Animal Spirits and the Business Cycle

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Abstract

This paper is a discussion on the distribution of Animal Spirits in a macroeconomic model. The new Keynesian model is the model used for aggregate demand, the new keynesian phillips curve was used for aggregate supply, and inflation will follow the Taylor Rule. We then varied the proportion of fundamentalist agents and inflation. We found that in almost all analysis there was a fat tailed distribution of animal spirits.

Business Cycle History

The idea of business cycles in economic literature is not a new idea. In *Nouveaux principes d'économie politique* Jean Charles Léonard de Sismondi proposed the idea of the business cycle theory but the idea did not take hold until Charles Dunoyer used the ideas in *Nouveaux principes d'économie politique* to refute the ideas in Say's Traité d'économie politique (Benkemoune, 2009). Another economicst from the same time period, Thomas Robert Malthus implied the idea of business cycles in *The First Essay on Population* in which he referred to periods of scantiness of room and food that happen on a irregular periodic basis.

In *General Theory of Employment Interest and Money* John Meyanard Keynes proposed a new business cycle theory to explain the flaws in classisical economic theory. Keynes disagreed with the idea of perfect wage and price flexibility and built his model on volitity of investments. In the Keynian business model increased demand for capital goods drive up prices as marginal costs increase due to rising marginal costs and the marginal efficiency of capital begins to fall. A rise in income causes a increase in the demand for money thus raising interest rates which in turn stalls some new growth. This places downward pressure on the investment demand which causes pessimism and stock prices will fall. Falling stock prices causes investment to fall even more and the downturn reduces household wealth. The wealth reduction causes firms to cut production at this point the Keynesian multiplier comes into play and this further reduces aggregate demand and GNP. This is the point in which outside assistance in the form of government spending is needed to re stabilize the economy. Keynes proposed the the economy will undergo long periods of growth but eventually the contraction described above will appear.

In the 1960's the Keynesian model started to falter. At the end to the 1960's there was high unemployment and high excess capacity. Since the traditional Keynesian model had a difficult time explaining what was happening with the economy the model proposed by the monetarists such as Milton Friedman started gaining traction (Hall, 1990).

The model that we will be using in this analysis will be a modified New-Keynesian Model. The New-Keynesian model incorporates elements of the monetarist, Old-Keynesian, and classical supply side models (Hall, 1990). The new Keynesian model introduces unstable aggregate demand and supply into the Keynesian model.

Behavioral History

The seminal tipping point in behavioral economics came with the publication of Daniel Kahneman and Amos Tversky's Prospect Theory: An Analysis of Decision Under Risk. Kaheman and Tversky's work has been influencing the micro-economic landscape since its publishing but has had very little influence on Macroeconomics.

Animal Spirits

Animal Spirits as defined by Keynes in *General Theory* are the spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities (Keynes, 1936). It is the distribution of these animal spirits that were the focus of this analysis. We analyzed the changes in animal spirits as distribution of the population changed from all of the population following the extrapolative rule to all of the population following the extrapolative rule. We also modified the model to see the effect of introducing inflation expectations based on geometrically weighted inflation expectations.

Model

The model that we used was based of three individual models. The new Keynesian model is the model used for aggregate demand, the new keynesian phillips curve was used for aggregate supply, and inflation will follow the Taylor Rule.

New Keynesian Model - Aggregate Demand Equation

$$y_t = a_1 \tilde{E} y_{t+1} + (1 - a_1) y_{t-1} + a_2 (r_t - \tilde{E}_t \pi_{t+1}) + \epsilon_t$$

New Keynesian Phillips Curve - Aggregate Supply Equation

$$\pi_t = b_1 \tilde{E}_t \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 y_t + \eta_t$$

Taylor Rule - Determination on interest rates

$$r_1 = c_1 (\pi_t - \pi^*) + c_2 y_t + c_3 r_{t-1} + \upsilon_t$$

1 Formulation of the Model

Notation used in the Model:

y_t = output gap in period t
r_t = nominal interest rate
π_t = rate of inflation
ϵ_t = Demand Shocks
$\tilde{E}_t$ = Expectations Operator
π^* = inflation target
c_1 = Taylor inflation rate increase constant
c_2 = Taylor output gape increase constant
c_3 = Taylor output stabilization constant
η_t = Supply Shocks
υ_t = Interest Rate Shocks
$\alpha_{f,t}$ = Probability that agents use fundamentalist rule
$\alpha_{e,t}$ = Probability that agents use extrapolative rule
$U_{f,t}$ = Fundamentalist Forecast Utility
$U_{e,t}$ = Extrapolative Forecast Utility
ω_k = geometrically declining forecast weight
U_{tar} = Fundamentalist Forecast Utility
U_{exp} = Extrapolative Forecast Utility
$\beta_{tar,t}$ = Probability of target inflation expectation
$\beta_{exp,t}$ = Probability of target extrapolated expectation
ρ = measure of agent's memory

The model is formulated from the following equations:

Agents are assumed to use one of two heuristics to forecast future output. The Fundamentalist rule is where agents estimate the steady state output gap and use this to forecast the future output. The Extrapolative rule is where agents only base the future on the the previous output gap.

Fundamentalist Rule

$$\tilde{E}_t^f y_{t+1} = 0$$

Extrapolation Rule

$$\tilde{E}_e^f y_{t+1} = y_{t-1}$$

Weighted Average of the rules

$$\tilde{E}_t y_{t+1} = \alpha_{f,t} 0 + \alpha_{3,t} y_{t-1}$$

Thus,

$$\alpha_{f,t} + \alpha_{et} = 1$$

Forecasting Performance (Mean Squared Forecasting Errors)

The agents will use the forecasting performance to determine the effectiveness of the equations and allow the agents to switch between the forecasting rules when they determine that the other forecasting is rule is more successful. The model also builds in geometrically declining weights to simulate forgetfulness.

$$U_{f,t} =$$

$\sum_{n=0}^{\infty} \omega_k [y_{tk-1} - \tilde{E}_{f,t-k2} y_{t-k1}]^2$

$$U_{e,t} =$$

$\sum_{n=0}^{\infty} \omega_k [y_{tk-1} - \tilde{E}_{e,t-k2} y_{t-k1}]^2$

Probability of choosing each rule (Includes random component)

$$\alpha_{ft} = P[U_{f,t} + \epsilon_{ft} > (U_{e,t} + \epsilon_{e,t})]$$

Therefore,

$$\alpha_{ft} = \frac{exp(\gamma U_{f,t})}{exp(\gamma U_{e,t}) + exp(\gamma U_{e,t})}$$

Thus,

$$\alpha_{e,t} = 1 - \alpha_{f,t}$$

Inflation Modeling

We will assume that there are two ways for agents to determine expected inflation. The fundamentalist rule uses the central bank inflation target to forecast future inflation. The Extrapolative rule is where agents only base the future inflation on the previous period's inflation.

Fundamentalist inflation targeting

$$\tilde{E}^{tar}{}_t \pi_{t+1} = \pi^*$$

$$\tilde{E}^{ext}{}_t \pi_{t+1} = \pi_{t-1}$$

The weighed average is as follows:

$$\tilde{E}_t \pi_{t+1} = \beta_{tar,t} \pi^* = \beta_{ext,t} \pi_{t-1}$$

Also,

$$\beta_{tar+} \beta_{ext=} 1$$

$$\beta_{tar,t} = \frac{exp(\gamma U_{tar,t})}{exp(\gamma U_{tar,t}) + exp(\gamma U_{ext,t})}$$

$$\beta_{ext,t} = \frac{exp(\gamma U_{ext,t})}{exp(\gamma U_{tar,t}) + exp(\gamma U_{ext,t})}$$

Capacity to forget

The capacity to forget is built into ω by using ρ as the memory as the agents we were able to model the effect of geometrically declining memory. Therefore when ρ equals zero there is no learning and when ρ is 1 there is complete knowledge and therefore also no learning.

$$\omega_k = (1 - \rho)\rho^k$$

$$0 \leq \rho \leq 1$$

$$U_{ft} = \rho U_{f,t-1} - (1 - \rho)[y_{t-1} - \tilde{E}_{f,t-2} y_{t-1}]^2$$

$$U_{et} = \rho U_{e,t-1} - (1 - \rho)[y_{t-1} - \tilde{E}_{e,t-2} y_{t-1}]^2$$

Behavioral Model Fixed Parameters

$pstar = 0.02$; Central Bank's Inflation Target
$a1 = .5$; Coefficient of expected output in output equation
$a2 = -.2$; the interest elasticity of output demand
$b1 = .5$; the coefficient of of expected inflation
$b2 = .05$; the coefficient of output in inflation equation
$c1 = 1.5$; the coefficient of inflation in Taylor equation
$c2 = .5$; the is coefficient of output in Taylor equation
$c3 = .5$; the interest smoothing parameter in Taylor equation
$\beta = 1$; the fixed divergence of beliefs
$\delta = 2$; the variable component in divergence of beliefs
$\gamma = 1$; the intensity of choice parameter
$\sigma_1 = .5$; the standard deviation shocks output
$\sigma_2 = .5$; the standard deviation shocks inflation
$\sigma_3 = .5$; the standard deviation shocks Taylor
$\rho = .5$; the speed of declining weights in mean

Analysis of Model

The US Economy there is strong cyclical movement which give strong autocorrelation in the output gap numbers. We will use the autocorrelation as an indicator of how well our model performs compared to the historical data. We will also focus on the distribution of animal spirits in the economy. In this model we have to make some simplifying assumptions such as constant target inflation and only two types of learning.

We will compare the results of this model to the US output gap from 1960-2009. Using the autococorrelation of the output gap numbers we can then compare historical output to our model. We use the autocorrelation of the output gap because we are focusing on the output gap and the animal spirits in the model. Using autocorrelation allows us to ensure that we have an output that is cyclical movement of the output. The autocorrelation cofefficient for the US economy from 1960-2009 was .94, so that is our target autocorrelation in this model (DeGrawe, 2009).

Impact of Target Inflation

In this analysis we focused on changes of animal spirits in the model. The first analysis that was completed focused on varying the expected inflation (π^*). What we found was that there was very little impact on the distribution of animal spirits when the target inflation was zero compared to the base model of 2% or even 5% see Figure 1 and 2. This indicates that strict inflation targeting may not be effective minimizing business cycle fluctuations.

Impact of Memory

In this analysis we focused on the analysis of ρ and its impact on animal spirits. We found that when ρ was zero (no memory) animal spirits have a fat tailed distribution (Figure 3). When ρ is 1 (perfect memory) there is no learning because there is perfect knowledge thus there is are no animal spirits in the the economy. This shows that the amount of collective memory has a major impact on the animal spirits in the economy. As technology advances and there is more information available to the agents in the economy we should see fewer drastic cycles.

