DIY seminal macroeconomic models

DIY-Macro-Sim

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Welcome

This project provides a DIY - "Do it yourself" - open source code repository and online script for numerical simulations of some seminal macroeconomic models (codes are currently provided in R, but we invite everyone to provide scripts based on other programming languages). Comments, questions and corrections are welcome! Please create an issue or pull request.

Maybe add some stuff from our proposal.

Overview

...

(maybe some other categorisation, maybe also with sub-categories)

1 How to use this site

1.1 ...

Maybe some general notes here, e.g. from our project proposal draft.

1.2 How to simulate

TO DO: Add some notes based on KK slides.

2 How to contribute

TO DO: Add some notes on how to contribute.

References

Part I

Static models

...

3 A Neoclassical Macro Model

4 An IS-LM Model

4.1 Overview

The IS-LM model was developed by John R. Hicks (1937) to formalise some key ideas of John Maynard Keynes' 1936 book The General Theory of Employment, Interest and Money. The model contains two equilibrium relationships: a goods market equilibrium between investment and saving (IS) and a money market equilibrium between money demand and money supply (LM). In the goods market, aggregate supply adjusts to the level of aggregate demand given by the expenditure decisions of households, firms, and the government. Households form their consumption demand based on a constant marginal propensity to consume out of income. Firms take investment decisions based on the rate of interest. Money demand is determined by aggregate income (transactions demand) and the interest rate on bonds (speculative demand). The money supply is assumed to be exogenous and under the control of the central bank. The two markets pin down equilibrium output and the interest rate. The goods market equilibrium may well coincide with involuntary unemployment. Adverse shocks to autonomous investment ('animal spirits') or autonomous money demand ('liquidity preference') reduce output and raise unemployment. The government can use monetary policy, fiscal spending, and income taxes to stimulate economic activity and achieve full employment.

In this short-run model, prices and the capital stock are fixed. The focus is thus on goods market equilibrium rather than economic growth. As all endogenous variables adjust instantaneously, the model is static. We consider a version with linear functions, adapted from Blanchard & Johnson (2013, chap.5).

$$Y = C + I + G \tag{4.1}$$

$$C = c_0 + c_1(Y - T), \quad c_1 \in (0,1) \tag{4.2}$$

$$I = i_0 - i_1 r, \quad i_1 > 0 \tag{4.3}$$

$$G = G_0 \tag{4.4}$$

$$T = T_0 \tag{4.5}$$

$$M_s = M_0 \tag{4.6}$$

$$M_d = m_0 + m_1 Y - m_2 r, \quad m_1 > 0 \tag{4.7}$$

$$M = M_d = M_s \tag{4.8}$$

$$N = aY, \quad a > 0 \tag{4.9}$$

$$U = 1 - \frac{N}{N^f} \tag{4.10}$$

where $Y, C, I, G, T, r, M_d, M_s, N, U$, and N^f are output, consumption, investment, government spending, taxes, the interest rate on bonds, money demand, money supply, employment, the unemployment rate, and the labour force, respectively. The constant price level has been normalised to unity.

Equation (1) is the goods market equilibrium condition. Aggregate supply (Y) accommodates to the level of aggregate demand which is the sum of consumption, investment, and government spending. Equation (2) is the consumption function consisting of autonomous consumption demand (c_0) and a marginal propensity to consume (c_1) out of disposable income ($Y - T$). Investment demand in equation (3) has an autonomous component (i_0) capturing Keynesian animal spirits and a component that is negatively related to the rate of interest on bonds. By equations (4) and (5), government spending and taxation are exogenous. Similarly, the money supply in equation (6) is assumed to be exogenous. By equation (7), households' money demand is positively related to income (capturing the transaction demand for money) and negatively related to the interest rate on bonds (capturing speculative demand). There is also an autonomous term (m_0) capturing Keynesian liquidity preference. Equation (9) is a fixed-coefficient production function through which employment is determined. In conjunction with an exogenously given labour force (N^f), the level of employment can be used to obtain an unemployment rate in equation (10).

4.2 Simulation

4.2.1 Parameterisation

Table 1 reports the parameterisation used in the simulation. Besides a baseline (labelled as scenario 1), five further scenarios will be considered. Scenarios 2 and 3 model a switch towards pessimistic sentiments: a fall in animal spirits (i_0) and an increase in liquidity preference (m_0). Scenarios 4 to 6 consider three different government policies to stimulate the economy: a monetary expansion (M_0), a tax cut (T_0), and a fiscal expansion (G_0).

