Prediction of exchange rate using ANFIS
Comparative method study

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Abstract

The following paper looks at 2 ways of predicting the fluctuation of the ISK to USD exchange rate. ANFIS is used as a system to predict the future actions of the exchange rate. ANFIS proves very simple to use and relatively fast, some stability problems do arise that need to be dealt with before ANFIS can be fully utilized to predict the exchange rate.

The main conclusion is that more investigations need to take place before it is possible to use an ANFIS system to predict the exchange rate. GARCH systems are rarely used as the only means of estimating time series, but can give very useful information. Perhaps in conjunction with an ANFIS system the GARCH could foresee when the ANFIS would be likely to be going unstable, this way retraining could take place and re-estimation of the parameters could also be conducted.
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Introduction

The exchange rate between currencies is very important – especially currently considering the week exchange rate between the Icelandic Krona (ISK) and the United States Dollar (USD). The exchange rate influences the Icelandic export industry greatly. The fewer ISK you can get for every USD, the worse the bottom line is for these companies. This is largely due to the expenses being paid in ISK such as salaries. The past few months have been particularly bad for the Icelandic export industry due to oil prices going up and the dollar going down. Oil price is directly linked to export cost.

Any model to predict the exchange rate can help the private industry. If indications of large variation in the exchange rate were known in advance, preventive measures such as cutting cost or buying futures and options. Other useful applications could be to predict behaviors and trade accordingly.

Many classical approaches to modeling the exchange rate exist. Most methods of time series analysis can be used for this purpose. In this paper the GARCH method is used as a comparison with the ANFIS Approach in order to assess the usefulness of the ANFIS approach for this kind of modeling. The reason for using a GARCH rather then other methods is because of the ability of GARCH to deal with variation.

The time series used for this project will be the final exchange rate (ISK-USD) from 2001 until 2005. Data is available from the national bank going back to January 1, 1981, but this data is not useful in the modern environment since the national bank changed its policy from a fixed interest rate policy to a fixed inflation policy in 2001. The change is clearly visible on the timeline below

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1 Data and information from the national bank of Iceland. [www.sedlabanki.is](http://www.sedlabanki.is)
The data

The data used in this paper is the daily value of the ISK-USD exchange rate. The average between the asking and the offering price is used. The data was taken from the webpage of the National Bank of Iceland. This approach gives a total of 952 observation points (From the 1st of June 2001 until the 31st of March 2005).

A new law concerning the National Bank was adapted in May 2005, which changed the strategy from being a fixed interest strategy to being a fixed inflation strategy. In this change the exchange rate was set afloat – which can be clearly seen on the graph in the introduction.

The data contains the final price for each working day. No trading takes place during weekends and national holidays, which explains the gaps that there are in the data. No particular actions are taken because of this, it is simply expected that the models pick up the effect of this.

Example: Rate January 2005

The table shows the trading prices for January 2005. As can be seen the trading was open a total of 20 days during this period.

<table>
<thead>
<tr>
<th>Date</th>
<th>Rate</th>
<th>Date</th>
<th>Rate</th>
<th>Date</th>
<th>Rate</th>
<th>Date</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.05</td>
<td>62,41</td>
<td>11.1.05</td>
<td>63,18</td>
<td>18.1.05</td>
<td>62,51</td>
<td>25.1.05</td>
<td>62,4</td>
</tr>
<tr>
<td>5.1.05</td>
<td>62,92</td>
<td>12.1.05</td>
<td>63,1</td>
<td>19.1.05</td>
<td>62,15</td>
<td>26.1.05</td>
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<tr>
<td>6.1.05</td>
<td>63,02</td>
<td>13.1.05</td>
<td>62,72</td>
<td>20.1.05</td>
<td>62,76</td>
<td>27.1.05</td>
<td>62,34</td>
</tr>
<tr>
<td>7.1.05</td>
<td>63,04</td>
<td>14.1.05</td>
<td>62,61</td>
<td>21.1.05</td>
<td>62,76</td>
<td>28.1.05</td>
<td>62,14</td>
</tr>
<tr>
<td>10.1.05</td>
<td>63,43</td>
<td>17.1.05</td>
<td>62,6</td>
<td>24.1.05</td>
<td>62,14</td>
<td>31.1.05</td>
<td>62,32</td>
</tr>
</tbody>
</table>

The first 476 points will be used as training data and the last 476 as testing data.
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**Theory**

**GARCH**
G-Arch models are frequently used in economics. G-Arch stands for Generalized Autoregressive Conditional Heteroscedasticity model. A time-series technique in which past observations of the variance and variance forecast are used to forecast future variances.

