some observable patterns, especially for the 17th and the 18th century. We will conclude this chapter by dividing the data into three sub periods according to historical developments and the data available. Each of the following chapters will discuss one of these sub periods.

1.1 A consumer price index for Norway – The construction

In a recent paper, Grytten (2004) published a CPI for Norway covering the years from 1516 to 2003[2]. This new index covers a considerably longer time period than the indices that had previously been available. The main price index prior to Grytten (2004), the CPI published by Statistics Norway[3], only stretches back to 1865. The new index gives a much better starting point for studying historical movements in the general price level, than the older indices.

The new CPI[4] is constructed by splicing several new indices with some existing indices and the official CPI. For the first period, covering the years from 1516 to 1666, only grain prices are included in the index. The index covering these years will not be a proper CPI, but it can give some limited information about the general price level since the consumption of grain constituted approximately 20 % of the total consumption. Another problem with this period is that the number of price observations is too few to report an annual price index. As a result, only the average price level for each period (covering 3 to 21 years) is reported. After 1666 the price data is much richer, which makes the construction of an annual index

[2] It has later been updated with numbers for 2004.
[3] The CPI is available at the web site of Statistics Norway (SSB): http://www.ssb.no/kpi/tab-01.html
[4] For details about the construction of the CPI see Grytten (2004).

possible. From 1666 to 1819, up to 21 commodities are included in the index. These commodities constituted more than half of the total consumption. From 1819 to 1830, 29 commodities representing about 80 % of total consumption are included, and from 1830 to 1871, 47 commodities representing about 90 % of total consumption are included. From 1871 to 2004 the index is spliced with other available price indices from Jan Ramstad, Statistical Office of Christiania, Ministry of Social Affairs and Statistics Norway. Grytten (2004) concluded that the new index has moderate reliability prior to 1666. The reliability is fairly good from 1666 to 1819, even better for the years from 1819 to 1830 and good after 1830.

1.2 The general price level from 1516 to 2004

In 1516 the CPI was 9.8 and in 2004 it reached 6047.1 (the index is 100 in 1850). In other words; the price level was 617 times higher in 2004 than it was 488 years earlier. This increase in the price level corresponds to an annual inflation rate of 1.33 per cent. A look at the figure below shows that the general price level has not been increasing at a steady pace. It has been relatively stable for long periods. In other periods it has changed dramatically.

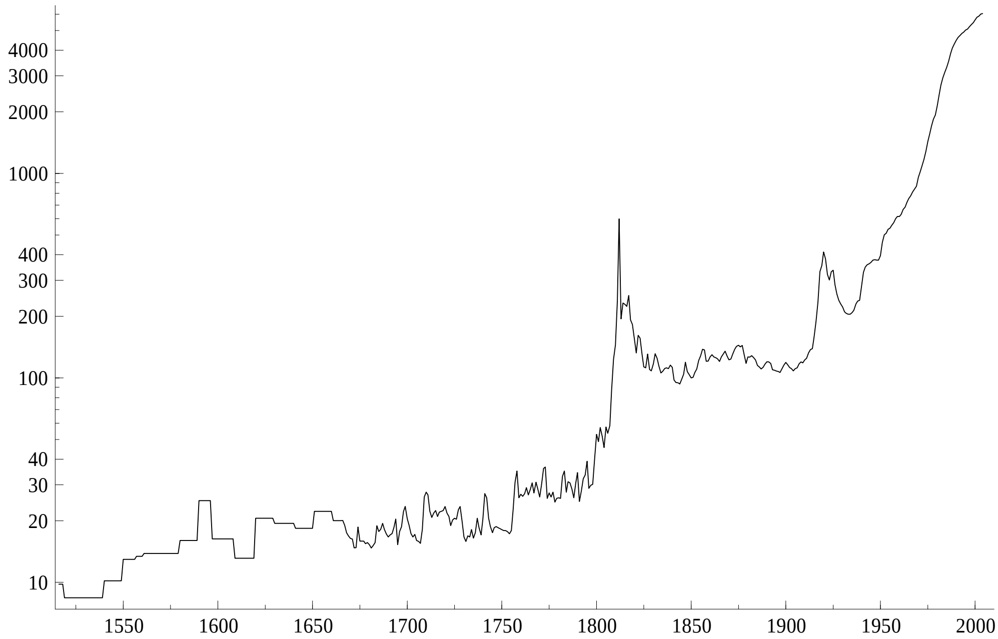

Figure 1: CPI for Norway from 1516 to 2004, 1850 = 100

First we identify a considerable increase in the price level during the 16th century. This is an international phenomenon and is known as “The 16th Century Price Revolution”. In one of the classics on this topic, Hamilton (1970) focuses on the import of American silver and gold to Spain as the main source to this inflationary trend. In a resent paper, Munro (2003) focuses on the Central European mining boom from the 1460s to the 1530s as the main monetary foundations of the Price Revolution, but he ends his paper by stating that "*the origins and mechanics of European inflation are much too complex to rest upon one single factor, monetary or real, though clearly, au fond, they had strong monetary components, especially in precious metals*". We will not discuss the origin of the Price Revolution, but it might be noticed that the inflationary trend was considerably stronger in England[5] than in Norway.

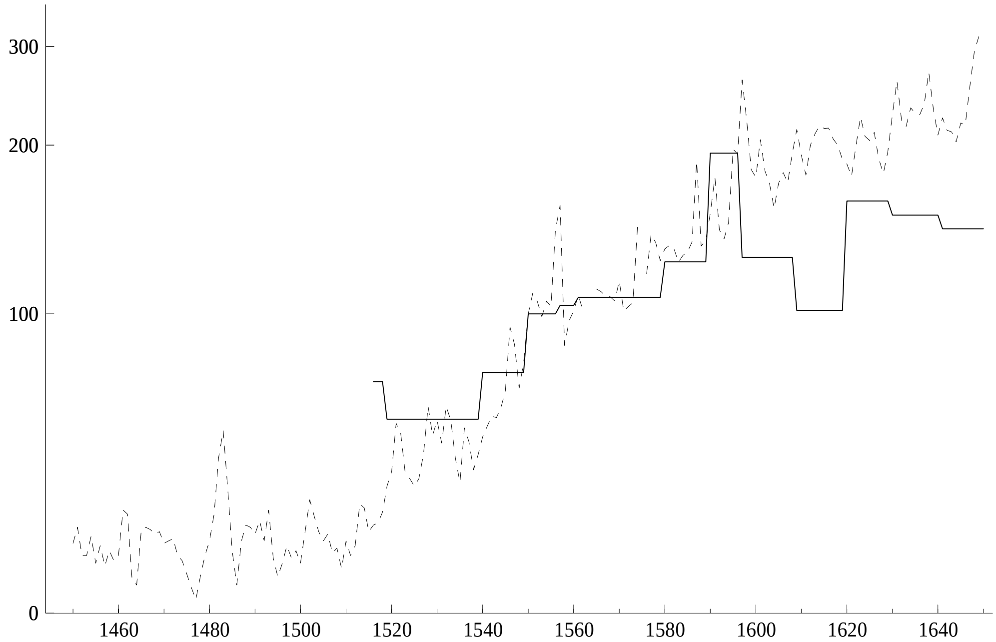

Figure 2: CPI for Norway (solid line) and England (broken line), 1550 = 100

After the Price Revolution, the price level was fluctuating around a fairly stable level for the next one and a half century. The price level was not constant, but it did always return to the same level as in the early 17th century. First in the late 1750s, prices increased to a new and higher level without returning to the price level of the 17th century. For the rest of the 18th century prices where fluctuating around this new and higher price level.

Around the turn of the century, prices started to increase again. The inflation soon turned into hyperinflation and at the price top in 1812, the price level was 20 times higher than 15 years earlier. From the top in 1812, prices decreased for the next 30 years. The price level in

[5] The source of the English CPI is Phelps Brown and Hopkins (1956).

the early 1840s was only one sixth of the price level in 1812, but it was still three times as high as in the 1790s. In the rest of the 19th century prices were very stable. In fact, the price level around 1905 was the same as in 1825, 80 years earlier.

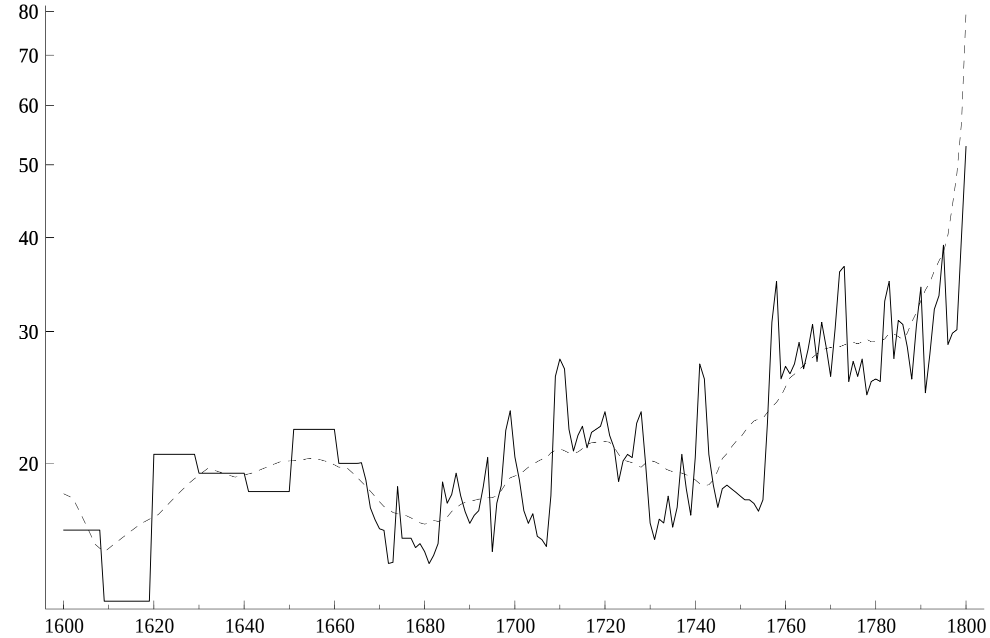

Figure 3: Annual CPI (solid line) and 25 years moving average of CPI (broken line), 1850 = 100

Figure 4: CPI for Norway, 1850 = 100

Around 1910 prices started to increase again. At the price top in 1920, the price level was four times the price level of 1910. Prices fell during most of the 1920s and the first half of the 1930s. From the mid 1930s prices started to increase, and the price level is still increasing, 70 years later.

From this short introduction to the history of the Norwegian price level we can identify our first finding. Prior to 1900, and especially 1800, the price level was fluctuating. If it increased one year, it would decrease a few years later. In the last century these fluctuations have disappeared. If prices first started to increase, they continued to increase. Inflation was no longer followed by deflation.

We can illustrate this development by the autocorrelation function of Norwegian inflation. We observe close to none autocorrelation in the 18th and the 19th century. This observed pattern changed dramatically in the 20th century. It is a clear tendency that inflation one year is followed by inflation of the same size the following year. We can conclude that the persistence of inflation has increased. This represents a challenge for modelling.

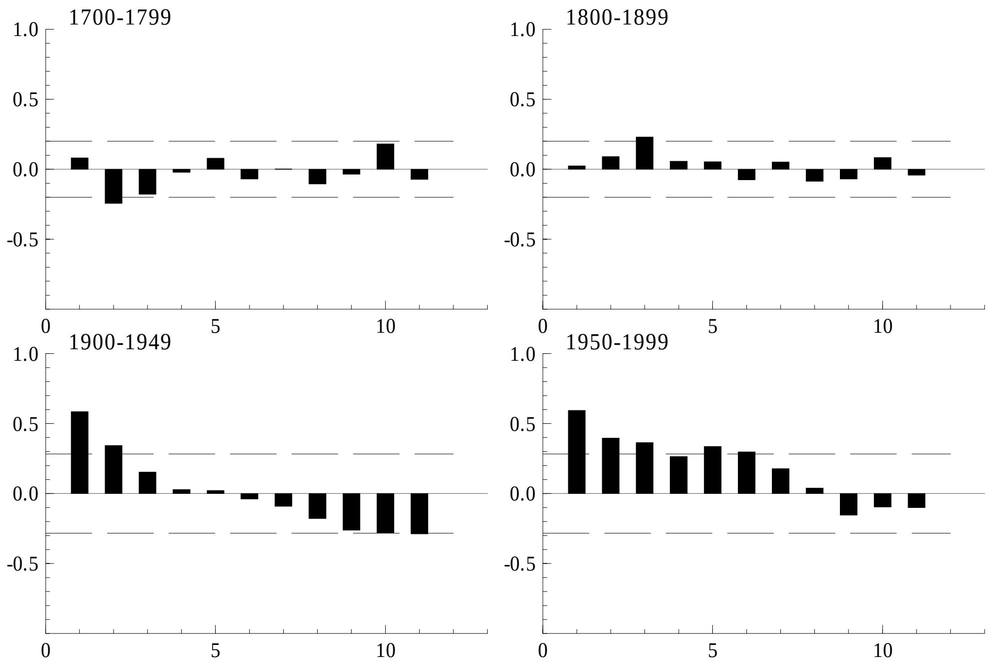

Figure 5: Autocorrelation function for Norwegian inflation

Another interesting observation, which may be related to the higher persistence, is that the phenomenon of deflation seems to have disappeared. To illustrate this point, a dummy variable equal one in every year with deflation, zero otherwise, is constructed. Then we took a 25 years moving average of this dummy variable. The resulting variable shows how the relative frequency of deflation has changed over time. We observe that until the 1930s, the relative frequency of deflation was fluctuating between 0.3 and 0.7. Then it dropped quickly and has been equal to zero since 1973. Illustrated in this way, we clearly understand that the last 70 years has been extraordinary in a price historic perspective.

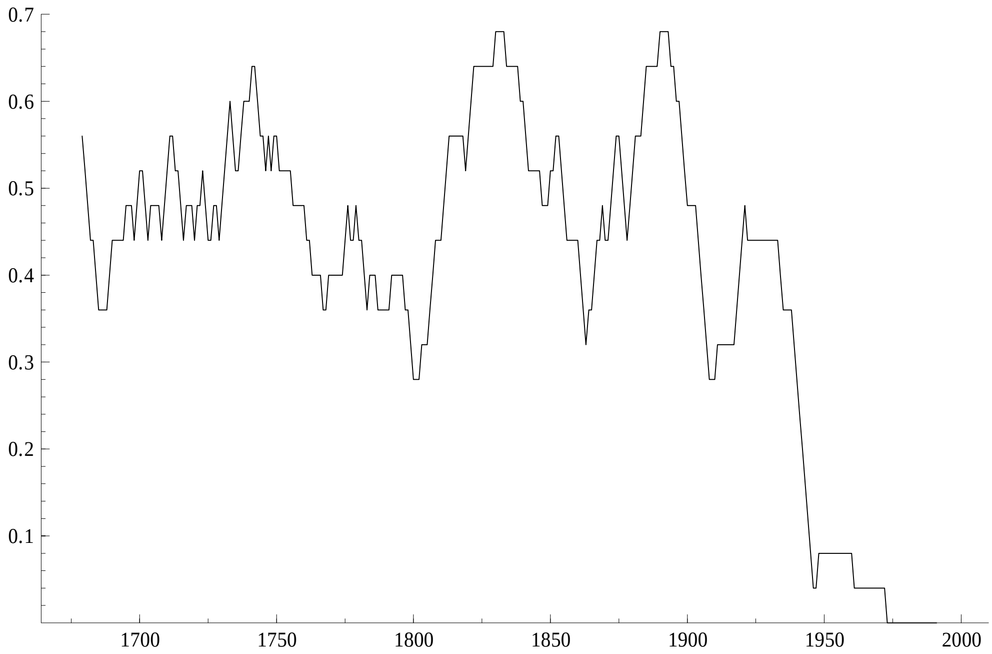

Figure 6: The relative frequency of deflation

1.3 A simple theoretical framework

We start out our preliminary analysis by using the basic aggregate supply and demand framework. The aggregate demand curve is downward sloping in our standard price-quantity diagram which we think of as representing the "total" demand and supply. The consumers will demand more and more goods when prices are decreasing. The aggregate supply curve is upward sloping.

The Norwegian Economy prior to the 19th century was mainly an agrarian economy.[6] In an agrarian economy with constant technology, supply is more or less given by nature, typically showing diminishing return to scale. In good years, the supply will be above normal and prices will be below normal, and vice versa. If supply is given by nature, prices will not influence the supply and we would expect a close to vertical aggregate supply curve.

[6] A good introduction to Norwegian economy prior to 1800 is Dyrvik et al. (1990).

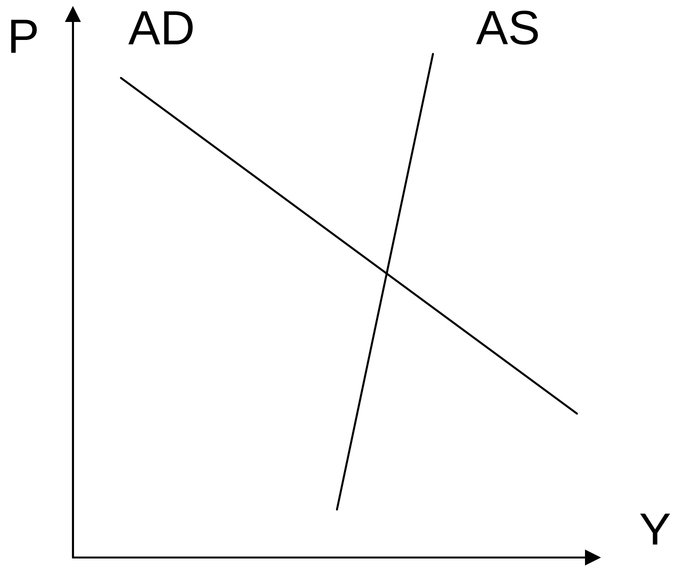

Figure 7: Aggregate demand (AD) and aggregate supply (AS) in a price-quantity diagram (P and Y)

Given demand, fluctuations in supply will give similar fluctuations in prices. In a good year, the supply will be above normal and the aggregate supply curve moves to the right. Since the demand is constant, prices will decrease. If the next years harvest is a normal, the supply curve will move to the left and prices will increase to the normal level. The effect of a bad year can be found in a similar way. We have now identified one possible explanation of the observed fluctuations in the price level prior to 1800.

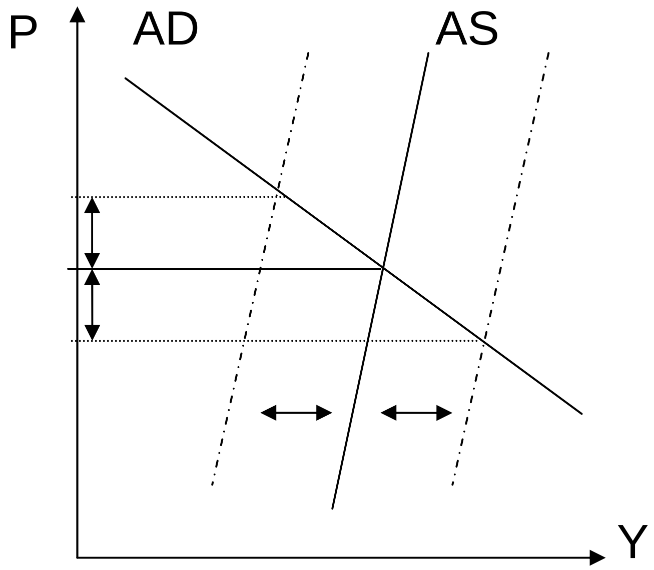

Figure 8: The effect of changes in the aggregate supply curve

In the long run, aggregate supply and demand will of course not be constant. The transformation of the economy from an agrarian to an industrial economy will change both the slope and the volatility of the supply curve. When a smaller part of the economy is directly influenced by nature, we would expect the supply curve to be less steep than in an agrarian economy. As a result, short-term fluctuations in demand will cause less change in prices than in the historical periods with a steep supply curve. In addition, when the output of an economy is primarily given by other factors than nature, there is no reason to expect that the supply will be fluctuating around a stable level. It’s reasonable to assume that improvements in technology will cause the aggregate supply curve to move to the right. Also the aggregate demand curve will be moving. One obvious reason is the population growth. Other reasons can be monetary and fiscal changes.

Though the supply and demand framework will not always be in the forefront of our formal analysis in the following chapters, it will provide a useful backdrop throughout the thesis.

1.4 Three sample periods

The CPI published by Grytten (2004) covers the years from 1516 to 2004. The data for the first 150 years are 3 to 21 years averages. Since we will focus on annual changes in the price level, we decided to exclude the observations prior to 1666. The Norwegian economy in 1666 was basically an agrarian economy. Most people were farmers or worked at farms, but fishing, forestry and mining were also major industries. Later in the 17th and in the 18th century, some new industries like trade, craft and international trade (the merchant fleet) gained significance, but Norway was still primarily an agrarian economy. During the 19th century the economy was dramatically changed. People moved from the countryside to the cities, manufacturing industries grew and also the financial sector grew at a remarkable speed. The number of banks increased from one in 1822 to 496 in 1900 (Eitrheim et al. 2004; p.395-396). In the early 20th century, the agrarian economy had developed into a modern industrial economy.