Table 1: Parameterisation

Scenario	c_(0)	c_(1)	i_(0)	i_(1)	m_(0)	m_(1)	m_(2)	M_(0)	T_(0)	G_(0)	a	N^(f)
1: baseline	2	0.6	2	0.1	6	0.2	0.4	5	1	1	1.5	18
2: fall in animal spirits (i_(0))	2	0.6	1	0.1	6	0.2	0.4	5	1	1	1.5	18
3: increased liquidity preference (m_(0))	2	0.6	2	0.1	7	0.2	0.4	5	1	1	1.5	18
4: monetary expansion (M_(0))	2	0.6	2	0.1	6	0.2	0.4	6	1	1	1.5	18

Scenario	c_(0)	c_(1)	i_(0)	i_(1)	m_(0)	m_(1)	m_(2)	M_(0)	T_(0)	G_(0)	a	N^(f)
5: tax cut (T_(0))	2	0.6	2	0.1	6	0.2	0.4	5	0	1	1.5	18
6: fiscal expansion (G_(0))	2	0.6	2	0.1	6	0.2	0.4	5	1	2	1.5	18

4.2.2 Simulation code

```
#Clear the environment
rm(list=ls(all=TRUE))

# Set number of scenarios (including baseline)
S=6

#Create vector in which equilibrium solutions from different parameterisations will be sto
Y_star=vector(length=S) # Income/output
C_star=vector(length=S) # Consumption
I_star=vector(length=S) # Investment
r_star=vector(length=S) # Real interest rate
N_star=vector(length=S) # Employment
U_star=vector(length=S) # Unemployment rate

# Set exogenous variables that will be shifted
i0=vector(length=S) # autonomous investment
m0=vector(length=S) # Autonomous demand for money
M0=vector(length=S) # money supply
G0=vector(length=S) # government spending
T0=vector(length=S) # taxes
i0[]=2
m0[]=6
M0[]=5
G0[]=1
T0[]=1
```

```
for (i in 1:S){
  if (i==2){ # scenario 2: fall in animal spirits
    i0[2]=1
  }
  if (i==3){ # scenario 3: increase in liquidity preference
    m0[3]=7
  }
  if (i==4){ # scenario 4: monetary expansion
    M0[4]=6
  }
  if (i==5){# scenario 5: reduction in tax rate
    T0[5]=0
  }
  if (i==6){# scenario 6: fiscal expansion
    G0[6]=2
  }
}

#Set constant parameter values
c0=2   # Autonomous consumption
c1=0.6 # Sensitivity of consumption with respect to the income (marginal propensity to con
i1=0.1 # Sensitivity of investment with respect to the interest rate
m1=0.2 # Sensitivity of money demand with respect to income
m2=0.4 # Sensitivity of money demand with respect to interest rate
a=1.5  # labour coefficient
Nf=18  # Full employment/labour force

# Initialise endogenous variables at some arbitrary positive value
Y=1
C=1
I=1
r=1

#Solve this system numerically through 1000 iterations based on the initialisation

for (i in 1:S){

  for (iterations in 1:1000){

    #Model equations
```

```
    # Goods market equilibrium
    Y = C + I + G0[i]

    # Consumption demand
    C = c0 + c1*(Y-T0[i])

    # Investment demand
    I = i0[i] - i1*r

    # Money market, solved for interest rate
    r = (m0[i] - M0[i])/m2 + m1*Y/m2

    # Employment
    N = a*Y

    #Unemployment rate
    U = (1 - N/Nf)

  }
  #Save results for different parameterisations in vector
  Y_star[i]=Y
  C_star[i]=C
  I_star[i]=I
  r_star[i]=r
  N_star[i]=N
  U_star[i]=U
}
```