The basic model for the GARCH \((m,s)\) is as follows

\[
\epsilon_t = \sigma_t z_t, \\
\sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{s} \beta_j \sigma_{t-j}^2
\]

Where \(\{z_t\}\) is a sequence of random variables with mean 0 and variance 1.0 and
\[
\alpha_0 > 0, \alpha_i \geq 0, \beta_j \geq 0, \sum_{i=1}^{m} (\alpha_i + \beta_j) < 1.
\]

\(z_t\) is assumed to be a standard normal or standardized Student-t distribution.

GARCH is often used to model variance in the market. Although GARCH models are usually applied to return series, Decisions are rarely based solely on GARCH models. GARCH models are parametric specifications that operate best under relatively stable conditions. Although GARCH is explicitly designed to model time-varying conditional variances, GARCH models often fail to capture highly irregular phenomena, including wild market fluctuations (e.g., crashes and subsequent rebounds), and other highly unanticipated events.

The GARCH Approach was decided after the initial ANFIS work

**ANFIS**
In the solution of this project ANFIS was used as another method of trying to estimate exchange rate.

To explain ANFIS we can take an example from [1]. Say we are given a common rule set which contains two fuzzy if-then rules:

Rule 1: If x is A_1 and y is B_1 then \(f_1 = p_1x + q_1y + r_1\)
Rule 2: If x is A_2 and y is B_2 then \(f_1 = p_2x + q_2y + r_2\)

The following figure shows the architecture of the system that follows this logic:
A simple diagram of a two-input first-order Sugeno fuzzy model [1].

Each of the fuzzy rules are then mapped into Membership functions. To view each layer and model behind them.

**Layer 1**

Has i notes, these notes are adaptive and have node functions

\[ O_{1,i} = \mu A_i(x) \quad \text{for } I = 1, 2 \]

\[ O_{1,i} = \mu B_{i-2}(x) \quad \text{for } I = 3, 4, \]

X is the input to node I and A_i (B_{i-2}) is a linguistic label (i.e. “big”) associated with the note. O is the membership function for example the generalized bell function:

\[ \mu A(x) = \frac{1}{1 + \left| \frac{x - c_i}{a_i} \right|^{2b}} \]

Where \{a_i, b, c_i\} are the parameters of the bell function.

**Layer 2**

Every node is a fixed node and labeled π, the input is the product of all incoming signals:

\[ O_{2,i} = w_i = \mu A_i(x) \mu B_i(x) \quad I = 1, 2. \]

Each node is the firing strength of that a rule.

**Layer 3**

Every node in this layer is a fixed node labeled N.

\[ O_{3,i} = \bar{w}_i = \frac{w_i}{w_1 + w_2} \quad i = 1, 2 \]

This is the normalized fire strength.

**Layer 4**

Every node \( I \) is an adaptive node

\[ O_{4,i} = \bar{w}_i f_I = \bar{w}_i (p_i x + q_i y + r_i) \]

p, q, r are the consequent parameters. This is an adaptive node.

**Layer 5**

Overall output = \( O_{5,i} = \sum \bar{w}_i f_I = \frac{\sum_i w_i f_I}{\sum_i w_i} \)

Summation of all incoming signals.
Results

First some general observations were made about the data. The data series that was used looked as can be seen in the figure below. The data is as mentioned before from June 2001 until 31 March 2005.

- An overall downwards trend seems to be ongoing, there seem to be steep fluctuations where the data moves very fast upwards or very fast downwards.

- No apparent signs of leveling off can be observed in the data.

Now two methods will be used. The reason for choosing GARCH modeling in conjunction with the ANFIS study was because of observations that were made in the early stages of this study. It was always the aim to compare different methods; ANFIS to a more classical time series approach. Since a variation towards the end of the training was observed in the ANFIS GARCH, it was thought of as a good candidate to deal with variation.
ANFIS

Matlab was used to train the ANFIS system. A small code was written to use on the 952 exchange points available. Some time delays were put into the system. –7 –2 –1 days and +1 +2 days as well. These delays were chosen after having tried various combinations. Adding information didn’t seem to help the system and other combinations showed the same or a worse performance.

The Data was divided into 2 equally long series, the first part of it was used for training and the second part was used for checking. A data set was created which contained the data, 7 lags 2 lags 1 lag 1 ahead 2 ahead and the data unbiased. This series was then used with the Genfis1 in order to create a Fuzzy inference system.

