Monetary Assignment -2

Siddharth Chatterjee
Student ID: 14452750

1) Consider a standard baseline New Keynesian model described in "New Perspectives of Monetary Policy, Inflation, and Business Cycle", by Jordi Gali.

   a) Explain the difference between traditional backward looking Phillips curve and the New Keynesian Phillips Curve. Write down the expression for NKPC and provide some intuition behind it. What are the main criticisms of the NKPC?

   Explain the difference between traditional backward looking Phillips curve and the New Keynesian Phillips Curve.

   In 1950's professor A.W. Phillips at LSE noticed a correlation between the speed at which wages rise and the size of unemployment. While drawing the "*line of best of fit*" he deduced an inverse relationship between unemployment and wages. The relation was also found to work when wages were replaced by price inflation.

   The traditional Phillips curve shows the relationship between inflation and unemployment in the following form:

$$\pi_t = \alpha - \gamma U_t$$

   Where π_t stands for inflation and U_t for unemployment.

   Milton Friedman in late 1960'ss modified the traditional Phillips curve by introducing an expectation component. He theorized that expectations by agents are formed adaptively as a result of past experiences or by price-setting behavior based on a backward-looking rule of thumb. Inflation relationship took the form:

$$\pi_t = \pi_{t-1} - \gamma(U_t - U^*) + \nu$$

   U^* here is the natural rate of unemployment and ν is an exogenous shock.

   The above equation is what is now referred to as the traditional backward-looking Phillips curve. The curve relates inflation to its own lagged values and a cyclical component (unemployment). This cyclical component can also be output. The above equation can be re-written in the form:

$$\pi_t = \pi_{t-1} + Kx_t + \mu_t$$ [1]

x_t here is the real output and μ_t is the shock in aggregate supply.

The New Keynesian Phillips Curve (NKPC) by contrast is a forward-looking model with no backward components (unless specified in hybrid models). The forward-looking nature of NKPC is caused by a staggered price setting regime followed by the firms due to prevalence of sticky prices. This leads to interesting theoretical implications when assessing the real output effects of monetary policy shocks on the two models.

The NKPC is given by the equation:

$$\pi_t = \beta E_t \{\pi_{t+1}\} + Kx_t + \mu_t$$

Here, $E_t \{\pi_{t+1}\}$ is next period's expected inflation rate. X_t is output gap with respect to natural level of output. μ_t is a shock that implies a change in the equilibrium level of inflation consistent with natural level of output. The shock is known as "cost-push" shock.

Before discussing the differences between models in response to monetary shocks, it is important to note that both models imply money's effect on the economy is neutral in the long-run. It is only in the short run that the models have different outcomes.

Herz and Roeger in their paper "*Traditional versus New Keynesian Phillips Curves: Evidences from Output Effects*", conduct a one-period positive shock to monetary policy rate in order to see the effects on output:

In the backward-looking model, the authors deduce a strict inter-temporal trade-off when a monetary shock hits. A positive shock to monetary policy rate (in the form of higher interest rates) leads to negative output effect in first period. This is because higher interest rate lead to a fall in demand and a downward adjustment of inflation expectation in next period. This, despite the fact that negative demand shock has already passed and actual inflation is re-adjusting upwards. This positive inflation surprise in the next period leads to an increase of output above potential during adjustment process. Hence, the positive effect on output in second period compensates for the loss of output in first period.

The forward looking NKPC model, in contrast, firms correctly anticipate a rising inflation after initial drop and respond by lowering prices sufficiently. Therefore, prices are too high over adjustment period, which keeps output below potential and implies that cumulated

[1] Okun's law gives relationship between unemployment and output. The identity is then replaced into the traditional backward-looking Phillip's curve.

output effects are negative.

