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Exchange Rate Intervention and Inflation:
An Analysis of the Maximum Floor in Switzerland.

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Markus Mayer, Feldkirch, May 2012

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1 Introductory Remarks

The analysis of time series is one of the oldest activities of scientific man.

Wayne Fuller (1996)

In September 2011, the Swiss National Bank (SNB) announced, they will not tolerate an euro exchange rate of less than 1.20 Swiss francs. The main justification for this measure is to protect Swiss companies, which are exporting into the euro zone, from an unexpected low exchange rate. During the year 2011, it became evident, euro zone countries like Greece may face problems paying back their debts. Many investors tried to protect their assets from devaluation by converting them into Swiss francs. The implementation of this de facto fixed exchange rate raised many fears in the Swiss public, the inflation rate may raise significantly.

The aim of the first part of this thesis is to conduct a univariate time series forecast for the Swiss inflation and to contrast our findings with predictions of other institutions, which already contain the information, the intervention occurred. The sample we use for the time series forecast covers a time span of 20 years up to the moment of the intervention. Therefore our forecast will not consider the implications of the measure of the Swiss National Bank. This approach allows us to identify the additional inflation rate caused by the intervention of the Swiss National Bank by comparing the time series forecast with other forecasts.

In the second part of this thesis, we estimate the relationship of the valuation of the Swiss franc and the growth rate of the Swiss economy. The approach we applied allows us to identify the costs associated with an intervention at a certain exchange rate, in terms of lost growth. In the conclusion, we use the results of both parts to derive a statement about the optimal moment of the intervention.

The main part of this thesis concentrates on the standard ARIMA model and neglects extensions and special versions of the ARIMA model and much more complicated alternative techniques like Artificial Neural Networks. This narrow focus is motivated by the principle of parsimony. Econometricians advise us to choose a model with as few parameters as possible. Models, which are fitted too closely to the data usually produce inferior forecasts.

Not always has the ARIMA model been the workhorse to forecast inflation. In the sixties, economic research was dominated by forecasts based on simultaneous-equation models with many equations. It was a standard approach to use multivariate procedures of forecasting. In the eighties, it became clear univariate models

often provide superior forecasts. This change in the perception laid the ground for the success of the univariate ARIMA model, suggested by Box-Jenkins (1984) (Greene, 2003).

Today, the standard forecasting method to conduct a univariate forecast is the ARIMA model. Canova (2002) found in his comparison of different forecasting methods for the countries of the G-7, forecasting models with two or three variables are just slightly superior to univariate models. Only the inclusion of some variables increases the quality of the prediction and only by a certain small margin. Forecasters, who conducted successful multivariate forecasts, included different variables. In a bivariate model, a model with two variables, unemployment can be included as a second variable to account for the relationship predicted by the Phillips curve. Economic theory suggests the inclusion of other variables like GDP growth, nominal M2 growth, real M2 growth and many more. The state of the world can be modelled by the inclusion of international variables, like the GDP growth of the US economy. Canova shows, according to the MSE, a measure of forecasting accuracy, the unemployment rate is the best second variable for most G-7 countries. International variables have a small positive effect on the forecast of some countries. The forecasting of inflation with the Phillips curve is widely accepted among econometricians, despite the fact, there is mixed evidence, if the inclusion of unemployment increases the forecast accuracy. Canova compared the forecast accuracy of the Consumer Price Index (CPI) with the accuracy of the GDP deflator. He found no significant difference. In this investigation, we use data of the CPI. Monthly data for the CPI is compiled by the Swiss National Bank and easily accessible on the internet. In summary, it is advisable to use univariate forecasting methods like ARIMA, if the analyst is not an experienced forecaster. The results of univariate methods are usually sufficiently precise.

Inflation forecasting became highly relevant for monetary policy. In recent years, central banks have adopted a strategy called inflation targeting. Central banks define targeting goals for the inflation on a medium-term and long-term horizon. The bylaws of the Swiss National Bank clearly define the target of an inflation of less than two percent, if there is no recession in Switzerland. Inflation targeting was introduced to achieve two goals. To increase the transparency of the central banks policy and to define the goal variable instead of the intermediary variable. The second aspect avoids changes in the relationship between the intermediary variable and the goal variable have a negative effect on the outcome. It can be shown, it is ideal to target forecasts of medium-term inflation instead of inflation itself. Three types of forecasts can be targeted by central banks. Forecasts conducted by the private sector can be used as targets. The second option is to derive the inflation

from certain asset prices. The third option for central banks is to target their own internal inflation forecasts (Bernanke, 1997).

This thesis has the following structure. In the next chapter, we introduce the time series and their main properties. Chapter 3 reviews the intervention of the Swiss National Bank in detail. The section "Theory of Inflation" aims to help the reader to appraise the importance of inflation forecasts. The econometric methodology of the ARIMA model is developed step by step in chapter 4. Chapter 5 estimates the ARIMA model. After we have checked the specification of the model and found the specification to be acceptable, we use the model to forecast the inflation for the next two years. We conduct a point forecast in chapter 6. The section "Interpretation of Forecasting Results" contrasts our estimation results with forecasts which are carried out after the announcement of the lower bound. In the last chapter of this thesis, we estimate the optimal moment for the intervention of the SNB. The conclusion sums up our results.

We employ the statistical package R for our estimations, which became a standard tool in econometrics. The package `tseries` makes the application of R more convenient for the estimation of ARIMA models.

2 Time-Series Properties of Data

2.1 Data Sources

The present investigation employs monthly data for the first part of the analysis. The time period under consideration starts with January 1992 and ends with December 2011. We rely on the judgement of Canova (2002), a time span of 20 years is sufficiently long. All data we used can be freely accessed on the internet. The data for the German exports EXPG and for the exports of the Swiss economy to the euro zone EXPS are used to make the decision of the Swiss National Bank more understandable. Data on the monetary base MONB and yields on Swiss government bonds YIELDS are used to pursue the same objective.

The exports of the German economy to the rest of the world can be found on the website of the Deutsche Bundesbank. We use the series BBK01.JJ5005: VGR - Exporte (preisbereinigt):

http://www.bundesbank.de/Navigation/DE/Statistiken/Zeitreihen_Datenbanken/zeitreihen_datensbank.html

EXPG German exports: Annual, 1992 to 2011 (12 observations), obtained from the website of the Deutsche Bundesbank.

To show the development of the Swiss exports in the past, we use annual data for the exports to all euro-zone countries:

<http://www.bfs.admin.ch/bfs/portal/de/index/themen/06/05/blank/data.html>

EXPS Swiss exports to euro-zone countries: Annual, 1992 to 2011 (12 observations), obtained from the website of the Eidgenössisches Bundesamt für Statistik.

Monthly data for the monetary base (Notenbankgeldmenge B1) can be found on the website of the Swiss National Bank:

http://www.snb.ch/en/iabout/stat/statpub/statmon/stats/statmon/statmon_B1

MONB Monetary base: Monthly, 1992 to 2011 (240 observations), obtained from the website of the Swiss National Bank.

Yields on Swiss government bonds with a duration of 3 years are used as data for interest rates to show the effect of the monetary policy:

http://www.snb.ch/en/iabout/stat/statpub/akziwe/stats/akziwe/akziwe_S1_Zins

YIELDS Yields on Swiss government bonds, 3 Years: Monthly, 1992 to 2011 (120 observations), obtained from the website of the Swiss National Bank.

To show the development of the Swiss exports in the past, we use annual data for the exports to all euro-zone countries:

<http://www.bfs.admin.ch/bfs/portal/de/index/themen/06/05/blank/data.html>

EUR/CHF Euro against Swiss franc: Daily, Jan 1992 to Dec 2011 (2562 observations), retrievable from the time series database of the Deutsche Bundesbank.

The series for the CPI are taken from the Swiss National Bank database:

http://www.snb.ch/de/iabout/stat/statpub/statmon/stats/statmon/statmon_O1_1

CPI Consumer Price Index: O11 Konsumentenpreise - Total: Monthly, Jan 1992 to Dec 2011 (240 observations), obtained from the Statistisches Monatsheft, Preise und Löhne, published by the Swiss National Bank.

In section 6.2, we will compare our time series based forecast with forecasts of the Swiss National Bank, the wealth management bank UBS, the Konjunkturforschungsinstitut of the ETH Zürich and the life insurance Swiss Life. They were conducted in the first quarter of 2012 and contain the information, the maximum floor was introduced. They are available online:

SNB Inflation forecast of the Swiss National Bank: Annual, 2012 to 2013 (2 observations), downloadable from <http://www.snb.ch/de/iabout/pub/oecpub>.

UBS Inflation forecast of UBS: Annual, 2012 to 2013 (2 observations), obtained from http://www.ubs.com/global/wealth_management/wealth_management_research/Swiss_economic_forecast.html.