Proportion of Agents in Model

In the model we had to decide how to distribute the proportion of agents that used the fundamentalist analysis and those who used the extrapolative theory. We started with 100% of the population using the extrapolative assumptions and this gave us an output gap autocorrelation of .957 compared to the historical output gap of .94 thus giving us our best model. We then increased the proportion of fundamentalist agents in the population in 25% increments. What we found was that as the proportion of fundamentalist agents increased the distribution of animal spirits started to normalize but the distributions were still fat tailed. Example distributions are shown in Figures 4 through 8.

The next analysis that we did was to increase the amount of time the agents looked back. In the original model the extrapolative agents based their expections on the month before. We first increased the time period to three months that were geometrically weighted. This analysis gave us an even more normalized output with lower fat tails see Figure 9.

We then took this one step further to use the quarterly memory and geometrically weight for quarters so that the agents would look back annually. This gave us a nearly normalized distribution of animal spirits that had only a small fat tailed distribution see Figure 10.

The last analysis that we did was geometrically weight 12 months. What we found was that this gives us a nearly normally distribution of animal spirits with almost no fat tails.This is shown as Figure 11 in the Appendix.

Conclusion

The analysis showed that the distributions for animal spirits were fat-tailed in every test expect for when there was perfect knowledge. This contrasts the traditional new Keynesian model where the assumption is that agents are rational. The fat-tailed distribution of this irrationality partially explains why there are business cycles in the economy. This model shows that as technology advances and there is more access to the historical record the business cycles will still exist but there will be fewer times with excessive booms followed by deep recessions. This is especially true if the agents have an annual memory.

Further Discussion

Though we focused on autocorrelation in the model we do not feel that it gives us the best model. The monthly annualized model was the most realistic of all the models because it incorporated more than just one discounted time period. The next step in this model would be to include seasonality into the annual model.

References

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Appendix

Matlab Code

```
%Behavioral Model
%pstar=0;          %Central Bank's Inflation Target
%a1=.5;            %Coefficient of expected output in output equation
%a2=-.2;           %a is the intereste elasticty of output demand
%b1=.5;            %b1 is the coefficient of of expected inflation
%b2=.05;           %b2 is coefficient of output in inflation equation
%c1=1.5;           %c1 is coefficient of inflation in Taylor equation
%c2=.5;            %c2 is coefficient of output in Taylor equation
%c3=.5;            %interest smoothing parameter in Taylor equation
%beta=1;           %fixed divergence of beliefs
%delta=2;          %variable component in divergence of beliefs
%gamma=1;          %intensity of choice parameter
%sigma1=.5;        %standard deviation shocks output
%sigma2=.5;        %standard deviation shocks inflation
%sigma3=.5;        %standard deviation shocks Taylor
%rho=.5;           % rho measures the speed of declining weights in mean square errors (memory parameter)
                   %errors (memory parameter)


%Rational Model
%pstar=0;          %Central Bank's Inflation Target
%a1=.5;            %Coefficient of expected output in output equation
%a2=-.2;           %a is the intereste elasticty of output demand
%b1=.5;            %b1 is the coefficient of of expected inflation
%b2=.05;           %b2 is coefficient of output in inflation equation
%c1=1.5;           %c1 is coefficient of inflation in Taylor equation
%c2=.5;            %c2 is coefficient of output in Taylor equation
%c3=.5;            %interest smoothing parameter in Taylor
```

```
    equation
%sigma1=.5;     %standard deviation shocks output
%sigma2=.5;     %standard deviation shocks inflation
%sigma3=.5;     %standard deviation shocks Taylor


%% Parameters of the model
mm = 1;    %switching parameter gamma in Brock Hommes
pstar = .02; % the central bank's inflation target
eprational=0   % if all agents have rational forecast of inflationthis parameter is 1%
epextrapol=0;   % if all agents use inflation extrapolation this parameter is 1%
a1 = .5;     %coefficient of expected output in output equation
a2 = -0.2;   %a is the interest elasticity of output demand
b1 = .5;     %b1 is coefficient of expected inflation in inflation equation
b2 = 0.05;   %b2 is coefficient of output in inflation equation
c1 = 1.5;   %c1 is coefficient of inflation in Taylor equation
c2 = 0.5;   %c2 is coefficient of output in Taylor equation
c3 = 0.5;   %interest smoothing parameter in Taylor equation
A = [1 -b2;-a2*c1 1-a2*c2];
B = [b1 0;-a2 a1];
C = [1-b1 0;0 1-a1];
T = 600;
TI = 250;
K = 50;     %length of period to compute divergence
sigma1 = 0.5;  %standard deviation shocks output
sigma2 = 0.5;  %standard deviation shocks inflation
sigma3 = 0.5;  %standard deviation shocks Taylor
rho=1;       %rho in mean squares errors
rhoout=0;    %rho in shocks output
rhoinf=0;    %rho in shocks inflation
rhotayl=0;   %rho in shocks Taylor
rhoBH=0.5;
epfs=pstar;    %forecast inflation targeters
p = zeros(T,1);
y = zeros(T,1);
plagt = zeros(T,1);
ylagt = zeros(T,1);
```

```
r = zeros(T,1);
epf = zeros(T,1);
epc = zeros(T,1);
ep = zeros(T,1);
ey = zeros(T,1);
CRp = zeros(T,1);
FRp = zeros(T,1);
alfapt = zeros(T,1);
eyfunt = zeros(T,1);
CRy = zeros(T,1);
FRy = zeros(T,1);
alfayt = zeros(T,1);
anspirits = zeros(T,1);
epsilont = zeros(T,1);
etat = zeros(T,1);
ut = zeros(T,1);

%%%%%%%%%%%%%%
%Model
%%%%%%%%%%%%%%%
    alfap=0.5;
    alfay=0.5;
    K1=K+1;
for t=2:T; epsilont(t) = rhoout*epsilont(t-1) + sigma1*randn; %shocks in output equation (demand shock)
    etat(t)= rhoinf*etat(t-1) + sigma2*randn;   %shocks in inflation equation (supply shock)
    ut(t) = rhotayl*ut(t-1) + sigma3*randn;      %shocks in Taylor rule (interest rate shock)
    epsilon = epsilont(t);
    eta = etat(t);
    u = ut(t);
    shocks = [eta;a2*u+epsilon];
    epcs=p(t-1);
if eprational==1 ;epcs=pstar;
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=p(t-1);
end
    eychar=y(t-1);
    eyfun=0+randn/2;
    eyfunt(t)=eyfun;
    eys=alfay*eychar+(1-alfay)*eyfun;
    forecast = [eps;eys];
    plag=p(t-1);
    ylag=y(t-1);
```

```
       rlag=r(t-1);
       lag = [plag;ylag];
       smooth = [0;a2*c3];
       D = B*forecast + C*lag + smooth*rlag + shocks;
       X = A\D;
       p(t)= X(1,1);
       y(t)= X(2,1);
       r(t)= c1*p(t)+c2*y(t)+c3*r(t-1)+u;
if  (r(t))^2== 1; r(t)= c1*(p(t))^2+c2*y(t)+c3*r(t-1)+u;
end
       plagt(t)=p(t-1);
       ylagt(t)=y(t-1);
       CRp(t) = rho*CRp(t-1) - (1-rho)*(epcs-p(t))^2;
       FRp(t) = rho*FRp(t-1) - (1-rho)*(epfs-p(t))^2;
       CRy(t) = rho*CRy(t-1) - (1-rho)*(eychar-y(t))^2;
       FRy(t) = rho*FRy(t-1) - (1-rho)*(eyfun-y(t))^2;
       alfap = rhoBH*alfapt(t-1)+(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(mm * FRp(t)));
       alfay = rhoBH*alfayt(t-1)+(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(mm * FRy(t)));
       alfapt(t) = alfap;
       alfayt(t) = alfay;
if eychar>0;anspirits(t)=alfay;
end
if eychar<0;anspirits(t)=1-alfay;
end
end
autocory = corrcoef(y,ylagt);
autocorp = corrcoef(p,plagt);
coroutputanimal = corr(y,anspirits); %% mean, median, max, min, standard deviation, kurtosis
Kurt    = kurtosis(y); %% jarque-bera test
[jb,pvalue,jbstat] = jbtest(y,0.05);
```