<u>Write down the expression for NKPC and provide some intuition behind it.</u>

The New Keynesian Phillips Curve is described by the equation:

$$\pi_t = \beta E_t \pi_{t+1} + \{(1-\theta)(1-\theta\beta)/\theta\}\lambda y_t$$

If we define $\{(1-\theta)(1-\theta\beta)/\theta)\}\lambda = K$

We can re-write the above equation as:

$$\pi_t = \beta E_t \pi_{t+1} + K y_t$$

This equation states that inflation is a function of two variables and their parameters:

a) Next period's expected inflation rate - $E_t \pi_{t+1}$
b) Output gap - y_t

In order to get intuition behind the NKPC we need to understand how monetary policy affects the economy. After the rationalist critique on the lack of microfoundations of traditional Phillips curve, there arose a need to have a microeconomic rationale on how monetary policy might have an impact on the real economy at least in the short-run. This came in the form of concepts of nominal rigidities in the economy and in particular: *sticky prices.* With sticky prices, an increase in the money stock can produce a short-run increase in real spending power and thus boost real output. (Whelan, 2007)

The basis of modeling sticky prices in the New Keynesian framework is taken from <u>Calvo-pricing</u> mechanism. The model states that only a random fraction of firms (1-θ) are able to reset their price in a given period and all other firms have to keep their prices unchanged. This is the underlying theme that makes economic agents be forward looking with regards to inflation. When firms do get to reset price, they must take into account the fact that they may not be able to change prices for many periods.

In such a scenario the firm would like to reset its price such that the future losses accrued due to price rigidity are minimized. The optimal solution to the price setting problem would be equal to a weighted average of future prices that firm would have expected to set if there were no price rigidities. When there is no friction firms set prices as a fixed markup over marginal cost. This can be by equation:

$$p_t^* = \mu + mc_t$$

We can denote deviation of real marginal cost from its frictionless level of $-\mu$ as:

$$mc_t^r = \mu + mc_t - p_t$$

Empirically speaking however, it is very hard to observe data for real marginal cost. Instead many researchers implement the NKPC using a measure of output gap as a proxy for real marginal cost. (Whelan, 2007) The relationship assumed in literature is:

$$mc_t^r = \lambda y_t$$

When these values are applied for the derivation of NKPC we get the identity:

$$\pi_t = \beta E_t \pi_{t+1} + K y_t$$

Where $\{(1-\theta)(1-\theta\beta)/\theta)\}\lambda = K$

<u>What are the main criticisms of the NKPC?</u>

The NKPC is theoretically sounder than the less formal backward-looking Phillips curve. It does not suffer the hurdles of Lucas critique and has a microfounded basis with introduction of the concept of sticky prices. However, empirically, the NKPC does suffer from certain pitfalls.

Theoretically speaking, Laurence Ball showed that a credible commitment by central bank to lower inflation target could generate an economic boom followed by rapid disinflation (Ball, 1991). But this is against the empirical evidence on nature of inflation. Inflation in the data is seen to show a level of persistence as predicted by traditional Phillips curve rather than the forward-looking Phillips curve. It tends to move up and down in a gradual manner rather than sudden changes. This indicates that there are backward looking agents in the economy. Hence, the creation of the hybrid version of NKPC which takes into account both forward and backward looking agents.

The second criticism has to do with persistence of sticky prices. The NKPC tends to overestimate the stickiness of prices. Bils and Klenow constructed a CPI price index that showed average duration of price changes is around six months. By contrast, NKPC predicts changes once every 20 months. (Bils & Klenow, 2004)

b) <u>In this model, the nominal interest rate can be written in the following way:</u>

$$r_t - \rho = \frac{(\sigma-1)}{(1+\eta)} \sum_{k=1}^{\infty} \frac{\eta}{(1+\eta)}^{k-1} E_t\{\Delta y_{t+k}\} + \frac{\rho_m}{1+\eta(1-\rho_m)} \Delta m_t$$

<u>Derive this expression</u>.

As suggested in the footnotes of the paper we start from the standard money demand equation.

$$m_t - p_t = y_t - \eta r_t \qquad (1)$$

By leading one period forward we have

$$m_{t+1} - p_{t+1} = y_{t+1} - \eta r_{t+1} \qquad (2)$$

If we subtract (1) from (2) we obtain the first difference equation of the money demand equation.

$$\Delta m_{t+1} - \Delta p_{t+1} = \Delta y_{t+1} - \Delta \eta r_{t+1} \qquad (3)$$

Where $\Delta p_{t+1} = \pi_{t+1}$.

