1 Sticky prices and the real effects of money

• Recall the “monetary neutrality” property of the RBC model. This implicitly requires flexible prices.

• What if prices are not so flexible?

• Hume (1752):

“When any quantity of money is imported into a nation, it is not at first dispersed into many hands but is confined to the coffers of a few persons, who immediately seek to employ it to advantage. Here are a set of manufacturers or merchants, we shall suppose, who have received returns of gold and silver for goods which they have sent to Cadiz. They are thereby enabled to employ more workmen than formerly, who never dream of demanding higher wages, but are glad of employment from such good paymasters. [The artisan] ...carries his money to the market, where he finds every thing at the same price as formerly, but returns with greater quantity and of better kinds for the use of his family. The farmer and gardener, finding that all their commodities are taken off, apply themselves with alacrity to raising more...It is easy to trace the money in its progress through the whole commonwealth, where we shall find that it must first quicken the diligence of every individual before it increases the price of labour.” (emphasis added)

• Link between not raising prices and producing more goods. How do we model this?

• Elements of the model:
  – Built on top of the neoclassical/RBC model
  – Slow or imperfect adjustment of prices. In the extreme, purely fixed prices
  – Quantities adjust instead of prices
2 The RBC model with money

- Recall the equations that described the two-period RBC model

\begin{align*}
    u'(c_0) &= \beta F_K(K_1, L_1) u'(c_1) \\
    v'(1 - L_0) &= F_L(K_0, L_0) u'(c_0) \\
    v'(1 - L_1) &= F_L(K_1, L_1) u'(c_1) \\
    K_1 &= Y_0 - c_0 + (1 - \delta) K_0 \\
    c_1 &= Y_1
\end{align*}

- And recall that

\[ r_1 = F_K(K_1, L_1) - \delta \]

- Now add money-market equilibrium:

\[ M_0 = m^D(Y_0, i_1) P_0 \]

- And the Fisher equation that relates real and nominal interest rates:

\[ r_1 = i_1 - \pi_1 = i_1 - \frac{P_1}{P_0} - 1 \]

- We are going to assume that in the long-run (represented here by period 1) the quantity theory of money holds so

\[ P_1 = \kappa M_1 \]

- How does this economy work?

- Equations (1) - (6) are just the RBC and can be solved for all the real variables, including the real interest rate
- Equation (9) determines the price level in period 1
- Equations (7) and (8) determine the price level in period 0 ($P_0$) and the nominal interest rate.
- Money is neutral - real and nominal side of the economy are separable.
3 Modifications towards the New Keynesian Model

- We are going to start with a simplified RBC model and then add the two defining assumptions of the New Keynesian model:
  1. Producers have monopoly power
  2. Prices are set in advance, at least to some extent

- First, a simplified RBC model:
  1. No capital, so
     \[ Y_0 = AL_0 \]
  2. Period 1 is an endowment economy with no labour supply, so \( Y_1 \) is exogenous

- From this we would get:
  \[
  u'(Y_0) = \beta (1 + r_1) u'(Y_1) \\
  v'(1 - L_0) = Au'(Y_0) \\
  Y_0 = AL_0
  \]
  (the real economy), together with
  \[
  M_0 = m^D(Y_0, i_1) P_0 \\
  r_1 = i_1 - \frac{P_1}{P_0} - 1 \\
  P_1 = \kappa M_1
  \]
  (the nominal side)

- Still an RBC economy with monetary neutrality, just a bit simplified.

3.1 Add monopoly power

- Imagine the each household produces a slightly different good, using its own labour. Each household is a producer

- (More complicated models have firms producing different goods and workers supplying different types of labour. Here we don’t really make the distinction between workers and firms, each worker is self-employed)

- Therefore they don’t take prices as given
• Recall monopoly pricing formula from microeconomics:

\[
p = mc \cdot \frac{\eta}{\eta - 1}
\]

price \hspace{1cm} marginal cost \hspace{1cm} monopoly markup

(which depends on the elasticity of demand)

• In our model, the expression

\[
P \frac{v'(l)}{Au'(c)}
\]

is the nominal marginal cost of producing an extra unit. Why?