Quarterly Monthy Code

```
%Behavioral Model
%pstar=0;          %Central Bank's Inflation Target
%a1=.5;            %Coefficient of expected output in output equation
%a2=-.2;           %a is the intereste elasticty of output demand
%b1=.5;            %b1 is the coefficient of of expected inflation
%b2=.05;           %b2 is coefficient of output in inflation equation
%c1=1.5;           %c1 is coefficient of inflation in Taylor equation
%c2=.5;            %c2 is coefficient of output in Taylor equation
%c3=.5;            %interest smoothing parameter in Taylor equation
%beta=1;           %fixed divergence of beliefs
%delta=2;          %variable component in divergence of beliefs
%gamma=1;          %intensity of choice parameter
%sigma1=.5;        %standard deviation shocks output
%sigma2=.5;        %standard deviation shocks inflation
%sigma3=.5;        %standard deviation shocks Taylor
%rho=.5;           % rho measures the speed of declining weights in mean square errors (memory parameter)
                   %errors (memory parameter)


%Rational Model
%pstar=0;          %Central Bank's Inflation Target
%a1=.5;            %Coefficient of expected output in output equation
%a2=-.2;           %a is the intereste elasticty of output demand
%b1=.5;            %b1 is the coefficient of of expected inflation
%b2=.05;           %b2 is coefficient of output in inflation equation
%c1=1.5;           %c1 is coefficient of inflation in Taylor equation
%c2=.5;            %c2 is coefficient of output in Taylor equation
%c3=.5;            %interest smoothing parameter in Taylor
```

```
    equation
%sigma1=.5;     %standard deviation shocks output
%sigma2=.5;     %standard deviation shocks inflation
%sigma3=.5;     %standard deviation shocks Taylor


%% Parameters of the model
mm = 1;   %switching parameter gamma in Brock Hommes
pstar = 0.02; % the central bank's inflation target
eprational=0;  % if all agents have rational forecast of inflationthis parameter is 1%
epextrapol=0;  % if all agents use inflation extrapolation this parameter is 1%
a1 = .5;    %coefficient of expected output in output equation
a2 = -0.2;  %a is the interest elasticity of output demand
b1 = .5;    %b1 is coefficient of expected inflation in inflation equation
b2 = 0.05;  %b2 is coefficient of output in inflation equation
c1 = 1.5;  %c1 is coefficient of inflation in Taylor equation
c2 = 0.5;  %c2 is coefficient of output in Taylor equation
c3 = 0.5;  %interest smoothing parameter in Taylor equation
A = [1 -b2;-a2*c1 1-a2*c2];
B = [b1 0;-a2 a1];
C = [1-b1 0;0 1-a1];
T = 2000;
TI = 250;
K = 50;        %length of period to compute divergence
sigma1 = 0.5;  %standard deviation shocks output
sigma2 = 0.5;  %standard deviation shocks inflation
sigma3 = 0.5;  %standard deviation shocks Taylor
rho=0.5;       %rho in mean squares errors
rhoout=0.0;    %rho in shocks output
rhoinf=0.0;    %rho in shocks inflation
rhotayl=0.0;   %rho in shocks Taylor
rhoBH=0.0;
epfs=pstar;    %forecast inflation targeters
p = zeros(T,1);
y = zeros(T,1);
plagt = zeros(T,1);
ylagt = zeros(T,1);
```

```
r = zeros(T,1);
epf = zeros(T,1);
epc = zeros(T,1);
ep = zeros(T,1);
ey = zeros(T,1);
CRp = zeros(T,1);
FRp = zeros(T,1);
alfapt = zeros(T,1);
eyfunt = zeros(T,1);
CRy = zeros(T,1);
FRy = zeros(T,1);
alfayt = zeros(T,1);
anspirits = zeros(T,1);
epsilont = zeros(T,1);
etat = zeros(T,1);
ut = zeros(T,1);

%%%%%%%%%%%%%%%
%Model
%%%%%%%%%%%%%%%%
    alfap=0.5;
    alfay=0.5;
    K1=K+1;
for t=2:3;
    epsilont(t) = rhoout*epsilont(t-1) + sigma1*randn;  % shocks in output equation (demand shock)
    etat(t)= rhoinf*etat(t-1) + sigma2*randn;    %shocks in inflation equation (supply shock)
    ut(t) = rhotayl*ut(t-1) + sigma3*randn;       %shocks in Taylor rule (interest rate shock)
    epsilon = epsilont(t);
    eta = etat(t);
    u = ut(t);
    shocks = [eta;a2*u+epsilon];
    epcs=p(t-1);
if eprational==1 ;epcs=pstar;
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=p(t-1);
end
    eychar=y(t-1);
    eyfun=0+randn/2;
    eyfunt(t)=eyfun;
    eys=alfay*eychar+(1-alfay)*eyfun;
    forecast = [eps;eys];
    plag=p(t-1);
```

```
      ylag=y(t-1);
      rlag=r(t-1);
      lag = [plag;ylag];
      smooth = [0;a2*c3];
      D = B*forecast + C*lag + smooth*rlag + shocks;
      X = A\D;
      p(t)= X(1,1);
      y(t)= X(2,1);
      r(t)= c1*p(t)+c2*y(t)+c3*r(t-1)+u;
if  (r(t))^2== 1; r(t)= c1*(p(t))^2+c2*y(t)+c3*r(t-1)+u; %it says squared =1 in book code?
end
      plagt(t)=p(t-1);
      ylagt(t)=y(t-1);
      CRp(t) = rho*CRp(t-1) - (1-rho)*(epcs-p(t))^2;
      FRp(t) = rho*FRp(t-1) - (1-rho)*(epfs-p(t))^2;
      CRy(t) = rho*CRy(t-1) - (1-rho)*(eychar-y(t))^2;
      FRy(t) = rho*FRy(t-1) - (1-rho)*(eyfun-y(t))^2;
      alfap = rhoBH*alfapt(t-1)+(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(mm * FRp(t)));
      alfay = rhoBH*alfayt(t-1)+(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(mm * FRy(t)));
      alfapt(t) = alfap;
      alfayt(t) = alfay;
if eychar>0;anspirits(t)=alfay;
end
if eychar<0;anspirits(t)=1-alfay;
end
end %Line 123 is broken

for  t=4:T;
      epsilont(t) = 0.6*rhoout*epsilont(t-1) + 0.3*rhoout*epsilont(t-2) + 0.1*rhoout*epsilont(t-3) + sigma1*randn;  %shocks in output equation (demand shock)
      etat(t)= 0.6*rhoinf*etat(t-1) + 0.3*rhoinf*etat(t-2) + 0.1*rhoinf*etat(t-3) + sigma2*randn;     %shocks in inflation equation (supply shock)
      ut(t) = 0.6*rhotayl*ut(t-1) + 0.3*rhotayl*ut(t-2) + 0.1*rhotayl*ut(t-3) + sigma3*randn;        %shocks in Taylor rule (interest rate shock)
      epsilon = epsilont(t);
      eta = etat(t);
      u = ut(t);
      shocks = [eta;a2*u+epsilon];
      epcs=0.6*p(t-1) + 0.3*p(t-1) + 0.1*p(t-3);
if eprational==1 ;epcs=pstar;
```

```
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=0.6*p(t-1) + 0.3*p(t-2) + 0.1*p(t-3);
end
    eychar=0.6*y(t-1) + 0.3*y(t-2) + 0.1*y(t-3);
    eyfun=0+randn/2;
    eyfunt(t)=eyfun;
    eys=alfay*eychar+(1-alfay)*eyfun;
    forecast = [eps;eys];
    plag=0.6*p(t-1) + 0.3*p(t-2) + 0.1*p(t-3);
    ylag=0.6*y(t-1) + 0.3*y(t-2) + 0.1*y(t-3);
    rlag=0.6*r(t-1) + 0.3*r(t-2) + 0.1*r(t-3);
    lag = [plag;ylag];
    smooth = [0;a2*c3];
    D = B*forecast + C*lag + smooth*rlag + shocks;
    X = A\D;
    p(t)= X(1,1);
    y(t)= X(2,1);
    r(t)= c1*p(t)+c2*y(t)+0.6*c3*r(t-1)+0.3*c3*r(t-2)+0.1*c3*r(t-3)+u;
if  (r(t))^2== 1; r(t)= c1*(p(t))^2+c2*y(t)+0.6*c3*r(t-1)+0.3*c3*r(t-2)+0.1*c3*r(t-3)+u;  %it says squared =1 in book code?
end
    plagt(t)=0.6*p(t-1) + 0.3*p(t-2) + 0.1*p(t-3);
    ylagt(t)=0.6*y(t-1) + 0.3*y(t-2) + 0.1*y(t-3);
    CRp(t) = 0.6*rho*CRp(t-1) + 0.3*rho*CRp(t-2) + 0.1*rho*CRp(t-3) - (1-rho)*(epcs-p(t))^2;
    FRp(t) = 0.6*rho*FRp(t-1) + 0.3*rho*FRp(t-2) + 0.1*rho*FRp(t-3) - (1-rho)*(epfs-p(t))^2;
    CRy(t) = 0.6*rho*CRy(t-1) + 0.3*rho*CRy(t-2) + 0.1*rho*CRy(t-3) - (1-rho)*(eychar-y(t))^2;
    FRy(t) = 0.6*rho*FRy(t-1) + 0.3*rho*FRy(t-2) + 0.1*rho*FRy(t-3) - (1-rho)*(eyfun-y(t))^2;
    alfap = 0.6*rhoBH*alfapt(t-1)+0.3*rhoBH*alfapt(t-2)+0.1*rhoBH*alfapt(t-3)+(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(mm * FRp(t)));
    alfay = 0.6*rhoBH*alfayt(t-1)+0.3*rhoBH*alfayt(t-2)+0.1*rhoBH*alfayt(t-3)+(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(mm * FRy(t)));
    alfapt(t) = alfap;
    alfayt(t) = alfay;
if eychar>0;anspirits(t)=alfay;
end
if eychar<0;anspirits(t)=1-alfay;
```

```
end
end
autocory = corrcoef(y,ylagt);
autocorp = corrcoef(p,plagt);
coroutputanimal = corr(y,anspirits); %%  mean, median,
    max, min, standard deviation, kurtosis
Kurt     = kurtosis(y); %% jarque-bera test
[jb,pvalue,jbstat] = jbtest(y,0.05);
```