Thus $\pi_{t+1} = \Delta m_{t+1} - \Delta y_{t+1} + \Delta \eta r_{t+1}$ (4)

Now from the Dynamic IS equation found in Gali's paper (equation 20) we have that

$$x_t = -\frac{1}{\sigma}(r_t - E_t\{\pi_{t+1}\} - \overline{rr}_t) + E_t\{x_{t+1}\} \qquad (5)$$

Where $\overline{rr}_t = \rho$ and $\bar{y}_t = 0$, thus $x_t = y_t - \bar{y}_t = y_t$.

Accordingly, substituting π_{t+1} with the expression in (4) we can rewrite the DIS (5) as follows:

$$y_t = -\frac{1}{\sigma}(r_t - E_t\{\Delta m_{t+1} - \Delta y_{t+1} + \Delta \eta r_{t+1}\} - \rho) + E_t\{y_{t+1}\}$$

(6)

As $\Delta \eta r_{t+1} = \eta r_{t+1} - \eta r_t$, we can take ηr_t out of the Expectation, in that is a contemporaneous, thus known, value. Furthermore $E_t\{y_{t+1}\} - y_t = \mathrm{E}\{\Delta y_{t+1}\}$.

Rearranging we have

$$0 = E_t\{\Delta y_{t+1}\} - \frac{1}{\sigma}((1+\eta)r_t - E_t\{\Delta m_{t+1} - \Delta y_{t+1} + \eta r_{t+1}\} - \rho) \qquad (7)$$

$$(1+\eta)r_t = \sigma E_t\{\Delta y_{t+1}\} + \rho + E_t\{\Delta m_{t+1}\} - E_t\{\Delta y_{t+1}\} + E_t\{\eta r_{t+1}\}$$

$$r_t = \frac{\sigma-1}{(1+\eta)} E_t\{\Delta y_{t+1}\} + \frac{\rho}{(1+\eta)} + \frac{E_t\{\Delta m_{t+1}\}}{(1+\eta)} + \frac{E_t\{\eta r_{t+1}\}}{(1+\eta)} \qquad (8)$$

Hence, we use Gali's specification for the money growth process

$$\Delta m_{t+1} = \rho_m \Delta m_t + \varepsilon_t^m$$

(9)

Where $\varepsilon_t^m$is an exogenous stochastic disturbance such that $E_t\{\Delta m_{t+1}\} = \rho_m \Delta m_t$

Thus by inserting (9) into (8)

$$r_t = \frac{\sigma-1}{(1+\eta)} E_t\{\Delta y_{t+1}\} + \frac{\rho}{(1+\eta)} + \frac{E_t\{\rho_m \Delta m_t + \varepsilon_t^m\}}{(1+\eta)} + \frac{E_t\{\eta r_{t+1}\}}{(1+\eta)}$$

$$r_t = \frac{1}{(1+\eta)}[(\sigma-1)E_t\{\Delta y_{t+1}\} + \rho + \rho_m \Delta m_t + E_t\{\eta r_{t+1}\}] \quad (10)$$

We lead equation (10) one period forward to have

$$r_{t+1} = \frac{1}{(1+\eta)}[(\sigma-1)E_{t+1}\{\Delta y_{t+2}\} + \rho + E_t\{\rho_m \Delta m_{t+1}\} + E_{t+1}\{\eta r_{t+2}\}] \qquad (11)$$

Rearranging recursively (11) in (10) we obtain

$$r_t = \frac{1}{(1+\eta)}\Big\{(\sigma-1)E_t\{\Delta y_{t+1}\} + \rho + \rho_m \Delta m_t + \eta E_t\Big[\frac{1}{(1+\eta)}((\sigma-1)E_{t+1}\{\Delta y_{t+2}\} + \rho + E_t\{\rho_m \Delta m_{t+1}\} + E_{t+1}\{\eta r_{t+2}\})\Big]\Big\}$$

$$r_t = \frac{1}{(1+\eta)}\Big[(\sigma-1)E_t\{\Delta y_{t+1}\} + \rho + \rho_m \Delta m_t + \frac{\eta}{(1+\eta)}\{[(\sigma-1)E_{t+1}\{\Delta y_{t+2}\} + \rho + E_t\{\rho_m \Delta m_{t+1}\} + E_{t+1}\{\eta r_{t+2}\}]\}\Big]$$