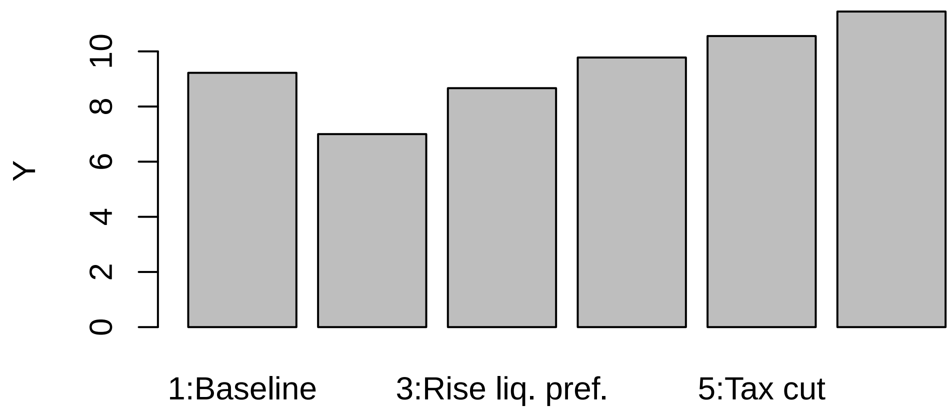
4.2.3 Plots

Figures 1-2 depict the response of the model's key endogenous variables, output and the interest rate, to various shifts. A fall in animal spirits (scenario 2) and an increase in liquidity preference (scenario 3) both have contractionary effects. While the fall in animal spirits directly reduces aggregate demand and thereby output (despite a fall in the interest rate), the rise in liquidity preference depresses output through its positive effect on the interest rate. Both scenarios raise the unemployment rate (Figure 3). Scenarios 4 to 6 assess three different macroeconomic policy tools to stimulate output. It can be seen in Figure 1 that fiscal policy is more effective than monetary policy for the parameterisation in Table 1.[1] Direct fiscal stimulus is more effective than tax cuts due to the constant marginal propensity to consume. The effect on output is a

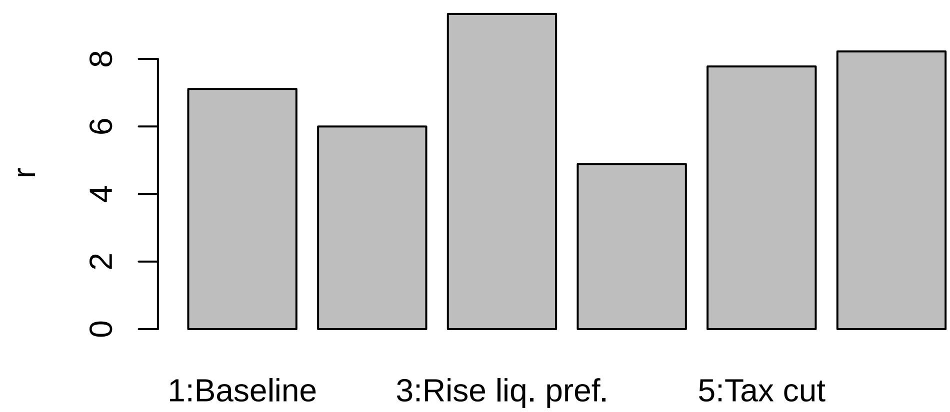
[1] The appendix shows formally that fiscal policy is more effective than monetary policy if $m_2 > i_2$.

multiple of the one-unit stimulus thanks to the multiplier effect. However, it can also be seen that fiscal policy raises the interest rate, which crowds out some of the expansionary effect.

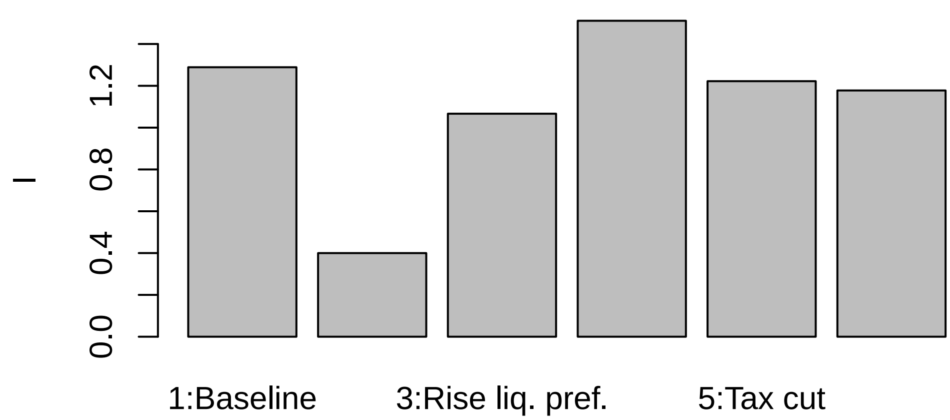
```
barplot(Y_star, ylab="Y", names.arg=c("1:Baseline", "2:Fall animal spirits", "3:Rise liq.
                                      "4:Monetary exp.", "5:Tax cut", "6:Fiscal exp."))
```




```
barplot(r_star, ylab="r", names.arg=c("1:Baseline", "2:Fall animal spirits", "3:Rise liq.
                                      "4:Monetary exp.", "5:Tax cut", "6:Fiscal exp."))
```