Quarterly to Annual Matlab Code

```
%Behavioral Model
%pstar=0;          %Central Bank's Inflation Target
%a1=.5;            %Coefficient of expected output in output equation
%a2=-.2;           %a is the intereste elasticty of output demand
%b1=.5;            %b1 is the coefficient of of expected inflation
%b2=.05;           %b2 is coefficient of output in inflation equation
%c1=1.5;           %c1 is coefficient of inflation in Taylor equation
%c2=.5;            %c2 is coefficient of output in Taylor equation
%c3=.5;            %interest smoothing parameter in Taylor equation
%beta=1;           %fixed divergence of beliefs
%delta=2;          %variable component in divergence of beliefs
%gamma=1;          %intensity of choice parameter
%sigma1=.5;        %standard deviation shocks output
%sigma2=.5;        %standard deviation shocks inflation
%sigma3=.5;        %standard deviation shocks Taylor
%rho=.5;           % rho measures the speed of declining weights in mean square errors (memory parameter)              %errors (memory parameter)


%Rational Model
%pstar=0;          %Central Bank's Inflation Target
%a1=.5;            %Coefficient of expected output in output equation
%a2=-.2;           %a is the intereste elasticty of output demand
%b1=.5;            %b1 is the coefficient of of expected inflation
%b2=.05;           %b2 is coefficient of output in inflation equation
%c1=1.5;           %c1 is coefficient of inflation in Taylor equation
%c2=.5;            %c2 is coefficient of output in Taylor equation
%c3=.5;            %interest smoothing parameter in Taylor
```

```
    equation
%sigma1=.5;     %standard deviation shocks output
%sigma2=.5;     %standard deviation shocks inflation
%sigma3=.5;     %standard deviation shocks Taylor


%% Parameters of the model
mm = 1;    %switching parameter gamma in Brock Hommes
pstar = 0.02; % the central bank's inflation target
eprational=0;   % if all agents have rational forecast of
     inflationthis parameter is 1%
epextrapol=0;   % if all agents use inflation
    extrapolation this parameter is 1%
a1 = .5;     %coefficient of expected output in output
    equation
a2 = -0.2;   %a is the interest elasticity of output
    demand
b1 = .5;     %b1 is coefficient of expected inflation in
    inflation equation
b2 = 0.05;   %b2 is coefficient of output in inflation
    equation
c1 = 1.5;   %c1 is coefficient of inflation in Taylor
    equation
c2 = 0.5;   %c2 is coefficient of output in Taylor
    equation
c3 = 0.5;   %interest smoothing parameter in Taylor
    equation
A = [1 -b2;-a2*c1 1-a2*c2];
B = [b1 0;-a2 a1];
C = [1-b1 0;0 1-a1];
T = 2000;
TI = 250;
K = 50;         %length of period to compute divergence
sigma1 = 0.5;  %standard deviation shocks output
sigma2 = 0.5;  %standard deviation shocks inflation
sigma3 = 0.5;  %standard deviation shocks Taylor
rho=0.5;        %rho in mean squares errors
rhoout=0.0;     %rho in shocks output
rhoinf=0.0;     %rho in shocks inflation
rhotayl=0.0;    %rho in shocks Taylor
rhoBH=0.0;
epfs=pstar;     %forecast inflation targeters
p = zeros(T,1);
y = zeros(T,1);
plagt = zeros(T,1);
ylagt = zeros(T,1);
```

```
r = zeros(T,1);
epf = zeros(T,1);
epc = zeros(T,1);
ep = zeros(T,1);
ey = zeros(T,1);
CRp = zeros(T,1);
FRp = zeros(T,1);
alfapt = zeros(T,1);
eyfunt = zeros(T,1);
CRy = zeros(T,1);
FRy = zeros(T,1);
alfayt = zeros(T,1);
anspirits = zeros(T,1);
epsilont = zeros(T,1);
etat = zeros(T,1);
ut = zeros(T,1);

%%%%%%%%%%%%%%%
%Model
%%%%%%%%%%%%%%%%
    alfap=0.5;
    alfay=0.5;
    K1=K+1;
for t=2:3;
    epsilont(t) = rhoout*epsilont(t-1) + sigma1*randn;  % shocks in output equation (demand shock)
    etat(t)= rhoinf*etat(t-1) + sigma2*randn;    %shocks in inflation equation (supply shock)
    ut(t) = rhotayl*ut(t-1) + sigma3*randn;       %shocks in Taylor rule (interest rate shock)
    epsilon = epsilont(t);
    eta = etat(t);
    u = ut(t);
    shocks = [eta;a2*u+epsilon];
    epcs=p(t-1);
if eprational==1 ;epcs=pstar;
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=p(t-1);
end
    eychar=y(t-1);
    eyfun=0+randn/2;
    eyfunt(t)=eyfun;
    eys=alfay*eychar+(1-alfay)*eyfun;
    forecast = [eps;eys];
    plag=p(t-1);
```

```
107      ylag=y(t-1);
108      rlag=r(t-1);
109      lag = [plag;ylag];
110      smooth = [0;a2*c3];
111      D = B*forecast + C*lag + smooth*rlag + shocks;
112      X = A\D;
113      p(t)= X(1,1);
114      y(t)= X(2,1);
115      r(t)= c1*p(t)+c2*y(t)+c3*r(t-1)+u;
116 if  (r(t))^2== 1; r(t)= c1*(p(t))^2+c2*y(t)+c3*r(t-1)+u; %it says squared =1 in book code?
117 end
118      plagt(t)=p(t-1);
119      ylagt(t)=y(t-1);
120      CRp(t) = rho*CRp(t-1) - (1-rho)*(epcs-p(t))^2;
121      FRp(t) = rho*FRp(t-1) - (1-rho)*(epfs-p(t))^2;
122      CRy(t) = rho*CRy(t-1) - (1-rho)*(eychar-y(t))^2;
123      FRy(t) = rho*FRy(t-1) - (1-rho)*(eyfun-y(t))^2;
124      alfap = rhoBH*alfapt(t-1)+(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(mm * FRp(t)));
125      alfay = rhoBH*alfayt(t-1)+(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(mm * FRy(t)));
126      alfapt(t) = alfap;
127      alfayt(t) = alfay;
128 if eychar>0;anspirits(t)=alfay;
129 end
130 if eychar<0;anspirits(t)=1-alfay;
131 end
132 end %Line 123 is broken
133
134 for t=4:12;
135      epsilont(t) = 0.6*rhoout*epsilont(t-1) + 0.3*rhoout*epsilont(t-2) + 0.1*rhoout*epsilont(t-3) + sigma1*randn;  %shocks in output equation (demand shock)
136      etat(t)= 0.6*rhoinf*etat(t-1) + 0.3*rhoinf*etat(t-2) + 0.1*rhoinf*etat(t-3) + sigma2*randn;    %shocks in inflation equation (supply shock)
137      ut(t) = 0.6*rhotayl*ut(t-1) + 0.3*rhotayl*ut(t-2) + 0.1*rhotayl*ut(t-3) + sigma3*randn;        %shocks in Taylor rule (interest rate shock)
138      epsilon = epsilont(t);
139      eta = etat(t);
140      u = ut(t);
141      shocks = [eta;a2*u+epsilon];
142      epcs=0.6*p(t-1) + 0.3*p(t-1) + 0.1*p(t-3);
143 if eprational==1 ;epcs=pstar;
```

```
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=0.6*p(t-1) + 0.3*p(t-2) + 0.1*p(t-3);
end
    eychar=0.6*y(t-1) + 0.3*y(t-2) + 0.1*y(t-3);
    eyfun=0+randn/2;
    eyfunt(t)=eyfun;
    eys=alfay*eychar+(1-alfay)*eyfun;
    forecast = [eps;eys];
    plag=0.6*p(t-1) + 0.3*p(t-2) + 0.1*p(t-3);
    ylag=0.6*y(t-1) + 0.3*y(t-2) + 0.1*y(t-3);
    rlag=0.6*r(t-1) + 0.3*r(t-2) + 0.1*r(t-3);
    lag = [plag;ylag];
    smooth = [0;a2*c3];
    D = B*forecast + C*lag + smooth*rlag + shocks;
    X = A\D;
    p(t)= X(1,1);
    y(t)= X(2,1);
    r(t)= c1*p(t)+c2*y(t)+0.6*c3*r(t-1)+0.3*c3*r(t-2)+0.1*c3*r(t-3)+u;
if (r(t))^2== 1; r(t)= c1*(p(t))^2+c2*y(t)+0.6*c3*r(t-1)+0.3*c3*r(t-2)+0.1*c3*r(t-3)+u;  %it says squared =1 in book code?
end
    plagt(t)=0.6*p(t-1) + 0.3*p(t-2) + 0.1*p(t-3);
    ylagt(t)=0.6*y(t-1) + 0.3*y(t-2) + 0.1*y(t-3);
    CRp(t) = 0.6*rho*CRp(t-1) + 0.3*rho*CRp(t-2) + 0.1*rho*CRp(t-3) - (1-rho)*(epcs-p(t))^2;
    FRp(t) = 0.6*rho*FRp(t-1) + 0.3*rho*FRp(t-2) + 0.1*rho*FRp(t-3) - (1-rho)*(epfs-p(t))^2;