The previous paragraph shows that a division of Norwegian price history post 1666 in three sub periods can be justified. The first period will cover the agrarian economy that ended early in the 19th century. The next period will cover the transformation process during most of the 19th century and the first years of the 20th century. The last period will be the modern industrial economy of the 20th century.

This periodicity can also be justified by the data available. Prior to 1819, very few economic time series are available, but this changes in the 1820s. Norges Bank has recently published a book "Historical Monetary Statistics for Norway 1819-2003" (Eitrheim et al. 2004) that include bond yields, monetary aggregates, the gross domestic product, exchange rates among other data series starting around the 1820s. In the early 20th century even more data is available. Of particular interest are the unemployment rate and the national accounts from the 1930s.

We have seen that there are both theoretical and historical reasons for dividing the period from mid 17th century to present into three sub periods. First we will study the period up to 1830 in chapter two, then we will investigate the transformation period from 1830 to 1914 in chapter three, and finally we will conclude by analysing the period post 1914 in chapter four. Some concluding remarks are offered in chapter five.

2. Inflation 1667-1830

In this chapter we will try to develop empirical models of Norwegian inflation prior to 1830. This is a difficult task because few data series are available for this period. One exception is a consumer price index for Norway published by Grytten (2004). This data series contains annual observations back to 1666. In section 2.1 we will do a simple analysis that only includes this variable.

In section 2.2 we will investigate the relationship between Norwegian and English inflation. We will use the dataset published in Phelps Brown and Hopkins (1956). They estimated a price index of a composite unit of consumables in southern England back to 1264.

The Norwegian economy was basically an agrarian economy in the 17th and 18th century. The supply was given by nature and the demand was given by the population. The main output was grain, but quantity data is not available. Instead we will use proxies for the production of grain. If the harvest fails, people will experience hunger and possibly starvation. If this is true, the death rate can be used as a proxy for the supply of food. An increase in the death rate indicated a negative supply shock, but it may also reflect wars and plagues. We will study this relationship in section 2.3.

One important factor determining the harvest is the temperature during spring and summer. A cold summer can cause a failed harvest. When production of grain fails, supply of food will decrease and prices will increase. We can conclude that temperature can be included in our analysis as our second proxy for the supply side of the economy. This relationship will be studied in section 2.4.

Paper money was introduced in Denmark-Norway during the 18th century. One of the main reasons was to finance governmental expenses during and after the Great Nordic War (1709-20). The introduction of paper money changed the financial system. The government can easily be tempted to issue too many notes. The relationship between notes and real production will then change and prices will increase. In section 2.5 we will investigate whether the issuing of paper money affected inflation or not.

In the last centuries, wars have been associated with inflation. In countries that take direct part in a war, governmental expenses increase and this will give a positive shift in the aggregate demand. The economy is transformed into a “war economy”. (Sometimes domestic inflation during wartime is kept low through rationing, but historically this is not typical. In any case international prices of traded commodities tend to increase.) This was observed during the Crimean War (1854-56), the two World Wars and the Korean War (1950-51) when prices increased significantly. This affected Norway as well, even though the country only took directly part in WW2. In the 17th and 18th century wars occurred much more frequent than today. We should therefore suspect that because of the frequent wars, inflation was a very common phenomenon. This question will be studied in section 2.6.

We will conclude this chapter with the presentation of a model that includes most of the effects discussed in this chapter. The model will be estimated with both OLS and IV, and the choice of estimation method will be discussed.

2.1 The effect of lagged inflation

Since the Second World War we have experienced permanent inflation, in particular in the period 1970 to 1990. Not only have prices increased, but the rate of increase has been more or less the same from one year to the next. A good prediction of next year’s inflation has been this year’s inflation. Will this be true if we instead consider data of inflation in the 17th and 18th century?

Figure 9 below shows that inflation typically has been very volatile over the period 1667 to 1830. There are several years with inflation above 10 percent per year, and several years with deflation below 10 percent per year. The most extreme episode took place at the end of the Napoleonic War. In 1812 prices increased with 152 percent. The next year they decreased with 57 percent. Although 1812-13 is extreme, it is typical of a general pattern. After every increase in the general price level, prices will typically decrease the next year or a few years later. A boom is followed by a bust.

An autoregressive model of order 3, for the sample period 1669-1800, gives the following results.

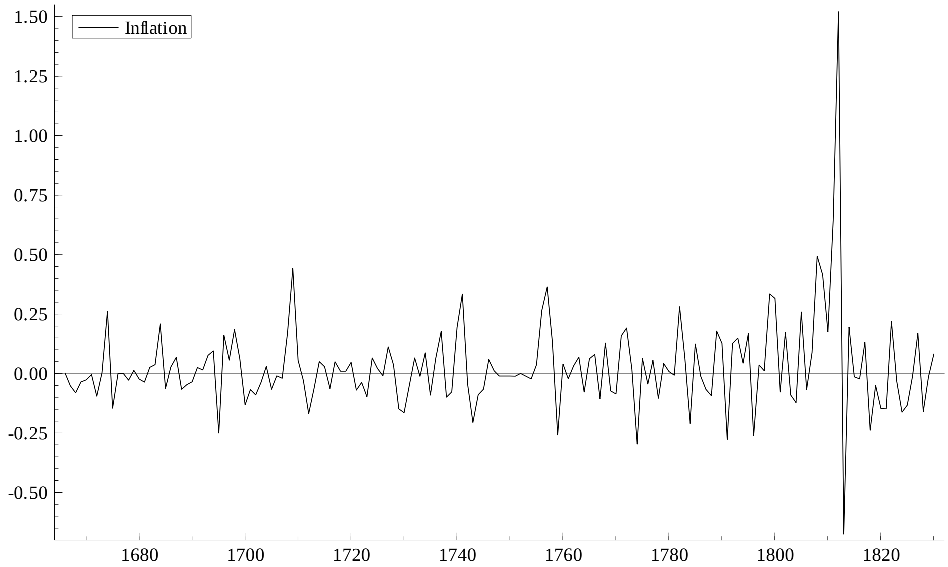

Figure 9: Inflation in Norway 1666-1830

MODEL 1 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1669 to 1800

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	0.0551491	0.08911	0.619	0.537
Inflation_2	-0.229838	0.08906	-2.58	0.011
Inflation_3	-0.144195	0.09139	-1.58	0.117
Constant	0.0192989	0.01090	1.77	0.079

sigma[7]	0.123425	RSS	1.94992622
R^2	0.074966	F(3,128) =	3.458 [0.018]*
log-likelihood	90.8908	DW	2
no. of observations	132	no. of parameters	4
mean(Inflation)	0.0161965	var(Inflation)	0.0159693

The sign of the first lag is positive, but this coefficient is not significantly different from zero. The signs of the second and third lags are both negative as we expected from the graph, but only the coefficient of the second lag is significantly different from zero. The standard error of the error term (sigma) is as large as 0.12 and the coefficient of determination (R^2) is only 0.07. We can conclude that it is impossible to predict the inflation in one year if you only know past inflation. Some more information about the economic environment is

[7] The output shows the standard deviation of the error term (sigma), the residual sum of squares (RSS), the coefficient of determination (R^2), the F-value of the test with null hypothesis that all coefficients except the constant term is equal to zero (F) with the significance level of the test in brackets, the log-likelihood and the Durban-Watson statistic (DW). All calculations are done by PcGive (see Hendry & Doornik (2001) and http://www.pcgive.com)

necessary. If this model is solved for steady state, we observe that 1.46 percent inflation will be a stable situation. It's interesting to notice that this is not far from present day inflation[8].

In the model above, we have chosen to end the sample in 1800. The reason is the extreme price movements during the Napoleonic War. If the sample is extended to 1830 and we include dummies for 1812 and 1813, we obtain the following results.

MODEL 2 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1669 to 1830

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	0.106684	0.08026	1.33	0.186
Inflation_2	0.0357345	0.06213	0.575	0.566
Inflation_3	0.0578920	0.06046	0.958	0.340
Constant	0.0193437	0.01179	1.64	0.103
d1812	1.40216	0.1583	8.86	0.000
d1813	-0.890509	0.1990	-4.48	0.000

sigma	0.1458	RSS	3.31620495
R^2	0.456052	F(5,156) =	26.16 [0.000]**
log-likelihood	85.1228	DW	1.9
no. of observations	162	no. of parameters	6
mean(Inflation)	0.0279315	var(Inflation)	0.037633

We observe that the signs of the 2nd and 3rd lag changes, but those coefficients are not significantly different from zero. A calculation of steady state inflation in this model will give a value of 2.41 percent. This is very close to the present inflation target of Norges Bank which is 2.5 percent.

In an agrarian economy supply is given by technology, effort and nature. Technology was developing slowly, so on a year to year basis it is reasonable to take technology as given. There is no reason to suspect that the effort put into agrarian production should differ much from one year to the next. We can conclude that the main reason for variation in output is nature itself. The demand is given by population and taste. From one year to the next, population is relatively constant. Most people did not have much more than they needed to survive. This indicates that taste did not influence demand much. We can conclude that aggregate demand did not change much from one year to the next. If this is true, only nature will influence the market equilibrium. If nature is "normal", the harvest will be normal and prices will be normal. If, on the other hand, nature causes a poor harvest, prices will increase

[8] 1.0 % from March 2004 to March 2005 (http://www.ssb.no/english/subjects/08/02/10/kpi_en/)

to a higher level. When the harvest some time in the future is back to normal, prices will decrease to the former price level. A transitory shock in nature will temporarily push prices away from its normal level.

This story fits very well with our analysis so far. We have observed that almost every price shock seems to be followed by a price movement of the same size but in the opposite direction. The price index is fluctuating around a fairly stable level. The nominal anchor that keeps the price level stable is the monetary regime; the silver standard. The value of each coin was the value of the silver that it contained.[9] As long as the supply of silver followed the same trend as the overall production, and that the government didn't try to fool the public by reducing the silver content of the coins, the "normal" price level would be constant. There are two episodes of permanent shifts in the price level between the 1660s and the 1830s. The first took place at the end of the 1750's and the second started in the late 1790's. As we will se later, both shifts were related to major European wars.

2.2 Norwegian and English inflation – A close relationship

A popular view is that the world has become more and more integrated during the last centuries. According to this view, we should expect that price movements in different countries are much closer linked today, than they were hundreds of years ago.

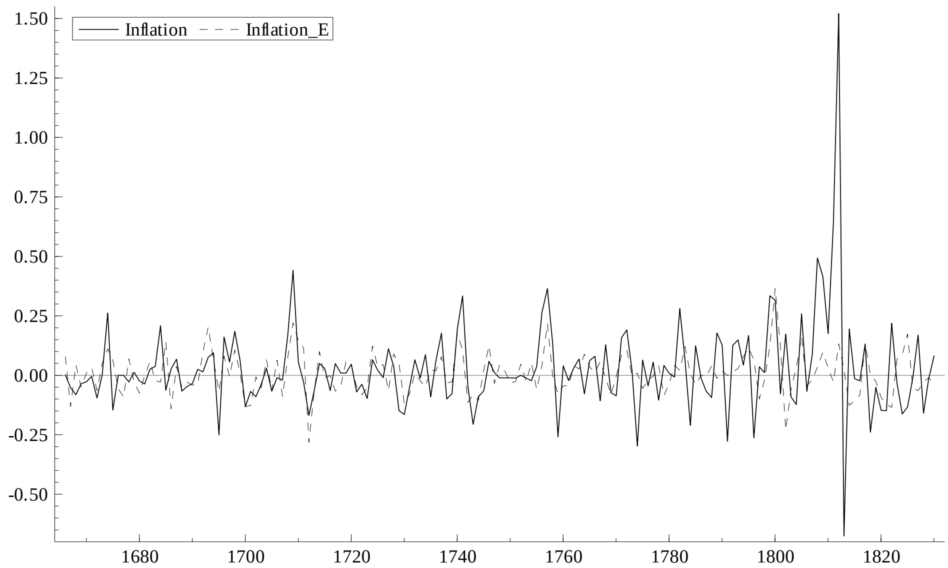

Figure 10: Norwegian and English inflation 1666-1830

[9] When bank notes were introduced, they were convertible into precious metal (silver and later gold).

From the graph we observe that the developments in Norwegian and English rates of inflation were closely linked, even in the 17th and 18th century. The main difference is that Norwegian inflation is more volatile. The means, standard deviations and correlations are given by the table below.

Table 1: Norwegian and English inflation

	1667-1800	1667-1830
Mean Infl NOR	0.014959	0.026778
Mean Infl ENG	0.0098389	0.0069940
St.d. Infl NOR	0.12631	0.19368
St.d. Infl ENG	0.083841	0.086394
Correlation	0.51591	0.32665

A simple model of Norwegian inflation might then include lags of Norwegian inflation and English inflation with lags. One such model is the following.

MODEL 3 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1668 to 1800

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.246402	0.08807	-2.80	0.006
Inflation_2	-0.272533	0.07855	-3.47	0.001
Constant	0.00909175	0.009035	1.01	0.316
Inflation_E	0.834725	0.1156	7.22	0.000
Inflation_E_1	0.444354	0.1382	3.22	0.002

sigma	0.102686	RSS	1.34967199
R^2	0.362577	F(4,128) =	18.2 [0.000]**
log-likelihood	116.549	DW	2.01
no. of observations	133	no. of parameters	5
mean(Inflation)	0.0154633	var(Inflation)	0.0159202

We observe that all the t-values are greater than 2 (except for the constant term), which means that all the parameters in the model are significantly different from zero. We notice that the lagged values of Norwegian inflation have negative signs. This indicates a negative autocorrelation, even if we control for English inflation. As we expected after studying the graph, the coefficient of English inflation is close to one. How should this result be interpreted?

These results seem to indicate that our interpretation of Norwegian price movements from the previous section, namely that prices are fluctuating around a stable level, is valid, even if we control for English inflation. A new interpretation is that Norway was already a part of an international economy. The Norwegian climate made it impossible to supply the growing population with food produced in Norway. Import of grain was necessary. According to Dyrvik et al. (1990; p.69) about one third of the grain consumed in Norway around 1665 was imported. International price movements were already influencing the Norwegian price level. When prices increased abroad, they would increase in Norway as well. Another possible interpretation is that Norway and England were exposed to the same types of shocks. If the summer was cold in England, it would most likely be cold in Norway too. We will suspect that both import prices and the similarities in shocks determine the close relationship.

If the estimation period is extended from 1800 to 1830, the results changes somewhat. The main change is that all coefficients, except the one for English inflation (and the dummies) will be insignificant. This is due to the extreme price movements in Norway during the Napoleonic War.

MODEL 4 Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1668 to 1830

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.0302802	0.08633	-0.351	0.726
Inflation_2	0.0311477	0.06290	0.495	0.621
Constant	0.0174680	0.01099	1.59	0.114
Inflation_E	0.610779	0.1342	4.55	0.000
Inflation_E_1	0.0530519	0.1446	0.367	0.714
d1812	1.43788	0.1498	9.60	0.000
d1813	-0.689243	0.1954	-3.53	0.001

sigma	0.137418	RSS	2.94585488
R^2	0.517738	F(6,156) =	27.91 [0.000]**
log-likelihood	95.8011	DW	1.92
no. of observations	163	no. of parameters	7
mean(Inflation)	0.0272612	var(Inflation)	0.0374749

A possible problem with the introduction of English inflation is that the OLS-estimator can be biased. The reason is that we do not know *á priori* that English inflation is exogenous. We have argued that English inflation influence Norwegian inflation, but it’s reasonable that the influence goes in the opposite direction too. Norway was a major exporter of fish, timber and copper and Norwegian prices could influence English inflation via export prices. It's possible to avoid this problem by using the instrument variable method. In the last section of this chapter we will show that the results from IV-estimation are not very different from the OLS results. For the time being, we will continue to use the OLS estimator.

2.3 The effect of demographic crises

A demographic crisis is an episode where the death rate is considerably higher than the normal death rate. The demographic material available for Norway is indeed very good. Drake (1969) has reported death- and birth-rates back to 1735. Before 1735 the data is not of the same quality, but studies of church books have given the death/birth-ratio for several communities. A study by Dyrvik, Mykland and Oldervoll (1976) gave an estimate of this death/birth-ratio back to 1645. From the graph below we can identify several demographic crises. The most serious ones, with death/birth-ratio above 1.5, took place in 1676, 1695, 1741-42, 1773 and 1809[10].

What is the effect of a demographic crisis on the price level? The effect will depend on what causes the crisis. According to Herstad (2000; p.247) there are three kinds of demographic crises. The first is a scarcity crisis. A failed harvest will result in lack of food which can result in famine and an increase in the death rate. There will be a decrease in supply, but an unchanged demand in the short run. Prices will start to increase. Crops will probably not fail the next year. The supply of food is back to normal and the death rate will decrease to normal. Supply will increase compared to the previous year while demand is unchanged. Prices will start to decrease and finally the previous price level is reached. According to this view, a scarcity crisis will not affect the price level in the long run, only in the short run.

The second type is an epidemic crisis. The most devastating one was the Black Death around 1350 that killed more than one third of the Norwegian population (Bagge and Mykland 1996; p.23). In the period of interest (post 1660), no epidemic caused major changes in the

[10] In 1676 Norway was at war with Sweden (Gyldenløvefeiden). In the army camps on the eastern border typhus broke out and soon spread to the civilian population. It was combined with failed harvest in most of the country. In the 1690's the weather was extraordinary and in 1695 the harvest failed completely. The crisis was probably reinforced by an epidemic. (Dyrvik et al., 1976; p.11-12). According to Herstad (2000, Ch.5) the crisis of 1741-42 was a result of several failed harvests but also of epidemics in parts of the country. This was true for the for the 1773 crisis too. In 1809 Norway took part in the Napoleonic War on French side. The British fleet introduced a blockade so no import of food was possible. When the harvest failed people started to starve. Combined with a dysentery spreading from the military camps, this caused a demographic crisis (Hodne & Grytten 2000; p.26-27).

population. The effect on prices of a minor epidemic is uncertain, but price changes would probably be small (Rogoff et al. 2001). The third kind of crisis is a combined one. The effect of a combined crisis will not differ much from the effects of a scarcity crisis.

According to the last paragraphs, it is reasonable to expect that a demographic crisis will cause inflation. The reason is that most crises were scarcity crises or combined crises where shortfall of supply was important. This is why the death/birth-ratio can be used as a proxy for supply. On the other hand, there is no reason to expect that a minor demographic crisis will cause any permanent changes in the price level.

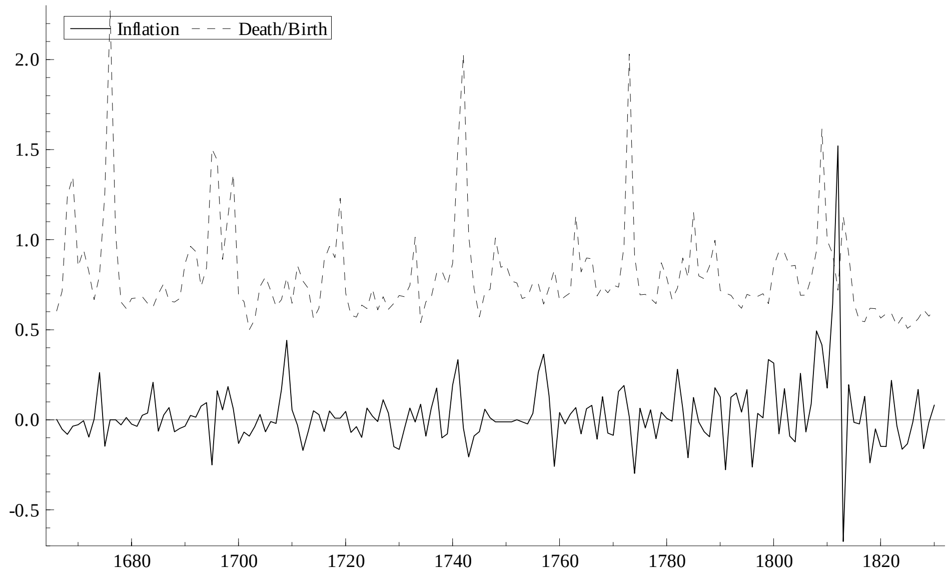

Figure 11: Inflation and the death/birth-ratio 1666-1830

A simple model of inflation will include only lagged values of inflation and the death/birth-ratio. Regression based on Norwegian data gave the following result.

MODEL 5 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1669 to 1800

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	0.0445305	0.08895	0.501	0.617
Inflation_2	-0.239680	0.09055	-2.65	0.009
Inflation_3	-0.0931049	0.09348	-0.996	0.321
Constant	0.0371499	0.03982	0.933	0.353
Death/Birth	0.0734678	0.04493	1.64	0.105
Death/Birth_1	-0.0953084	0.04453	-2.14	0.034

sigma	0.121919	RSS	1.87289767
R^2	0.111508	F(5,126) =	3.163 [0.010]*
log-likelihood	93.5509	DW	1.99
no. of observations	132	no. of parameters	6
mean(Inflation)	0.0161965	var(Inflation)	0.0159693

We observe that the effect of lagged inflation is the same as in our previous models, and an increase in the death/birth-ratio gives higher inflation today, but lower inflation in the next period, and the sum of these two coefficients is close to zero. The R-squared is 0.11 which means that this model explains about 11 percent of the variation in inflation.