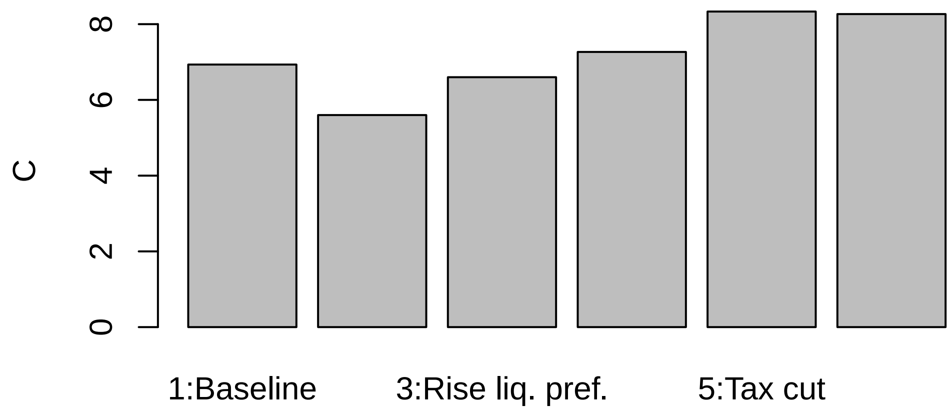



```
barplot(I_star, ylab="I", names.arg=c("1:Baseline", "2:Fall animal spirits", "3:Rise liq.
                                      "4:Monetary exp.", "5:Tax cut", "6:Fiscal exp."))
```

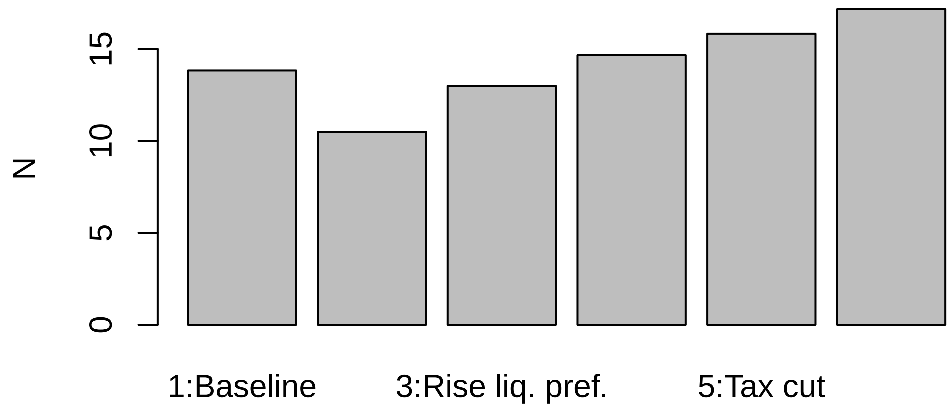


Figures 4-5 further show that monetary policy mostly stimulates investment, whereas fiscal policy boost consumption.