    CRy(t) = 0.6*rho*CRy(t-1) + 0.3*rho*CRy(t-2) + 0.1*rho*CRy(t-3) - (1-rho)*(eychar-y(t))^2;
    FRy(t) = 0.6*rho*FRy(t-1) + 0.3*rho*FRy(t-2) + 0.1*rho*FRy(t-3) - (1-rho)*(eyfun-y(t))^2;
    alfap = 0.6*rhoBH*alfapt(t-1)+0.3*rhoBH*alfapt(t-2)+0.1*rhoBH*alfapt(t-3)+(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(mm * FRp(t)));
    alfay = 0.6*rhoBH*alfayt(t-1)+0.3*rhoBH*alfayt(t-2)+0.1*rhoBH*alfayt(t-3)+(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(mm * FRy(t)));
    alfapt(t) = alfap;
    alfayt(t) = alfay;
if eychar>0;anspirits(t)=alfay;
end
if eychar<0;anspirits(t)=1-alfay;
```

```
end
end

for t=13:T;
    epsilont(t) = 0.32*rhoout*epsilont(t-1) + 0.16*rhoout*epsilont(t-2) + 0.11*rhoout*epsilont(t-3) + 0.08*rhoout*epsilont(t-4) + 0.06*rhoout*epsilont(t-5) + 0.05*rhoout*epsilont(t-6) + 0.05*rhoout*epsilont(t-7) + 0.04*rhoout*epsilont(t-8) + 0.04*rhoout*epsilont(t-9) + 0.03*rhoout*epsilont(t-10) + 0.03*rhoout*epsilont(t-11) + 0.03*rhoout*epsilont(t-12) + sigma1*randn;  %shocks in output equation (demand shock)
    etat(t)= 0.32*rhoinf*etat(t-1) + 0.16*rhoinf*etat(t-2) + 0.11*rhoinf*etat(t-3) + 0.08*rhoinf*etat(t-4) + 0.06*rhoinf*etat(t-5) + 0.05*rhoinf*etat(t-6) + 0.05*rhoinf*etat(t-7) + 0.04*rhoinf*etat(t-8) + 0.04*rhoinf*etat(t-9) + 0.03*rhoinf*etat(t-10) + 0.03*rhoinf*etat(t-11) + 0.03*rhoinf*etat(t-12) + sigma2*randn;    %shocks in inflation equation (supply shock)
    ut(t) = 0.32*rhotayl*ut(t-1) + 0.16*rhotayl*ut(t-2) + 0.11*rhotayl*ut(t-3) + 0.08*rhotayl*ut(t-4) + 0.06*rhotayl*ut(t-5) + 0.05*rhotayl*ut(t-6) + 0.05*rhotayl*ut(t-7) + 0.04*rhotayl*ut(t-8) + 0.04*rhotayl*ut(t-9) + 0.03*rhotayl*ut(t-10) + 0.03*rhotayl*ut(t-11) + 0.03*rhotayl*ut(t-12) + sigma3*randn;       %shocks in Taylor rule (interest rate shock)
    epsilon = epsilont(t);
    eta = etat(t);
    u = ut(t);
    shocks = [eta;a2*u+epsilon];
    epcs=0.32*p(t-1) + 0.16*p(t-1) + 0.11*p(t-3) + 0.08*p(t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t-7) + 0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) + 0.03*p(t-11) + 0.03*p(t-12);
if eprational==1 ;epcs=pstar;
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=0.32*p(t-1) + 0.16*p(t-2) + 0.11*p(t-3) + 0.08*p(t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t-7) + 0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) + 0.03*p(t-11) + 0.03*p(t-12);
end
    eychar=0.32*y(t-1) + 0.16*y(t-2) + 0.11*y(t-3) +
```

```
    0.08*y(t-4) + 0.06*y(t-5) + 0.05*y(t-6) + 0.05*y(t
    -7) + 0.04*y(t-8) + 0.04*y(t-9) + 0.03*y(t-10) +
    0.03*y(t-11) + 0.03*y(t-12);
eyfun=0+randn/2;
eyfunt(t)=eyfun;
eys=alfay*eychar+(1-alfay)*eyfun;
forecast = [eps;eys];
plag=0.32*p(t-1) + 0.16*p(t-2) + 0.11*p(t-3) + 0.08*p
    (t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t-7) +
    0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) + 0.03*p(
    t-11) + 0.03*p(t-12);
ylag=0.32*y(t-1) + 0.16*y(t-2) + 0.11*y(t-3) + 0.08*y
    (t-4) + 0.06*y(t-5) + 0.05*y(t-6) + 0.05*y(t-7) +
    0.04*y(t-8) + 0.04*y(t-9) + 0.03*y(t-10) + 0.03*y(
    t-11) + 0.03*y(t-12);
rlag=0.32*r(t-1) + 0.16*r(t-2) + 0.11*r(t-3) + 0.08*r
    (t-4) + 0.06*r(t-5) + 0.05*r(t-6) + 0.05*r(t-7) +
    0.04*r(t-8) + 0.04*r(t-9) + 0.03*r(t-10) + 0.03*r(
    t-11) + 0.03*r(t-12);
lag = [plag;ylag];
smooth = [0;a2*c3];
D = B*forecast + C*lag + smooth*rlag + shocks;
X = A\D;
p(t)= X(1,1);
y(t)= X(2,1);
r(t)= c1*p(t)+c2*y(t)+0.32*c3*r(t-1)+0.16*c3*r(t-2)
    +0.11*c3*r(t-3)+0.08*c3*r(t-4)+0.06*c3*r(t-5)
    +0.05*c3*r(t-6)+0.05*c3*r(t-7)+0.04*c3*r(t-8)
    +0.04*c3*r(t-9)+0.03*c3*r(t-10)+0.03*c3*r(t-11)
    +0.03*c3*r(t-12)+u;
if (r(t))^2== 1; r(t)= c1*(p(t))^2+c2*y(t)+0.32*c3*r(t
  -1)+0.16*c3*r(t-2)+0.11*c3*r(t-3)+0.08*c3*r(t-4)+0.06*
  c3*r(t-5)+0.05*c3*r(t-6)+0.05*c3*r(t-7)+0.04*c3*r(t-8)
  +0.04*c3*r(t-9)+0.03*c3*r(t-10)+0.03*c3*r(t-11)+0.03*
  c3*r(t-12)+u;  %it says squared =1 in book code?
end
plagt(t)=0.32*p(t-1) + 0.16*p(t-2) + 0.11*p(t-3) +
    0.08*p(t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t
    -7) + 0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) +
    0.03*p(t-11) + 0.03*p(t-12);
ylagt(t)=0.32*y(t-1) + 0.16*y(t-2) + 0.11*y(t-3) +
    0.08*y(t-4) + 0.06*y(t-5) + 0.05*y(t-6) + 0.05*y(t
    -7) + 0.04*y(t-8) + 0.04*y(t-9) + 0.03*y(t-10) +
    0.03*y(t-11) + 0.03*y(t-12);
CRp(t) = 0.32*rho*CRp(t-1) + 0.16*rho*CRp(t-2) +
    0.11*rho*CRp(t-3) + 0.08*rho*CRp(t-4)+ 0.06*rho*
```

```
            CRp(t-5)+ 0.05*rho*CRp(t-6)+ 0.05*rho*CRp(t-7)+
            0.04*rho*CRp(t-8)+ 0.04*rho*CRp(t-9)+ 0.03*rho*CRp
            (t-10)+ 0.03*rho*CRp(t-11)+ 0.03*rho*CRp(t-12)-
            (1-rho)*(epcs-p(t))^2;
        FRp(t) = 0.32*rho*FRp(t-1) + 0.16*rho*FRp(t-2) +
            0.11*rho*FRp(t-3) + 0.08*rho*FRp(t-4)+ 0.06*rho*
            FRp(t-5)+ 0.05*rho*FRp(t-6)+ 0.05*rho*FRp(t-7)+
            0.04*rho*FRp(t-8)+ 0.04*rho*FRp(t-9)+ 0.03*rho*FRp
            (t-10)+ 0.03*rho*FRp(t-11)+ 0.03*rho*FRp(t-12)-
            (1-rho)*(epfs-p(t))^2;
        CRy(t) = 0.32*rho*CRy(t-1) + 0.16*rho*CRy(t-2) +
            0.11*rho*CRy(t-3) + 0.08*rho*CRy(t-4)+ 0.06*rho*
            CRy(t-5)+ 0.05*rho*CRy(t-6)+ 0.05*rho*CRy(t-7)+
            0.04*rho*CRy(t-8)+ 0.04*rho*CRy(t-9)+ 0.03*rho*CRy
            (t-10)+ 0.03*rho*CRy(t-11)+ 0.03*rho*CRy(t-12)-
            (1-rho)*(eychar-y(t))^2;
        FRy(t) = 0.32*rho*FRy(t-1) + 0.16*rho*FRy(t-2) +
            0.11*rho*FRy(t-3) + 0.08*rho*FRy(t-4)+ 0.06*rho*
            FRy(t-5)+ 0.05*rho*FRy(t-6)+ 0.05*rho*FRy(t-7)+
            0.04*rho*FRy(t-8)+ 0.04*rho*FRy(t-9)+ 0.03*rho*FRy
            (t-10)+ 0.03*rho*FRy(t-11)+ 0.03*rho*FRy(t-12)-
            (1-rho)*(eyfun-y(t))^2;
        alfap = 0.32*rhoBH*alfapt(t-1)+0.16*rhoBH*alfapt(t-2)
            +0.11*rhoBH*alfapt(t-3)+0.08*rhoBH*alfapt(t-4)
            +0.06*rhoBH*alfapt(t-5)+0.05*rhoBH*alfapt(t-6)
            +0.05*rhoBH*alfapt(t-7)+0.04*rhoBH*alfapt(t-8)
            +0.04*rhoBH*alfapt(t-9)+0.03*rhoBH*alfapt(t-10)
            +0.03*rhoBH*alfapt(t-11)+0.03*rhoBH*alfapt(t-12)
            +(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(
            mm * FRp(t)));
        alfay = 0.32*rhoBH*alfayt(t-1)+0.16*rhoBH*alfayt(t-2)
            +0.11*rhoBH*alfayt(t-3)+0.08*rhoBH*alfayt(t-4)
            +0.06*rhoBH*alfayt(t-5)+0.05*rhoBH*alfayt(t-6)
            +0.05*rhoBH*alfayt(t-7)+0.04*rhoBH*alfayt(t-8)
            +0.04*rhoBH*alfayt(t-9)+0.03*rhoBH*alfayt(t-10)
            +0.03*rhoBH*alfayt(t-11)+0.03*rhoBH*alfayt(t-12)
            +(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(
            mm * FRy(t)));
        alfapt(t) = alfap;
        alfayt(t) = alfay;
if eychar>0;anspirits(t)=alfay;
end
if eychar<0;anspirits(t)=1-alfay;
end
end
```

```
autocory = corrcoef(y,ylagt);
autocorp = corrcoef(p,plagt);
coroutputanimal = corr(y,anspirits); %%  mean, median,
    max, min, standard deviation, kurtosis
Kurt     = kurtosis(y); %% jarque-bera test
[jb,pvalue,jbstat] = jbtest(y,0.05);
```