KOF KOF consensus forecast: Annual, 2012 to 2013 (2 observations), available on <http://www.kof.ethz.ch/de/prognosen/kofconsensusforecast/>.

LIFE Inflation forecast published by the economic research department of Swiss Life: Annual, 2012 to 2013 (2 observations), obtained from www.Swisslife-am.com/content/internet/slam/de/home/Asset_Management/Expertise/Economy/_jcr_content/middlePar/download/.

In the last chapter of this thesis, we estimate the optimal moment for the exchange rate intervention. We base this estimation on the exchange rate (XRAT), purchasing power parity over GDP (PPP) and the real gross domestic product per capita in current prices (CGDP) for Switzerland. They are freely accessible on the website of the Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, informally called Penn World Tables:

<http://pwt.econ.upenn.edu/index.html>

XRAT Exchange rate: Five-year periods, 1950-1954 to 2000-2004 (11 observations).

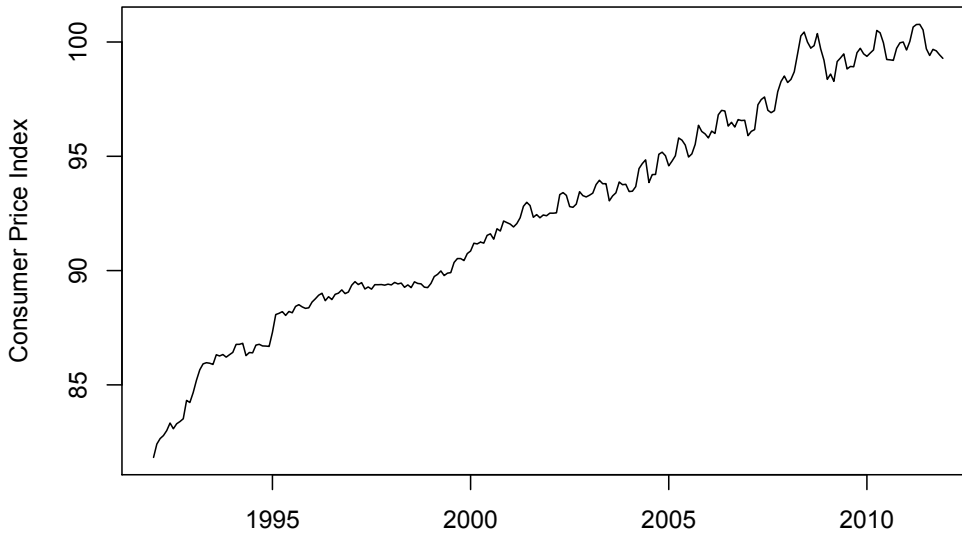
PPP Purchasing power parity: Five-year periods, 1950-1954 to 2000-2004 (11 observations).

CGDP Real gross domestic product per capita in current prices: Five-year periods, 1950-1954 to 2000-2004 (11 observations).

2.2 Preliminary Data Analysis

This section aims to describe the data by presenting a plot of the original data, the consumer price index (CPI), and the transformed data, a series for the inflation rate of Switzerland. The plot for the consumer price index gives us an idea whether we have to remove errors in the data. The data points in the plot appear to be reasonable. There are no obvious outliers or errors. We do not have to remove any data points. The time span of 20 years (1992M1-2011M12) is based on the judgement of Canova (2002).

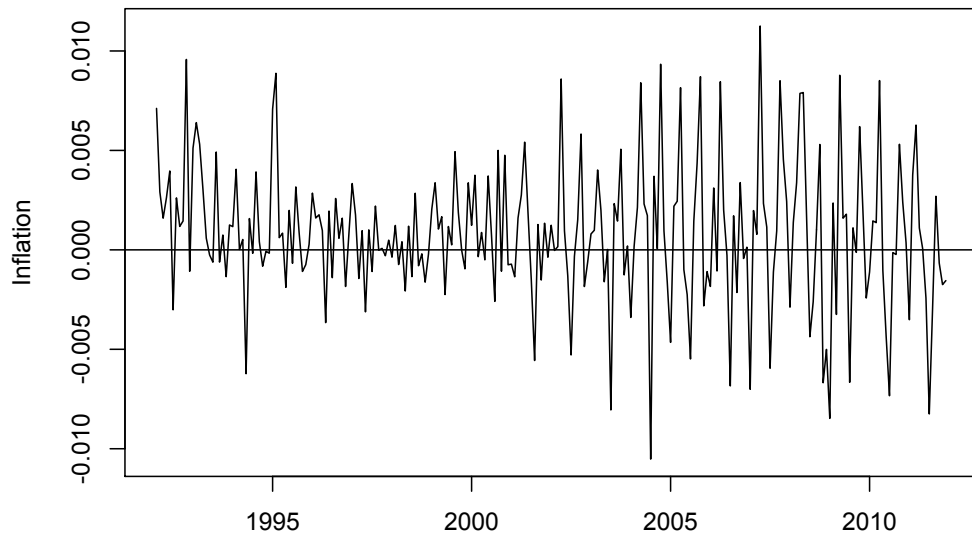
Figure 2.2.1: Consumer Price Index of Switzerland.



The main part of this thesis aims to conduct a forecast of the monthly inflation. We therefore have to take the logarithmic differences to transform the CPI into the monthly inflation π . Logarithmic differences of an index like the CPI approximately equal the percentage changes of successive periods.

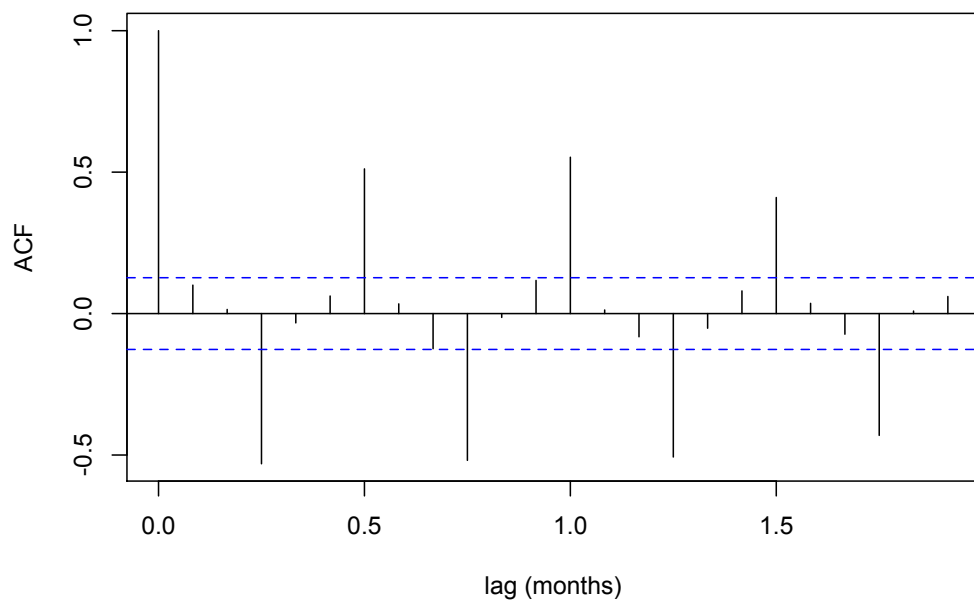
$$\pi = \ln CPI_t - \ln CPI_{t-1}$$

Figure 2.2.2: Inflation rate of Switzerland.



A short inspection of the autocorrelation function of the inflation series clearly shows seasonal effects. The seasonal patterns superimpose the information, we want to base our forecast on. They have to be removed. The next section is devoted to the deseasonalisation procedure X-12-ARIMA.

Figure 2.2.3: Autocorrelation function of the inflation.



2.3 Deseasonalisation

A short inspection of Figure 2.3.1 reveals strong seasonal patterns, which superimpose the inflation series. To obtain a reasonable forecast, we have to seasonally adjust the series. If the series is seasonally adjusted, we can fit a standard ARIMA model. Alternatively, we could use the more complicated SARIMA model, an ARIMA specification, which was designed to deal with seasonal effects in the data. Among all standard procedures to seasonally adjust the data, the X-12-ARIMA is the most sophisticated one. The procedure behind the X-12-ARIMA was developed by the United States Census Bureau in collaboration with Statistics Canada. The software package, which contains the procedure is freely available on the website of the United States Census Bureau. The application of the X-12-ARIMA procedure is recommended by the European Central Bank, the Deutsche Bundesbank as well as by the Eidgenössisches Bundesamt für Statistik as a standard tool to deseasonalise data.