- To produce an extra unit, the producer needs

\[
\frac{1}{A}
\]

extra units of labour.

- This extra labour gives the household

\[
\frac{1}{A}v'(l)
\]

disutility

- To compensate this disutility to the point of indifference, the household needs to get more consumption. How much more? (let’s call this \(\Delta c\))

\[
\Delta c \cdot u'(c) = \frac{v'(l)}{A}
\]

\[
\Rightarrow \Delta c = \frac{v'(l)}{Au'(c)}
\]

- What is the nominal cost of the goods required to compensate the household?

\[
P \cdot \Delta c = P \frac{v'(l)}{Au'(c)}
\]

• Conclusion: the producer chooses

\[
p = P \frac{v'(l)}{Au'(c)} \cdot \frac{\eta}{\eta - 1}
\]

(10)

• Since all households are the same they set the same price, so the price level \(P\) and the individual price \(p\) coincide.
• Therefore

\[
1 = \frac{v'(l)}{Au'(c) \eta - 1} \frac{\eta}{\eta - 1} Au'(c)
\]

\[\Rightarrow v'(l) = \frac{\eta - 1}{\eta} Au'(c)\]

• Monopoly power is a way to break the equation

\[
v'(l) = F_L(\cdot) u'(c)
\]

which was a central part of the RBC model!

• Now instead we have that

\[
v'(l) = \frac{\eta - 1}{\eta} F_L(\cdot) u'(c)
\]

• Monopoly power acts in the same way as a labour-income tax: households work/produce less than would be required to equate marginal product to marginal cost.

• Now the economy is NOT efficient. The First Welfare Theorem does NOT hold

• It would be desirable, from an efficiency perspective, to have higher employment and higher output

  – In the RBC model this is NOT true, because the marginal disutility of labour exactly equals the value of the marginal product

3.2 Assume prices are set in advance

• Household/producers set prices for their goods before period 0 (i.e. before they know of all the shocks that might take place)

• Then they adjust the quantity produced to satisfy the demand for their product by changing how much they work

• If few customers show up, they work less; if more customers show up, they work more

• In other words, the timing is:

  1. Set prices
  2. Shocks happen, which determine how much demand each producer faces
  3. The household/producer works exactly the necessary amount to meet demand
• Question: if demand is higher than expected, why don’t they say:

“Oh, in order to produce enough output to satisfy demand, I would have to work too hard, beyond the point where my marginal utility of leisure says I should stop, so I’ll just tell some customers that I can’t sell them any goods”

• Implication:

\[ v'(l_0) = \frac{\eta - 1}{\eta} A u'(c_0) \]

might NOT hold

• The household sets prices trying to get the equation to hold, but once prices are set, shocks will make it not hold and households will work more or less than planned.

• Why don’t they adjust prices in response to shocks?

  – They don’t observe the shocks
  – They could observe the shocks but they are (rationally) not paying that much attention to them
  – There are “menu costs”
  – There are explicit or implicit contracts that prevent them from changing them

• Refer back to Hume

• Once prices are set, output is determined by demand

  – In this model, demand comes from how much households choose to consume in period 0
  – More generally, could also include investment, government spending and net exports

• The equations that describe the economy become:

\[ u'(Y_0) = \beta (1 + r_1) u'(Y_1) \]
\[ Y_0 = AL_0 \]
\[ M_0 = m^D (Y_0, i_1) P_0 \]
\[ r_1 = i_1 - \frac{P_1}{P_0} - 1 \]
\[ P_1 = \kappa M_1 \]
\[ P_0 \text{ given} \]
4 The IS-LM model