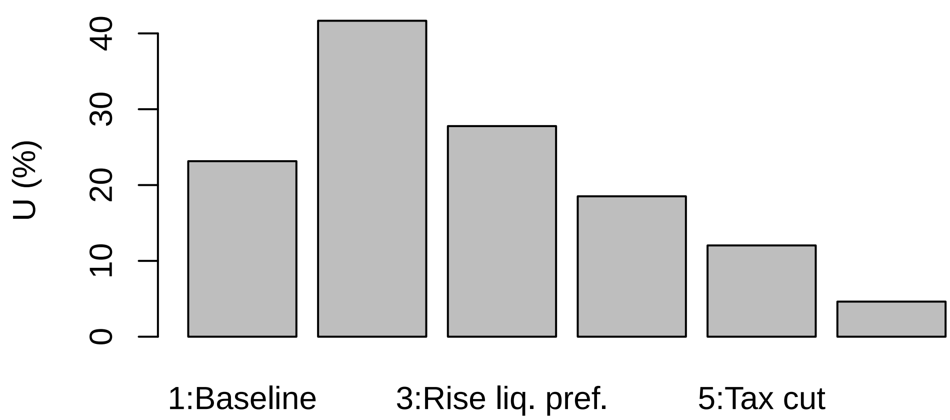
```
barplot(C_star, ylab="C", names.arg=c("1:Baseline", "2:Fall animal spirits", "3:Rise liq.
                                       "4:Monetary exp.", "5:Tax cut", "6:Fiscal exp."))
```




```
barplot(N_star, ylab="N", names.arg=c("1:Baseline", "2:Fall animal spirits", "3:Rise liq.
                                       "4:Monetary exp.", "5:Tax cut", "6:Fiscal exp."))
```




```
barplot(U_star*100, ylab="U (%)", names.arg=c("1:Baseline", "2:Fall animal spirits", "3:Ri
                                              "4:Monetary exp.", "5:Tax cut", "6:Fiscal ex
```



4.2.4 Calculate equilibrium fiscal multiplier

```
Y_star[6]-Y_star[1] # numerical approach
```

```
[1] 2.222222
```

```
m2/((1-c1)*m2+i1*m1) # analytical approach
```

```
[1] 2.222222
```

4.3 Directed graph

Another perspective on the model's properties is provided by its directed graph. A directed graph consists of a set of nodes that represent the variables of the model. Nodes are connected by directed edges. An edge directed from a node x_1 to node x_2 indicates a causal impact of x_1 on x_2.

```
# Construct auxiliary Jacobian matrix for 11 variables: Y, C, I, G, T, r, M0, N, i0, m0, M
# where non-zero elements in regular Jacobian are set to 1 and zero elements are unchanged

M_mat=matrix(c(0,1,1,1,0,0,0,0,0,0,0,
              1,0,0,0,1,0,0,0,0,0,0,
              0,0,0,0,0,1,0,0,1,0,0,
              0,0,0,0,0,0,0,0,0,0,0,
              0,0,0,0,0,0,0,0,0,0,0,
              0,0,0,0,0,0,1,0,0,0,1,
              0,0,0,0,0,0,0,0,0,0,0,
              1,0,0,0,0,0,0,0,0,0,0,
              0,0,0,0,0,0,0,0,0,0,0,
              0,0,0,0,0,0,0,0,0,0,0,
              1,0,0,0,0,1,0,0,0,1,0), 11, 11, byrow=TRUE)

# Create adjacency matrix from transpose of auxiliary Jacobian and add column names
A_mat=t(M_mat)
colnames(A_mat) = c("Y", "C", "I", "G0", "T0", "r", "M0", "N", "i0", "m0", "Md")

# Create and plot directed graph from adjacency matrix
library(igraph)
```

```
Attaching package: 'igraph'


The following objects are masked from 'package:stats':

    decompose, spectrum


The following object is masked from 'package:base':

    union
```

```
dg= graph_from_adjacency_matrix(A_mat, mode="directed", weighted=NULL)
plot(dg, main="", vertex.size=20, vertex.color="lightblue",
     vertex.label.color="black", edge.arrow.size=0.2, edge.width=1,
     edge.arrow.width=0.8, edge.color="black", vertex.label.cex=1.5, vertex.frame.color="N
```

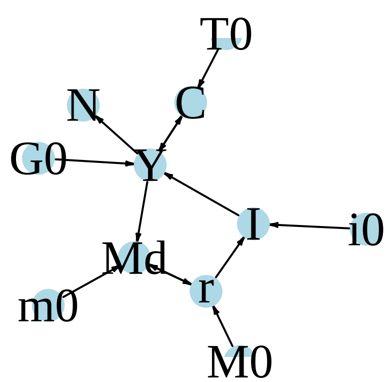


Figure 6: Directed graph of IS-LM model

5 A Neoclassical Synthesis Model (IS-LM-AS-AD)

Part II

Dynamic models

6 A New Keynesian 3-Equation Model

7 A Post-Keynesian Macro Model with Endogenous Money

8 A Post-Kaleckian Distribution and Growth Model

9 A Sraffian Supermultiplier Model

10 A Malthusian Model

11 A Ricardian One-Sector Model

12 A Ricardian Two-Sector Model