The demographic data material for England is considered to be of high quality. Wrigley and Schofield (1981) published birth- and death-rates back to 1541. We can use this data to check if we can find a similar relationship between inflation and the death/birth-ratio outside Norway.

MODEL 6 — Modelling Inflation_E by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1669 to 1800

	Coefficient	Std.Error	t-value	t-prob
Inflation_E_1	0.0742276	0.09331	0.795	0.428
Inflation_E_2	-0.169091	0.09092	-1.86	0.065
Inflation_E_3	-0.202321	0.08946	-2.26	0.025
Constant	0.0742004	0.04120	1.80	0.074
Death/Birth_E	0.148770	0.07098	2.10	0.038
Death/Birth_E_1	-0.219946	0.07105	-3.10	0.002

sigma	0.0772598	RSS	0.75210445
R^2	0.176992	F(5,126) =	5.419 [0.000]**
log-likelihood	153.767	DW	1.92
no. of observations	132	no. of parameters	6
mean(Inflation_UK)	0.0106523	var(Inflation_UK)	0.00692309

We observe that the signs of the coefficients are the same as in the model for Norway. The main difference is that the effect of the death/birth-ratio is much stronger in England. Notice that the R-squared in the model for England is close to twice as high as in the Norwegian model, but this is probably due to the less variability in English inflation compared to Norwegian inflation. The differences in the R-squared could also indicate that the two sets of proxy variables are not equally representative in Norway and England.

Finally, we will present a model for Norwegian inflation where we have included both English inflation and the death/birth-ratio. We will expect a negative effect of lagged Norwegian inflation, a positive effect of English inflation, and a positive first period effect of the death/birth-ratio followed by a negative second period effect.

MODEL 7 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1669 to 1800

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.243441	0.08853	-2.75	0.007
Inflation_2	-0.275943	0.07999	-3.45	0.001
Constant	-0.00236600	0.03380	-0.0700	0.944
Inflation_E	0.830273	0.1173	7.08	0.000
Inflation_E_1	0.362393	0.1441	2.51	0.013
Death/Birth	0.0647136	0.03845	1.68	0.095
Death/Birth_1	-0.0488924	0.03736	-1.31	0.193

sigma	0.102339	RSS	1.30917048
R^2	0.378937	F(6,125) =	12.71 [0.000]**
log-likelihood	117.185	DW	2.01
no. of observations	132	no. of parameters	7
mean(Inflation)	0.0161965	var(Inflation)	0.0159693

We observe that the effects of the first and the second lag of inflation are negative and significantly different from zero. The effect of English inflation is positive and significantly different from zero. The effects of the death/birth-ratio have the expected signs, but they are not significantly different from zero.

2.4 The effect of temperature

In the agrarian economy, the main resource is the crop. The crop can differ for many reasons. One of the main causes is temperature. A cold spring and summer will cause a poor harvest. The supply of food will decrease and prices will increase.

In several studies Nordli (2001, 2002 and 2004) at the Norwegian Meteorological Institute has studied spring and summer temperatures in Norway from the 18th century to present. His main data series include average spring and summer temperature for Trøndelag, Western Norway and South Eastern Norway. The Trøndelag series and the cross plots of the three series are shown in the figure below.

We observe that the temperatures in the different regions follow the same trend. The correlation between temperatures in Trøndelag and on the West Cost is 0.700. The correlation between Trøndelag and Eastern Norway is 0.575 and the final correlation between the West Cost and Eastern Norway is 0.617. We can now use the Trøndelag series to represent the temperature developments in Norway. An alternative is to use an average of the three series, but with this method we lose the observations from 1720 to 1749.

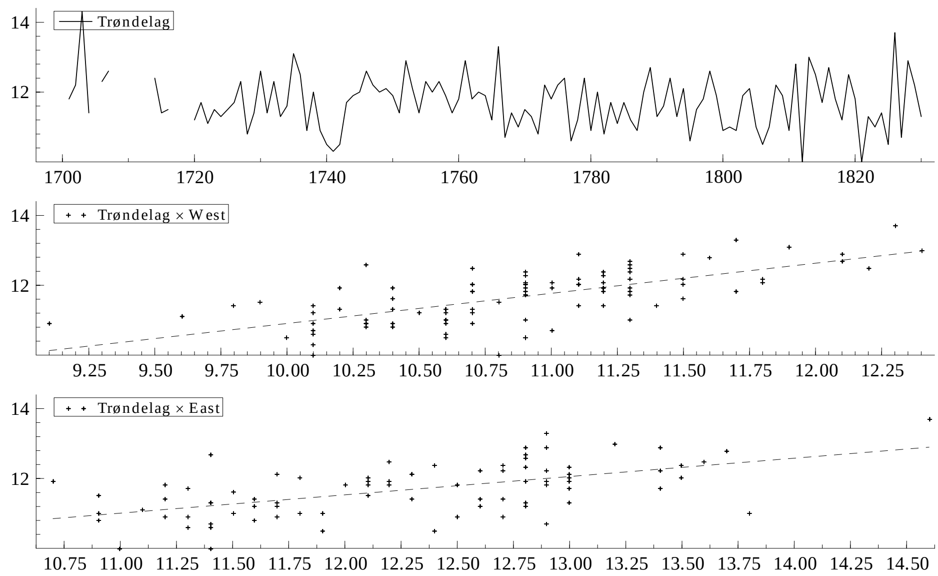

Figure 12: (a) Average spring and summer temperatures in Trøndelag 1700-1830. (b) Cross plot with temperatures from Trøndelag and Western Norway. (c) Cross plot with temperatures from Trøndelag and Eastern Norway

From the Trøndelag series we observe several cold years. The average spring- and summer temperature was below 11 degrees Celsius in 21 out of 111 years. In 11 out of these 21 years we observe more than 15 percent inflation[11]. This indicates that cold springs and summers may be a partial explanation of inflation.

A constant temperature gives a constant crop, everything else kept constant. If the temperature rises from one year to the next, the crops will increase. The increase in supply will result in falling prices, given constant demand. On the other hand, falling temperatures will cause higher prices. We extend our earlier model to include annual changes is the average spring and summer temperature in Trøndelag (DTemp_Tr).

[11] 1737, 1740, 1741, 1772, 1782, 1795, 1800, 1802, 1810, 1812 and 1827.

MODEL 8 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1721 to 1800

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.285601	0.1138	-2.51	0.014
Inflation_2	-0.286764	0.1085	-2.64	0.010
Constant	-0.0244705	0.05230	-0.468	0.641
Inflation_E	0.847496	0.1778	4.77	0.000
Inflation_E_1	0.395603	0.2355	1.68	0.097
Death/Birth	0.150409	0.06061	2.48	0.015
Death/Birth_1	-0.105551	0.05985	-1.76	0.082
DTemp_Tr	-0.0233889	0.01392	-1.68	0.097

sigma	0.107679	RSS	0.834822422
R^2	0.440156	F(7,72) =	8.087 [0.000]**
log-likelihood	68.9874	DW	1.94
no. of observations	80	no. of parameters	8
mean(Inflation)	0.0194428	var(Inflation)	0.0186396

We observe that the effects of lagged inflation and English inflation are approximately the same as before. The effect of the death/birth-ratio is two to three times as strong as in the model without temperature. A one degree increase in temperature will lower the inflation rate with 2.3 percentage points. The sign is not significant, but with a p-value of 0.097 we are not very far from a significant result.

2.5 The effect of paper money

Paper money was first introduced in China in the 11th century (Williams 1997; p.177). In Europe, paper money was introduced in the 17th century. The first notes were set in circulation by Johan Palmstruch and his Stockholm Banco in Sweden from 1661. The introduction was at first a success, but a few years later the bank collapsed. (Williams 1997; p.179-180). In Norway paper money was issued for the first time by Jørgen Thor Møhlen in 1695, but this attempt collapsed the next year (Skaare 1996; p.4-5). During the Great Nordic War (1709-13) governments' expenses increased. To help financing the war the first paper money in Denmark-Norway was issued in 1713 (Svendsen & Hansen 1968; p.17). By the end of 1728 these notes were taken out of circulation (Friis & Glamann 1958; p.7). The first paper money of lasting significance was issued by the private bank called *Den Kiøbenhavnske Assignation- Vexel- og Laane-banqve* (known as *Kurantbanken*) from 1737. The amount of *riksdaler dansk kurant* and *speciedaler* in circulation is given by figure 13 below (Svendsen & Hansen 1968).

From the quantity-theory of money we know that a growth rate of money supply that exceeds the growth rate of GDP will cause inflation, i.e., given a constant velocity of money.

(1)
$$CPI = \frac{M}{GDP} \times \bar{V}$$

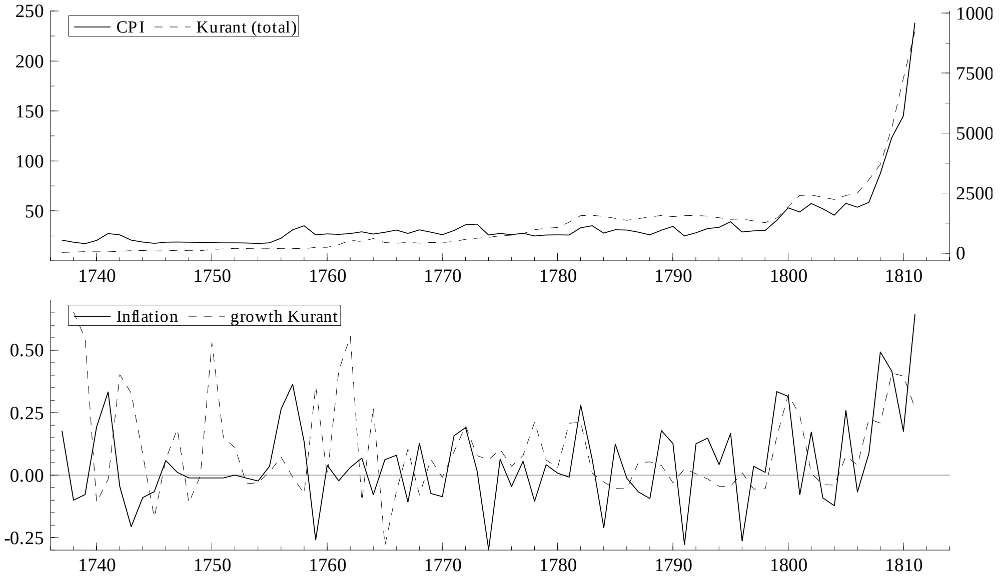

Figure 13: (a) CPI (left axis) and kurant notes in circulation (right axis), (b) The inflation rate and the growth rate of kurant notes in circulation

When the annual growth rate of *kurant* notes (gKurantNotes) is introduces in our regression, the results is as we expected. The huge increase in paper money from 1737 seems to have caused inflation, although the coefficients are not statistically significant. We notice that the rest of the model has the same interpretation as before. The R-squared is only 0.30, but this is without the use of dummy variables. If we include the dummies for 1812 and 1813 the R-squared increases to 0.67.

MODEL 9 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1740 to 1813

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.143936	0.1397	-1.03	0.307
Inflation_2	0.000676823	0.2047	0.00331	0.997
Constant	0.0223996	0.1153	0.194	0.847
Inflation_E	0.777476	0.3653	2.13	0.037
Inflation_E_1	-0.219559	0.3915	-0.561	0.577
Death/Birth	0.156008	0.1249	1.25	0.216
Death/Birth_1	-0.191102	0.1250	-1.53	0.131
DTemp_Tr	-0.0849958	0.02984	-2.85	0.006
gKurantNotes	0.295596	0.1812	1.63	0.108

gKurantNotes_1	0.134798	0.1739	0.775	0.441
gKurantNotes_2	0.299842	0.1627	1.84	0.070

sigma	0.231832	RSS	3.38600579
R^2	0.302422	F(10,63) =	2.731 [0.007]**
log-likelihood	9.12187	DW	1.77
no. of observations	74	no. of parameters	11
mean(Inflation)	0.0611356	var(Inflation)	0.0655939

One problem is that we have assumed that the direction of causality is from money to prices. Equation (1) can also give us the conflicting assumption that the direction of causality is from prices to money. When prices increase, people demand more money and the money supply has to increase. A regression on the growth rate of *kurant* notes in circulation gives the following results.

MODEL 10 Modelling gKurantNotes by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1740 to 1813

	Coefficient	Std.Error	t-value	t-prob
gKurantNotes_1	0.0804141	0.1185	0.678	0.500
gKurantNotes_2	-0.134917	0.1125	-1.20	0.235
Constant	-0.0618162	0.07815	-0.791	0.432
Inflation	0.137122	0.08405	1.63	0.108
Inflation_1	0.169396	0.09351	1.81	0.075
Inflation_2	0.101374	0.1388	0.730	0.468
Inflation_E	-0.0287652	0.2575	-0.112	0.911
Inflation_E_1	-0.182232	0.2663	-0.684	0.496
Death/Birth	0.0388686	0.08600	0.452	0.653
Death/Birth_1	0.122339	0.08533	1.43	0.157
DTemp_Tr	-0.00691464	0.02157	-0.321	0.750

sigma	0.157898	RSS	1.57070697
R^2	0.214945	F(10,63) =	1.725 [0.095]
log-likelihood	37.5425	DW	1.89
no. of observations	74	no. of parameters	11
mean(gKurantNotes)	0.0887813	var(gKurantNotes)	0.0270373

We observe that inflation seems to influence the growth rate of notes in circulations in a similar way as the opposite causality. On the basis of this result it is difficult to say anything about the direction of causality.

In the short period from 1791 to 1813 there were both *riksdaler dansk kurant* and *speciedaler* in circulation. The model below is able to explain almost all the variation in inflation during this period, even without the use of dummy variables. This strongly supports the monetarist view of inflation, but one must remember that this is a very short and special period. The Napoleonic War led to a very high governmental spending. It was impossible to finance the war by loans and taxes only. Both the national debt and the stock of paper money increased. The value of Danish money fell and in 1813 the monetary system collapsed (Dyrvik et al. 1990; p.221-222).

MODEL 11 Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1793 to 1814

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.570371	0.1531	-3.73	0.003
Inflation_2	-0.151620	0.1366	-1.11	0.289
Constant	0.815981	0.2575	3.17	0.008
Inflation_E	0.507495	0.4252	1.19	0.256
Inflation_E_1	-2.68288	0.4463	-6.01	0.000
Death/Birth	-0.0922850	0.2321	-0.398	0.698
Death/Birth_1	-0.995475	0.2916	-3.41	0.005
DTemp_Tr	-0.245441	0.04090	-6.00	0.000
gKurantNotes_1	3.79065	0.5440	6.97	0.000
gSpecieNotes_1	0.112259	0.04656	2.41	0.033

sigma	0.17892	RSS	0.384146849
R^2	0.890539	F(9,12) =	10.85 [0.000]**
log-likelihood	13.3089	DW	2.54
no. of observations	22	no. of parameters	10
mean(Inflation)	0.168983	var(Inflation)	0.15952

An R-squared of 0.89 without the use of dummy variables is very high. We observe that the coefficients have signs similar to the ones we have found earlier, except for the death/birth-ratio. We would expect this to be positive. This sign changes if we introduce dummies for 1812 and 1813.

MODEL 12 Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1793 to 1814

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.865302	0.3166	-2.73	0.021
Inflation_2	-0.321392	0.1971	-1.63	0.134
Constant	0.302093	0.2756	1.10	0.299
Inflation_E	0.798589	0.3548	2.25	0.048
Inflation_E_1	-1.68172	0.4523	-3.72	0.004
Death/Birth	0.194666	0.2050	0.950	0.365
Death/Birth_1	-0.567997	0.2715	-2.09	0.063
DTemp_Tr	-0.122720	0.04953	-2.48	0.033
gKurantNotes_1	2.92472	0.5455	5.36	0.000
gSpecieNotes_1	0.0909119	0.04296	2.12	0.060
d1812	0.926533	0.2885	3.21	0.009
d1813	0.221418	0.5007	0.442	0.668

sigma	0.135152	RSS	0.18266133
R^2	0.947952	F(11,10) =	16.56 [0.000]**
log-likelihood	21.4862	DW	2.41
no. of observations	22	no. of parameters	12
mean(Inflation)	0.168983	var(Inflation)	0.15952

We observe that the effect of an increase in money supply is significant, even after the introduction of dummies for the extreme observations. We can conclude that a large increase in money supply does create inflation.

2.6 The effect of wars

Wars were frequent phenomena in the 17th and 18th century. From 1600 to 1720, Norway (as a part of Denmark) took part in no less than seven wars, almost all of them against Sweden. Of interest to this study are the war from 1675 to 1679 (Gyldenløvefeiden) and the final war against Sweden, the Great Nordic War (1709-1720). Sweden was finally defeated and Scandinavia enjoyed a remarkably long period of peace. This period, called “the long peace” ended when the British navy attacked Copenhagen in 1807. The result of this attack was that Denmark-Norway was forced to join the French side in the Napoleonic War. After several tough years, Denmark-Norway lost the war in 1814. As a part of the peace treaty of Kiel, Norway was divided from Denmark and transferred as booty to Sweden. This was the last war in Norway until World War Two.

On the international scene there were even more wars. The great powers were fighting more or less constantly. The first main war after 1667 was the Dutch War (1672-78). This was followed by the War of the Grand Alliance (1688-1697). Then followed three wars of succession; the Spanish (1701-13), the Polish (1733-38) and finally the Austrian (1740-48). The first global war with fighting on both sides of the Atlantic Ocean was the Seven Years’ War (1756-1763). This was followed by the American War of Independence. It started in 1775 as a civil war within the British Empire, but from 1778 the colonies were joined by France, Spain and the Netherlands. The war ended in 1783 when Britain was defeated. The Storm on the Bastille (1789) marked the beginning of two and a half violent decades. The Revolutionary War broke out in 1792. This war continued as the Napoleonic War and did not end until the battle of Waterloo in 1815.

According to Hamilton (1977; p.13) wars did have little, if any, effect on price inflation in the 16th and 17th centuries. His main argument is that "*too high a percentage of the people was required to produce basic necessities for the civilian population for much manpower to be released to fight, produce munitions, and feed and clothe the armed forces*". The first war that "*clearly exerted upward pressure on prices in Spain was the War of the Spanish Succession*". Does the same result hold for Norway? We observe that the Norwegian price level increased considerably when the Great Nordic War broke out in 1709. This might have been the effect of the outbreak of the war, but even in England the prices rose considerably this year, and England was not involved in the Great Nordic War. The reason for the increase in prices may have been "*one of the most frigid winters that Europe has ever experienced*" (Hamilton 1969; p.143). When the War of the Austrian Succession broke out in 1740, prices in Norway increased by 19 percent and the next year by 33 percent. Norway did not take part in this war, but Prussia did. When the war broke out, King Frederick 2nd (the great) of Prussia bought grain to his army's grain storehouses. According to Feldbæk (1998; p.91), this was the main reason of the increase in prices. The next main war was the Seven Year's War. Denmark-Norway was neutral, but had to spend a lot of money to defend the neutrality (Feldbæk 1998; p.74-75). This put an upward pressure on prices. The price level increased with 60 per cent and did never return to the old price level. The War of American Independence did not immediately cause inflation in Norway, but at the end of the war, rumours of peace started to spread. Speculation started, and the prices increased with 28 percent. When the peace came in 1783, terms of trade changed and a trade crisis developed (Svendsen & Hansen 1968; p.45). The last war is the Revolutionary War that started in 1792 and ended in 1815 as the Napoleonic War. This was a very expensive war, both in casualties and expenses. Because of the British blockade from 1807 imports to Norway were close to zero. Combined with failed harvests this caused considerably increase in prices, especially in 1812, when prices increased with 152 percent.

It's not easy to decide how the wars should be included in the analysis. From the short historic summary above, we observe that things happened to the price level at the beginning of a war. This is an argument for including a dummy at the start of a war. These dummies should also be lagged since the effects don't have to be immediate. Another method is to include war-dummy for every year of war. Should all wars be treated in the same way? Probably not. It is not obvious that we should treat a war that Norway took an active part in, in the same way as one that Norway was not involved in.

A first attempt is to include a dummy for every single war. We can use this to check if Hamilton's statement that only wars after 1700 put an upward pressure on prices is true for Norway. In the output below wN is a dummy for each war that Norway took directly part in and wE is a dummy for major European wars. All wars are mentioned in the short summary of European history above.