2 Annual Matlab Code

```
%Behavioral Model
%pstar=0;        %Central Bank's Inflation Target
%a1=.5;          %Coefficient of expected output in output equation
%a2=-.2;         %a is the intereste elasticty of output demand
%b1=.5;          %b1 is the coefficient of of expected inflation
%b2=.05;         %b2 is coefficient of output in inflation equation
%c1=1.5;         %c1 is coefficient of inflation in Taylor equation
%c2=.5;          %c2 is coefficient of output in Taylor equation
%c3=.5;          %interest smoothing parameter in Taylor equation
%beta=1;         %fixed divergence of beliefs
%delta=2;        %variable component in divergence of beliefs
%gamma=1;        %intensity of choice parameter
%sigma1=.5;      %standard deviation shocks output
%sigma2=.5;      %standard deviation shocks inflation
%sigma3=.5;      %standard deviation shocks Taylor
%rho=.5;         % rho measures the speed of declining weights in mean square errors (memory parameter)              %errors (memory parameter)


%Rational Model
%pstar=0;        %Central Bank's Inflation Target
%a1=.5;          %Coefficient of expected output in output equation
%a2=-.2;         %a is the intereste elasticty of output demand
%b1=.5;          %b1 is the coefficient of of expected inflation
%b2=.05;         %b2 is coefficient of output in inflation equation
%c1=1.5;         %c1 is coefficient of inflation in Taylor equation
%c2=.5;          %c2 is coefficient of output in Taylor equation
%c3=.5;          %interest smoothing parameter in Taylor
```

```
    equation
%sigma1=.5;     %standard deviation shocks output
%sigma2=.5;     %standard deviation shocks inflation
%sigma3=.5;     %standard deviation shocks Taylor


%% Parameters of the model
mm = 1;    %switching parameter gamma in Brock Hommes
pstar = 0.02; % the central bank's inflation target
eprational=0;   % if all agents have rational forecast of
     inflationthis parameter is 1%
epextrapol=0;   % if all agents use inflation
    extrapolation this parameter is 1%
a1 = .5;     %coefficient of expected output in output
    equation
a2 = -0.2;   %a is the interest elasticity of output
    demand
b1 = .5;     %b1 is coefficient of expected inflation in
    inflation equation
b2 = 0.05;   %b2 is coefficient of output in inflation
    equation
c1 = 1.5;   %c1 is coefficient of inflation in Taylor
    equation
c2 = 0.5;   %c2 is coefficient of output in Taylor
    equation
c3 = 0.5;   %interest smoothing parameter in Taylor
    equation
A = [1 -b2;-a2*c1 1-a2*c2];
B = [b1 0;-a2 a1];
C = [1-b1 0;0 1-a1];
T = 2000;
TI = 250;
K = 50;         %length of period to compute divergence
sigma1 = 0.5;  %standard deviation shocks output
sigma2 = 0.5;  %standard deviation shocks inflation
sigma3 = 0.5;  %standard deviation shocks Taylor
rho=0.5;        %rho in mean squares errors
rhoout=0.0;     %rho in shocks output
rhoinf=0.0;     %rho in shocks inflation
rhotayl=0.0;    %rho in shocks Taylor
rhoBH=0.0;
epfs=pstar;     %forecast inflation targeters
p = zeros(T,1);
y = zeros(T,1);
plagt = zeros(T,1);
ylagt = zeros(T,1);
```

```
r = zeros(T,1);
epf = zeros(T,1);
epc = zeros(T,1);
ep = zeros(T,1);
ey = zeros(T,1);
CRp = zeros(T,1);
FRp = zeros(T,1);
alfapt = zeros(T,1);
eyfunt = zeros(T,1);
CRy = zeros(T,1);
FRy = zeros(T,1);
alfayt = zeros(T,1);
anspirits = zeros(T,1);
epsilont = zeros(T,1);
etat = zeros(T,1);
ut = zeros(T,1);

%%%%%%%%%%%%%%%
%Model
%%%%%%%%%%%%%%%%
    alfap=0.5;
    alfay=0.5;
    K1=K+1;
for t=2:12;
    epsilont(t) = rhoout*epsilont(t-1) + sigma1*randn;  % shocks in output equation (demand shock)
    etat(t)= rhoinf*etat(t-1) + sigma2*randn;    %shocks in inflation equation (supply shock)
    ut(t) = rhotayl*ut(t-1) + sigma3*randn;       %shocks in Taylor rule (interest rate shock)
    epsilon = epsilont(t);
    eta = etat(t);
    u = ut(t);
    shocks = [eta;a2*u+epsilon];
    epcs=p(t-1);
if epratational==1 ;epcs=pstar;
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=p(t-1);
end
    eychar=y(t-1);
    eyfun=0+randn/2;
    eyfunt(t)=eyfun;
    eys=alfay*eychar+(1-alfay)*eyfun;
    forecast = [eps;eys];
    plag=p(t-1);
```

```
    ylag=y(t-1);
    rlag=r(t-1);
    lag = [plag;ylag];
    smooth = [0;a2*c3];
    D = B*forecast + C*lag + smooth*rlag + shocks;
    X = A\D;
    p(t)= X(1,1);
    y(t)= X(2,1);
    r(t)= c1*p(t)+c2*y(t)+c3*r(t-1)+u;
if  (r(t))^2== 1; r(t)= c1*(p(t))^2+c2*y(t)+c3*r(t-1)+u; %it says squared =1 in book code?
end
    plagt(t)=p(t-1);
    ylagt(t)=y(t-1);
    CRp(t) = rho*CRp(t-1) - (1-rho)*(epcs-p(t))^2;
    FRp(t) = rho*FRp(t-1) - (1-rho)*(epfs-p(t))^2;
    CRy(t) = rho*CRy(t-1) - (1-rho)*(eychar-y(t))^2;
    FRy(t) = rho*FRy(t-1) - (1-rho)*(eyfun-y(t))^2;
    alfap = rhoBH*alfapt(t-1)+(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(mm * FRp(t)));
    alfay = rhoBH*alfayt(t-1)+(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(mm * FRy(t)));
    alfapt(t) = alfap;
    alfayt(t) = alfay;
if eychar>0;anspirits(t)=alfay;
end
if eychar<0;anspirits(t)=1-alfay;
end
end %Line 123 is broken

for t=13:T;
    epsilont(t) = 0.32*rhoout*epsilont(t-1) + 0.16*rhoout*epsilont(t-2) + 0.11*rhoout*epsilont(t-3) + 0.08*rhoout*epsilont(t-4) + 0.06*rhoout*epsilont(t-5) + 0.05*rhoout*epsilont(t-6) + 0.05*rhoout*epsilont(t-7) + 0.04*rhoout*epsilont(t-8) + 0.04*rhoout*epsilont(t-9) + 0.03*rhoout*epsilont(t-10) + 0.03*rhoout*epsilont(t-11) + 0.03*rhoout*epsilont(t-12) + sigma1*randn;  %shocks in output equation (demand shock)
    etat(t)= 0.32*rhoinf*etat(t-1) + 0.16*rhoinf*etat(t-2) + 0.11*rhoinf*etat(t-3) + 0.08*rhoinf*etat(t-4) + 0.06*rhoinf*etat(t-5) + 0.05*rhoinf*etat(t-6) + 0.05*rhoinf*etat(t-7) + 0.04*rhoinf*etat(t-8) + 0.04*rhoinf*etat(t-9) + 0.03*rhoinf*etat(t-10) + 0.03*rhoinf*etat(t-11) + 0.03*rhoinf*etat(t
```

```
-12) + sigma2*randn;    %shocks in inflation equation (supply shock)
    ut(t) = 0.32*rhotayl*ut(t-1) + 0.16*rhotayl*ut(t-2) + 0.11*rhotayl*ut(t-3) + 0.08*rhotayl*ut(t-4) + 0.06*rhotayl*ut(t-5) + 0.05*rhotayl*ut(t-6) + 0.05*rhotayl*ut(t-7) + 0.04*rhotayl*ut(t-8) + 0.04*rhotayl*ut(t-9) + 0.03*rhotayl*ut(t-10) + 0.03*rhotayl*ut(t-11) + 0.03*rhotayl*ut(t-12) + sigma3*randn;      %shocks in Taylor rule (interest rate shock)
    epsilon = epsilont(t);
    eta = etat(t);
    u = ut(t);
    shocks = [eta;a2*u+epsilon];
    epcs=0.32*p(t-1) + 0.16*p(t-1) + 0.11*p(t-3) + 0.08*p(t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t-7) + 0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) + 0.03*p(t-11) + 0.03*p(t-12);
if eprational==1 ;epcs=pstar;
end
    eps=alfap*epcs+(1-alfap)*epfs;
if epextrapol==1;eps=0.32*p(t-1) + 0.16*p(t-2) + 0.11*p(t-3) + 0.08*p(t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t-7) + 0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) + 0.03*p(t-11) + 0.03*p(t-12);
end
    eychar=0.32*y(t-1) + 0.16*y(t-2) + 0.11*y(t-3) + 0.08*y(t-4) + 0.06*y(t-5) + 0.05*y(t-6) + 0.05*y(t-7) + 0.04*y(t-8) + 0.04*y(t-9) + 0.03*y(t-10) + 0.03*y(t-11) + 0.03*y(t-12);
    eyfun=0+randn/2;
    eyfunt(t)=eyfun;
    eys=alfay*eychar+(1-alfay)*eyfun;
    forecast = [eps;eys];
    plag=0.32*p(t-1) + 0.16*p(t-2) + 0.11*p(t-3) + 0.08*p(t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t-7) + 0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) + 0.03*p(t-11) + 0.03*p(t-12);
    ylag=0.32*y(t-1) + 0.16*y(t-2) + 0.11*y(t-3) + 0.08*y(t-4) + 0.06*y(t-5) + 0.05*y(t-6) + 0.05*y(t-7) + 0.04*y(t-8) + 0.04*y(t-9) + 0.03*y(t-10) + 0.03*y(t-11) + 0.03*y(t-12);
    rlag=0.32*r(t-1) + 0.16*r(t-2) + 0.11*r(t-3) + 0.08*r(t-4) + 0.06*r(t-5) + 0.05*r(t-6) + 0.05*r(t-7) + 0.04*r(t-8) + 0.04*r(t-9) + 0.03*r(t-10) + 0.03*r(t-11) + 0.03*r(t-12);
```

```
    lag = [plag;ylag];
    smooth = [0;a2*c3];
    D = B*forecast + C*lag + smooth*rlag + shocks;
    X = A\D;
    p(t)= X(1,1);
    y(t)= X(2,1);
    r(t)= c1*p(t)+c2*y(t)+0.32*c3*r(t-1)+0.16*c3*r(t-2)
        +0.11*c3*r(t-3)+0.08*c3*r(t-4)+0.06*c3*r(t-5)
        +0.05*c3*r(t-6)+0.05*c3*r(t-7)+0.04*c3*r(t-8)
        +0.04*c3*r(t-9)+0.03*c3*r(t-10)+0.03*c3*r(t-11)
        +0.03*c3*r(t-12)+u;
if  (r(t))^2== 1;  r(t)= c1*(p(t))^2+c2*y(t)+0.32*c3*r(t
    -1)+0.16*c3*r(t-2)+0.11*c3*r(t-3)+0.08*c3*r(t-4)+0.06*
    c3*r(t-5)+0.05*c3*r(t-6)+0.05*c3*r(t-7)+0.04*c3*r(t-8)
    +0.04*c3*r(t-9)+0.03*c3*r(t-10)+0.03*c3*r(t-11)+0.03*
    c3*r(t-12)+u;  %it says squared =1 in book code?
end
    plagt(t)=0.32*p(t-1) + 0.16*p(t-2) + 0.11*p(t-3) +
        0.08*p(t-4) + 0.06*p(t-5) + 0.05*p(t-6) + 0.05*p(t
        -7) + 0.04*p(t-8) + 0.04*p(t-9) + 0.03*p(t-10) +
        0.03*p(t-11) + 0.03*p(t-12);
    ylagt(t)=0.32*y(t-1) + 0.16*y(t-2) + 0.11*y(t-3) +
        0.08*y(t-4) + 0.06*y(t-5) + 0.05*y(t-6) + 0.05*y(t
        -7) + 0.04*y(t-8) + 0.04*y(t-9) + 0.03*y(t-10) +
        0.03*y(t-11) + 0.03*y(t-12);
    CRp(t) = 0.32*rho*CRp(t-1) + 0.16*rho*CRp(t-2) +
        0.11*rho*CRp(t-3) + 0.08*rho*CRp(t-4)+ 0.06*rho*
        CRp(t-5)+ 0.05*rho*CRp(t-6)+ 0.05*rho*CRp(t-7)+
        0.04*rho*CRp(t-8)+ 0.04*rho*CRp(t-9)+ 0.03*rho*CRp
        (t-10)+ 0.03*rho*CRp(t-11)+ 0.03*rho*CRp(t-12)-
        (1-rho)*(epcs-p(t))^2;
    FRp(t) = 0.32*rho*FRp(t-1) + 0.16*rho*FRp(t-2) +
        0.11*rho*FRp(t-3) + 0.08*rho*FRp(t-4)+ 0.06*rho*
        FRp(t-5)+ 0.05*rho*FRp(t-6)+ 0.05*rho*FRp(t-7)+
        0.04*rho*FRp(t-8)+ 0.04*rho*FRp(t-9)+ 0.03*rho*FRp
        (t-10)+ 0.03*rho*FRp(t-11)+ 0.03*rho*FRp(t-12)-
        (1-rho)*(epfs-p(t))^2;
    CRy(t) = 0.32*rho*CRy(t-1) + 0.16*rho*CRy(t-2) +
        0.11*rho*CRy(t-3) + 0.08*rho*CRy(t-4)+ 0.06*rho*
        CRy(t-5)+ 0.05*rho*CRy(t-6)+ 0.05*rho*CRy(t-7)+
        0.04*rho*CRy(t-8)+ 0.04*rho*CRy(t-9)+ 0.03*rho*CRy
        (t-10)+ 0.03*rho*CRy(t-11)+ 0.03*rho*CRy(t-12)-
        (1-rho)*(eychar-y(t))^2;
    FRy(t) = 0.32*rho*FRy(t-1) + 0.16*rho*FRy(t-2) +
        0.11*rho*FRy(t-3) + 0.08*rho*FRy(t-4)+ 0.06*rho*
        FRy(t-5)+ 0.05*rho*FRy(t-6)+ 0.05*rho*FRy(t-7)+
```

```
    0.04*rho*FRy(t-8)+ 0.04*rho*FRy(t-9)+ 0.03*rho*FRy
    (t-10)+ 0.03*rho*FRy(t-11)+ 0.03*rho*FRy(t-12)-
    (1-rho)*(eyfun-y(t))^2;
    alfap = 0.32*rhoBH*alfapt(t-1)+0.16*rhoBH*alfapt(t-2)
        +0.11*rhoBH*alfapt(t-3)+0.08*rhoBH*alfapt(t-4)
        +0.06*rhoBH*alfapt(t-5)+0.05*rhoBH*alfapt(t-6)
        +0.05*rhoBH*alfapt(t-7)+0.04*rhoBH*alfapt(t-8)
        +0.04*rhoBH*alfapt(t-9)+0.03*rhoBH*alfapt(t-10)
        +0.03*rhoBH*alfapt(t-11)+0.03*rhoBH*alfapt(t-12)
        +(1-rhoBH)*exp(mm*CRp(t))/(exp(mm * CRp(t)) + exp(
        mm * FRp(t)));
    alfay = 0.32*rhoBH*alfayt(t-1)+0.16*rhoBH*alfayt(t-2)
        +0.11*rhoBH*alfayt(t-3)+0.08*rhoBH*alfayt(t-4)
        +0.06*rhoBH*alfayt(t-5)+0.05*rhoBH*alfayt(t-6)
        +0.05*rhoBH*alfayt(t-7)+0.04*rhoBH*alfayt(t-8)
        +0.04*rhoBH*alfayt(t-9)+0.03*rhoBH*alfayt(t-10)
        +0.03*rhoBH*alfayt(t-11)+0.03*rhoBH*alfayt(t-12)
        +(1-rhoBH)*exp(mm*CRy(t))/(exp(mm * CRy(t)) + exp(
        mm * FRy(t)));
    alfapt(t) = alfap;
    alfayt(t) = alfay;
if eychar>0;anspirits(t)=alfay;
end
if eychar<0;anspirits(t)=1-alfay;
end
end

autocory = corrcoef(y,ylagt);
autocorp = corrcoef(p,plagt);
coroutputanimal = corr(y,anspirits); %% mean, median,
    max, min, standard deviation, kurtosis
Kurt    = kurtosis(y); %% jarque-bera test
[jb,pvalue,jbstat] = jbtest(y,0.05);
```