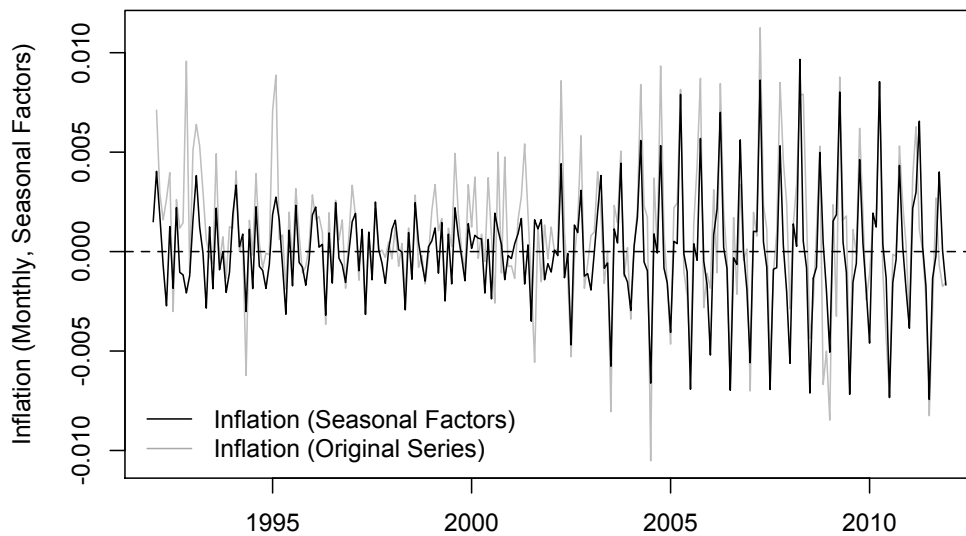
To obtain a seasonally adjusted series, we have to decompose the inflation series into the trend, the seasonal and the random component. Because the series is stationary and the variance is roughly constant over time, we assume an additive seasonal model. The trend, the seasonal and the random component have an additive relationship, like in the following formula.

$$X_t = trend_t + seasonal_t + random_t$$

In the multiplicative model, the relationship of the components is multiplicative. If the trend is positive and the series increases, the seasonal patterns become stronger. The output of the seasonal factors clearly shows (see Figure 2.3.1) the assumption of an additive model is justified. The optimal filter has been found by automatic model selection.

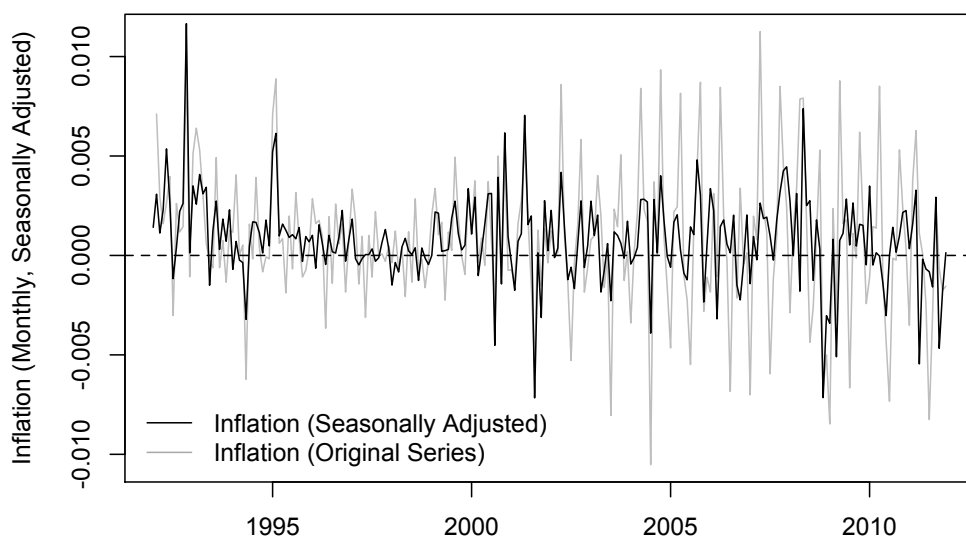
The inflation on the ordinate appears to be small. Note, we have monthly data, and therefore monthly inflation. The following table summarizes the properties of the monthly inflation series.

Figure 2.3.1: Identification of seasonal effects.



If we remove the seasonal factors from the original series of the inflation, we obtain a seasonally adjusted series. For the rest of the first part of this thesis, we will use this seasonally adjusted series to fit the ARIMA model to obtain our forecasting results.

Figure 2.3.2: Seasonally adjusted inflation series.



3 Exchange Rate Intervention of the Swiss National Bank

3.1 Theoretical Perspective on Inflation

3.1.1 Measures of Inflation

Inflation is one of the most important macroeconomic variables besides real GDP and unemployment rate. The inflation measures how fast prices are increasing. If they are decreasing, economists speak of deflation. In the decades after the second world war, inflation was not a big issue in the United States. As inflation rose significantly in the seventies, economists started to study inflation more intensively. Since the year 2000, inflation was between two and three percent in the United States and around two percent in the euro zone. A price level like that is called stable.

The two most important and most common measures for inflation are the GDP deflator and the Consumer Price Index (CPI). The GDP deflator is called deflator, because it extracts the inflation from the nominal GDP.

$$GDPdeflator = \frac{NominalGDP}{RealGDP}$$

A more precise tool to measure the costs of living is the CPI. Statistical offices have the responsibility to gather the data for the CPI. To fulfill this responsibility, they measure the prices of thousands of goods and services. The CPI is the price of the basket of goods and services divided by the price of the same basket in the base year. The consumer price index for n goods and services is calculated as follows.

$$CPI = \sum_{i=1}^n CPI_i \times w_i$$

where w_i is the weight of the good i in the calculation of the CPI. There are different indices for different subsets of the society. The consumer price index measures the price level relative to the base year for the average consumer. The difference between the GDP deflator and the CPI is given by three aspects. The GDP deflator is a measure of the price level of the goods and services, which are produced inside the economy. The CPI measures the price level of all goods and services consumed in the economy. Secondly, the GDP deflator only includes the goods and services, which are produced inside the economy. The price level of imported goods and services has no effect on the GDP deflator. The third difference is, the GDP deflator measures the price level of a basket, which changes

over time, where the CPI measures the price level of a basket, which is fixed in the base period. An index with a fixed basket is called Laspeyres index, an index with a changing basket is called Paasche index. In the past, the difference between the GDP deflator and the CPI has not been a big one. There is just minor evidence the CPI has a tendency to overstate inflation. Decision makers in public service rely on the CPI to justify decisions (Mankiw, 2011).

On a more fundamental level, inflation describes the increase of the general level of prices and prices are the ratio at which goods and services are exchanged. Therefore, if we aim to understand what inflation is, we have to understand what money is. Today the quantity of money is controlled by central banks. Many central banks like the European Central Bank and the Swiss National Bank have a high degree of independence from the government. Among economists, it is a convention to define money as the stock of assets, which can be immediately used to conduct transactions. In microeconomics, prices are defined in a relative way, as the ratio of exchange of goods and services to other goods and services. The advantage of money over a pure barter economy is, money makes indirect and complex transactions possible. It is not necessary anymore for the individuals to deal with each other directly. Most major currencies have at least to a high degree no intrinsic value. The United States abolished the gold standard during the Nixon administration in the seventies. This type of money, with no intrinsic value is called fiat money in economics. The term fiat describes the fact that money of this type is established by the government by decret. Fiat money can only fulfill the functions of money as long as people accept it as money. Because the gold standard evolved into a fiat money system, people never questioned the value of fiat money. The amount of money called money supply is subject to the responsibility of the central banks. This responsibility is called monetary policy. The money supply is controlled by open-market operations. They buy and sell government bonds. If the central bank sells government bonds, they receive money from the public and as a result, the money in circulation decreases. There are different measures available for the quantity of money. There is disagreement among econometricians, which one is the best. The most commonly used measures in empirical analysis are M1 and M2. The definition of M1 includes currency, demand deposits, traveler's checks and other checkable deposits. The definition of M2 includes all elements of M1 and extends them by retail money market mutual fund balances, saving deposits and short time deposits (Mankiw, 2011).

3.1.2 Money Demand Function

Monetary economic theory aims to understand how the amount of money in circulation affects the real economy. The money demand function gives us this relationship:

$$(M/P)^d = kY$$

where P denotes the price level and Y the income. The constant k contains the information, how much money people demand for one euro more of income. If we set supply and demand equal, we obtain the expression:

$$M/P = kY$$

If we reorder this expression, we obtain the following expression:

$$M(1/k) = PY$$

We can substitute $1/k$ by the term V for the velocity of money in the economy.