MODEL 13 Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1668 to 1830

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.254250	0.08115	-3.13	0.002
Inflation_2	-0.253019	0.06575	-3.85	0.000
Constant	-0.0626031	0.03996	-1.57	0.119
Inflation_E	0.640053	0.1180	5.43	0.000
Inflation_E_1	0.238852	0.1300	1.84	0.068
Death/Birth	0.0894141	0.04250	2.10	0.037
Death/Birth_1	-0.0234948	0.04210	-0.558	0.578
wN-Gyldenløve	-0.0383904	0.07259	-0.529	0.598
wN-Great Nordic	0.0338530	0.03849	0.879	0.381
wN-Napoleonic	0.397891	0.06381	6.24	0.000
wE-Dutch	0.00517270	0.06193	0.0835	0.934
wE-Grand Alliance	-0.0214476	0.04317	-0.497	0.620
wE-Spanish	0.0231856	0.03720	0.623	0.534
wE-Polish	0.0438231	0.04989	0.878	0.381
wE-Austrian	0.00614156	0.04316	0.142	0.887
wE-7 years	0.109430	0.04450	2.46	0.015
wE-American	0.0569126	0.04989	1.14	0.256
wE-Napoleonic	0.0603282	0.03281	1.84	0.068
d1812	1.21243	0.1344	9.02	0.000
d1813	-0.653521	0.1738	-3.76	0.000

sigma	0.117099	RSS	1.96083853
R^2	0.678994	F(19,143) =	15.92 [0.000]**
log-likelihood	128.974	DW	2.02
no. of observations	163	no. of parameters	20
mean(Inflation)	0.0272612	var(Inflation)	0.0374749

We regain the same effects of lagged inflation, English inflation and the death/birth-ratio as above. When we study the wars we notice that the only Nordic war before 1700 had a negative effect on inflation, though the effect is not significant. It seems that the Great Nordic War caused some inflation, and that the Napoleonic War definitively put an upward pressure on prices. The first European War that caused any significant inflation was the Seven Year's War. The War of American Independence and the Napoleonic War seem both to have caused inflation, but the effects are not significant. From the analysis below we can conclude like Hamilton that only wars after 1700 put an upward pressure on prices.

The next step is to introduce a general dummy for the outbreak of a war (wN-out and wE-out). At the beginning of a war, or perhaps even before the war, resources were allocated from civilian purposes to war use. This transformation process will take some time. To allow for this process, we will include three lags of the outbreaks dummies.

MODEL 14 Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1668 to 1830

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.0782309	0.09202	-0.850	0.397
Inflation_2	0.0245960	0.06629	0.371	0.711
Constant	-0.00547132	0.04198	-0.130	0.896
Inflation_E	0.603447	0.1373	4.40	0.000
Inflation_E_1	-0.00929895	0.1467	-0.0634	0.950
Death/Birth	0.0616715	0.04894	1.26	0.210
Death/Birth_1	-0.0430114	0.04836	-0.889	0.375
wN-out	0.0874599	0.08203	1.07	0.288
wN-out_1	0.132839	0.08293	1.60	0.111
wN-out_2	0.104667	0.08394	1.25	0.214
wN-out_3	0.0410784	0.08362	0.491	0.624
wE-out	0.0152548	0.04996	0.305	0.761
wE-out_1	0.0836103	0.04986	1.68	0.096
wE-out_2	0.0313210	0.05081	0.616	0.539
wE-out_3	-0.0809136	0.05120	-1.58	0.116
d1812	1.48720	0.1509	9.86	0.000
d1813	-0.619535	0.2038	-3.04	0.003

sigma	0.135872	RSS	2.69533599
R^2	0.55875	F(16,146) =	11.55 [0.000]**
log-likelihood	103.045	DW	1.93
no. of observations	163	no. of parameters	17
mean(Inflation)	0.0272612	var(Inflation)	0.0374749

Notice that the effects of lagged inflation are not significant anymore. The effect of an outbreak of a war that Norway takes part in is stronger than the effect of a war that Norway is not involved in. The reason is obvious, if you take part in a war; the war related expenses are much higher than if you don't take part. If you don't take part, you will only have expenses on defending neutrality.

2.7 English inflation revisited

So far all the explanatory variables have been treated as exogenous. For a variable like temperature, this must obviously be correct. On the other hand, it's doubtful that English inflation is independent with respect to Norwegian inflation. Norway has always been an exporting country, and a lot of exports have had England as its destination. A change in

Norwegian prices will influence English inflation by their import prices. If this argument is true, the results from the OLS-regressions may suffer from simultaneity bias.

To avoid this problem of endogenous right hand side variable, we use the instrument variable (IV) estimation procedure. First we estimate an equation for English inflation using instruments, and then we use this estimate when we estimate present Norwegian inflation. This method is also known as two stages least squares (2SLS).

The final model of Norwegian inflation that we want to estimate with the IV-method includes most of the effects we have studied so far. We will not include the effect of paper money because then we would have to exclude several observations both at the beginning and at the end of our sample, but all the other effects will be included. A standard OLS-estimation of this model give the following results.

MODEL 15 — Modelling Inflation by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1725 to 1830

	Coefficient	Std.Error	t-value	t-prob
Inflation_1	-0.0929934	0.1211	-0.768	0.445
Inflation_2	-0.0239401	0.1016	-0.236	0.814
Constant	-0.0414607	0.06165	-0.673	0.503
Inflation_E	0.476024	0.1907	2.50	0.014
Inflation_E_1	-0.0457618	0.2059	-0.222	0.825
Death/Birth	0.134098	0.07495	1.79	0.077
Death/Birth_1	-0.100462	0.07132	-1.41	0.162
wN	0.196833	0.2122	0.927	0.356
wE	0.0641739	0.03294	1.95	0.055
wN-out	-0.160730	0.2395	-0.671	0.504
wN-out_1	0.216334	0.2601	0.832	0.408
wN-out_2	0.0767883	0.2725	0.282	0.779
wE-out	0.00817885	0.07048	0.116	0.908
wE-out_1	0.127590	0.06966	1.83	0.070
wE-out_2	-0.0304130	0.07179	-0.424	0.673
d1812	1.29673	0.2744	4.73	0.000
d1813	-0.823483	0.3273	-2.52	0.014

sigma	0.142586	RSS	1.80942755
R^2	0.66642	F(16,89) =	11.11 [0.000]**
log-likelihood	65.3252	DW	1.99
no. of observations	106	no. of parameters	17
mean(Inflation)	0.0385199	var(Inflation)	0.0511724

We observe that all our previous results hold for this model too. Our next task is to find instruments for English inflation. We will use all the variables from the regression above, but we will include some additional instruments.

It's reasonable to include lagged values of English inflation. We will also include the growth rate of notes in circulation in England (Coppieters 1955). The death/birth-ratio for England and a dummy for the Napoleonic War are included. At the end, two special dummies are included. In 1800 the price index by Phelps Brown and Hopkins moves considerably different from the wholesales price index published by Mitchell (1975) as shown in the graph below. Something must have happened between the wholesales and the consumer markets. This movement should allow us to use a dummy for this year. The other episode took place in 1825. A liquidity crisis developed into a major bank crisis when the Bank of England decided to build reserves instead of supplying the local banker with liquidity (Clapham 1944; p.98). This abnormal situation might have caused more inflation than would otherwise been the case.

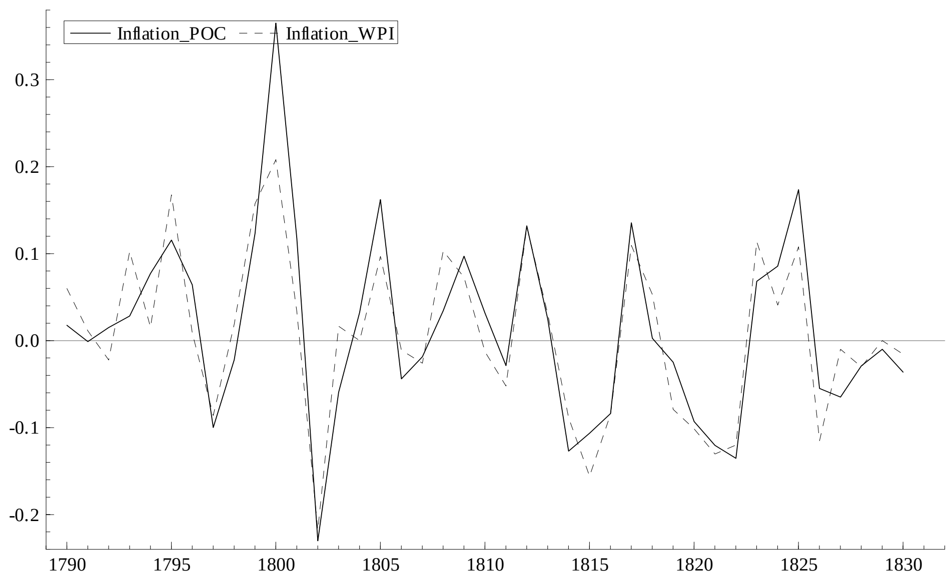

Figure 14: To alternative inflation rates for England/United Kingdom

When estimating the model 15 with the instrumental variable method, we get the following results.

MODEL 16	Modelling Inflation by IVE (using skeie-masterthesis.xls) The estimation sample is: 1725 to 1830			
	Coefficient	Std.Error	t-value	t-prob
Inflation_E Y	0.612877	0.2792	2.20	0.031
Inflation_1	-0.119472	0.1277	-0.936	0.352
Inflation_2	-0.0253164	0.1019	-0.248	0.804
Inflation_E_1	-0.0671672	0.2089	-0.322	0.749
Constant	-0.0505605	0.06329	-0.799	0.426
Death/Birth	0.139675	0.07562	1.85	0.068
Death/Birth_1	-0.0939910	0.07217	-1.30	0.196
wN	0.196813	0.2129	0.925	0.358
wE	0.0629467	0.03308	1.90	0.060
wN-out	-0.159088	0.2402	-0.662	0.510
wN-out_1	0.213495	0.2609	0.818	0.415
wN-out_2	0.0727164	0.2734	0.266	0.791
wE-out	0.00105941	0.07147	0.0148	0.988
wE-out_1	0.125557	0.06993	1.80	0.076
wE-out_2	-0.0232799	0.07278	-0.320	0.750
d1812	1.29571	0.2752	4.71	0.000
d1813	-0.783482	0.3336	-2.35	0.021

sigma	0.142998	RSS	1.81989813
Reduced form sigma	0.13679		
no. of observations	106	no. of parameters	17
no. endogenous var.	2	no. of instruments	27
mean(Inflation)	0.0385199	var(Inflation)	0.0511724

The reader will immediately notice that this estimation gives results that are not very different from the OLS estimation. Both the coefficients and the standard errors for lagged inflation is practically unchanged. This is true for all the variables treated an exogenous. The effect of the only endogenous variable, English inflation is somewhat stronger when using the IV-method, but the standard error has increased so the t-value is lower, though still above two. We can conclude that treating English inflation as exogenous will cause an underestimation of the effect of English inflation on Norwegian inflation, but this simultaneity bias will not change the estimation results drastically. OLS estimation will most likely give the correct effects (signs) and approximately the same value as IV estimation.

3. Inflation 1830-1914

During the 19th century the Norwegian and the international economy underwent dramatic changes. In the early 19th century the economy was dominated by the primary industries and the financial sector was not very developed. During the century money economy spread and new industries developed. New technology like steamboats and railways made long distance trade much easier. We can look at the 19th century as the period when the economy was transformed from the old agrarian economy to a modern economy.

Another reason to treat the 19th century separately is of a more practical nature. In the first few decades after Norwegian independence from Denmark in 1814 the data situation is improved. From 1819 monetary data is available and from 1830 the national accounts are available. This makes it possible to specify models that we could not estimate in the previous chapter, namely the conventional models of academic economics, monetary models and the Philips Curve for example.

In section 3.1 and 3.2 we will investigate the money demand function as an inflation model. We will investigate both simple models in differenced data and more complex error correction models. In section 3.3 and 3.4 we will develop the P*-model. It is a monetarist inflation model that explains inflation as a function of previous inflation and last period prices deviation from an equilibrium level. We will conclude this chapter by the Phillips curve model.

3.1 The inverted money demand function

The standard textbook money market equilibrium (the LM-equation) states that the real supply of money is equal to the demand for money. The demand for money is determined by the need for money for transaction purposes and the alternative cost of holding money. The alternative cost of holding money is given by the interest rate and we assume that the volume of transactions is proportional to real GDP.

(2) $$\frac{M_t}{P_t} = m\left(Y_t, R_t\right) = AY_t^{\beta_1} R_t^{\beta_2}$$

In equation (2) money demand at time t is given by a Cobb-Douglas function where Y_t is real GDP at time t and R_t is one plus the nominal interest rate (i), $R_t = 1 + i$. The supply of real money is the nominal money stock (M_t) divided by the price level (P_t). A is a constant term. According to standard theory an increase in income will increase the demand for money for transaction purposes. We can conclude that β_1 is positive. When the nominal interest rate increases, the alternative cost of holding money increases. People will want to hold less money since there is no interest on money. We can conclude that β_2 is negative.

Taking logs of equation (2) and solving with respect to the price level yields

(3) $$p_t = -a - \beta_1 y_t - \beta_2 r_t + m_t$$

where lower case letters denotes the logarithms of the original variables. To get a model of inflation we take the first difference of equation (3).

(4) $$\Delta p_t = -\beta_1 \Delta y_t - \beta_2 \Delta r_t + \Delta m_t$$

We have now inverted a money demand function to get a model of inflation. Hendry and Ericsson (1991) have pointed out that this inversion may be invalid. If the money demand function is non-invertible, the parameters may be unstable, making policy implications and forecasts inaccurate. As a consequence, we must take some reservations concerning the interpretations of the regression results in section 3.2 and 4.1.

Equation (4) states that there is a deterministic relationship between prices, money stock, GDP and the interest rate. In other words, that equation (2) always holds as a short run relationship. We do not believe that the relationship is deterministic, but rather in a stochastic relationship.

(5) $$\Delta p_t = \alpha_0 + \alpha_1 \Delta y_t + \alpha_2 \Delta r_t + \alpha_3 \Delta m_t + \varepsilon_t$$

If the theory of equation (2) and (4) is correct, we should expect that $\alpha_0 = 0$, $\alpha_1 = -\beta_1 < 0$, $\alpha_2 = -\beta_2 > 0$ and $\alpha_3 = 1$. One problem with this model is that it has been derived from the static equation (2). It assumes that we always will be in steady state. This is not a reasonable assumption. A better model will include some dynamics.

An alternative starting point is to specify an autoregressive distributed lag model (ADL) of the price level based on equation (3) where we include one lag of the explanatory variables. In this model equation (2) and (3) are interpreted as the long run relationship, and not as a short run relationship as in our previous model.

$$p_t = \beta_0 + \beta_1 m_t + \beta_2 m_{t-1} + \beta_3 y_t + \beta_4 y_{t-1} + \beta_5 r_t + \beta_6 r_{t-1} + \alpha p_{t-1} + \varepsilon_t \qquad (6)$$

We can subtract p_{t-1} from both side of the equation. After some manipulations we will get the following error correction model (ECM)

$$\begin{aligned}\Delta p_t = {} & \beta_0 + \beta_1 \Delta m_t + (\beta_1 + \beta_2) m_{t-1} + \beta_3 \Delta y_t + (\beta_3 + \beta_4) y_{t-1} + \beta_5 \Delta r_t + (\beta_5 + \beta_6) r_{t-1} \\ & + (\alpha - 1) p_{t-1} + \varepsilon_t\end{aligned} \qquad (7)$$

It is useful to collect the level terms for time t-1 inside a bracket, as in

$$\Delta p_t = \beta_0 + \beta_1 \Delta m_t + \beta_3 \Delta y_t + \beta_5 \Delta r_t - (1-\alpha)\left\{ p - \frac{\beta_1 + \beta_2}{1-\alpha} m - \frac{\beta_3 + \beta_4}{1-\alpha} y - \frac{\beta_5 + \beta_6}{1-\alpha} r \right\}_{t-1} + \varepsilon_t \qquad (8)$$

which is valid mathematically and stable if α is between -1 and 1. This is the unrestricted version of the ECM. It can be simplified if we impose restrictions on the long run relationship between prices, money stock, real GDP and the interest rate. A closer investigation of the ADL model (6) will reveal that the fractions in front of the money stock, the real GDP and the nominal interest rate (inside the bracket) are the respective long run multipliers of the explanatory variables on the price level. These expressions can be simplified if we impose restrictions on the long run multipliers from economic theory.

The quantity theory of money was formalized by Fisher (1911). The modern version of Fishers theory define the velocity of money (V) as the price level (P) multiplied with real

GDP (Y) and divided by the money stock. This relationship is known as the "equation of exchange". If we assume that the velocity of money is constant, the long run relationship is defined by equation (9).

(9) $$V \equiv \frac{PY}{M} = \bar{V} \Leftrightarrow p = m - y$$

This formulation of the "equation of exchange" explains the price level as the result of a monetary expansion that is larger than the growth rate of real GDP. On the basis of this result Friedman (1963; p.17) stated that "inflation is always and everywhere a monetary phenomenon". We observe from equation (9) that the long run multipliers of the money stock, real GDP and the interest rate are one, minus one and zero respectively. We can now use this information to impose restrictions on equation (8). The ECM equation simplifies to

(10) $$\Delta p_t = \beta_0 + \beta_1 \Delta m_t + \beta_3 \Delta y_t + \beta_5 \Delta r_t - (1-\alpha)\big(p-(m-y)\big)_{t-1} + \varepsilon_t$$

We observe that inflation is explained by two components: first the changes in the explanatory variables and second, the partial correction for the extent to which last period price level deviated from the equilibrium price level.

A general version of the ADL equation with k lags can be expressed as

(11) $$\begin{aligned} p_t &= \alpha_0 + \beta_0 m_t + \ldots + \beta_k m_{t-k} + \gamma_0 y_t + \ldots + \gamma_k y_{t-k} + \delta_0 r_t + \ldots + \delta_k r_{t-k} \\ &\quad + \alpha_1 p_{t-1} + \ldots + \alpha_k p_{t-k} + \varepsilon_t \end{aligned}$$

Following the same manipulations as above, this ADL equation can be transformed into a ECM equation.

(12)
$$\begin{aligned}\Delta p_t = \alpha_0 &+ \left(\sum_{i=0}^{k}\beta_i\right)\Delta m_t - \left(\sum_{i=1}^{k}\beta_i\right)\Delta m_{t-1} - \ldots - \beta_k \Delta m_{t-k+1} \\ &+ \left(\sum_{i=0}^{k}\gamma_i\right)\Delta y_t - \left(\sum_{i=1}^{k}\gamma_i\right)\Delta y_{t-1} - \ldots - \gamma_k \Delta y_{t-k+1} \\ &+ \left(\sum_{i=0}^{k}\delta_i\right)\Delta r_t - \left(\sum_{i=1}^{k}\delta_i\right)\Delta r_{t-1} - \ldots - \delta_k \Delta r_{t-k+1} \\ &- \left(1 - \sum_{i=1}^{k}\alpha_i\right)\left(p - (m - y)\right)_{t-1} + \varepsilon_t\end{aligned}$$

This ECM equation explains inflation in the same way as the more simple version of equation (10), by present and previous changes in the explanatory variables and last period's deviation from the equilibrium price level.

The previous models have all explained inflation as a function of the money stock, the real GDP and the interest rate. When we estimate this model, our estimated equation will give the conditional expectations of inflation given changes in money stock, real GDP and interest rate. In the same way the error terms will be conditional on the same explanatory variables. Our implicit assumption is that causality runs from money stock to prices. This assumption may be incorrect. It may be as likely that the money stock is increased as a response to the increase in prices. The reason is that people will demand more money for transaction purposes when prices increase. Another possibility is that the relationship is circular. Prices affect money and money affects prices.

A second problem with the previous models is that it assumes constant velocity of money. This might be true for a short period of time, but it's reasonable to believe that the velocity has changed dramatically due to technological improvements and the enlargement of the financial sector over the past centuries.

3.2 Modelling the inverted money demand function

We start out this section by modelling equation (5), the simple inflation model based on the money demand function. GDP is real GDP, R is one plus the discount rate of Norges Bank and M2 is the broad money stock. The DL in front of a variable name represents the first difference of the logarithms of the variables. This is approximately the percentage change in the variable.

MODEL 17	Modelling DLCPI by OLS (using skeie-masterthesis.xls) The estimation sample is: 1831 to 1914			
	Coefficient	Std.Error	-value	t-prob
Constant	-0.0115081	0.008792	-1.31	0.194
DLGDP	-0.350960	0.1931	-1.82	0.073
DLR	2.31591	1.040	2.23	0.029
DLM2	0.446835	0.1603	2.79	0.007

sigma	0.0475383	RSS	0.180791098
R^2	0.130625	F(3,80) =	4.007 [0.010]*
log-likelihood	138.741	DW	1.69
no. of observations	84	no. of parameters	4
mean(DLCPI)	0.00203986	var(DLCPI)	0.00247566

We observe results in accordance with the theory discussed in the previous section. There is a negative effect of GDP growth on prices and a positive effect of an increase in the short term interest rate. Notice that the positive effect of interest on prices is the opposite effect of what central bankers believe in today. In present monetary policy regimes, interest rate is increased to lower the inflation. We observe a strong effect of the money stock, but the coefficient is significantly less than one, which means that our model fails. We have chosen to model changes in CPI, but we could alternatively try to model the GDP deflator. If we do so, we can not reject the hypothesis that the coefficient of DLM2 is one.