Notice that for the law of iterated expectation$E_t[E_{t+1}\{x_t\}] = E_t\{x_t\}$. Thus we rewrite

$$r_t = \frac{1}{(1+\eta)}\Big[(\sigma-1)E_t\{\Delta y_{t+1}\} + \rho + \rho_m \Delta m_t + \frac{\eta}{(1+\eta)}\{[(\sigma-1)E_t\{\Delta y_{t+2}\} + \rho + \rho_m E_t\{\Delta m_{t+1}\} + \eta E_t\{r_{t+2}\}]\}\Big] \quad (12)$$

If we continue to solve recursively, we can solve (12) in an expression composed of three main blocks. For simplicity, we list the solution of the blocks one by one.

- The first block collects the terms in Δy_{t+1}

$$\frac{1}{(1+\eta)}\Big[(\sigma-1)E_t\{\Delta y_{t+1}\} + \frac{\eta}{(1+\eta)}(\sigma-1)E_t\{\Delta y_{t+2}\}\Big]$$
$$= \frac{(\sigma-1)}{(1+\eta)}E_t\{\Delta y_{t+1}\} + \frac{\eta(\sigma-1)}{(1+\eta)^2}E_t\{\Delta y_{t+2}\} \quad (13)$$

For $\rightarrow \infty$, (13) can be rewritten as

$$\frac{(\sigma-1)}{(1+\eta)}\sum_{k=1}^{\infty}\left(\frac{\eta}{(1+\eta)}\right)^{k-1} E_t\{\Delta y_{t+k}\} \quad (14)$$

- The second block groups the elements involving ρ

$$\frac{1}{(1+\eta)}\left[\rho + \frac{\eta}{(1+\eta)}\rho + \left(\frac{\eta}{1+\eta}\right)^2 \rho + \ldots\right] = \frac{\rho}{(1+\eta)}\left[1 + \frac{\eta}{(1+\eta)} + \left(\frac{\eta}{1+\eta}\right)^2 + \ldots\right]$$

As, in general $\sum_{k=0}^{\infty} r^k = \frac{1}{1-r}$, we can solve in the following way

$$\frac{\rho}{(1+\eta)}\left[\frac{\frac{1}{1+\eta-\eta}}{1+\eta}\right] = \rho \quad (15)$$

- The third block considers the elements related to Δm_t

$$\frac{1}{(1+\eta)}\Big[\rho_m \Delta m_t + \frac{\eta}{(1+\eta)}\rho_m E_t\{\Delta m_{t+1}\}\Big]$$
$$= \frac{1}{(1+\eta)}\Big[\rho_m \Delta m_t + \frac{\eta}{(1+\eta)}\rho_m E_t\{\rho_m \Delta m_t + \varepsilon_t^m\}\Big]$$
$$= \frac{1}{(1+\eta)}\rho_m \Delta m_t + \frac{\eta}{(1+\eta)^2}{\rho_m}^2 \Delta m_t + \frac{\eta^2}{(1+\eta)^3}{\rho_m}^3 \Delta m_t$$

$$= \frac{\rho_m \Delta m_t}{(1+\eta)}\left[1 + \frac{\eta\rho_m}{(1+\eta)} + \left(\frac{\eta\rho_m}{(1+\eta)}\right)^2 + \left(\frac{\eta\rho_m}{(1+\eta)}\right)^3\right]$$
$$= \frac{\rho_m \Delta m_t}{(1+\eta)}\left[\frac{1}{1-\frac{\eta\rho_m}{(1+\eta)}}\right] = \frac{\rho_m \Delta m_t}{(1+\eta)}\left[\frac{\frac{1}{1-\eta-\eta\rho_m}}{1+\eta}\right]$$
$$= \frac{\rho_m \Delta m_t}{(1+\eta)}\left[\frac{1+\eta}{1+\eta(1-\rho_m)}\right] = \frac{\rho_m}{1+\eta(1-\rho_m)}\Delta m_t$$
(16)