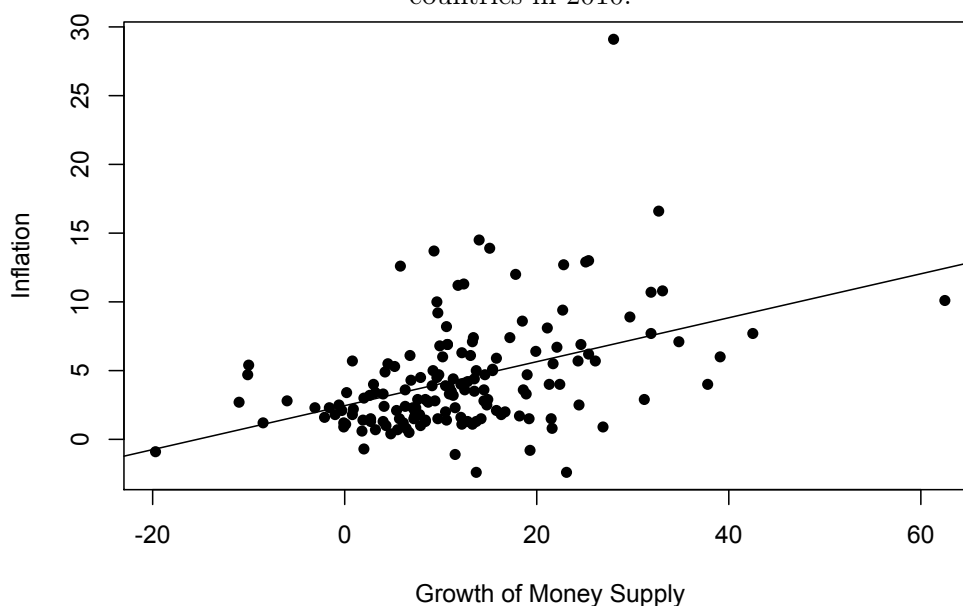
$$MV = PY$$

If we assume, the velocity is fixed, which is just a rough approximation to reality, the quantity equation can be rewritten as:

$$M\bar{V} = PY$$

A change in the quantity of money M of one percent, changes the value of the production of the economy by one percent. In summary, according to the quantity theory of money, central banks control the inflation rate by adopting the money supply. This relationship between growth in the money supply and the inflation rate can easily be shown empirically. We obtained the data for 159 countries for the year 2010 from the website of the Worldbank. The original data was provided by the International Monetary Fund. Figure 3.1.1 gives us the scatterplot for the variables inflation and growth of money supply. The line shows a linear regression and was fitted by ordinary least squares estimation (Mankiw, 2011).

Figure 3.1.1: Scatterplot of inflation and growth of money supply for 159 countries in 2010.



3.1.3 Social Costs of Inflation

After we clarified the question what inflation is and why it occurs, we want to understand the consequences on the social system. The social costs of inflation can be identified by studying periods of hyperinflation in the past. There is no consensus among economists about the magnitude of the social costs. Average people and the news media tend to be more concerned about inflation than economists. Menu costs and the shoe leather costs are among the most famous costs of inflation. Menu costs describe the costs, which arise by changing price labels as a consequence of unexpected inflation. If people hold less cash in the banks in high inflation periods, they have to go to the banks more often. This second consequence is called shoe leather effect, because the more often they go to the banks, the brighter their shoes are. Further costs of inflation can include the redistribution of incomes. Inflation can also lead to pure confusion and uncertainty. Unanticipated inflation leads to the redistribution of income and assets. Additionally, people become more careful with respect to long-term contracts in periods of high inflation. Many more social costs of inflation can be identified by studying hyperinflation. Qualitatively they are the same as in periods of low inflation (Mankiw, 2011).

An interesting concept associated with forecasts is the concept of self-fulfilling forecasts. Decision makers inside a social system under investigation may react to

forecasts. The current inflation usually plays a prominent role in the news media. An inflation forecast by a leading researcher or institution can affect the demand of wage bargaining situations and affect the resulting inflation. A forecast of high inflation can result in a wage-price spiral and lead to higher inflation, caused by higher wages and therefore higher prices for goods. In long-run inflation forecasts it is essential to consider the concept of self-fulfilling forecasts (Kunst, 2004). Because this thesis does not conduct a long-term forecast, we will not consider it in the empirical part of the thesis.

If the data appears to be insufficient, economists tend to lay the emphasis on theory. This phenomenon is called dominance of theory. The implication of the dominance of theory is, we have to contrast our empirical findings with the economic theory of inflation. If the estimation results deviate from what is consistent with the model, we have to reexamine the estimation procedure step by step (Kunst, 2007).

3.2 Implementation of the Maximum Floor

When the president of the Swiss National Bank Phillip Hildebrand announced the intervention, he stated this measure will be enforced with all consequences and is limitless, with respect to time. The National Bank is ready to buy as many foreign exchange as necessary by open market transactions. By making such a strong statement, he made a bet on the credibility of the Swiss National Bank. The Swiss public feared, the financial markets will not believe that the intervention will work and speculate against it. This could force the SNB to create large amounts of money by bank money creation, which ultimately could lead to higher inflation in Switzerland.

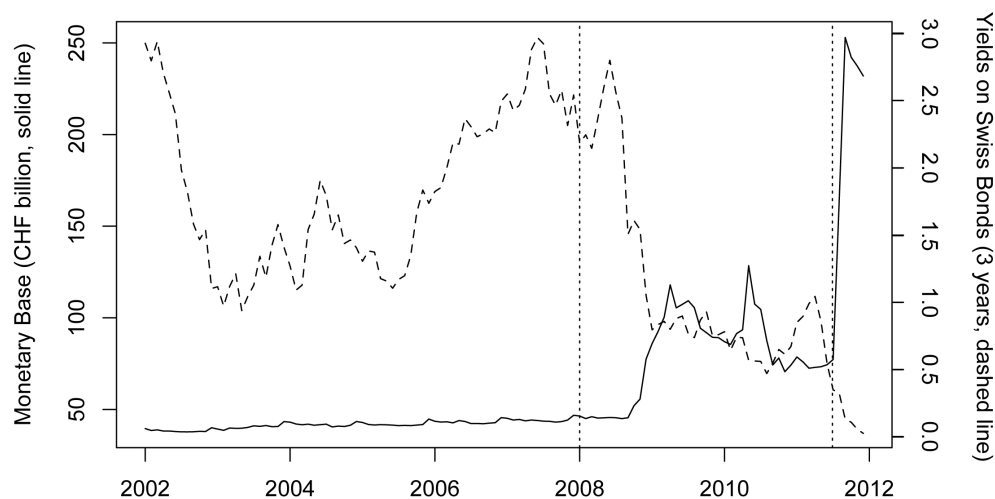
Central bank interventions into the foreign exchange market are common all around the world, despite the fact that they are contradictory to recommendations of scientific publications. Economic theory is in favor of free floating exchange rates. Even well implemented interventions contain the risk of a currency war. Trading partners may have the feeling that the resulting exchange rate is unfair. This could trigger further interventions. In the case of the intervention in Switzerland 2011, the intentions of the Swiss National Bank are clear. They wanted to protect the Swiss export industry from an exchange rate, which deviated from the long-run equilibrium. The situation in Switzerland in 2011 is typical for small open economies. The exchange rate of small open economies can easily be affected by speculative capital flows. Central banks buy and sell foreign exchange to influence the exchange rate. The main problem is that there is no clear empirical perspective on the effect of those transactions on the exchange rate. If the central bank neutralises the effect of the intervention on the monetary base, the intervention is called sterilised. If the intervention affects the monetary base, the intervention is called unsterilised. The effect of unsterilised interventions on the exchange rate is well understood, while the effect of sterilised interventions is controversial. The neutralisation takes place by buying domestic securities by open market transactions. There are two major channels through which a sterilised intervention can affect the exchange rate. The first channel is called portfolio-balance channel. This channel describes the intervention changes the relative demand and supply of foreign assets, which are not perfect substitutes. If the Swiss National Bank buys foreign exchange to hold the maximum floor, the monetary base increases by this amount. The second one is called signaling channel and describes that the interventions signal future interventions. The president of the Swiss National Bank Phillip Hildebrand used this channel by making several remarks that there may be additional interventions if necessary (Finger & Reitz, 2012).

All successful exchange rate interventions achieved to restore the confidence of

investors, who base their decisions on fundamentals. The higher the confidence, the faster the convergence back to the long-run equilibrium. Non-speculative capital movements can dominate the exchange rate again.

In September 2011, the Swiss National Bank flooded the markets with liquidity by reducing the interest rates to zero. Figure 3.2.1 illustrates the interaction of the monetary base and the interest rate and shows, the monetary base increased by factor five. The first dotted vertical line indicates the beginning of the financial crisis in the real economy, the second one the moment of the intervention of the SNB. The Swiss National Bank reduced the interest rates between the year 2008 and 2011 drastically to 0.5%. After the euro crisis escalated in the last quarter of 2011, the conventional instrument of reducing the interest rate to stimulate the economy was practically not available anymore. The Swiss National Bank therefore made the decision to reduce the interest rate to zero to flood the markets with liquidity and in addition, they considered it to be necessary to intervene in the exchange rate by imposing a lower bound. They used open market transactions to increase the monetary base by the factor five, from CHF 50 billion to CHF 250 billion.