A more general model will include additional lags. This does not mean that we have changed our assumption about equation (2) being a short run relationship, but we have allowed for some dynamics. We started out with a model with three lags, and by systematically excluding the longest insignificant lags the model was simplified to

MODEL 18	Modelling DLCPI by OLS (using skeie-masterthesis.xls) The estimation sample is: 1831 to 1914			
	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.0350722	0.09851	0.356	0.723
DLCPI_2	-0.0689565	0.09397	-0.734	0.465
DLCPI_3	-0.189936	0.08756	-2.17	0.033
Constant	-0.0257385	0.007702	-3.34	0.001
DLGDP	-0.342230	0.1692	-2.02	0.047
DLR	2.01529	0.8962	2.25	0.027
DLM2	-0.106831	0.1548	-0.690	0.492
DLM2_1	0.852397	0.1547	5.51	0.000

sigma	0.0381857	RSS	0.110819498
R^2	0.467099	F(7,76) =	9.517 [0.000]**
log-likelihood	159.297	DW	1.92
no. of observations	84	no. of parameters	8
mean(DLCPI)	0.00203986	var(DLCPI)	0.00247566

We observe that the effect of lagged inflation on present inflation is unclear. The only significant result is that the third lag has a negative effect. This fits very well with the results from the 17th and the 18th century. We regain the results of GDP and the interest rate from our previous model. The effect of present changes in the money stock is insignificant, but lagged change in the money stock has a positive effect and the coefficient is not significantly different from one. The R-squared is as high as 0.47. This simple model fits surprisingly well.

So far we have only studied simple models in differenced data. An alternative way of modelling dynamics is to use an ADL model or an ECM representation. The error correction term is the previous period's deviation from the long run price level. This can be expressed as $p-(m-y)$ where the lower case letters represents the logs of prices, money stock and real GDP. An estimation of a simple model with only one lag gives the following results.

MODEL 19 — Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1831 to 1914

	Coefficient	Std.Error	t-value	t-prob
Constant	0.0474024	0.08293	0.572	0.569
DLGDP	-0.352523	0.1937	-1.82	0.073
DLR	2.28122	1.044	2.19	0.032
DLM2	0.433314	0.1619	2.68	0.009
p-(m-y)_1	-0.00582601	0.008155	-0.714	0.477

sigma	0.0476844	RSS	0.179630607
R^2	0.136205	F(4,79) =	3.114 [0.020]*
log-likelihood	139.011	DW	1.69
no. of observations	84	no. of parameters	5
mean(DLCPI)	0.00203986	var(DLCPI)	0.00247566

We observe that this model gives results that are very close to those of the simple model without the error correction term (17) and that our error correction term is insignificant. The reason is that we have tried to model a stationary variable (DLCPI) by a variable showing a clear trend. This trend of the error correction term is shown in the figure below.

What is the interpretation of the falling trend in the error correction term? Let us return to the "equation of exchange" (9). Taking logs of all the variables yields

(13) $$v = p + y - m = p - (m - y)$$

The error correction term is in fact the velocity of money. We can conclude that the velocity of money has followed a decreasing trend through the 19th century. This observation contradicts the initial assumption that the velocity of money is constant in the long term. The decreasing velocity is a consequence of the monetization of the economy. During the 19th century the banking sector increased. In 1822 there was only one saving bank and no commercial banks in Norway. In 1914 there were 125 commercial banks and 526 savings banks (Eitrheim et al. 2004, p.395-396).

Figure 15: The error correction term $p - (m - y)$

A solution to this problem can be to introduce an alternative error correction term, the deviation of the velocity of money from its trend. The main question with this procedure is how to identify the trend. In this section we will use the Hodrick-Prescott (HP) filter (Hodrick & Prescott 1997) to smooth the velocity. This method requires the researcher to choose the value of a smoothing parameter λ. An λ equal to zero will give a trend that is equal to the observed variables and an λ equal to infinity will give a linear trend. We have chosen an λ equal to 100. The deviations, which we will call the velocity gap is shown in the graph below. The HP-filter is a symmetric filter, which means that we are using information about future velocity, and therefore prices, when calculating the trend velocity. When using the HP smoothed velocity to explain inflation, the model is greatly helped by the use of a two sided filter for velocity. This is an obvious problem, never the less this approach is commonly used in the literature.

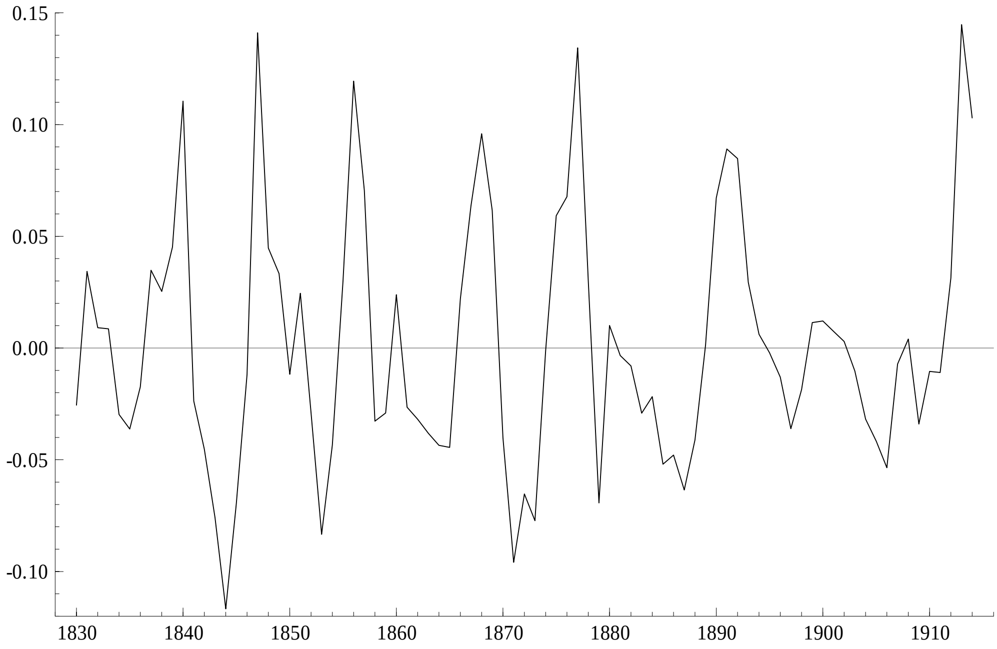

Figure 16: The velocity gap (λ =100)

We will first estimate a model very similar to model 19. The only difference is that the velocity of money is replaced with the HP calculated velocity gap (vgaphp).

MODEL 20 Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1831 to 1914

	Coefficient	Std.Error	t-value	t-prob
Constant	0.00261902	0.007474	0.350	0.727
DLGDP	-0.538516	0.1597	-3.37	0.001
DLR	2.51234	0.8459	2.97	0.004
DLM2	0.247240	0.1339	1.85	0.069
vgaphp_1	-0.545301	0.08416	-6.48	0.000

sigma	0.0386575	RSS	0.118057942
R^2	0.432291	F(4,79) =	15.04 [0.000]**
log-likelihood	156.64	DW	1.31
no. of observations	84	no. of parameters	5
mean(DLCPI)	0.00203986	var(DLCPI)	0.00247566

We observe that the velocity gap turns out to have a significant negative effect, in contrast to the insignificant effect of the error correction term of model 19. Our last model gives a much stronger effect of the GDP and a much smaller effect of the money stock. The effect of the interest rate has approximately the same effect in both models. An R-squared of 0.43 shows that the last model fits much better than the previous model. One reason for the improvement might have been the construction of the velocity gap, as we noted above.

So far we have assumed that the direction of causality is from money to prices. As we have stated before, the opposite causality may be equally likely. To investigate the question of causality, we will estimate two models. First we estimate inflation as a function of lagged changes in the money stock, controlling for GDP growth, changes in the interest rate and international prices inflation and exchange rate movements, measured by the import deflator (DLZdef). In addition we control for lagged velocity and a trend variable representing the monetization of the economy. To make interpretations simple, we exclude the contemporary money growth variable in our inflation equation. Then we will estimate a money demand equation using the same approach and discuss the results.

MODEL 21 — Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1833 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.271981	0.1222	2.23	0.029
DLCPI_2	-0.0262682	0.1106	-0.237	0.813
Constant	3.24646	1.324	2.45	0.017
DLM2_1	0.732322	0.1955	3.75	0.000
DLM2_2	-0.187030	0.2382	-0.785	0.435
DLGDP	-0.347192	0.1733	-2.00	0.049
DLGDP_1	0.211399	0.1743	1.21	0.230
DLGDP_2	0.115867	0.1778	0.652	0.517
DLR	1.82372	0.9515	1.92	0.060
DLR_1	-1.11153	0.9107	-1.22	0.227
DLR_2	0.523115	0.8871	0.590	0.557
DLZdef	0.0279204	0.05732	0.487	0.628
DLZdef_1	-0.153555	0.05969	-2.57	0.012
DLZdef_2	0.0298981	0.06190	0.483	0.631
p-(m-y)_1	-0.170077	0.06788	-2.51	0.015
Trend	-0.00439542	0.001803	-2.44	0.017

sigma	0.0363831	RSS	0.0873663765
R^2	0.5467	F(15,66) =	5.307 [0.000]**
log-likelihood	164.266	DW	1.99
no. of observations	82	no. of parameters	16
mean(DLCPI)	0.00132743	var(DLCPI)	0.00235042

AR 1-2 test[12]:		F(2,64) =	0.87993 [0.4198]
Normality test[13]:		Chi^2(2) =	7.8544 [0.0197]*
hetero test[14]:		F(30,35) =	1.1922 [0.3065]
RESET test[15]:		F(1,65) =	0.94480 [0.3347]

MODEL 22 Modelling DLM2 by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1833 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLM2_1	0.602184	0.1504	4.00	0.000
DLM2_2	-0.0304755	0.1832	-0.166	0.868
Constant	-2.01424	1.018	-1.98	0.052
DLCPI_1	-0.146508	0.09398	-1.56	0.124
DLCPI_2	-0.0394962	0.08505	-0.464	0.644
DLGDP	0.255494	0.1333	1.92	0.060
DLGDP_1	-0.140550	0.1341	-1.05	0.298
DLGDP_2	0.00524338	0.1367	0.0384	0.970
DLR	-0.431191	0.7316	-0.589	0.558
DLR_1	-0.562006	0.7003	-0.803	0.425
DLR_2	-1.22227	0.6821	-1.79	0.078
DLZdef	0.0668923	0.04407	1.52	0.134
DLZdef_1	0.0143702	0.04590	0.313	0.755
DLZdef_2	-0.0437474	0.04759	-0.919	0.361
p-(m-y)_1	0.102408	0.05220	1.96	0.054
Trend	0.00282357	0.001386	2.04	0.046

sigma	0.0279761	RSS	0.0516556909
R^2	0.51696	F(15,66) =	4.709 [0.000]**
log-likelihood	185.812	DW	1.88
no. of observations	82	no. of parameters	16
mean(DLM2)	0.0491767	var(DLM2)	0.00130413

AR 1-2 test:		F(2,64) =	1.4990 [0.2311]
Normality test:		Chi^2(2) =	8.1129 [0.0173]*
hetero test:		F(30,35) =	0.84908 [0.6740]
RESET test:		F(1,65) =	1.6897 [0.1982]

We observe that lagged money growth has a strong and significant effect on inflation. On the other hand, we observe that inflation does not have any significant effect on money growth. On the basis of these regressions the direction of causality seems to be from money to prices.

In addition we observe a negative impact effect of GDP growth and a positive effect of interest rates on prices. The insignificant effect of contemporary import prices and the positive negative effect of lagged import prices are puzzles. We would expect a positive

[12] Testing for an AR(1) or AR(2) process in the error term. Significance level in brackets. See Hendry and Doornik (2001) and http://www.pcgive.com/ for details for this and the following tests.
[13] Testing for a normal distribution of the error terms.
[14] Testing for heteroskedasticity in the error term.
[15] Testing for model misspecification.

effect of import prices on CPI. In addition, lagged velocity has a negative effect on prices when we are controlling for a trend. The model seems to be fairly well specified according to the test statistics reported above.

The money demand function has the surprising property that an increasing price level will reduce the money demand. The coefficient is not significantly different from zero, so some reservations must be taken. The positive effect of GDP growth, the negative effect of interest rate and the positive effect of imported inflation is as expected. In addition the error correction term has a positive effect. This is as expected since we have defined the error correction term as equilibrium money stock (m*) minus actual money stock, and not in the opposite direction.

(1.14) $$p-(m-y)=-(m-(p+y))=-(m-m^*)=m^*-m$$

Norway in the 19th century was a small open economy with a fixed exchange rate through the silver and gold standards. We know from experiences in the 20th century that maintaining an independent monetary policy in such an environment is very difficult. In the first half of the sample, very few private banks were in operation. As a consequence the central bank was able to control the money stock through the interest rate. There were no banks that could create additional money through the money multiplier. When the number of banks increased at the end of the 19th century, the link between central bank money and the broad money stock was weakend. An additional explanation of an independent monetary policy in the 19th century is that transactions in the exchange markets where mostly related to trade in goods and services and not with pure financial transactions.

3.3 The P*-model

In the late 1980's, a new monetarist based inflation model was developed by researchers at the Board of Governors of the Federal Reserve System in the United States. The model was presented to an international audience by Hallman, Porter and Small (1991)[16]. The main idea is that in the long run, the price level is determined by the long-run equilibrium value of velocity, the current value of potential GDP and the current value of the money stock. As

[16] It had previously been presented by the same authors as Staff Study No. 157, Board of Governors of the Federal Reserve System (1989).

Humphrey (1989) pointed out, the P*-model is not a totally new model. The main ideas have been known to economists since David Hume (1711-76), and monetarist economists like Irving Fisher and Milton Friedman have both used arguments that could easily be transformed into the P*-model. Humphrey (1989) argues that "every economist who believed (1) that the long-term trend of prices is roughly determined by money per unit of full-capacity real output, (2) that actual prices adjust to this trend with a lag, and (3) that during the process of adjustment such prices will be rising faster (or slower) than their trend rate of change qualifies as a P-Star proponent."

In the same way as above, we note that the velocity of money at time t (V_t) is given by the nominal price level (P_t) multiplied by real GDP (Y_t) and divided by the monetary stock (M_t).

(15) $$V_t \equiv \frac{P_t Y_t}{M_t}$$

The basic concept of the P*-model is that in the long run, the equilibrium price level (P_t^*) is defined as the price level consistent with the current value of the money stock (M_t), the long-run equilibrium value of velocity (V_t^*) and the current value of potential real GDP (Y_t^*) (Hallman et al., 1991).

(16) $$V_t^* \equiv \frac{P_t^* Y_t^*}{M_t}$$

Taking logs of both equations yields (capital letters denote the original variables and lower-case letters the corresponding logarithms)

(17) $$v_t \equiv p_t + y_t - m_t \Leftrightarrow p_t = v_t + y_t - m_t$$

(18) $$v_t^* \equiv p_t^* + y_t^* - m_t \Leftrightarrow p_t^* = v_t^* + y_t^* - m_t$$

From equation (17) and (18) we can find an expression for the price gap defined as the difference between the actual price level and the equilibrium price level.

(19) $$p_t - p_t^* = \left(v_t - v_t^*\right) - \left(y_t - y_t^*\right)$$

We observe that the price gap is equal to the velocity gap minus the output gap. The determination of the long-run equilibrium values of prices, velocity and output will be discussed in section 3.4 below, but we can already notice that this model does allow for changes in the velocity of money.

The postulated inflation model in Hallman et al. (1991) is that present inflation is a function of expected inflation next period given the information available this period and the price gap.

(20) $$\pi_t = \alpha + \beta E_t\left[\pi_{t+1}\right] + \gamma\left(p_t - p_t^*\right) + \varepsilon_t$$

When prices are above the equilibrium level, the long run quantity equation (16) is not fulfilled. Inflation has to decrease until prices reach the equilibrium level. According to this model, α must be less than zero.

The model can be enlarged by including other explanatory variables. The model can then be written

(21) $$\pi_t = E_t\left[\pi_{t+1}\right] + \alpha\left(p_t - p_t^*\right) + \beta z_t + \varepsilon_t$$

The P*-model can alternatively be expressed in terms of the real money gap (Bårdsen et al., 2005). We observe from the equation below that the real money gap is the negative price gap.

(22) $$rm_t - rm_t^* = \left(m_t - p_t\right) - \left(m_t - p_t^*\right) = -\left(p_t - p_t^*\right)$$

According to Kool and Tatom (1994), empirical studies have indicated that the P*-model fits better for larger countries than for small countries. They suggest that the exchange rate regime will give the answer to this question. Suppose that a small country has fixed it's currency to the currency of a large country. Purchasing power parity then gives that the inflation rate in the small country must be exactly the same as the inflation rate in the large country. The relevant equilibrium price level for the small country will not be domestically determined, but will be determined by the equilibrium price level for the large country.

By definition, the real exchange rate is given by

(23) $$\Omega \equiv \frac{EP^f}{P^d} \Leftrightarrow P^d = \frac{EP^f}{\Omega} \Leftrightarrow p^d = e + p^f - \omega$$

where E is the exchange rate (price of foreign currency in terms of domestic currency) and P^f and P^d is the foreign and domestic price level. We assume that the equilibrium price level in the larger country is determined by internal factors in that particular country only. Given this price level, we can use equation (23) to calculate the equilibrium price level in the small country.

(24) $$p_t^{d*} = p_t^{f*} + e_t - \omega_t$$

The price gap is then given by the difference between the actual price level and the price level determined by equation (24). This price gap is often called the foreign price gap. Our previous price gap is then referred to as the domestic price gap.

(25) $$\pi_t = \alpha + \beta E_t\left[\pi_{t+1}\right] + \delta\left(p_t - p_t^{d*}\right) + \varepsilon_t$$

3.4 Modelling the P*-Model

The main methodical problem with the P*-model is the calculation of the equilibrium price level. As we saw in the previous section, the price gap is constructed as the difference between the velocity gap and the output gap. Both the velocity gap and the output gap are constructed as the difference between the current value and the equilibrium value of velocity and output respectively. The current values are observable, but the equilibrium values are not.

$$p_t - p_t^* = \left(v_t - v_t^*\right) - \left(y_t - y_t^*\right)$$

The output gap can be constructed in many ways. Frøyland and Nymoen (2000) studies two approaches[17]. One way is to estimate a production function for the economy and use the

[17] See Bernhardsen et al. (2004) for a discussion of several other output gap measures.

predicted values as the potential or trend GDP. This method requires at least real capital stock and labour data. Those data are not available for the 19th century. The second method is to use a filter, for instance the Hodrick-Prescott-filter. We have chosen a HP-filter with a lambda equal to 100.

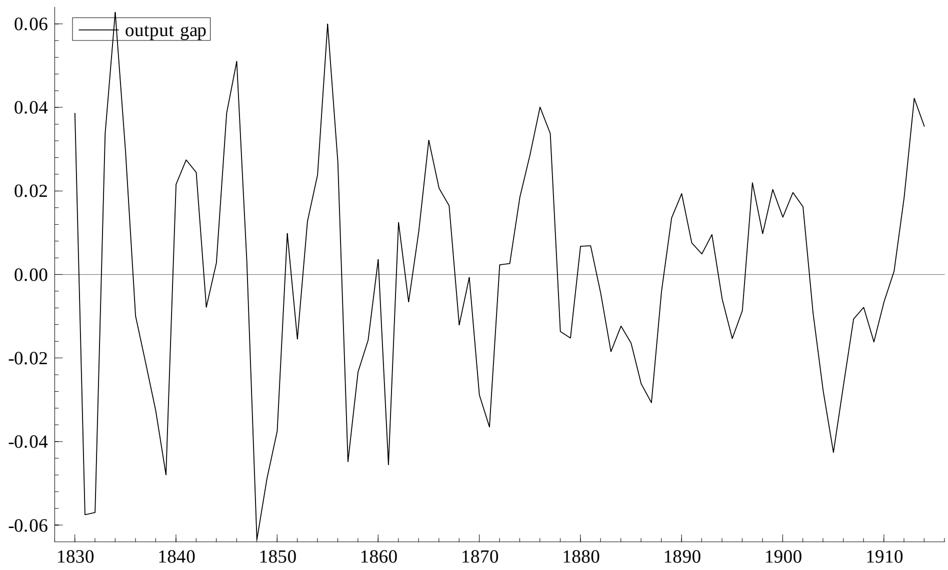

Figure 17: Output gap calculated by a HP-filter (λ = 100)

The velocity gap can be constructed in similar ways. One method is to use variables related to the financial development of the country, as in Bordo and Jonung (1990). The other method is to use a filter, for instance the HP-filter or a backward looking moving average. The choice of method is important because we are using the price level when we calculate the velocity. If we use information about future velocity when we construct the trend velocity, as we are doing when using a symmetric filter like the HP-filter, we are in fact using information about future prices. When we then use trend velocity (an element of the price gap) to explain inflation, we are in fact using future prices to explain future prices. This is obviously a problem and may lead us the conclusion that the model is better than it is.