Finally, putting together (14),(15),(16)we arrive to the expression found in the paper.

$$r_t - \rho = \frac{(\sigma-1)}{(1+\eta)}\sum_{k=1}^{\infty}\frac{\eta}{(1+\eta)}^{k-1} E_t\{\Delta y_{t+k}\} + \frac{\rho_m}{1+\eta(1-\rho_m)}\Delta m_t$$

c) <u>To the extent that money growth is positively serially correlated (assume ρ_m = 0.5), the nominal rate will necessarily increase in response to a monetary expansion. Under what conditions the liquidity effect can be restored?</u>

Gali defines liquidity effect as, "the observed *negative* co-movement between money supply and nominal interest rate".[2] However, in the calibrated model discussed in this paper the model does not predict the existence of liquidity effect. This can be seen from the expression of nominal interest rate given in the model:

$$i_t = \frac{\rho_m}{1+\eta(1-\rho_m)}\Delta m_t$$ [3]

As long as the value of ρ_m is greater than 0, nominal interest would rise along with an expansion in money supply (Δm_t), thus breaking the liquidity effect.

In order to restore liquidity effect we need to first understand the factors involved in determination of interest rate:

$$r_t = \frac{(\sigma-1)}{(1+\eta)}\sum_{k=1}^{\infty}\frac{\eta}{(1+\eta)}^{k-1} E_t\{\Delta y_{t+k}\} + \frac{\rho_m}{1+\eta(1-\rho_m)}\Delta m_t$$

Generally monetary expansion raises output on impact and the term

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[2] Jordi Gali – Monetary Policy, Inflation, and Business Cycle, page 9
[3] pp.24

$\sum_{k=1}^{\infty} \frac{\eta}{(1+\eta)}^{k-1} E_t\{\Delta y_{t+k}\}$ will be negative.[4] In order to restore liquidity effect the model would need a sufficiently high-risk aversion parameter (σ) for any given value of ρ_m. In this case, since we assume $\rho_m = 0.5$ the risk aversion parameter would have to be slightly above 4 in order to generate liquidity effect. [5]

d) <u>Using dynare replicate Figures 3 and 5 from Gali's paper. Explain the results.</u>
(SEE APPENDIX FOR CODES)