Figure 3.2.1: Development of monetary base in Switzerland and yields of Swiss government bonds.



According to the bylaws of the Swiss National Bank, the president is committed to assure price stability. Price stability is clearly defined, with an inflation rate of less than two percent. But he is also committed to consider the impact of business cycles on the Swiss economy. The mandate of the Swiss National Bank is therefore more flexible than the mandate of the European Central Bank (SNB, 2011). During the highs of the euro crisis 2011, the Swiss franc was close to parity with the euro. Many Swiss drove to Germany or Austria to buy goods and services, which became significantly cheaper for Swiss customers. Additionally, regular imports to Switzerland became cheaper. In this situation, the Swiss National Bank was afraid of a deflation and therefore hoped for a slightly higher inflation of one or two percent to compensate those two effects of a strong franc.

3.3 Justification for the Intervention

The type of central bank intervention, which was implemented in the year 2011, is called minimum floor or maximum floor, depending on the definition of the exchange rate. In our case, a maximum floor of 0.83 for the exchange rate of the Swiss franc against the euro (CHF/EUR) equals a minimum floor of 1.20 for the exchange rate of the euro against the Swiss franc (EUR/CHF).

The decision of the Swiss National Bank was opposed by advocates of the efficient market hypothesis. The president of the Swiss National Bank Phillip Hildebrand acted on the assumption, the extreme appreciation of the Swiss franc does not reflect differences in the valuations of underlying assets (SNB, 2011). There is an abundance of papers in scientific journals investigating market overreactions in periods of extreme attention by news media, like the euro crisis 2011. The resistance of short-run fluctuations in the exchange rate is called leaning-against-the-wind. The corrections of mid-term deviations from the long-run equilibrium is more costly for the monetary authority. The intervention of 2011 wanted to restore the competitiveness of the Swiss export industry. Neely (2001) found that 90% of the central banks intervene to correct short-run fluctuations and two-thirds use them to correct mid-term deviations from what is perceived to be the long-run equilibrium. Deviations from the equilibrium are impossible in the long-run according to standard economic theory.

One argument against the intervention is the relationship between expected inflation and unemployment, formalised in the expectations-augmented Phillips curve. If the financial markets do not believe in the credibility of the central bank and expect higher inflation, this could lead to a higher unemployment rate.

During the global financial crisis, the euro devaluated with respect to the Swiss franc by almost 40%, within a time span of four years. When the Swiss National Bank announced, they will intervene and reduce the exchange rate of the Swiss franc to 0.83 euro, the Swiss franc devaluated by 20%. The main motivation for the intervention was to protect the Swiss export industry. Most companies suffered from loosing much of their competitive advantage, relative to German competitors. The dotted horizontal line in Figure 3.3.1 indicates the upper bound of 0.83 euro for the Swiss franc. The dashed vertical line shows the time point of the intervention in September 2011.

The global financial crisis showed, the vulnerability of the Swiss industry to high volatility in the exchange rate. Even large Swiss industrial companies like OC Oerlikon do not have sophisticated exchange rate hedging strategies. Most export oriented companies are diversifying their exchange rate risks by natural hedging, by producing as much as possible in the sales markets. The euro crisis in the year

2011 especially affected the Swiss economy, because 57% of the Swiss exports were sold in the euro zone in 2011.

Figure 3.3.1: CHF/EUR exchange rate.

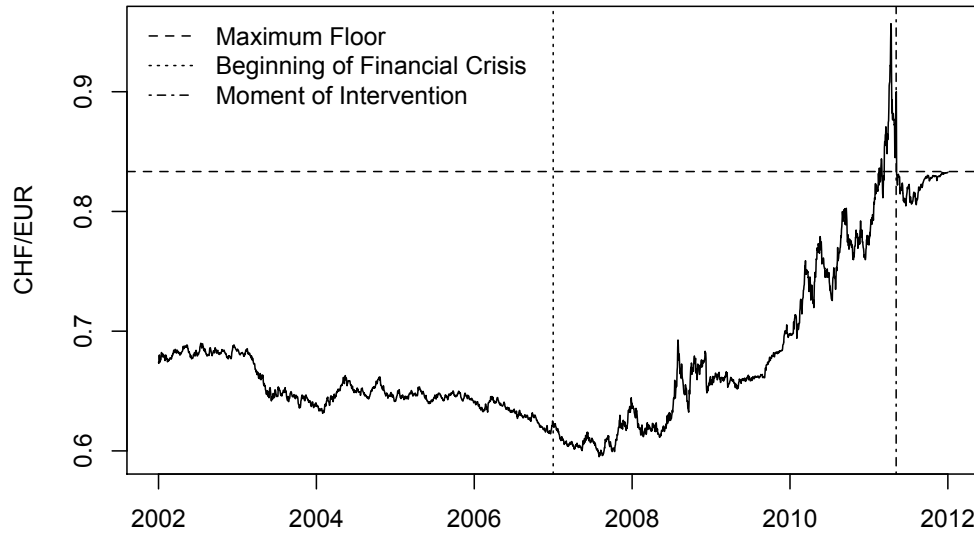


Figure 3.3.2 gives us the development of the Swiss exports since 2002. The year 2008 is marked by a horizontal line to highlight the impact of the global financial crisis on the exports. This year is considered to be the beginning of the crisis in the real economy, despite the fact the financial markets experienced the beginning of the crisis one year earlier. It is easy to see that German exports speedily recovered from the decline caused by the global financial crisis. A similar development in Switzerland was prevented by the strong Swiss franc. A survey conducted by the Swiss National Bank among Swiss companies found that 63% of the companies expect negative consequences as a result of the strong franc, every second company expect the consequences to be massive for their business. Only 8% of the companies expect positive consequences for their business. And 90% of the companies which are not affected, state they do not export or import significantly. Both plots are amended with a time series based forecast of the exports, beginning with 2008. Those forecasts aim to simulate the development of the exports for the underlying scenario that the global financial crisis has never occurred. The difference between the actual exports and the forecast for the exports can give a rough feeling for the impact of the strong Swiss franc on the Swiss economy. Three years after the financial crisis started, German exports are 5% below the forecasted level, whereas the difference in Switzerland is 22%. An ARIMA model with the parameter

combination (1,2,0) proved to be the best to fit the exports of Switzerland. The German exports can be described by the parameter combination (0,2,1). The econometric methodology is the same as in the first part of the thesis.

Figure 3.3.2: Mid-term perspective on Swiss exports.

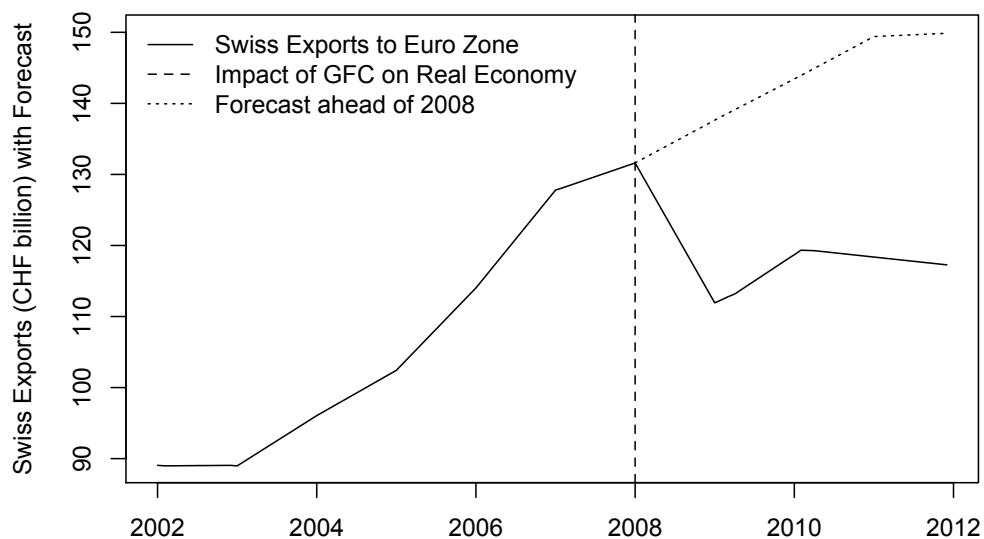
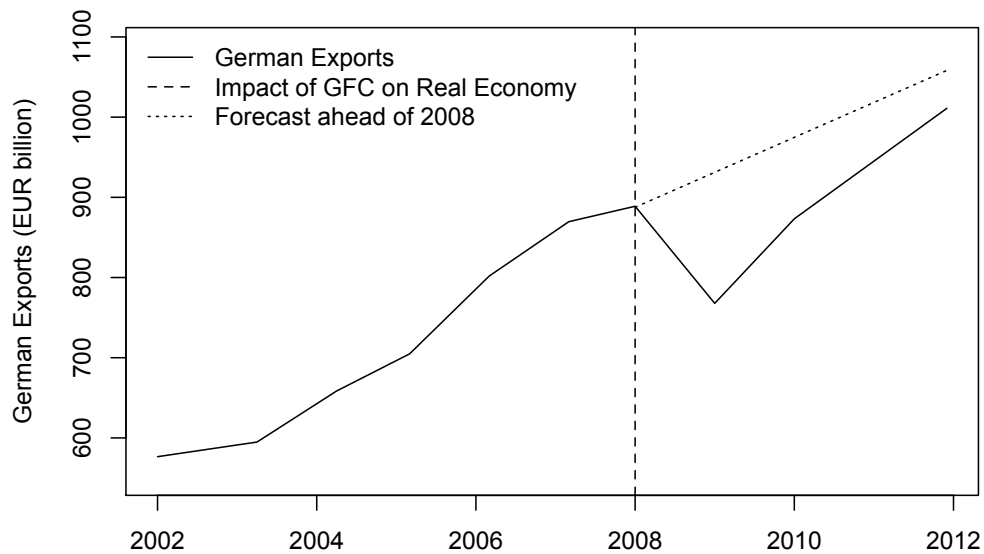