We start out by modelling the log of velocity (defined as $p-(m-y)$). Following Bordo and Jonung (1990) we will use proxy variables for the spread of the money economy and the expansion of commercial banking. Our model includes the log real GDP per capita (log GDP/capita), the discount rate of Norges Bank (BNDR), the log of the currency to money ration (log Currency/M2) and the number of banks (BANKS).

MODEL 23	Modelling log velocity by OLS (using skeie-masterthesis.xls)			
	The estimation sample is: 1830 to 1914			
	Coefficient	Std.Error	t-value	t-prob
Constant	6.32990	2.113	3.00	0.004
log GDP/capita	0.464900	0.2252	2.06	0.042
BNDR	0.0516274	0.01558	3.31	0.001
log Currency/M2	0.124840	0.06650	1.88	0.064
BANKS	-0.00353763	0.0003806	-9.29	0.000

sigma	0.0858349	RSS	0.589409811
R^2	0.983555	F(4,80) =	1196 [0.000]**
log-likelihood	90.6698	DW	0.387
no. of observations	85	no. of parameters	5
mean(v)	9.98216	var(v)	0.421668

The estimation shows that the growth of banks, from 7 in 1830 to 651 in 1914, has been a major contributor to the fall in velocity. The interpretation is that when the economy is developing from an agrarian economy to a modern economy, people choose to substitute nonmonetary assets for monetary assets both for savings and transactions. This causes the velocity to decline. The number of banks is a proxy for the monetization of the economy. We notice that the DW static is as low as 0.387, which indicate that the error terms of model 23 are autocorrelated. Therefore the standard errors of the coefficients may be too low.

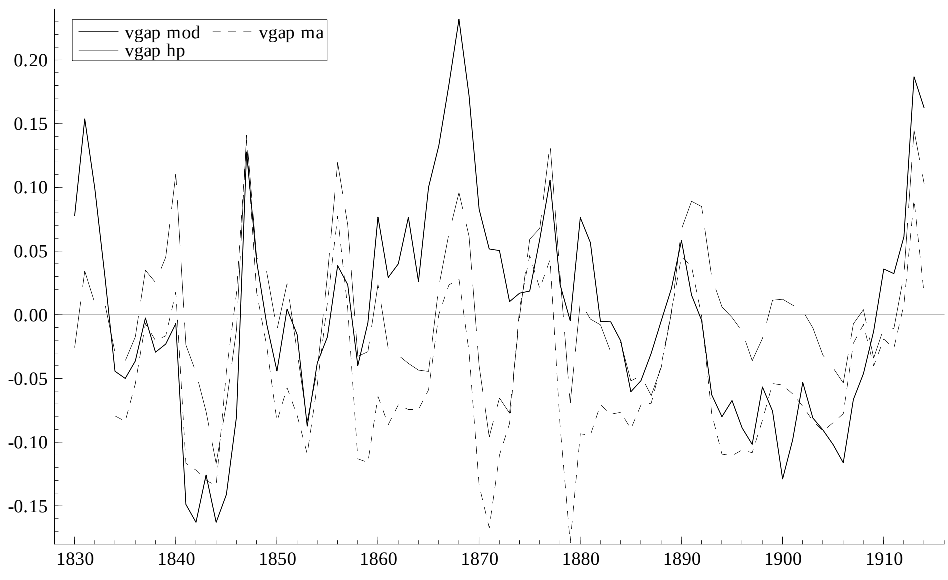

Figure 18: Different measures of the velocity gap (modelled, moving average, HP-filter)

The alternative measures of the trend velocity that we will use are a five year backward looking moving average and a HP-filter with λ equal 100. Figure 18 shows that the velocity gap follows the same trend irrespectively of the calculation methods, but the numerical values will differ considerable.

We will continue by modelling a very simple model where the inflation rate is explained by previous inflation and the price gap only. First we use the Hodrick-Prescott calculated price gap (p*gap(HP), then the moving average based price gap (p*gap(MA)), and finally we conclude by using the price gap based on our velocity model (23) (p*gap(MOD)). The estimation results are given below.

MODEL 24 — Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1835 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.275028	0.08003	3.44	0.001
Constant	0.00267545	0.003834	0.698	0.487
p*gap(HP)_1	-0.554548	0.06826	-8.12	0.000

sigma	0.0342511	RSS	0.0903314181
R^2	0.492958	F(2,77) =	37.43 [0.000]**
log-likelihood	157.937	DW	1.87
no. of observations	80	no. of parameters	3
mean(DLCPI)	0.00342163	var(DLCPI)	0.00222692

AR 1-2 test:	F(2,75) =	0.98888 [0.3768]
Normality test:	Chi^2(2) =	0.35962 [0.8354]
hetero test:	F(4,72) =	3.1811 [0.0183]*
RESET test:	F(1,76) =	0.20935 [0.6486]

MODEL 25 — Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1835 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.408349	0.09795	4.17	0.000
Constant	-0.0197643	0.006109	-3.24	0.002
p*gap(MA)_1	-0.439990	0.08143	-5.40	0.000

sigma	0.0397474	RSS	0.121648905
R^2	0.317169	F(2,77) =	17.88 [0.000]**
log-likelihood	146.031	DW	1.97
no. of observations	80	no. of parameters	3
mean(DLCPI)	0.00342163	var(DLCPI)	0.00222692

AR 1-2 test:	F(2,75) =	1.0492 [0.3553]
Normality test:	Chi^2(2) =	3.6930 [0.1578]
hetero test:	F(4,72) =	2.0360 [0.0984]
RESET test:	F(1,76) =	0.57546 [0.4504]

MODEL 26 Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1835 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.275570	0.1046	2.64	0.010
Constant	0.00160589	0.004996	0.321	0.749
p*gap(MOD)_1	-0.168453	0.05995	-2.81	0.006

sigma	0.0444542	RSS	0.152165395
R^2	0.145876	F(2,77) =	6.575 [0.002]**
log-likelihood	137.077	DW	1.84
no. of observations	80	no. of parameters	3
mean(DLCPI)	0.00342163	var(DLCPI)	0.00222692

AR 1-2 test:	F(2,75) =	3.0851 [0.0516]
Normality test:	Chi^2(2) =	7.7115 [0.0212]*
hetero test:	F(4,72) =	1.1211 [0.3534]
RESET test:	F(1,76) =	1.7586 [0.1888]

We observe that the lagged value of inflation has a significant, but fairly small positive effect and that the price gap has a significant negative effect, exactly as we would expect from a theoretical view. This result holds irrespectively of the method used to calculate the price gap. The main difference is how strong the effect of the price gap is. The HP-filter gives the largest effect and the modelled price gap gives the weakest effect. In the P*-literature the HP-method is the most commonly used, and we will follow the literature in the rest of this section, but remember that the use of a symmetric filter is problematic.

As we have seen, the price gap consists of the velocity gap and the output gap. By definition they should have effects of the same strength but with opposite signs on inflation (se equation (19)). We can relax this assumption, allowing the output gap (ygap) and the velocity gap (vgap) to have independent effects on inflation, and use this specification as an implicit test of model misspecification.

MODEL 27	Modelling DLCPI by OLS (using skeie-masterthesis.xls) The estimation sample is: 1831 to 1914			
	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.317298	0.07821	4.06	0.000
Constant	0.00152295	0.003857	0.395	0.694
ygap_1	0.595874	0.1450	4.11	0.000
vgap_1	-0.584086	0.07277	-8.03	0.000

sigma	0.0352898	RSS	0.0996294121
R^2	0.520909	F(3,80) =	28.99 [0.000]**
log-likelihood	163.768	DW	1.82
no. of observations	84	no. of parameters	4
mean(DLCPI)	0.00203986	var(DLCPI)	0.00247566

We observe a positive effect of the output gap, a negative effect of the velocity gap and that the absolute value of the coefficients is approximately identical. Both results are exactly as we expected, which indicates that the P*-model is well specified. The model is able to explain approximately 52 per cent of the variation in inflation, with a reservation concerning the use of a symmetric filter as noted above. These results indicate that the P*-model is a good inflation model.

As we noticed in the previous section, empirical studies have shown that the P*-model has a tendency to fit better for large than for small countries. The explanation is that in a fixed exchange rate regime, the equilibrium price level is determined abroad. If we include the foreign price gap (fp*gap), we should expect improved fit.

The dominating economic power in the 19th century was England. We will first calculate the equilibrium price level for England and then transform it into an equilibrium price level in Norwegian prices. Then we will model a variation of the P*-model that include both the domestic price gap and the foreign price gap.

The money stock of United Kingdom is constructed by splicing the data series of Friedman and Schwartz (1982) and Huffman and Lothian (1980). They both report the stock of high powered money. The data series overlap in the period 1871 to 1879, but the reported data differ. Friedman and Schwarz are reporting a money stock that is on average 6.3 per cent lower than reported by Huffman and Lothian. When we divide the Huffman-Lothian series with 1.063 we get a spliced data set of the British stock of high powered money from 1833 to 1914. In addition we make use of GDP data of Officer (2003) and the price series of

Phelps Brown and Hopkins. We can now estimate English inflation (DLPOC_E) as a function of lagged inflation and the UK price gap (p*gap_UK).

MODEL 28 Modelling DLPOC_E by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1834 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLPOC_E_1	0.314792	0.09111	3.45	0.001
Constant	0.00213992	0.004837	0.442	0.659
p*gap_UK_1	-0.599879	0.08262	-7.26	0.000

sigma	0.0434819	RSS	0.147472485
R^2	0.416186	F(2,78) =	27.8 [0.000]**
log-likelihood	140.563	DW	2.04
no. of observations	81	no. of parameters	3
mean(DLPOC_E)	0.000561514	var(DLPOC_E)	0.00311854

We observe the same effects as in the model estimated for Norwegian data (24). The coefficients are approximately the same. We observe that the model of English inflation has an R-squared that is a little lower than the Norwegian model. This result does not support the view that the P*-model fits better for larger countries than for smaller.

We can now introduce the foreign price gap (fp*gap) in our model of Norwegian inflation. From a theoretical point of view we should expect a significant foreign price gap and a less significant domestic price gap. In our model we include lagged inflation and both lagged domestic price gap and lagged foreign price gap.

MODEL 29 Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1834 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.307095	0.07996	3.84	0.000
Constant	-0.0229357	0.08617	-0.266	0.791
p*gaphp_1	-0.542745	0.07416	-7.32	0.000
fp*gap_1	0.0110181	0.03826	0.288	0.774

sigma	0.0349505	RSS	0.0940581167
R^2	0.488411	F(3,77) =	24.5 [0.000]**
log-likelihood	158.777	DW	1.89
no. of observations	81	no. of parameters	4

We observe that the foreign price gap has no significant effect on domestic inflation. This result indicates that the equilibrium price level is determined by domestic factors, and not by international as suggested by Kool and Tatom (1994), even though the fixed excange rate regime was very credible in most of the period. This deviation from the expected theoretical result can possibly be explained by the quality of data. First, we have used two different measures of the money stock, broad money (M2) for Norway and high powered money (approximately M0) for England and second, some of the foreign data are for England and some are for the entire United Kingdom.

3.5 The Phillips Curve

The Phillips Curve was first described in an article by Phillips (1958) as a strong negative relationship between the rate of change of money wage rates and the unemployment rate. His finding was based on annual data for the United Kingdom from 1861 to 1957. The policy implication often drawn is that the government can choose a point on the Phillips Curve. It can not choose both low inflation and low unemployment. If the government wants low inflation, it has to accept high inflation, and vice versa.

(26) $$\Delta w_t = f\left(u_t\right), \quad f'\left(u_t\right) < 0$$

The original Phillips Curve was soon criticized by Phelps (1967) and Friedman (1968). They argued that the fatal mistake of the original Phillips Curve was that it ignored expectations. If people expected prices to increase with a certain rate, they would demand the same rate of wage increase just to keep the real wage constant. Then, on top of the expectation effect, would the effect of the unemployment rate come. The expectations-augmented Phillips Curve can be written as

(27) $$\Delta w_t = E_t\left[\Delta p_{t+1}\right] + \beta u_t, \quad \beta < 0$$

Instead of representing the relationship between wage inflation and unemployment, the Phillips Curve is often viewed as the relationship between price inflation and an indicator of economic activity, for instance the output gap.

(28) $$\Delta p_t = \alpha + \beta E_t\left[\Delta p_{t+1}\right] + \gamma\left(y_t - y_t^*\right) + \varepsilon_t$$

We notice that this expression is not very different from the P*-model. The only difference is that the price gap has been exchanged with the output gap. We remember that the price gap consists of the velocity gap and the output gap, which means that the Phillips Curve is a special case of the P*-model where the velocity gap has no effect.

Roberts (1995) showed that several New Keynesian Models with rational expectations have (28) as a common representation. They include the Quadratic Price Adjustment Cost Mode and both Calvo's and Taylor's Staggered-Contract Model. In this model people are only forward looking. This may lead to large and sudden shifts in inflation if expected inflation changes. If this model is true, it should be possible for a central bank to reduce inflation very quickly and without costs in terms of reduced output or increased unemployment with only stating that they would do anything to keep inflation low. If people trust the central bank, the expected inflation will decrease and so will the actual inflation.

Empirical studies have shown that inflation is a persistent phenomenon. The lack of jump behaviour of inflation has led a number of researchers to consider a modified version of the Phillips Curve, the so called *New Hybrid Phillips Curve*. They have chosen to include a lag of inflation to include an element of persistence in the inflation model. The theoretical arguments have been discussed by Galí and Gertler (1999), and the main assumption is that a fraction of the firms are forward looking when they set prices, and the rest use the rule of thumb that next years inflation will be approximately the same as last years inflation.

(29) $$\Delta p_t = \alpha + \beta E_t \left[\Delta p_{t+1}\right] + \gamma \Delta p_{t-1} + \delta\left(y_t - y_t^*\right) + \varepsilon_t$$

In our first model we will assume that expected inflation is equal to last period's inflation. Our simple backward looking Phillips curve model will include only lagged inflation and output gap as explanatory variables. The output gap is calculated in the usual way by a HP-filter with lambda equal to 100.

MODEL 30 — Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1830 to 1914

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.271838	0.1045	2.60	0.011
Constant	0.00214214	0.005251	0.408	0.684
ygap	0.331291	0.1922	1.72	0.089

sigma	0.0483423	RSS	0.191632543
R^2	0.103579	F(2,82) =	4.737 [0.011]*
log-likelihood	138.42	DW	1.9
no. of observations	85	no. of parameters	3
mean(DLCPI)	0.0029427	var(DLCPI)	0.002515

We observe a positive effect of lagged inflation and a positive but insignificant effect of the output gap. The estimated model has an R-squared of only 0.10. We can conclude that this model is too simple to be able to explain inflation in this period. A more sophisticated model will try to model inflation expectations. This can be done by instrument variable estimation where next periods inflation (expDLCPI(t+1)) is an endogenous variable instrumented by five lags of both lagged inflation and the output gap.

MODEL 31 — Modelling DLCPI by IVE (using skeie-masterthesis.xls)
The estimation sample is: 1835 to 1914

	Coefficient	Std.Error	t-value	t-prob
expDLCPI(t+1) Y	0.431179	0.2647	1.63	0.107
Constant	0.00130936	0.005396	0.243	0.809
ygap	0.341744	0.2499	1.37	0.175

sigma	0.0468583	RSS	0.169068773
Reduced form sigma	0.04368		
no. of observations	80	no. of parameters	3
no. endogenous var.	2	no. of instruments	12
mean(DLCPI)	0.00342163	var(DLCPI)	0.00222692

This alternative model results in a stronger effect of the inflation expectation. The output gap has approximately the same effect. The main difference is that in model 31 neither of the coefficients are significant, but in model 30, expected inflation has a significant effect.

From figure 19 we observe that the model seems to fit data well, except for the fact that the fitted values lead actual inflation. It seems that the fit can be approximated by a random walk (Bårdsen, Jansen and Nymoen 2002). A solution to this problem is to add an element of inflation persistence. The hybrid version is a combination of our two previous Phillips curve models. It includes both inflation expectations and lagged inflation in addition to the output gap. We will use up to 5 lags of inflation and the output gap as instruments for the expected inflation.

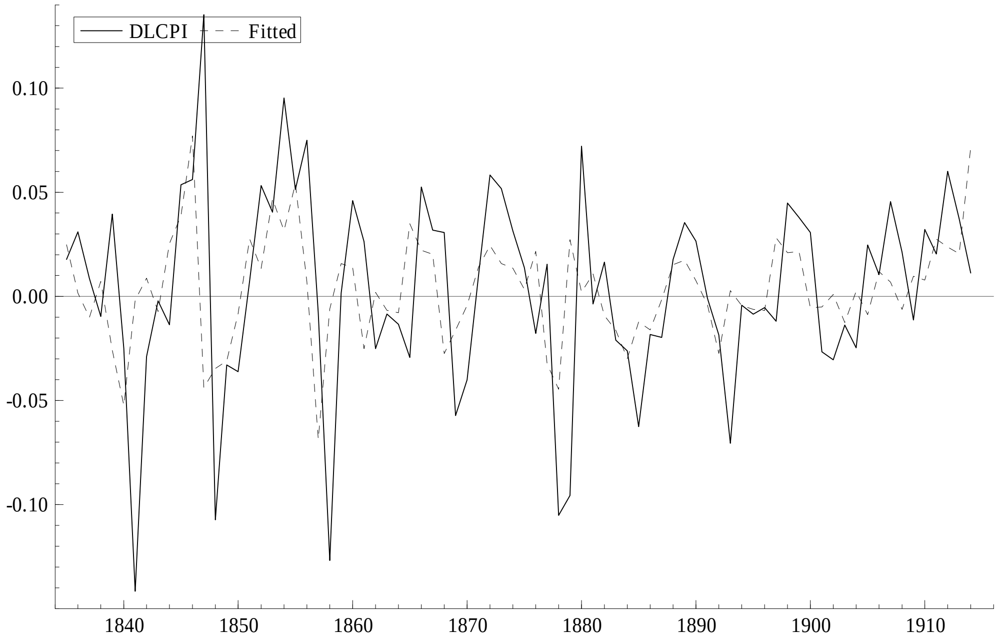

Figure 19: Inflation and fitted value from model 31

MODEL 32	Modelling DLCPI by IVE (using skeie-masterthesis.xls) The estimation sample is: 1835 to 1914			
	Coefficient	Std.Error	t-value	t-prob
expDLCPI(t+1) Y	0.565024	0.2774	2.04	0.045
DLCPI_1	0.248114	0.1161	2.14	0.036
Constant	6.83606e-005	0.005539	0.0123	0.990
ygap	0.195032	0.2642	0.738	0.463

sigma	0.0478405	RSS	0.173942263
Reduced form sigma	0.04368		
no. of observations	80	no. of parameters	4
no. endogenous var.	2	no. of instruments	12
mean(DLCPI)	0.00342163	var(DLCPI)	0.00222692

As expected we observe positive and significant effects of both inflation expectations and lagged inflation. The coefficient of the output gap is positive, but it is not significantly different from zero.

So far we have not included international prices. To investigate the effect of international prices we include current and last period growth rates of import prices. The rest of the model is unchanged.

MODEL 33	Modelling DLCPI by IVE (using skeie-masterthesis.xls) The estimation sample is: 1835 to 1914			
	Coefficient	Std.Error	t-value	t-prob
expDLCPI(t+1) Y	0.514789	0.2678	1.92	0.058
DLCPI_1	0.296711	0.1149	2.58	0.012
Constant	0.000247686	0.005302	0.0467	0.963
ygap	0.258556	0.2451	1.06	0.295
DLZdef	0.129739	0.06366	2.04	0.045
DLZdef_1	-0.116582	0.07371	-1.58	0.118

sigma	0.0450177	RSS	0.149967744
Reduced form sigma	0.041949		
no. of observations	80	no. of parameters	6
no. endogenous var.	2	no. of instruments	14
mean(DLCPI)	0.00342163	var(DLCPI)	0.00222692

We observe that the effects of expected and previous inflation are approximately unchanged. The effect of the output gap is somewhat stronger, but still far from significant. As expected the effect of import prices is positive and significant, but lagged import prices have a negative effect.

We have not been able to find a significant effect of the output gap in our previous models. The failure of the output gap based Phillips Curve model is not an unknown phenomenon in economic literature. First, the output gap will always include measurement errors and second, according to Gali and Gertler (1991) the relevant indicator of economic activity is the marginal cost and not the output gap. Under certain conditions they show that the output gap is equivalent to the marginal cost, but these conditions will not always be satisfied. Gali and Gertler solve this problem by deriving a measure of the unobservable real marginal cost from observable variables like real capital and labour supply. Those variables are not available for the period under investigation, so we have to stick with the output gap.