Outputs of the Model

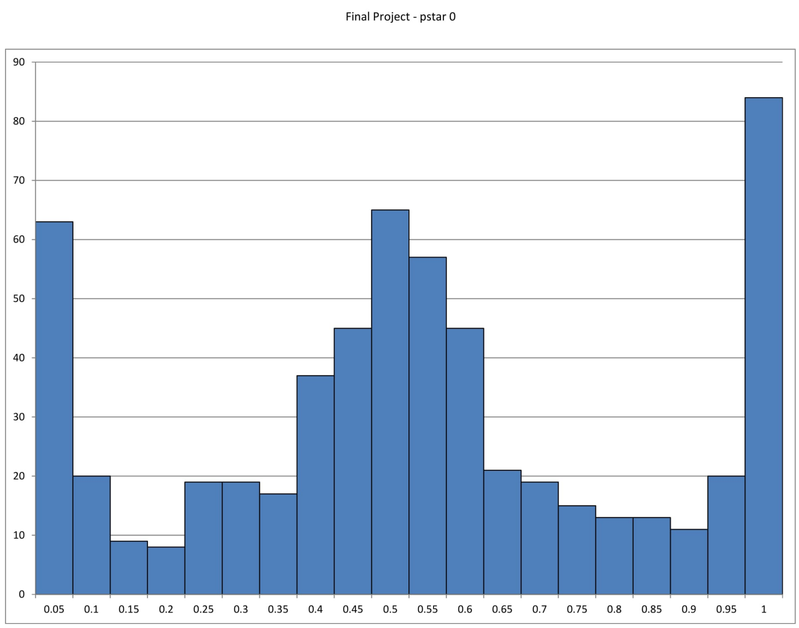

Figure 1: Inflation Target 0

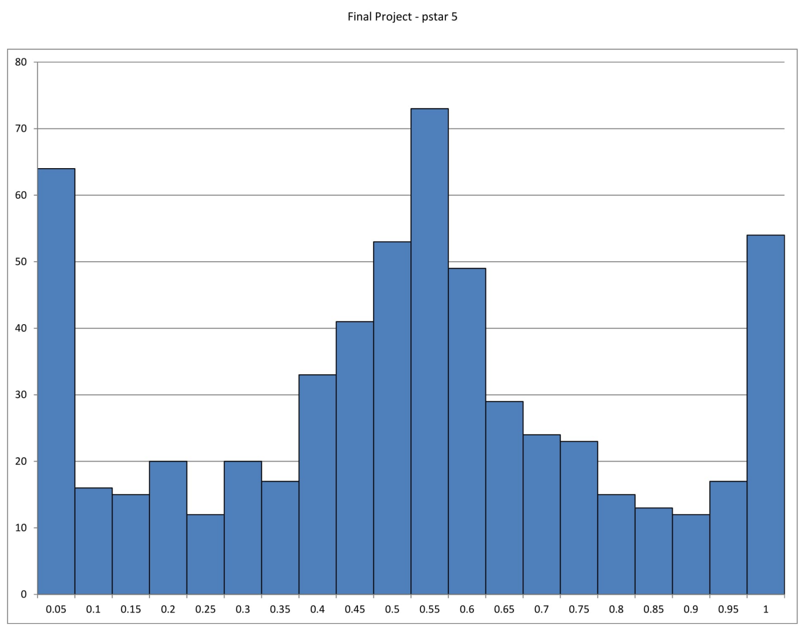

Figure 2: Inflation Target 5%

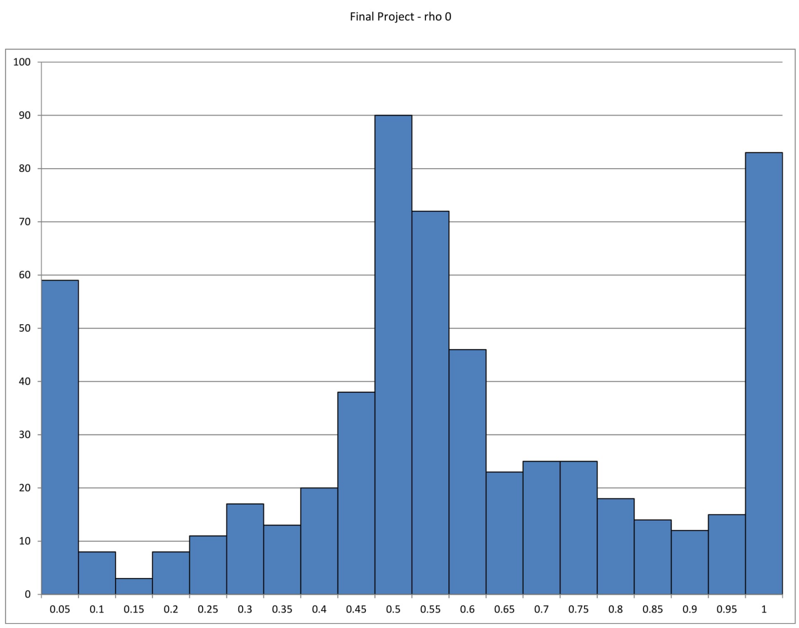

Figure 3: No Memory

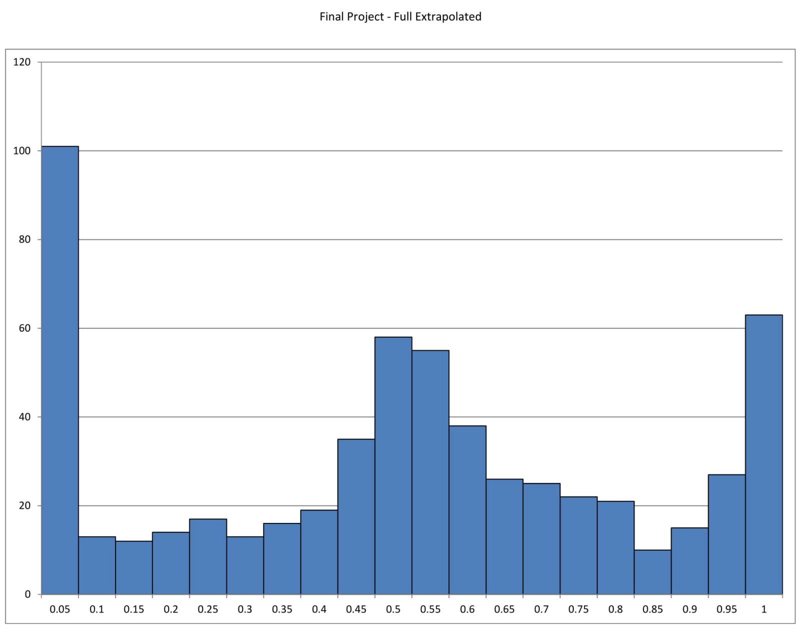

Figure 4: Fully Extrapolated, 0% Fundamental

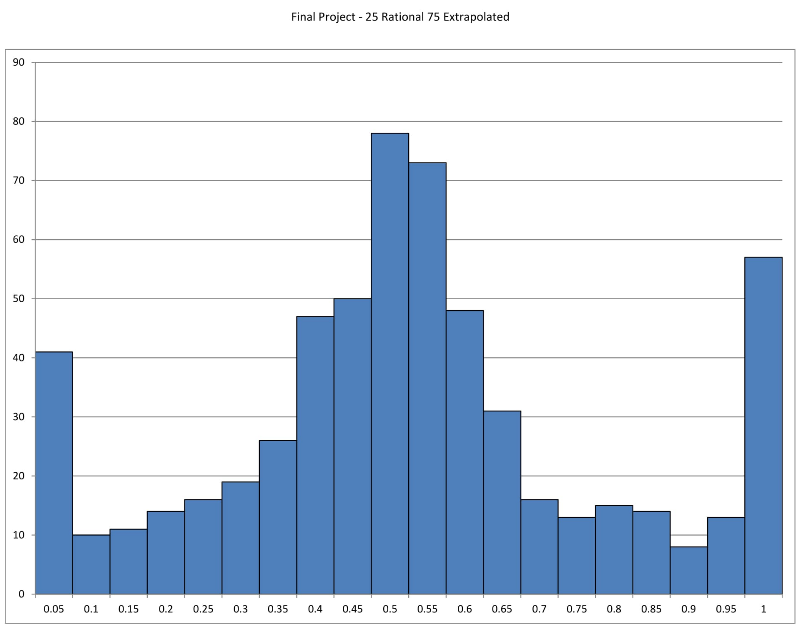

Figure 5: 75% Extrapolated, 25% Fundamental

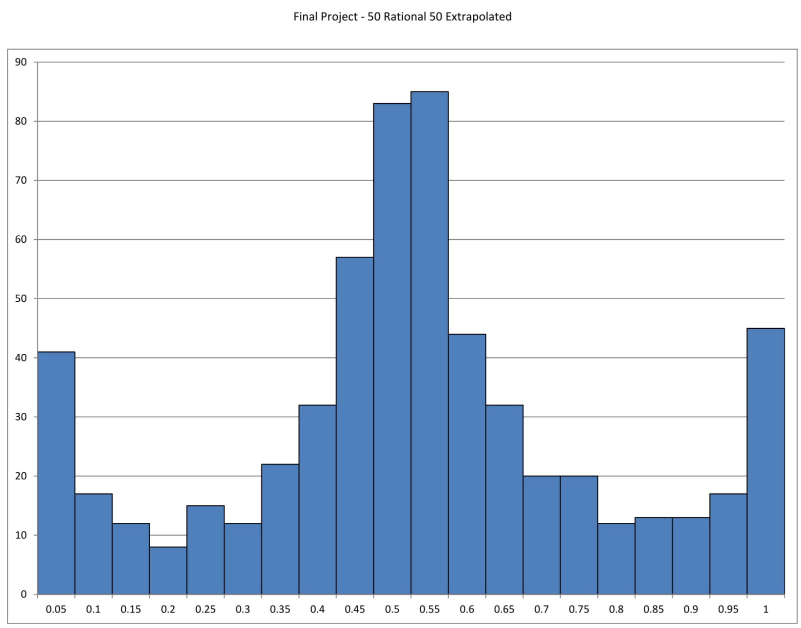