Figure 3.3.3: Mid-term perspective on German exports.



4 Econometric Methodology

4.1 Autoregressive Integrated Moving-Average Processes

The first part of this thesis aims to conduct a time series based forecast. Canova (2002) found that a univariate forecast of the inflation based on a standard autoregressive integrated moving-average (ARIMA) model is sufficiently precise. The ARIMA process has two main elements, the autoregressive (AR) process and the moving-average (MA) process. The difference between an ARMA and an ARIMA model is given by the ability of the ARIMA model to deal with nonstationarity in the series. An extensive introduction into the ARIMA model is given by Greene (2003).

4.2 Unit Root Test

The property of stationarity in the series can be tested with the unit root test. If there is a unit root present, the original series is nonstationary and the first differences are stationary. We conduct the unit root test with the augmented Dickey-Fuller test (1979). The Dickey-Fuller test is especially helpful for inflation data. These series are quite possibly nonstationary but there is no long-term trend behavior. The null hypothesis states, there is a unit root present (Kunst, 2004).

4.3 Information Criterion

The ARIMA model with the parameter combination, which describes the model best, can be identified with information criterias. We will employ the most common one, the Akaike Information Criterion (AIC) (1974). The smallest value of the information criterion indicates the best model. In the days of computational methods, the estimation procedure is simple. We use our statistical package to estimate all ARIMA models for all parameter combinations $p = 0, \dots, P$, $d = 0, \dots, D$ and $q = 0, \dots, Q$.

4.4 Forecast Accuracy

There are several methods to measure the accuracy of a forecast. We rely on the two most common ones, the Mean Absolute Error MAE and the Root Mean Square Error RMSE. The MAE is based on the assumption that the loss function, which measures the loss in the forecast errors is linear. If the assumption of a quadratic loss function is justified, we should apply the RMSE as a measure of forecast accuracy. The idea behind a quadratic loss function is, a forecast error twice as high is considered to be four times as bad. The smallest value of the MAE and the RMSE indicates the forecast with the highest accuracy.

$$MAE = \frac{1}{k} \sum_{j=1}^k |y_{t+j} - \widehat{y_{t+j}}|$$

$$RMSE = \sqrt{MSE}$$

$$\text{where } MSE = \frac{1}{k} \sum_{j=1}^k (y_{t+j} - \widehat{y_{t+j}})^2$$

(Chatfield, 2000)

5 Estimation of the ARIMA model

5.1 Model Identification

The result of the augmented Dickey-Fuller test is -3.4249 (p-value 0.0567). We can therefore reject the null hypothesis, which states an unit root of 1 exists. The series exhibits stationarity. The AIC estimations for different parameter combinations confirm this result. The AIC for the seasonally adjusted series is lowest for the parameters $p = 2$, $d = 0$ and $q = 2$.

Table 5.1.1: AIC values for parameter combinations of the ARIMA model.

ARIMA (p, d, q)	AIC
(1, 0, 0)	-2255.22
(0, 0, 1)	-2254.68
(1, 0, 1)	-2256.84
(1, 1, 1)	-2242.90
(1, 1, 0)	-2186.05
(0, 1, 1)	-2244.38
(2, 0, 0)	-2259.60
(0, 0, 2)	-2259.75
(2, 0, 2)	-2261.14
(2, 1, 2)	-2248.64
(2, 1, 0)	-2191.35
(0, 1, 2)	-2242.78

5.2 Model Checking

Table 5.2.1 gives the Mean Absolute Error MAE and the Root Mean Square Error RMSE for the parameter combinations of the ARIMA model, which showed the best fit. Because the AIC values of those model are not significantly different, we want to use these additional measures to choose the best model. The ARIMA (2, 0, 2) showed the lowest AIC and therefore has the best fit to the data. The six parameter combinations (1, 0, 0), (0, 0, 1), (1, 0, 1), (2, 0, 0), (0, 0, 2) and (2, 0, 2) showed AIC values, which adjoin each other. If the values for the MAE and the RMSE are significantly different, it may be fruitful to choose one of the models with a slightly higher AIC but superior forecasting abilities, indicated by the MAE and the RMSE. Our division of the sample into a training set and a test set is guided by Canova (2002). We use the first 15 years to fit our ARIMA model and the last 5 years to obtain our estimates for the MAE and the RMSE.

Table 5.2.1: MAE and RMSE values for the best parameter combinations.

ARIMA (p, d, q)	AIC	MAE	RMSE
(1, 0, 0)	-2255.22	0.00189856	0.002570709
(0, 0, 1)	-2254.68	0.00189847	0.002570566
(1, 0, 1)	-2256.84	0.00190972	0.002578514
(2, 0, 0)	-2259.60	0.00189702	0.002568988
(0, 0, 2)	-2259.75	0.00190067	0.002571112
(2, 0, 2)	-2261.14	0.00189819	0.002570209

The results for the MAE and the RMSE are not significantly different. There is no reason to deviate from our choice of the parameter combination (2, 0, 2).

6 Forecasting Inflation

A forecast can be understood as an approximation of data points in the future based on observed data during a certain time period. Forecasts can aim to achieve different goals. One may be pure interest in the future, caused by curiosity associated with the human nature. Another one may be to enable planning and control to manage the risks involved, with the uncertainty of the future. There are many more reasons to conduct a forecast (Kunst, 2004).

Chatfield (2000) suggests a division of forecasting methods into three groups. Judgmental forecasts are sometimes applied to short-term questions in economics. They are conducted by experts, based on their experience. The second group is given by univariate forecasting procedures. The term univariate refers to the fact that we use data of a single variable to approximate the future. Univariate methods show some black-box characteristics. They do not explain how the phenomenon under investigation works. The third group is given by multivariate procedures. These methods use the data of several variables jointly. More formally, we are dealing with a vector of variables to conduct the forecast. The optimal forecast horizons can be derived by the needs of the policy makers. They usually base their decisions on three time horizons, one quarter, one year and two year. Long horizon forecasts are usually superior to short horizon forecasts (Canova, 2002). We conduct a forecast with a horizon of two years, the year 2012 and the year 2013.

6.1 Point Forecast

Table 6.2.1 gives the estimated values for the next 27 periods, ahead of October 2011. The table gives the predictions in absolute numbers and annualised numbers in percent. The following formula describes, how we calculated the annualised data.

$$\text{Annualised Data} = (1 + \text{Monthly Data})^{12} - 1$$

The forecast for the average of all month for 2012 is 1.0401% and 1.0261% for 2013. The point forecast for the seasonally adjusted series lies exactly between the minimum and the maximum target of the Swiss National Bank for the inflation.

Figure 6.2.1: Point forecast of seasonally adjusted series.