Gali (2002): Figure 3 Dynamic Responses to a Monetary Shock

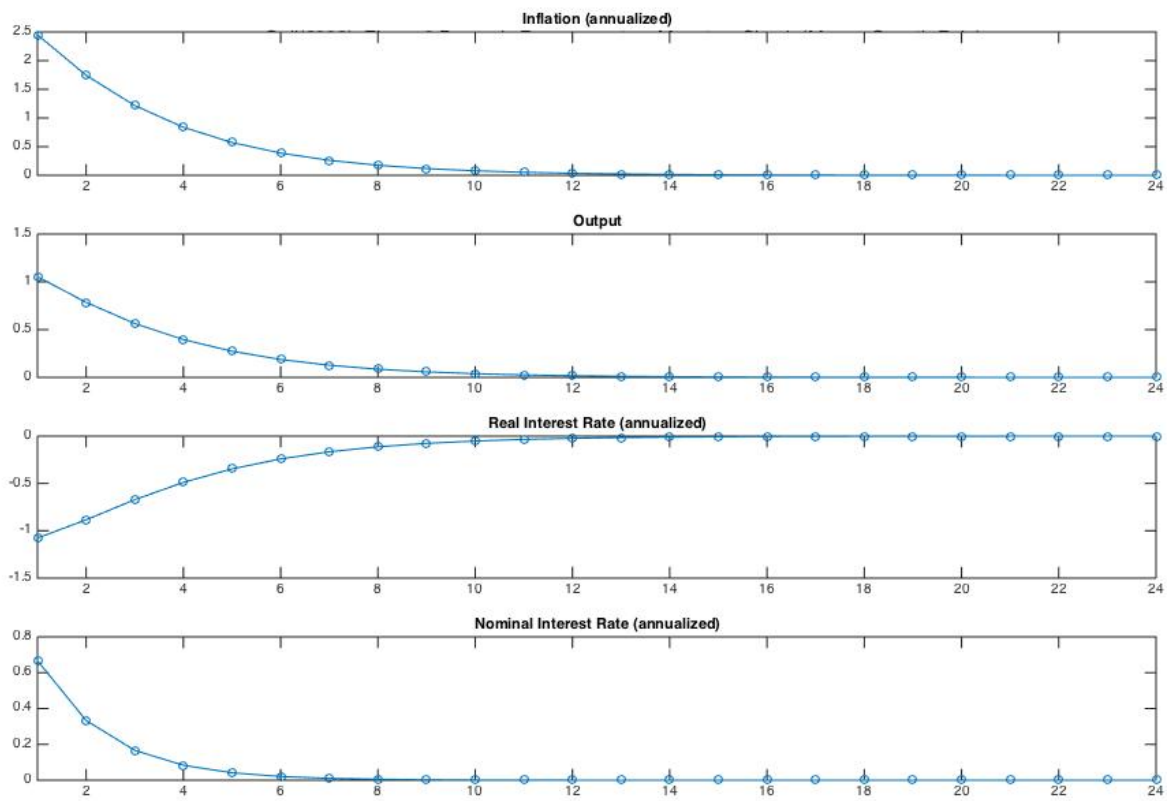

Figure 3 displays the dynamic response of output, inflation, nominal interest rate and real rates to a one-standard deviation money supply shock, under baseline calibration. The rates of inflation and interest rate are annualized. The important aspects to note in this model are:

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[4] (Gali, New Perspectives on Monetary Policy, Inflation, and the Business Cycle, 2002) page 16
[5] pp16

i) In a simple sticky price model a typical monetary shock has a highly persistent effect on output. On impact, a one percent increase in the money supply raises output by more than 1 percent. The persistence is seen to last for 3.2 quarters.[6]
ii) Under baseline calibration a monetary expansion is predicted to raise nominal rate; in other words the calibrated model does not predict the existence of liquidity effect.[7]
iii) Price level in response to a monetary shock increases by about 2.4 percent (annualized)[8]