![Membership functions](image)

The membership functions for the 5 inputs into the system. As can be seen the membership functions are all the same, this is not surprising since the data essentially is the same although lagged a bit.

When the membership functions for the checking data were also the same after the anfis command had been used. The resulting system that ANFIS gave was plotted against the inputs from the
The above figure shows the training of the ANFIS. The result was not good since the ANFIS system became unstable towards the end of the checking data. The ANFIS result does not yield a good result. It is likely that actual inputs such as the interest rate, inflation rate and other factors would do a better job in conjunction with time lags to create a useful ANFIS system. However in the final example the National bank basic interest was added and it yielded a instable result towards the end.

The overall result regarding the ANFIS is that it is not enough to use only the data for the exchange rate; exterior factors need to be taken into consideration. A combination of the GARCH and the ANFIS might be investigated since ANFIS is better at catching actual price trends where as GARCH is good at dealing with the variation of the data.

A series of bank interest rates were also tried into the data – that gave even worse results The series became highly instable towards the end
Here the interest rate has been added in. Note instability issues!!

**GARCH**

Because the GARCH model assumes a return series rather than a price series a conversion was needed (this is also done in the matlab script in appendix 1)

The return series of the Exchange data
The Autocorrelation of the return series. None of the parameters seem significant.

The Partial correlation of the return series, no significance seen here either.
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With a squared return autocorrelation we see that lag 1 is significant and lag 12 is barely significant as well.

After having gone through this pre analysis, it was estimated that it would be good to try GARCH(1,1) GARCH(2,1) and GARCH(2,2) – higher order GARCH is seldom used. This estimation is also a part of the Matlab function

Number of Parameters Estimated: 4

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Error</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.00066272</td>
<td>0.00020167</td>
<td>-3.2862</td>
</tr>
<tr>
<td>K</td>
<td>3.6228e-006</td>
<td>1.4538e-006</td>
<td>2.4920</td>
</tr>
<tr>
<td>GARCH(1)</td>
<td>0.83361</td>
<td>0.04654</td>
<td>17.9117</td>
</tr>
<tr>
<td>ARCH(1)</td>
<td>0.082508</td>
<td>0.018577</td>
<td>4.4415</td>
</tr>
</tbody>
</table>

Number of Parameters Estimated: 5

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Error</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.00020426</td>
<td>-3.2438</td>
</tr>
<tr>
<td>K</td>
<td>3.6649e-006</td>
<td>1.4496e-006</td>
<td>2.5283</td>
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<tr>
<td>GARCH(1)</td>
<td>0.61724</td>
<td>0.050837</td>
<td>12.1417</td>
</tr>
<tr>
<td>GARCH(2)</td>
<td>0.2082</td>
<td>0.021934</td>
<td>9.4919</td>
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<tr>
<td>ARCH(1)</td>
<td>0.089616</td>
<td>0.028503</td>
<td>3.1441</td>
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Number of Parameters Estimated: 5

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Error</th>
<th>Statistic</th>
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<tr>
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<td>0.00020426</td>
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<tr>
<td>K</td>
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<tr>
<td>ARCH(2)</td>
<td>0</td>
<td>0.028503</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

From the table above it can be seen that The GARCH(1,1) is the most significant model. This can be seen from the value of the T statistic (estimate that a value of over 2 is needed for a high enough level of significance)

The GARCH(1,1) model was therefore used to model the exchange data. The parameters of the model can be seen in the table. In order to see how well this model fitted to the actual data two pictures were added
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Here we see the Innovations or the output of the GARCH(1,1) model.

Here we see the two returns together.
It is not very obvious how well this fits, so in order to get a better idea zoom was applied between point 380 and 460.

Here it can be seen that the model (red) fits really well to the Data (blue) This means that the GARCH(1,1) model is a good model for the exchange rate. However it might also be useful to model the exchange rate (price) itself rather then the return. This was also done and can seen in the following graph.
This is the result of the GARCH modeling. The obvious divergence of the GARCH with regards to the actual exchange rate can be explained by the way this model was obtained. The GARCH was transformed from the Return rate to the Price. The trend (movement) is therefore removed from the series. However the shape of the model is very convincing. And it GARCH can be used to estimate returns in a very convincing manner.

The GARCH model seems to do very well at estimating

**Conclusion**

ANFIS encounters problems with stability. This might be due to the fact that only the data it self with time lags was discovered. GARCH is much better at predicting the system and it seems to predict the return almost perfectly. However since GARCH deals with the return it is difficult to map it back into the price range.