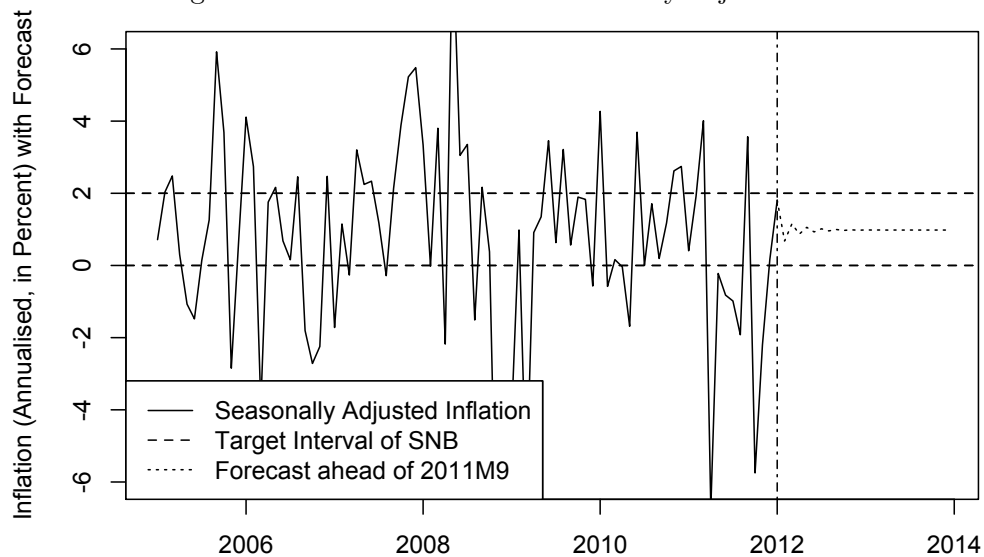


Table 6.2.1: Forecasting Results.

Year, Month	Monthly, Absolute	Annualised, in %
2011, Oct	0.0009268099	1.1178%
2011, Nov	0.0013141808	1.5885%
2011, Dec	0.0004780716	0.5752%
2012, Jan	0.0011010630	1.3293%
2012, Feb	0.0006895876	0.8306%
2012, Mar	0.0009545466	1.1515%
2012, Apr	0.0007849265	0.9460%
2012, May	0.0008933645	1.0773%
2012, Jun	0.0008240625	0.9934%
2012, Jul	0.0008683496	1.0470%
2012, Aug	0.0008400487	1.0127%
2012, Sep	0.0008581338	1.0346%
2012, Oct	0.0008465769	1.0206%
2012, Nov	0.0008522585	1.0275%
2012, Dec	0.0008503313	1.0103%
2013, Jan	0.0008515629	1.0267%
2013, Feb	0.0008507759	1.0257%
2013, Mar	0.0008512788	1.0263%
2013, Apr	0.0008509574	1.0260%
2013, May	0.0008512788	1.0263%
2013, Jun	0.0008509574	1.0260%
2013, Jul	0.0008511628	1.0262%
2013, Aug	0.0008510316	1.0260%
2013, Sep	0.0008511154	1.0261%
2013, Oct	0.0008510618	1.0260%
2013, Nov	0.0008510961	1.0261%
2013, Dec	0.0008510742	1.0261%

6.2 Interpretation of Results

In this subsection, we contrast our estimations with other estimates, which are conducted after the intervention took place. The economic research department of the Swiss bank UBS published its inflation forecast for 2012 and 2013 in march 2012. The Swiss National Bank publishes its own forecast for the inflation in their online quarterly publication SNB Quartalsheft. The asset management department of the life insurance Swiss Life published their inflation forecasts in may 2012. The KOF of the ETH Zuerich conducts a survey among leading economists in the Swiss private sector called KOF Consensus Forecast. They are available on the internet. The sources are described in the chapter "Time Series Properties of Data". The prediction accuracy of the average of forecasts is usually superior to single forecasts. We can calculate the average forecast, by applying a linear combination.

$$f_{average} = w_1 f_1 + w_2 f_2 + \dots + w_n f_n$$

The weights of the forecasts sum up to 1 ($\sum_{i=1}^n w_i = 1$). The forecasts are weighed according to their reputation and the reputation of the economic research departments. The weights are based on the judgement of the author. From a scientific point of view, this aggregation procedure is invalid. We nonetheless apply this procedure to make it easier to see the difference between our forecast and the other forecasts in Figure 6.3.1.

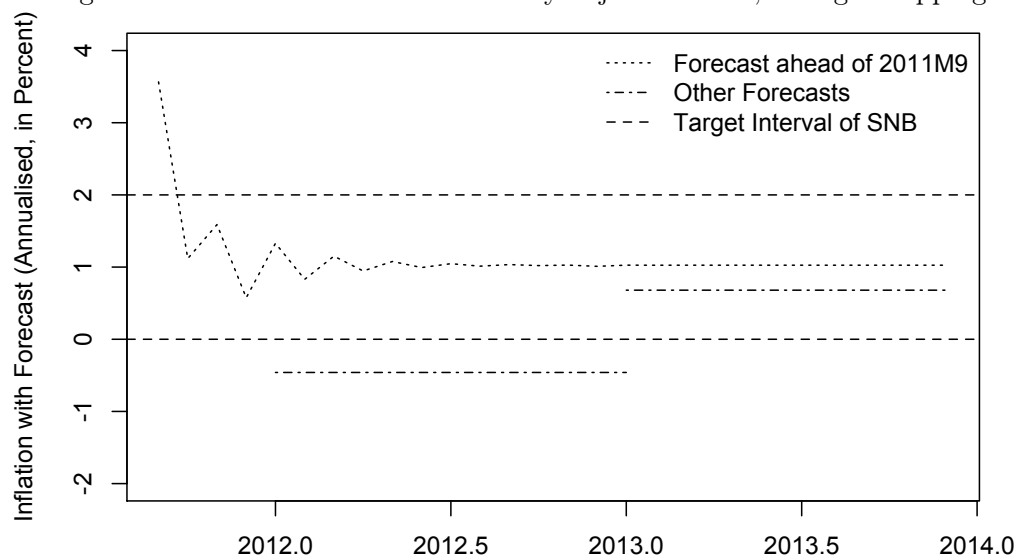
Table 6.3.1: Summary of forecasts, conducted after the intervention.

Institution	2012	2013	w_i
SNB	-0.6	0.3	0.4
UBS	-0.5	1.2	0.3
KOF Consensus Forecast	-0.1	0.8	0.2
Swiss Life Asset Management	-0.5	0.4	0.1
Average	-0.46	0.68	-

Table 6.3.1 provides us with an overview of those forecasts. The average values for 2012 and 2013 are illustrated in Figure 6.3.1. The difference between our forecast and the average value for 2012 is 1.5001% and for the year 2013, the difference is 0.3461%.

It appears the credibility of the Swiss National Bank successfully prevented speculative attacks on the Swiss franc. The social costs of the intervention in terms of additional inflation are therefore low.

Figure 6.3.1: Forecast for the seasonally adjusted series, enlarged clipping.



7 Optimal Moment of Intervention

7.1 Estimation Methodology

Rodrik (2008) presents an econometric approach to estimate the relationship between the variables real exchange rate and economic growth. He shows that undervaluation of a currency stimulates economic growth. There is little evidence for non-linearities. That means, a lower overvaluation has the same effect on growth as a lower undervaluation. We can therefore generalise this approach to situations in which currencies are overvaluated. The real exchange rate is the relative price of tradable goods to non-tradable goods. The time span for data used in this chapter is 50 years.

Rodrik's approach makes it necessary to calculate the undervaluation index $\ln\text{UNDerval}$ in three steps. Based on data, obtained from the Penn World Tables, we construct the variable real exchange rate, which has to be adjusted for the Balassa-Samuelson effect. The Balassa-Samuelson effect describes the observation, as countries become richer the ratio of tradable to nontradable goods changes. In the first step, we calculate a measure for the real exchange rate (RER), by dividing the exchange rate (XRAT) by purchasing power parity data (PPP).

$$\ln RER_{it} = \ln(XRAT_{it}/PPP_{it})$$

The 5-year time periods are captured by the time index t . The countries are captured by the country index i . We omit the second step of Rodrik's procedure and use his results to proceed. He estimated the Balassa-Samuelson effect with the following equation and estimated the value -0.24 for the parameter $\hat{\beta}$.