4. Inflation in the 20th Century

We will conclude our analysis by re-estimating some of our 19th century models with data from the 20th century. We will follow the same approach as in the previous chapter. In section 4.1 we will be investigating the inverted money demand function. We will also extend the analysis by studying the effect of asset prices on inflation. In section 4.2 we will investigate the P*-model and we will conclude this chapter with a section on the Phillips Curve and some related inflation models.

4.1 The inverted money demand function

In section 3.1 and 3.2 we investigated the relationship between prices, money, GDP and the interest rate in the years between 1830 and 1914. We showed that the inverted money demand function could be treated as a model of inflation, though with some reservations concerning stability (Hendry and Ericsson 1991). Our main findings were that in the 19th century money growth had a positive effect, output growth had a negative effect and interest rate had a positive effect on inflation. We also found some support for the view that the direction of causality is from money growth to inflation, and not vice versa. In this section we will estimate the same models, but on data from 1914 to 2004. The question of interest is whether the relationships found for the 19th century will be valid even for the 20th century?

We will start out by investigating the slightly modified error correction specification of the simple inflation model based on the money demand function (similar to model 20). The endogenous variable inflation is a function of the exogenous variables; GDP growth, growth in the nominal interest rate, money growth and the velocity gap. These variables are in general not independent of the inflation rate. A more appropriate approach would have been to model and estimate the relationship as a system, but for simplicity we would continue the single equation approach. The nominal interest rate is defined as the one plus the key rate of Norges Bank. We have used the discount rate up to 1986, the overnight lending rate minus 1.5 percentage point from 1987 to 1990 and the sight deposit rate from 1991. In addition we have included a World War Two dummy (WW2(40-44)) equal one in 1940 to 1944[18], zero otherwise.

[18] We have chosen to exclude 1945 since the war ended in the spring.

MODEL 34 — Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1914 to 2003

	Coefficient	Std.Error	t-value	t-prob
Constant	0.00357686	0.008857	0.404	0.687
DLGDP	-0.181082	0.1427	-1.27	0.208
DLR	1.03746	0.6194	1.68	0.098
DLM2	0.642600	0.06783	9.47	0.000
vgaphp_1	-0.127787	0.06808	-1.88	0.064
WW2(40-44)	-0.0336457	0.02526	-1.33	0.186

sigma	0.0480383	RSS	0.193844601
R^2	0.560118	F(5,84) =	21.39 [0.000]**
log-likelihood	148.618	DW	1.55
no. of observations	90	no. of parameters	6
mean(DLCPI)	0.0419903	var(DLCPI)	0.00489638

We immediately observe that the signs of the estimators are the same as in the 19th century model. The coefficient of output growth is still negative, but it is not significant anymore. Its absolute value has decreased to 1/3 of its previous value. The effect of the interest rate is still positive, but even this coefficient is not significant anymore. On the other hand, the effect of money growth has increased in significance. In the 19th century the parameter was insignificant and equal 0.25. For our new sample period the parameter has increased to 0.64 and the t-value is close to 9.5. On the other hand, the very significant error correction term has now lost its significance. The parameter is close to one fifth of what it used to be. At last we notice that the WW2 dummy has a negative sign. In chapter 2 we identified a positive relationship between inflation and wars. The negative sign, though not significant, is still an interesting result. The reason is probably the very strict price and wage control by the price authorities. It slowed the inflationary process during the war, but didn't do anything with the fundamental driving forces behind the inflationary process. (Hodne and Grytten 2002, p.181).

We have identified a positive relationship between prices and money supply, but the causality is not clear. In model 21 and 22 we found some evidence that in the 19th century; causality ran from money to prices. We will continue by estimating two models very close to model 21 and 22 with data from the 20th century[19].

[19] The import deflator is missing from 1940 to 1945. We have filled this gap by assuming that import prices have followed the same trend as English consumer prices.

MODEL 35 Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1914 to 2004

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.182583	0.1268	1.44	0.154
DLCPI_2	-0.00725882	0.1102	-0.0659	0.948
Constant	0.0270642	0.01064	2.54	0.013
DLM2_1	-0.100324	0.1022	-0.982	0.329
DLM2_2	0.196159	0.1031	1.90	0.061
DLGDP	-0.136840	0.1106	-1.24	0.220
DLGDP_1	-0.222009	0.1015	-2.19	0.032
DLGDP_2	-0.104591	0.1091	-0.959	0.341
DLR	0.452307	0.4368	1.04	0.304
DLR_1	0.547162	0.4343	1.26	0.212
DLR_2	-0.213094	0.4593	-0.464	0.644
DLZdef	0.384101	0.03763	10.2	0.000
DLZdef_1	0.137717	0.06506	2.12	0.038
DLZdef_2	-0.0117384	0.05941	-0.198	0.844
WW2(40-44)	-0.0531782	0.02132	-2.49	0.015
vgaphp_1	0.0173541	0.07832	0.222	0.825

sigma	0.0323995	RSS	0.0787295688
R^2	0.821907	F(15,75) =	23.08 [0.000]**
log-likelihood	191.77	DW	1.97
no. of observations	91	no. of parameters	16
mean(DLCPI)	0.0415775	var(DLCPI)	0.00485791

AR 1-2 test:	F(2,73) =	0.57426 [0.5656]
Normality test:	Chi^2(2) =	7.6988 [0.0213]*
hetero test:	F(29,45) =	5.5343 [0.0000]**
RESET test:	F(1,74) =	0.44876 [0.5050]

MODEL 36 Modelling DLM2 by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1914 to 2003

	Coefficient	Std.Error	t-value	t-prob
DLM2_1	0.513122	0.09322	5.50	0.000
DLM2_2	0.300833	0.09442	3.19	0.002
Constant	0.0131144	0.009711	1.35	0.181
DLCPI_1	-0.217906	0.1158	-1.88	0.064
DLCPI_2	-0.180526	0.1005	-1.80	0.076
DLGDP	0.251300	0.1009	2.49	0.015
DLGDP_1	-0.210646	0.09306	-2.26	0.027
DLGDP_2	-0.0132923	0.09941	-0.134	0.894
DLR	-0.241294	0.4181	-0.577	0.566
DLR_1	0.341336	0.4184	0.816	0.417
DLR_2	-0.467553	0.4203	-1.11	0.270
DLZdef	0.201813	0.03443	5.86	0.000
DLZdef_1	0.182806	0.05929	3.08	0.003
DLZdef_2	0.0727871	0.05445	1.34	0.185
WW2(4044)	-0.0130910	0.01953	-0.670	0.505
vgaphp_1	0.463934	0.07142	6.50	0.000

sigma	0.0295288	RSS	0.0645243506
R^2	0.892131	F(15,74) =	40.8 [0.000]**
log-likelihood	198.119	DW	1.93
no. of observations	90	no. of parameters	16
mean(DLM2)	0.0725444	var(DLM2)	0.00664636

AR 1-2 test:	F(2,72) =	0.26757 [0.7660]
Normality test:	Chi^2(2) =	4.5948 [0.1005]
hetero test:	F(29,44) =	0.78438 [0.7527]
RESET test:	F(1,73) =	2.2860 [0.1349]

In these two models we have included more lags in addition to the growth rate of import prices and the velocity gap. In the inflation equation the immediate effect of money growth is excluded and in the money growth equation the immediate effect of inflation is excluded. We find a positive effect of interest rate and a negative effect of GDP on prices. It seams that there is a positive effect of money growth on prices, but only after two lags. Compared with the 19th century model, the effect of money on prices seems to be slower. Another striking result is the very strong effect of import prices. We found a significant negative effect of the first lag of import prices in our 19th century model. This has now changed into a very strong positive both immediate and the first lagged effect.

What about causality? As noticed above the second lag of money growth has a positive effect on inflation. On the other hand, we are not able to find any significant positive effect of consumer price inflation on money growth. What we observe is a close to significant negative effect. This seams to indicate that if there is any short run causality between money and prices, the direction of causality is from money to prices.

On the other hand, we observe a strong positive effect of the velocity gap in the money demand function, but no significant effect of the velocity gap in the inflation equation. This indicates that there is no tendency to reduction in the price level if prices are above its long run equilibrium value defined as the trend of money per output, but if money is above its long run equilibrium value defined as the trend of prices times output, the money stock will decline. The direction of the long run causality seems to be from prices to money. The reason might be that in a fiat monetary system, where money has no value as a good in itself, people will demand more money when prices increases and the government will print money to meet the demand. In a gold standard regime, such increase in the money supply would not be possible.

We will extend the analyses by including house prices, stock prices and the yield spread following the approach of Goodhart and Hofmann (2000). Their main theory is that prices and wages are sticky, which means that they will respond with a lag to monetary shocks. Asset prices on the other hand are flexible, and will respond directly to monetary shocks. Changes in asset prices caused by monetary shocks should lead changes in consumer prices. The yield spread, defined as the long-term nominal interest rate minus the short-term nominal interest rate, contains information about inflation expectations. From the theory of term structures, we know that long-term interest rate is an average of expected short term interest rates. A higher long-term interest rate than a short term interest rate will imply that the short-term interest rate is expected to increase. Using the Fisher equation that defines the real interest rate as the nominal interest rate minus expected inflation,

(30) $$r_t = i_t - E_t\left[\pi_{t+1}\right]$$

and assuming both a constant real interest rate and a constant risk premium, an increasing yield gap is a result of an increase in expected inflation. We will estimated an extended version of model 35 by including the impact effect of money growth, percentage changes in house prices (DLHouse Prices), stock prices (DLStock Prices), and the yield spread (YS(l-s)) of long term government bonds and Norges Banks key interest rate defined as in the beginning of this section.

MODEL 37 Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1917 to 2000

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.224577	0.1218	1.84	0.070
DLCPI_2	-0.0389663	0.1076	-0.362	0.719
Constant	0.0260731	0.01113	2.34	0.023
DLM2	0.0979785	0.1313	0.746	0.458
DLM2_1	-0.207219	0.1307	-1.58	0.118
DLM2_2	0.209552	0.08723	2.40	0.019
DLGDP	-0.207615	0.1123	-1.85	0.070
DLGDP_1	-0.192476	0.1051	-1.83	0.072
DLGDP_2	-0.157380	0.1129	-1.39	0.169
DLR	0.684511	0.8431	0.812	0.420
DLR_1	-0.0467873	0.8575	-0.0546	0.957
DLR_2	-0.301960	0.5641	-0.535	0.594
DLZdef	0.363622	0.05230	6.95	0.000
DLZdef_1	0.146659	0.07230	2.03	0.047
DLZdef_2	-0.0480821	0.06640	-0.724	0.472
DLHouse Prices	0.0798266	0.05764	1.38	0.171

DLHouse Prices_1	0.00368072	0.06033	0.0610	0.952
DLHouse Prices_2	0.00824318	0.06055	0.136	0.892
DLStock Prices	0.0128214	0.02889	0.444	0.659
DLStock Prices_1	-0.0385713	0.02945	-1.31	0.195
DLStock Prices_2	0.0530358	0.02430	2.18	0.033
YS(l-s)	1.07909	0.7850	1.37	0.174
YS(l-s)_1	-0.971841	1.147	-0.847	0.400
YS(l-s)_2	-0.00506952	0.7916	-0.00640	0.995
WW2(40-44)	-0.0524864	0.02156	-2.43	0.018

sigma	0.031865	RSS	0.059907165
R^2	0.854511	F(24,59) =	14.44 [0.000]**
log-likelihood	185.132	DW	2.01
no. of observations	84	no. of parameters	25
mean(DLCPI)	0.0403604	var(DLCPI)	0.00490197

We observe that controlling for house and stock prices and the yield spread does not change the results of model 35 significantly. The effect of house prices is positive (not significant) as expected. According to the theory, we would expect a delayed effect, but with annual data the effect may be present already in the same period. The effect of stock prices is difficult to interpret. The immediate effect is insignificant, the first lag is negative (also insignificant) and the second lag is positive. We should expect a positive lagged effect, but an effect after two lags might be spurious. The effect of the yield spread is according to our expectations. A high yield spread, which means that inflation is expected to rise, gives a positive (tough not significant) effect on current inflation. Do asset prices help to predict consumer price inflation? Goodhart and Hofmann (2000) concluded that "*such asset prices, especially house prices, do help (…) to assess (predict) future CPI inflation*". We can not conclude that we have found support for this view on our sample. The reason is the lack of significant coefficients, but the model indicates that asset prices might have an effect on inflation. An analysis of quarterly data may give an answer to the problem.

4.2 The P*-Model

We remember that the P*-model is based on the assumption that in the long run, the price level is determined by the long run equilibrium of velocity, the potential GDP and the money stock. Inflation is then modeled as a function of lagged inflation and last period's deviation from the long run equilibrium price level. The 19th century models showed a significant positive effect of lagged inflation and a negative effect of the price gap. This result is as expected from theory. We will now re-estimate this model based on 20th century data.

MODEL 38	Modelling DLCPI by OLS (using skeie-masterthesis.xls) The estimation sample is: 1914 to 2004			
	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.667341	0.08434	7.91	0.000
Constant	0.0112858	0.006761	1.67	0.099
p*gap_1	-0.312842	0.1045	-2.99	0.004
WW2(40-44)	0.0436318	0.02638	1.65	0.102

sigma	0.0536362	RSS	0.250285389
R^2	0.433833	F(3,87) =	22.22 [0.000]**
log-likelihood	139.145	DW	1.75
no. of observations	91	no. of parameters	4
mean(DLCPI)	0.0415775	var(DLCPI)	0.00485791

AR 1-2 test:	F(2,85) =	5.4577 [0.0059]**
Normality test:	Chi^2(2) =	26.663 [0.0000]**
hetero test:	F(5,81) =	8.6742 [0.0000]**
RESET test:	F(1,86) =	3.6538 [0.0593]

We have constructed the price gap by using a HP-filter with λ equal 100 to calculate both potential GDP and trend velocity. We must remember that the use of a HP-filter to smooth velocity will result in a problem with endogenous right side variables (see section 3.4), but it is still the most commonly used method.

The main difference between model 24 and 38 is the changes in the relative effect of lagged inflation and the price gap. In model 24 the coefficient of lagged inflation was 0.27 and the corresponding t-value was 3.44. We observe that lagged inflation has increased in significance. On the other hand, the effect of the price gap has decreased from -0.55 to -0.31. The t-value has decreased from (in absolute values) 8 to 3. This result confirm figure 5 in chapter 1. The persistence of Norwegian inflation has increased. In addition we observe that the model fails most of our tests, and we remember that it passed all tests in our 19th century sample.

In section 3.3 we saw that the price gap is equal to the velocity gap minus the output gap. As a result, if we split the price gap and include both the velocity gap and the output gap in our regression, the resulting coefficients should be of the same size but with opposite signs. We remember from model 27 that this was exactly the result we got estimating the function over the 19th century sample. We will re-estimate this equation based on our 20th century sample.

MODEL 39	Modelling DLCPI by OLS (using skeie-masterthesis.xls) The estimation sample is: 1914 to 2004			
	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.698389	0.07916	8.82	0.000
Constant	0.00875666	0.006347	1.38	0.171
ygap_1	0.974346	0.2027	4.81	0.000
vgap_1	-0.448136	0.1041	-4.30	0.000
WW2(40-44)	0.0586615	0.02495	2.35	0.021

sigma	0.0500611	RSS	0.215525946
R^2	0.512462	F(4,86) =	22.6 [0.000]**
log-likelihood	145.948	DW	1.86
no. of observations	91	no. of parameters	5
mean(DLCPI)	0.0415775	var(DLCPI)	0.00485791

We notice that the coefficients of the output gap and the velocity gap in this sense are widely different when using the 20th century sample. The model fails our implicit test of misspecification, confirming the test results above. One interpretation is that the P*-Model has changed somewhat in the direction of a backward looking Phillips curve. If the coefficient of the velocity gap was equal to zero, our model would in fact be a backward looking Phillips curve.

As mentioned in section 3.4, some comparative studies have shown that the P*-Model fits better for larger countries than for smaller countries. The reason is that in a fixed exchange rate regime, the equilibrium price level is determined abroad. In model 29 we observed that the foreign price gap had an insignificant effect on domestic inflation. We will now re-estimate this model with a minor difference in the definition of the foreign price gap. We will use the British GDP-deflator (Officer 2003) as our price measure and a spliced series of high powered money (Friedman and Schwartz 1982) and an annualized series of Bank of England's monthly M0[20] series as our measure of the UK money stock.

MODEL 40	Modelling DLCPI by OLS (using skeie-masterthesis.xls) The estimation sample is: 1914 to 2001			
	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.630309	0.08883	7.10	0.000
Constant	0.152119	0.1001	1.52	0.132
p*gaphp_1	-0.307062	0.1058	-2.90	0.005
fp*gap_1	0.0323804	0.02308	1.40	0.164
WW2(40-44)	0.0449814	0.02666	1.69	0.095

[20] LPMAVAD: Monthly average amount outstanding of total sterling. URL: *http://www.bankofengland.co.uk/*

sigma	0.054124	RSS	0.243141206
R^2	0.446771	F(4,83) =	16.76 [0.000]**
log-likelihood	134.357	DW	1.73
no. of observations	88	no. of parameters	5
mean(DLCPI)	0.0425213	var(DLCPI)	0.00499426

We observe that the foreign price gap has a positive sign, though not significant, this is the opposite of what we had expected. A possible explanation is that the relevant foreign price gap is not determined by United Kingdom. United Kingdom might have been the relevant country for the first part of the sample, but it's reasonable to assume that USA or Germany would be more relevant for the last part of the sample. This question is open for further studies. Another possibility is that the P*-model is misspecified as indicated by the previous paragraphs.

4.3 The Phillips Curve

In section 3.5 we estimated different Phillips Curve models for the 19th century. We found a positive effect of both expected and lagged inflation and the output gap. These results are as expected from economic theory. We will start this section by re-estimating model 33 on our 20th century sample using 5 lags of inflation and output gap as additional instruments.

MODEL 41 — Modelling DLCPI by IVE (using skeie-masterthesis.xls)
The estimation sample is: 1914 to 2003

	Coefficient	Std.Error	t-value	t-prob
expDLCPI(t+1) Y	0.225283	0.1333	1.69	0.095
DLCPI_1	0.244142	0.08984	2.72	0.008
Constant	0.00848465	0.005276	1.61	0.112
ygap	-0.136504	0.1057	-1.29	0.200
DLZdef	0.296429	0.06505	4.56	0.000
DLZdef_1	0.118981	0.05550	2.14	0.035
WW2(40-44)	-0.0269635	0.01837	-1.47	0.146

sigma	0.0347557	RSS	0.100260702
Reduced form sigma	0.032134		
no. of observations	90	no. of parameters	7
no. endogenous var.	2	no. of instruments	15
mean(DLCPI)	0.0419903	var(DLCPI)	0.00489638

The most striking result is the negative effect of the output gap. The effect of output gap is not changed when exchanging current value with the lagged value. We can conclude that the output gap is not a good indicator of pressure in this Phillips Curve framework. Gali and

Gertler (1999) suggested marginal cost as the relevant variable. In the rest of this section we will re-estimate model 41 using other indicators of economic activity and expectations. We will also try to improve the fit of our model by including some dummy variables for special events.

An alternative measure of the pressure in the economy is the unemployment rate. High activity gives a positive output gap and a low unemployment rate. On the other hand, low activity gives a negative output gap and a high unemployment rate. We should expect a negative effect of unemployment on inflation. One explanation is that with a high unemployment rate, people without jobs are willing to work for low salaries and people with jobs don't want to push for higher wages in fear loosing their jobs to people currently unemployed. High unemployment leads to low wage inflation. If companies set prices as a markup over wages, and the markup is constant, then low wage inflation will lead to low price inflation.

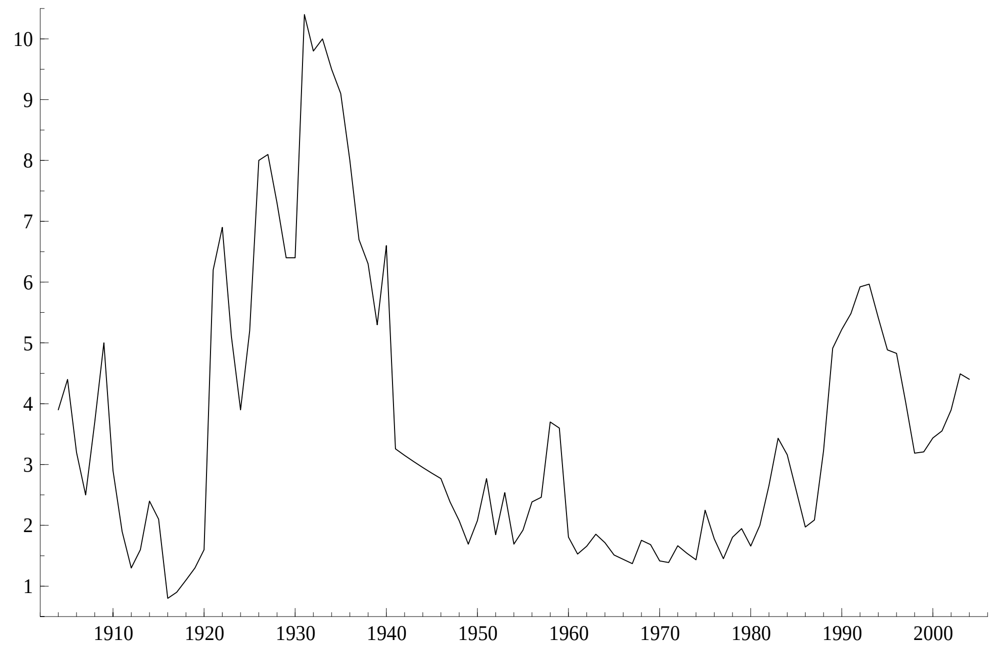

Figure 20: The calculated unemployment rate in Norway as a percentage of total labour force

The first problem that arises is the lack of a continuous unemployment rate series. The solution has been to construct one by splicing existing series and filling in the gaps. We have used the series of unemployed trade unionists from 1904 to 1917. During the crisis in the interwar years we have used the numbers in Grytten (1995), covering the years from 1918 to

1939. From 1939 to 1940 the unemployment rate of trade unionists increased by ¼ and from 1940 to 1941 it decreased by ½. We have assumed that total unemployment changed by the same proportions. During the Second World War, data is not available. We have assumed an exponential decrease in unemployment for this period. We can find some support in Hodne and Grytten (2002). They conclude that the unemployment of the 1930s disappeared during the two first years of the war. From 1946 the unemployment rate of trade unionists series continues. We have divided the numbers with 1.3 to match the OECD numbers that starts in 1960. The only missing years are 1958 and 1959. We have estimated the unemployment rate for these years by using the numbers of unemployed registered at the employment offices.