Figure 6: 50% Extrapolated, 50% Fundamental

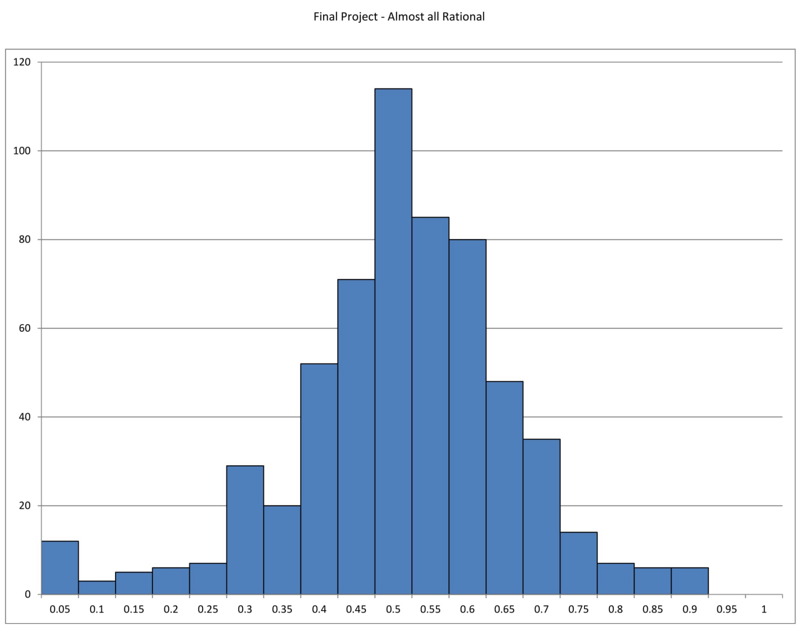

Figure 7: Nearly All Rational

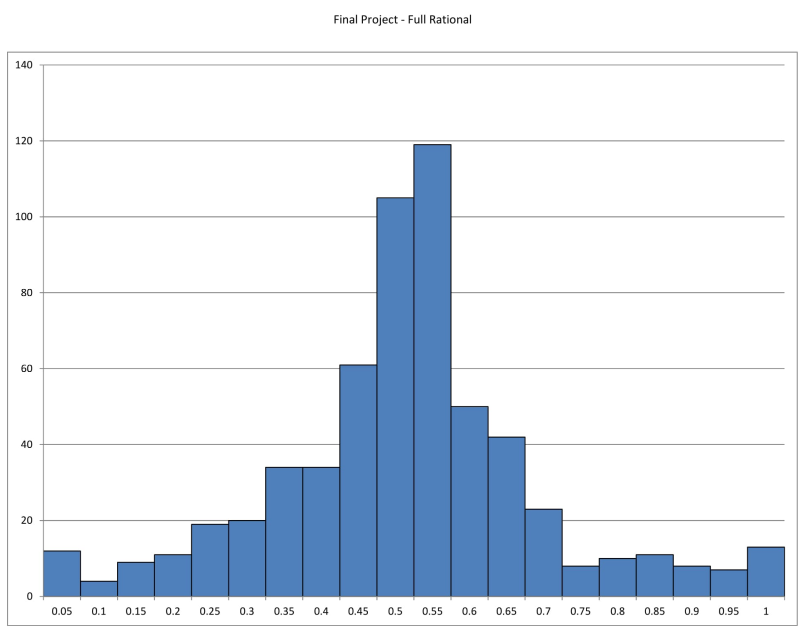

Figure 8: 0% Extrapolated, Fully Fundamental

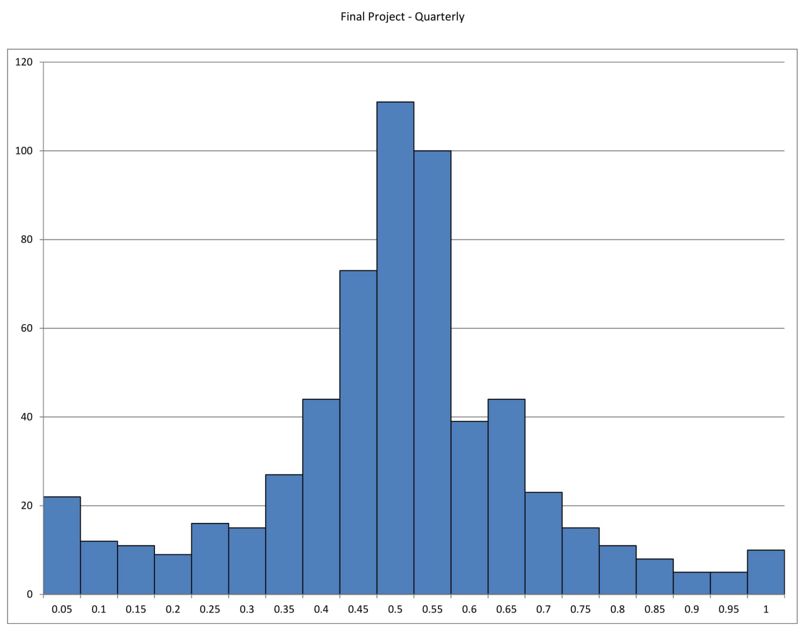

Figure 9: Quarterly Extrapolation

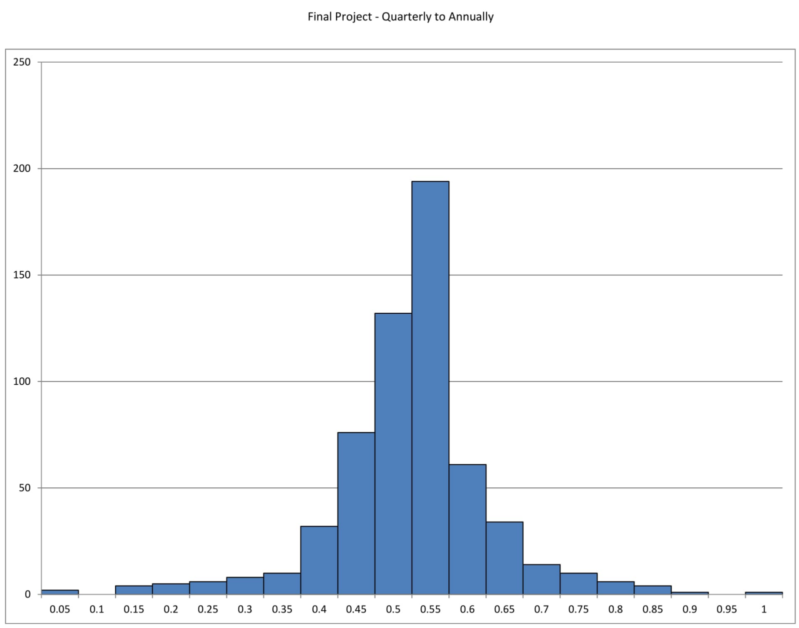

Figure 10: Quarterly to Annual Extrapolation

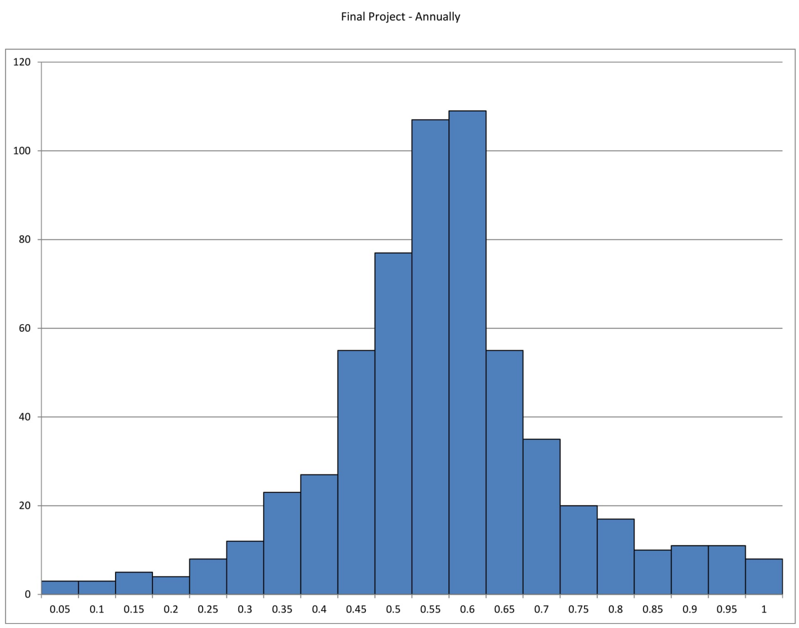

Figure 11: Annual Extrapolation