The main conclusion is that more investigations need to bake place before it is possible to use an ANFIS system to predict the exchange rate. GARCH systems are rarely used as the only means of estimating time series, but can give very useful information. Perhaps in conjunction with an ANFIS system the GARCH could foresee when the ANFIS would be likely to be going unstable, this way retraining could take place and re-estimation of the parameters could also be conducted

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**References**


Appendix 1 – Matlab programs

This script was utilized for the ANFIS part of the assignment

load exchange1.dat
%load interest.dat
t = exchange1(:, 1); x = exchange1(:, 2); figure(1); plot(t, x);
for k=9:950,
   % Putting one week, 2 and 1 day delay and +1 and 2 days
   Data(k-8,:)=[x(k-7) x(k-2) x(k-1) x(k) x(k+1) x(k+2)];
   %Data(k-8,:)=[x(k-7) interest(k) x(k-1) x(k) x(k+1) x(k+2)];
end
len=size(Data);
% The Training Data
TRNData=Data(1:(len(1)/2), :);
% The Checking Data
CHKData=Data(((len(1)/2)+1):end, :);
FIS = genfis1(TRNData);
figure(2)
%plotting the membership functions
for i=1:5
   subplot(2,3,i)
   plotmf(FIS, 'input', i)
end
% Creating the ANFIS
[FIS,ERROR,STEPSIZE,CHKFIS,CHKERROR] = anfis(TRNData,FIS,[],[],CHKData);
figure(3)
% plotting the membership functions
for j=1:5
   subplot(2,3,j)
   plotmf(CHKFIS, 'input', 1)
end
figure(4)
TRN=[TRNData(:,1) TRNData(:,2) TRNData(:,3) TRNData(:,4) TRNData(:,5)];
CHK=[CHKData(:,1) CHKData(:,2) CHKData(:,3) CHKData(:,4) CHKData(:,5)];
output = evalfis([TRN; CHK], CHKFIS);
index = 1:len(1);
t = exchange1(:, 1);
% plotting the data and the predicated data
subplot(2,1,1), plot(t(index), [x(index) output]);
% plotting the error
subplot(2,1,2), plot(t(index), x(index) - output,'r');
figure(5)
plot([ERROR; CHKERROR]);

This script was used for the GARCH part of the assignment

GARCH
%Garch assumes a return series
load exchange1.dat
isk2usd = price2ret(exchange1(:,2));
figure(1)
plot(isk2usd)
% set(gca,'XTick',[1 659 1318 1975])
% set(gca,'XTickLabel',{'Jan 1984' 'Jan 1986' 'Jan 1988' ... 
% 'Jan 1992'})
ylabel('Return')
title('ISK USD daily returns')
figure(2)
% The autocorrelation function
autocorr(isk2usd)
title('ACF with Bounds for Raw Return Series')
figure(3)
% The partial correlation series
parcorr(isk2usd)
title('PACF with Bounds for Raw Return Series')

figure(4)
% Checking for correlation on the squared return
autocorr(isk2usd.^2)
title('ACF of the Squared Returns')
% create a garch(1,1) model
spec11 = garchset('P',1,'Q',1,'Display','off');
[coeff11,errors11,LLF11] = garchfit(spec11,isk2usd);
garchdisp(coeff11,errors11)

% create a garch(2,1) model
spec21 = garchset('P',2,'Q',1,'Display','off');
[coeff21,errors21,LLF21] = garchfit(spec21,isk2usd);
garchdisp(coeff21,errors21)

% create a garch(1,2) model
spec12 = garchset('P',1,'Q',2,'Display','off');
[coeff12,errors12,LLF12] = garchfit(spec12,isk2usd);
garchdisp(coeff12,errors12)

figure(5)
% Display the results of the GARCH(1,1)
[Coeff,Errors,LLF,Innovations,Sigmas,Summary] = garchfit(spec11,isk2usd)
figure(6)
% plotting the data against the model
plot(isk2usd,'r --')
hold
plot(Innovations)
figure(7)
% change the return to a price data
startingpoint=exchange1(1,2);
modeling=ret2price(Innovations,startingpoint);
plot(modeling,'r');
hold
plot(exchange1(:,2))

% Finally lets do a forecast
horizon = 30;  % Define the forecast horizon
[sigmaForecast,meanForecast,sigmaTotal,meanRMSE] = garchpred(Coeff,isk2usd,horizon);