We will continue our analysis by re-estimating model 41 with the calculated unemployment rate (U) instead of the output gap.

MODEL 42 — Modelling DLCPI by IVE (using skeie-masterthesis.xls)
The estimation sample is: 1914 to 2003

	Coefficient	Std.Error	t-value	t-prob
expDLCPI(t+1) Y	-0.140801	0.2741	-0.514	0.609
DLCPI_1	0.285686	0.1040	2.75	0.007
Constant	0.0286175	0.01450	1.97	0.052
U	-0.286503	0.2247	-1.28	0.206
DLZdef	0.414040	0.1124	3.68	0.000
DLZdef_1	0.106045	0.05831	1.82	0.073
WW2(40-44)	-0.0269002	0.01898	-1.42	0.160

sigma	0.0350891	RSS	0.102193483
Reduced form sigma	0.033944		
no. of observations	90	no. of parameters	7
no. endogenous var.	2	no. of instruments	15
mean(DLCPI)	0.0419903	var(DLCPI)	0.00489638

We observe that the coefficient of the unemployment rate has a negative sign, just as expected, but a t-value of -1.28 indicates that the coefficient is not significantly different from zero. Another problem with this model is the negative sign of the inflation expectations. The coefficient is not significant, but we had expected the coefficient to be positive.

An alternative approach is to use the yield spread as a proxy for expected future inflation. As discussed in section 4.1, a high yield spread can be interpreted as expectations of high inflation in the future. Following the expected augmented Phillips Curve approach, we are only interested in expected inflation next year. Therefore, we should use the difference between the interest on a two year government bond (ST2) and the short money market interest rate. Unfortunately we don't have data of any money market interest rate prior to 1978. We have to use an alternative measure of the short term interest rate. A possible measure is the average interest rate on bank deposits (BDIR). This is usually lower than the money market interest rate, but they will generally follow the same trend. The graph bellow illustrates this point showing the NIBOR[21] 3 month interest rate and the average bank deposit interest rate since 1975.

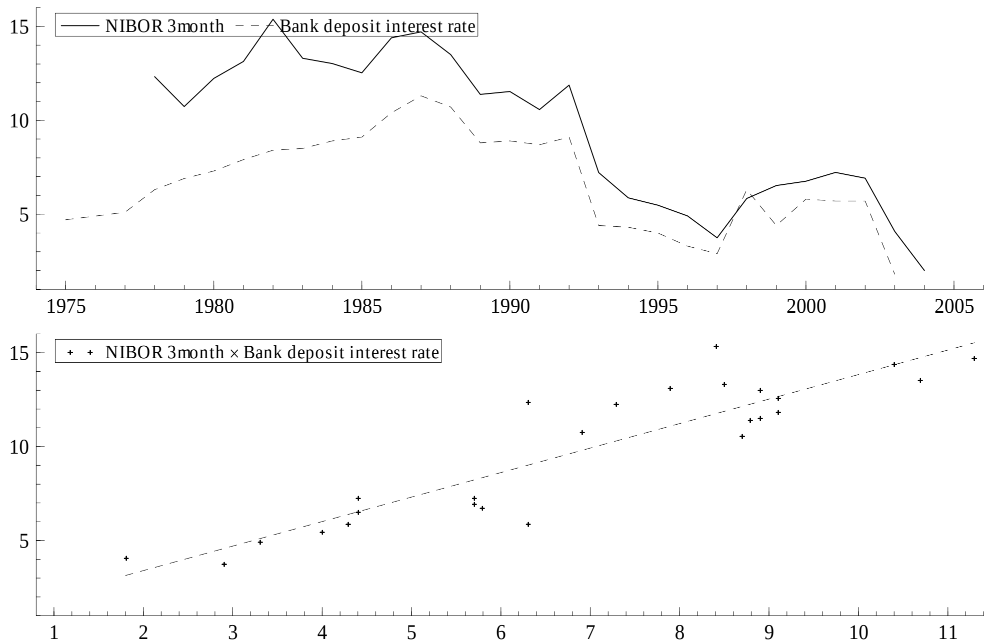

Figure 21: Money market and bank deposits interest rates

We continue our analysis by estimating the alternative Phillips Curve specification were inflation is a function of lagged inflation, the yield spread (YS(ST2-BDIR)), unemployment rate and import price inflation.

MODEL 43 — Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1922 to 2003

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.129612	0.08908	1.46	0.150
Constant	0.00706517	0.007813	0.904	0.369
YS(ST2-BDIR)	1.26757	0.2858	4.43	0.000
U	-0.267213	0.1360	-1.96	0.053
DLZdef	0.349629	0.03713	9.42	0.000

[21] Norwegian Inter Bank Offered Rate

DLZdef_1	0.128569	0.05431	2.37	0.020

sigma	0.0243436	RSS	0.045038374
R^2	0.827615	F(5,76) =	72.97 [0.000]**
log-likelihood	191.432	DW	1.67
no. of observations	82	no. of parameters	6
mean(DLCPI)	0.0336141	var(DLCPI)	0.00318618

AR 1-2 test:	F(2,74) =	3.3071 [0.0421]*
Normality test:	Chi^2(2) =	7.2141 [0.0271]*
hetero test:	F(10,65) =	2.5259 [0.0123]*
RESET test:	F(1,75) =	0.71409 [0.4008]

We observe that all coefficients have expected signs and that they all are significant or close to significant. The model fits data very well, as indicated by an R^2 of 0.83. In addition, the test summary shows that the residuals do not fail any of our tests while using a 1 percentage significance level. A plot of actual and fitted values and the residuals will identify the main problems with this model.

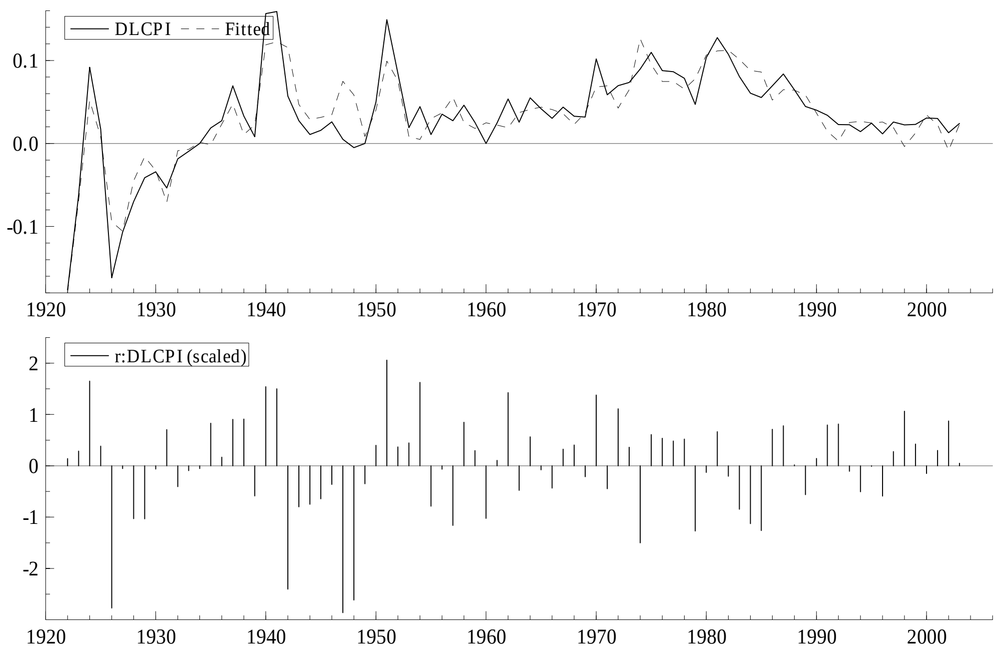

Figure 22: (a) Inflation and fitted value from model 43, (b) Scaled residuals from model 43

The major problem is the negative residuals in the 1940s. Our model predicts higher inflation than actually occurred. The reason is, as mentioned in section 4.1, the very strict price control both during the war and after the war (Hodne and Grytten 2002, p.182). Queues and rationing, not prices were the main market mechanism in function. A proper way to include this effect is to introduce a rationing dummy equal 1 from 1945 to 1950 in addition to our WW2 dummy. Additional dummies may be included for the VAT reform in 1970 and the price stop in 1979. Re-estimating the model with these dummies gives some minor changes to the results.

MODEL 44 Modelling DLCPI by OLS (using skeie-masterthesis.xls)
The estimation sample is: 1922 to 2003

	Coefficient	Std.Error	t-value	t-prob
DLCPI_1	0.0255780	0.08787	0.291	0.772
Constant	0.0244622	0.008403	2.91	0.005
YS(ST2-BDIR)	0.701902	0.2952	2.38	0.020
U	-0.336579	0.1304	-2.58	0.012
DLZdef	0.386376	0.03611	10.7	0.000
DLZdef_1	0.193892	0.05271	3.68	0.000
WW2(40-44)	-0.0209975	0.01225	-1.71	0.091
rationing(45-50)	-0.0469741	0.01183	-3.97	0.000
vat(70)	0.0259996	0.02256	1.15	0.253
pricestop(79)	-0.0424422	0.02279	-1.86	0.067

sigma	0.0220576	RSS	0.0350305911
R^2	0.86592	F(9,72) =	51.67 [0.000]**
log-likelihood	201.735	DW	1.87
no. of observations	82	no. of parameters	10
mean(DLCPI)	0.0336141	var(DLCPI)	0.00318618

AR 1-2 test:	F(2,70) =	6.9497 [0.0018]**
Normality test:	Chi^2(2) =	3.1965 [0.2022]
hetero test:	F(14,57) =	3.4107 [0.0005]**
RESET test:	F(1,71) =	0.10415 [0.7479]

The coefficient of lagged inflation turns out to be insignificant, the effect of the yield spread is reduced, the effect of the unemployment rate is strengthen and the effect of import prices is somewhat stronger. The effect of the dummy variables have the expected signs, though only the rationing dummy (1945-1950) has a significant effect.

Unfortunately, the introduction of dummy variables has as a consequence that the model fails both the tests for both autocorrelation and heteroskedasticity. On the other hand, it has no problem with the normality or the RESET test. We also observe that this model has a somewhat better fit than the previous model. To check the stability of the equation, we re-estimate it recursively with 22 observations used for initializing the recursive estimation. The graph below shows the model coefficients with an interval of $\pm$ 2 standard errors.

We observe that the model shows a remarkable stability since the late 1950s. The only instabilities are a minor change in the impact effect of import prices that occurred in the first half of the 1970s and a minor change in the constant term and the yield spread in the early 1980s. The first might have been an effect of the breakdown of the Bretton Woods system or an effect of the oil price shocks. The second is probably due to the deregulation of the financial markets in Norway.

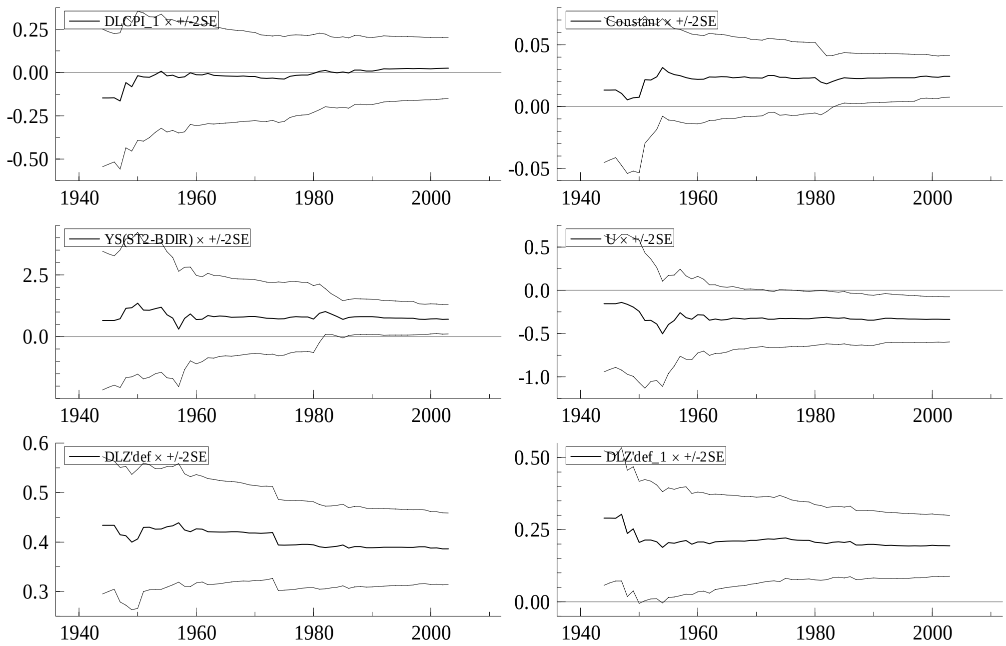

Figure 23: The beta coefficients of the non-dummy variables and their respective confidence intervals

We can conclude that though the model does not pass our main error term tests with a one percentage significance level, the model shows some very promising properties. It is able to explain a great deal of the variation in inflation and the parameters are very stable. The model is a well worth closer investigation, for instance by re-estimating it using quarterly or monthly data or by using it as the inflation equation in a multi-equation model of the economy. These suggestions are left for future studies.

5. Conclusions and suggestions for a more theoretical research

We have over the past three chapters been on a journey through the Norwegian price history using several simple inflation models to put this history in a more theoretical perspective. Some models have been standard models, widely used in the economic literature, while others have never (as far as we know) been used before. The main question at the end of this thesis is what conclusions can be drawn?

The most important conclusion is that such a study, making use of very long time series does make sense. It seems possible to get sensible results, even if the analysis stretches over 100 years or more. Some fundamental economic relationships have survived through periods of changing technology, changing policy regimes and fundamental changes in the society at large. We will in the following paragraphs remind the reader about some of our main results.

Our first finding is that the patterns of price movements have changed. Prior to World War One the general price level was fluctuating. Years of inflation was followed by years of deflation, keeping the average price level fairly constant. Fluctuations in supply caused minor price movements, while the monetary regime (the silver and gold standards) worked as the nominal anchor of the economy keeping the average price level fairly stable. Between 1660 and 1910 there were only two episodes with permanent changes in the price level. The first occurred in the late 1750s and was due to the extreme expenses Denmark-Norway had on defending neutrality during the Seven Years War, and the second major episode took place during the Napoleonic War when the war expenses caused the monetary regime to collapse. After 1914 the persistence of inflation has increased. One reason is that the nominal anchor was weakend. Efforts to reestablish the gold standard after the two world wars was not successful, and when the Bretton Woods regime collapsed in the early 1970s, the nominal anchor was very weak. At this point, people started to expect inflation to continue. The result was even higher and more persistent inflation. Another reason is that the nature of the supply side has changed. In our first sample periods, agrarian production was very important for the aggregate supply, and we know that agrarian production will fluctuate with the weather conditions. In the 20th century, industrial production and services, which is less vulnerable to changes in the weather conditions, was far more important for the aggregate supply. As a result, the annual fluctuations in supply are much smaller than they used to be, and as a consequence the annual fluctuations in prices will be less.

What determines Norwegian inflation? One of our main findings is the close relationship between Norwegian and international price movements. The relationship was surprisingly strong, especially in our first sample period. In most of our models, movements in international prices were the main explanatory variable, irrespectively of model specification and sample period. We can conclude that it is reasonably to maintain the view of Norway as a small open economy that has always[22] been dependent on international developments.

Another important question that has been studied is the relationship between money and prices. There is no doubt that changes in the money supply and in the price level seems to follow the same trend in the long run. It's more difficult to draw any categorical conclusions about the direction of causality. In our first sample (1740 – 1813) we were not able to draw any conclusions about the direction of causality. In the short sub sample covering the breakdown of the monetary system during the Napoleonic War, the direction of causality was from money to prices. Extreme growth in the money supply did create inflation. In our 19th century sample, we found evidence for a significant effect of money on prices, but not vice versa. This is the period of rapid monetization and development of the banking sector. In our 20th century sample, there were very difficult to find any causality, but we found some indications that in the short run, money effects prices, but in the long run the causality seems to be in the opposite direction, from prices to money. This may be due to changes in the monetary regime. The 19th century was dominated by the silver and gold standards. Every owner of a bank note had the right to a certain amount of silver or gold. An increase in the gold or silver stocks should result in more money printed and an increasing price level. In most of the 20th century, fiat money (money by declaration) was dominating. When the price level grew, the government had to print more money to keep up with the demand.

We have been studying three different types of inflation models in our post 1830 samples. The first is based on inverting a traditional money demand function, the second is the P*-model and the third is the Phillips Curve. We have found that all types of models are able to

[22] At least since 1666.

explain a considerable amount of the variation in inflation, but not all the specifications we have estimated has the expected properties.

The inverted money demand function explains inflation as a positive function of nominal interest rate and money supply, and a negative function of output. This result is stable even if we add more exogenous variables, more dynamics or use an error correction specification. The main drawback with this model is that it assumes one-way causality. A better starting point is a hypothesis that the causality is circular; prices affect money and money affect prices, and a system approach is needed to represent all channels of the transmission process.

The P*-model proved to fit data well and showed reasonable parameters in both periods. The most surprising result was that the effect of the foreign price gap was insignificant. This result contradicts our assumption that the equilibrium price level in a small open economy with a fixed exchange rate is given from abroad. The main problem with the P*-model is the calculation of trend velocity. Making use of a HP-filter to detrend velocity creates a problem with an endogenous right hand side variable. The best way to avoid this problem is to model the velocity. This will also give an economic interpretation that a uni-variate filter can not give. Another problem is that the model showed signs of misspecification on our 20th century sample. This may indicate that the model is too simple.

Our third model has been the Phillips Curve. In our 19th century sample we found that the inclusion of the expectation term made the model inaccurate. Fitted values tended to lead actual values. The reason is that the driving force, the output gap, does not have the explanatory power necessary to dominate the effect of expectations. In our 20th century sample the output gap has lost all explanatory power. These weaknesses have led several researchers to suggest other variables as driving forces. As shown in chapter 4, the unemployment rate worked much better as an indicator of economic activity than the output gap, in our Phillips Curve framework. We have also seen that the yield spread can be interpreted as a measure of inflation expectations, and that it showed to have strong explanatory power.

The present study has made use of several single equation models of inflation. We have focused on presenting a variety of models used on a couple of very long sample periods. At the sacrifice of depth, we have chosen to focus on width. A further analysis would include more in depth analysis of the models making use of more sophisticated econometric methods.

The main problem with our approach is that we are modeling the reduced form of a system of several equations. It's reasonable to assume that many of the variables treated as exogenous in this study, is in fact endogenous. This will create simultaneity bias in our estimates. The next and more challenging step is to formulate dynamic systems and estimate these systems simultaneously. The first system we will be thinking of is to model a price-wage system. In a forthcoming study by Grytten, Norwegian wage statistics from 1730 to 2004 will be published, and this will make a very interesting study of prices and wages possible.

We can also try to establish small empirical models for the Norwegian economy, trying to make more and more variables endogenous. One possible approach is to start with our last equation, viewing inflation as a function of the yield spread, the unemployment rate and import prices, and build a system around this equation making unemployment, yield spread and exchange rates endogenous.

Another possible approach is to focus on the period prior to 1830. With some effort it will be possible to gather more data, especially data on governmental finances and the minting of coins. In addition it might be possible to use taxes as a proxy for output, but then we will have to correct for changes in tax regimes. Another very interesting source is the exchange rates and price data for other countries. With these variables, in addition the forthcoming wage study by Grytten and those that have been used in this thesis, it should be possible to get a very good understanding of the Norwegian economy prior to 1830.

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