<u>Technology Shock</u>

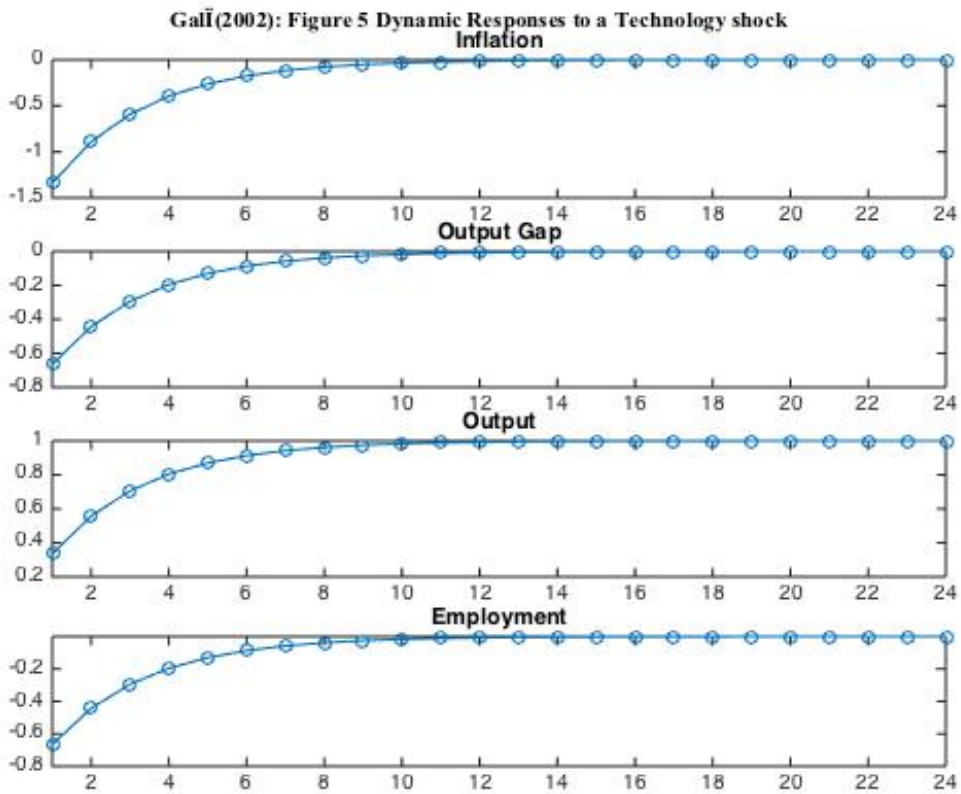

Figure 5 shows the dynamic response of inflation, the output gap, output, and employment to a one percent permanent increase in productivity using baseline model under the assumption of constant money supply.
The key result that Gali states here is the negative response of employment to a positive shock in technology. This happens despite all firms experiencing a decline in marginal cost. Price rigidities ensure that only a fraction of the firms will be adjust their prices downward in the short run (Calvo model). Accordingly, the aggregate price level will decline, and

[6] pp15
[7] pp15
[8] pp15

aggregate demand will rise, less than proportionally to increase in productivity. This, in turn, induces a decline in aggregate employment.[9]

[9] pp17

APPENDIX:

1) The following is the dynare code for Monetary Shock to produce figure 3:

Monetary Shock:

```
// Gali (2002), figure 3

//----------------------------------
//           Preamble
//----------------------------------


// endogenous 14 variables
var y, ygap, yn, p, pi, i, r, rn, n, m, ry, iy, piy ;

//y;output, ygap;gdp gap, yn;natural output, p;price level,
pi;inflation
//i;nominal interest, r;real interest, rn;natural real interest rate
//n;employment, m;money balance, ry;anual r, iy;anual i, piy;anual pi,

// exogenous 2 variables
varexo a, e_m;

//----------------------------------------
// Parameterization
//----------------------------------------

parameters SIGMA, PHI, ETA, THETA, EPSILON, BETA, RHO_M, RHO, LAMBDA,
KAPPA, PSI_YA;

SIGMA = 1;
PHI = 1 ;
ETA = 4 ;
THETA = 0.75;
EPSILON = 11;
BETA = 0.99;
RHO_M = 0.5;
RHO = -log(BETA);
LAMBDA =((1-THETA)*(1-BETA*THETA))/THETA;
KAPPA = LAMBDA*(SIGMA + PHI);
PSI_YA = (1+PHI)/(PHI+SIGMA);

//-----------------------------------
//      First Order Conditions
//-----------------------------------

model;
pi = p - p(-1); // inflation rate
pi = BETA*pi(+1) + KAPPA*ygap ;// NKPC
ygap = ygap(+1) - (1/SIGMA)*(i - pi(+1) - rn); //dynamic IS
y = a + n ; //production function
yn = PSI_YA*a ; // natural y
rn = RHO ; // natural interest rate
ygap = y - yn ; // output gap
```

```
m - p = y - ETA*i ; // money demand
r = i - pi(+1); // real interest rate
(m - m(-1)) = RHO_M*(m(-1)-m(-2)) + e_m ; // money supply
iy = 4*i ; // anualized
ry = 4*r ; // anualized
piy = 4*pi ; // anualized
end ;

steady; // find steady state
check ; //not complusory

//---------------------------
//     Generate IRFs
//---------------------------

shocks ;
var e_m; stderr 1;
end ;

//simulate the model
stoch_simul (irf=24, order=1) ;

//-------------------------------------
//   Generate Figure Monetary Shock
//-------------------------------------
figure (1);
subplot(4,1,1); plot(piy_e_m,'-o'); title ('Inflation (annualized)');
axis ([1 24 0 2.5]);
subplot(4,1,2); plot(y_e_m,'-o'); title ('Output'); axis ([1 24 0
1.5]);
subplot(4,1,3); plot(ry_e_m,'-o'); title ('Real Interest Rate
(annualized)'); axis ([1 24 -1.5 0]);
subplot(4,1,4); plot(iy_e_m,'-o'); title ('Nominal Interest Rate
(annualized)'); axis ([1 24 0 0.8]);
suptitle ('Gali(2002): Figure 3 Dynamic Responses to a Monetary Shock
(Money Growth Rule)');
```