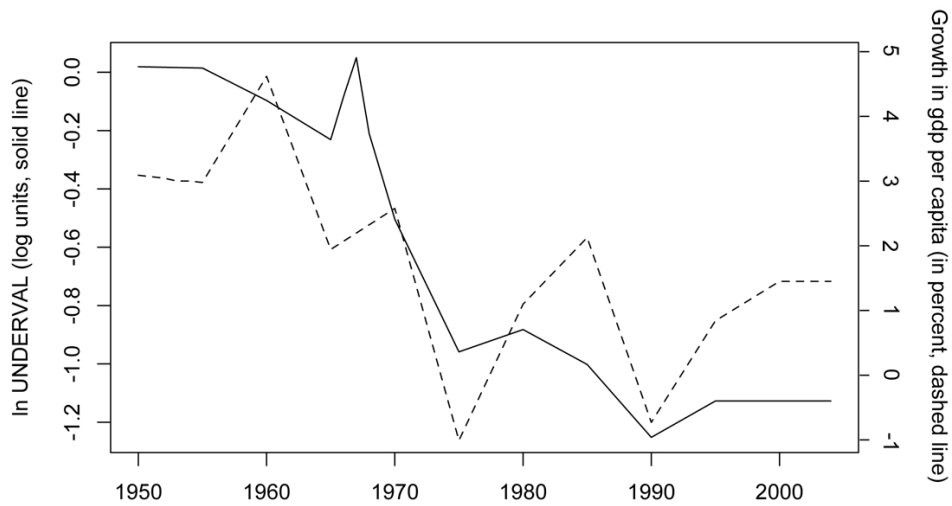
$$\ln RER_{it} = \alpha + \beta \ln CGDP_{it} + f_t + u_{it}$$

The variable $CGDP$ describes the gross domestic product per capita, f_t the fixed effect for the period t . In the last step of his approach, we have to subtract the exchange rate with the Balassa-Samuelson correction from the exchange rate to obtain the undervaluation index $\ln\text{UNDerval}$.

$$\ln\text{UNDerval}_{it} = \ln RER_{it} - \widehat{\ln RER_{it}}$$

If $\ln \text{UNDerval}$ is higher than one, the exchange rate is undervalued. If the exchange rate is lower than one, the exchange rate is overvalued. Figure 7.1.1. gives us a clear impression, how the level of overvaluation of the Swiss franc increased in the last decades. The observation that the growth rate of the GDP per capita and the undervaluation index $\ln \text{UNDerval}$ move closely together, gives us a feeling for the strong correlation between them. In the next section, we undertake a more systematic analysis of the relationship between the growth rate and the undervaluation index (Rodrik, 2008).

Figure 7.1.1.: Undervaluation and economic growth in Switzerland, 1950-2004.



7.2 Estimation of Optimal Moment of Exchange Rate Intervention

The next regression shows a positive relationship between the undervaluation of the currency and the growth rate of the GDP per capita. Despite the fact, statements about the causality are always difficult to make, Rodrik shows, the direction of the effect originates in the value of the currency. We estimate the effect of the value of the currency on the growth rate of the GDP per capita with the following specification, suggested by Rodrik. In our estimation, we omit the country index i , because we are estimating the effect only for Switzerland.

$$growth_t = \alpha + \beta \ln RGDPCH_{t-1} + \delta \ln UNDERVAL_t + u_t$$

where f_t is the time dummy and $RGDPCH_{t-1}$ is the initial income in the prior period. Again we estimate time periods of five years from 1950-1954 to 2000-2004. Our primary interest is the estimate for the parameter δ , which gives us the effect of the valuation of the currency on the growth rate. The inclusion of other regressors like government consumption in the equation does not change the magnitude of the effect, the variable $\ln UNDERVAL$ has on the growth rate (Rodrik, 2008). Our estimation gives us a coefficient of 0.04419 for the variable $\ln UNDERVAL$. The estimate is significant at a 0.05-level (t-statistic 2.7). Rodrik estimates a lower value for the variable $\ln UNDERVAL$ for the group of developed countries. The relative high value of 0.04419 may be explained by a high degree of outward-orientation of the Swiss economy. The estimate of this coefficient allows us to calculate the effect of different valuations of the currency on the growth rate. Table 7.2.1. summarizes these findings.

Table 7.2.1. Effect of different exchange rates on growth rate in percent.

EUR/CHF	CHF/EUR	Effect on growth rate
1.65	0.606	-0.183645305
1.60	0.625	-0.319655079
1.55	0.645	-0.459985530
1.50	0.666	-0.604913346
1.45	0.689	-0.754757155
1.40	0.714	-0.909859697
1.35	0.740	-1.070603561
1.30	0.769	-1.237414641
1.25	0.800	-1.410768972
1.20	0.833	-1.591200924
1.15	0.869	-1.779313099
1.10	0.909	-1.975788518
1.05	0.952	-2.181405542
1.00	1.000	-2.397056559

The growth rate of the GDP was 2.3 percent in Switzerland in the year 2011. An exchange rate of 1.20 EUR/CHF can already be responsible for a reduction of the growth rate of 1.59 percentage points. Without an intervention, an exchange rate around parity could have led to a recession in Switzerland. Our estimation shows, the difference of an intervention at an exchange rate of 1.20 EUR/CHF and 1.25 EUR/CHF can already be significant. So the optimal moment of intervention has to be chosen carefully. The result of the first part of this thesis highlighted the high credibility of the Swiss National Bank. If we consider the low costs of the intervention at 1.20 EUR/CHF associated with this credibility, an earlier intervention would have been optimal. The optimal point of intervention can only be identified, by estimating the costs of a reduction of the growth rate and the risk of speculative attacks on an intervention.

8 Concluding Remarks

This thesis reviews, why the Swiss National Bank intervened into the foreign exchange market in September 2011. We showed how the unexpected strong Swiss franc affected the Swiss export industry, by contrasting the exports of Swiss companies with the numbers for the German exports. The German industry has fully recovered four years after the crisis in the global financial industry showed its impact on the real economy in the year 2008. The strength of the Swiss franc is the result of the reputation of Switzerland as a safe haven in periods of uncertainty. Since 2008, large amounts of capital have been transferred to Switzerland.

The first part of this thesis is devoted to a time series based forecast of the inflation in Switzerland. We contrast our estimations with several other forecasts, which are conducted after the intervention. The forecasts do not differ significantly from the time series based forecast. It appears, the deflationary tendency of a strong Swiss franc balanced itself out with the additional inflation caused by the intervention. A further reduction of the exchange rate is intended by the Swiss National Bank and would lead to an inflation rate, which is still below or just slightly above the official maximum of two percent.

In the second part of this thesis, we estimate the relationship between the valuation of the Swiss franc and the growth rate of the Swiss economy. Our estimation results allow us to calculate the effect of several valuations of the Swiss franc on the growth rate. An exchange rate of 1.20 EUR/CHF is already responsible for a reduction of the growth rate of the GDP per capita of 1.59 percentage points. Without an intervention, an exchange rate around parity could have resulted in a recession of the Swiss economy.

The results of both parts allow us to derive the conclusion, the intervention should have been implemented at a higher EUR/CHF exchange rate. The high credibility of the Swiss National Bank allows a more optimal point of intervention from the standpoint of the Swiss export industry. The determination of the optimal point depends on estimations for the costs of a reduced growth rate and the risk of speculative attacks at the chosen exchange rate. The president of the Swiss National Bank signaled the intention to increase the lower bound of the EUR/CHF exchange rate in the months after the intervention. This can be seen as a sign, the Swiss National Bank derived the same conclusions.

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Abstract

In September 2011, the Swiss National Bank announced, they will adopt a maximum floor for the euro exchange rate of the Swiss franc. The scenario, this measure could lead to higher inflation concerned the public. This thesis aims to forecast the Swiss inflation by fitting an ARIMA model. We will contrast our time series based forecast with other forecasts, which already consider the measure of the central bank. According to our analysis, the intervention caused no additional inflation. This result can be seen as a proof of the credibility of the Swiss National Bank. Besides that, we estimate the optimal moment for the intervention with a model, which describes the relationship of the real exchange rate and economic growth.

Zusammenfassung

Im September 2011 hat die Schweizerische Nationalbank angekündigt, eine Untergrenze für den Euro Wechselkurs des Schweizer Frankens einzuführen. Die Möglichkeit, dass diese Intervention zu höherer Inflation führen könnte, hat die Öffentlichkeit beunruhigt. Das Ziel dieser Arbeit ist die Schweizerische Inflation mittels ARIMA Modell zu prognostizieren. Wir werden unsere zeitreihenbasierte Prognose mit anderen Prognosen kontrastieren, welche bereits die Intervention der Schweizerischen Nationalbank berücksichtigen. Unsere Analyse fand, dass die Intervention keine zusätzliche Inflation verursacht. Dieses Ergebnis kann als Beweis der Glaubwürdigkeit der Schweizerischen Nationalbank betrachtet werden. Ausserdem schätzen wir den optimalen Zeitpunkt für die Intervention mit einem Modell, dass den realen Wechselkurs mit dem Wirtschaftswachstum in Beziehung setzt.

Keywords

ARIMA Model, Exchange Rate Intervention, Forecasting, Inflation, Swiss National Bank

JEL Codes

C52, C53, E31

Short Curriculum Vitae

After civil service at the Hospital Munich-Schwabing, studies of economics at the University of Vienna and at The Australian National University in Canberra. I was awarded a full scholarship from the University of Vienna to deepen my education at The Australian National University in Canberra. Graduation as Mag. rer. soc. oec. (Master of Arts in Economics) in summer 2012. Specialization in quantitative economics and econometrics. During my studies I was employed at the Mondi Group in Vienna, Austria and at OC Oerlikon Balzers in Balzers, Fürstentum Liechtenstein.