2) The following is the dynare code to replicate figures of technology shock:

```
Technology Shock

// Gali (2002) figure 5

//---------------------------------
//           Preamble
//---------------------------------

//define (endogenous) variables, 14 variables
var y, a, ygap, yn, p, pi, i, r, rn, n, m, ry, iy, piy;

//y;output, ygap;gdp gap, yn;natural employment, pi;inflation,
i;interest,
//r; real interest, rn;natural real interest rate, n;employment,
//a;technology, ag;technology growht, m;money balance,
//mg; money growth, ry;anual r, iy;anual i, piy;anual pi,

varexo eps_a, e_m;

//---------------------------------------
// Parameterization
//---------------------------------------

parameters
BETA,THETA,SIGMA,PHI,EPSILON,ETA,RHO_M,RHO,LAMBDA,KAPPA,PSI_A;

BETA = 0.99;
THETA = 0.75;
SIGMA = 1;
PHI = 1;
EPSILON = 11;
ETA = 4;
RHO_M = 0.5;
RHO = -log(BETA);
LAMBDA = THETA^(-1)*((1-THETA)*(1-(BETA*THETA)));
KAPPA = LAMBDA*(SIGMA+PHI);
PSI_A = (1 + PHI)/(SIGMA + PHI);

//----------------------------------
//      First Order Conditions
//----------------------------------
model;
pi = BETA*pi(+1) + KAPPA*ygap;// NKPC
ygap = ygap(+1) - (1/SIGMA)*(i - pi(+1) - rn); //IS
pi = p - p(-1); // inflation rate
y = a + n; //production
yn = PSI_A*a ; // natural y
ygap = y - yn ; // output gap
rn = RHO + SIGMA*PSI_A*(a(+1) - a); //  natural interest rate
r = i - pi(+1); // real interest rate
m - p = y - ETA*i ; // money demand
(m - m(-1)) = RHO_M*(m(-1)- m(-2)) + e_m; // money supply
a = a(-1)+ eps_a;
iy = 4*i; // anualized
```

```
ry = 4*r; // anualized
piy = 4*pi; // anualized
end;

//------------------------
//      Steady States
//------------------------
initval;
a = 0;
ygap = 0;
y = 0;
yn = 0;
m = 0;
n = 0;
p = 0;
pi = 0;
rn = RHO;
r = RHO;
i = RHO;
ry = 4*r;
iy = 4*i;
piy = 4*pi;
end;

steady; // find steady state
check ; //not complusory

//---------------------------
//     Generate IRFs
//---------------------------
shocks;
var eps_a; stderr 1^2; //unit shock to technology
end;

stoch_simul(order = 1,irf=30);

//--------------------------------
//   Generate Figure Techshock
//--------------------------------
figure (2);
subplot(4,1,1); plot(piy_eps_a,'-o'); title ('Inflation'); axis ([1 24
-1.5 0]);
subplot(4,1,2); plot(ygap_eps_a,'-o'); title ('Output Gap'); axis ([1
24 -0.8 0]);
subplot(4,1,3); plot(y_eps_a,'-o'); title ('Output'); axis ([1 24 0.2
1]);
subplot(4,1,4); plot(n_eps_a, '-o'); title ('Employment'); axis ([1 24
-0.8 0]);
subtitle ('GalÏ(2002): Figure 5 Dynamic Responses to a Technology
shock');
```

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