- Focus on two equations from the system above: the Euler equation and the money-market equilibrium

\[
\begin{align*}
u'(Y_0) &= \beta(1 + i_1 - \pi_1) u'(Y_1) \\
M_0 &= mD(Y_0, i_1) P_0
\end{align*}
\] (11) (12)

- Suppose:
  - \(P_0\) is determined in advance
  - \(P_1\) depends on \(M_1\), which we hold constant
  - \(Y_1\) is exogenous

- Then the two equations above are a system of two equations in two unknowns: \(Y_0\) and \(i\)

- Equation (11) (our old friend the Euler equation) is renamed the IS equation.
  - IS stands for Investment=Savings.
  - In our model which has no capital, Investment=Savings=0.
  - Taking \(c_1\) as given, the household will consume more when interest rates are low
  - This creates a negative relation between interest rates and output
  - Demand for current output depends negatively on interest rates

- Equation (12) is renamed the LM equation.
  - LM stands for Liquidity = Money, i.e. Money Demand = Money Supply
  - Money demand increases with \(c_0\) and decreases with \(i_1\)
  - Therefore if you increase both by the right amount, you keep money demand constant
  - This creates a positive relationship between interest rates and output

- Graphical representation

- Exercises:
  - Increase the money supply just today
  - Increase in the money supply today and tomorrow
  - Increase \(\pi_1\) (expected future prices)
- Increase in future income

- Remark: small changes in our basic RBC model (pre-set prices) have huge implications for how the aggregate economy behaves:
  - Money is NOT neutral
  - Expectations of the future lead consumption and hours of work to move in the same direction

- Extend the model to include government spending

\[ Y_0 = c_0 + G_0 \]
\[ u'(Y_0 - G_0) = \beta (1 + i_1 - \pi_1) u'(Y_1) \]
\[ M_0 = m^D(c_0, i_1) P_0 \]

5 Partial price adjustment and the Philips curve

- Suppose
  - some producers (call them S types for “sticky”) have set their prices in advance. There are \( \mu \) producers like this.
  - others (call them F types for “flexible”) haven’t decided yet and will adjust their prices in response to any shocks. There are \( 1 - \mu \) producers like this.

- So the average price level will be an average of the prices chosen by both types of producers

\[ P_0 = \mu p_0^S + (1 - \mu) p_0^F \]

- For producers who set prices in advance, we can take \( p_0^S \) as given

- For producers who set prices in response to shocks,

\[ p_0^F = P_0 \frac{v'(L_0)}{A u'(c_0)} \frac{\eta}{\eta - 1} \]
\[ = P_0 \frac{v'(1 - L_0)}{A u'(Y_0)} \frac{\eta}{\eta - 1} \]  \( (13) \)
Now the economy is described by the following equations:

\[
\begin{align*}
    u'(Y_0) &= \beta (1 + r_1) u'(Y_1) \\
    Y_0 &= AL_0 \\
    M_0 &= m^D(Y_0, i_1) P_0 \\
    r_1 &= i_1 - \frac{P_1}{P_0} - 1 \\
    P_1 &= \kappa M_1 \\
    P_0 &= \mu _0 + (1 - \mu) p^F_0 \\
    p^S_0 &= \mu _0 + (1 - \mu)p^F_0 + (14) \\
    p^F_0 &= p_0 \frac{\nu'(1 - L_0)}{A u'(Y_0)} \frac{\eta}{\eta - 1}
\end{align*}
\]

How is that different from the economy where everyone fixes prices in advance?

Suppose we increase \( M_0 \)

- In the economy where all prices are fixed in advance, then \( P_0 \) doesn’t change and \( Y_0 \) increases
- Would the flexible-price producers want to change prices?
- \( \uparrow Y_0 \) (higher output) \( \Rightarrow \uparrow L_0 \) (more employment / longer hours) \( \Rightarrow \downarrow l_0 \) (less leisure) \( \Rightarrow \uparrow v'(l) \) (higher marginal utility of leisure).
- Also:
- \( \uparrow Y_0 \) (higher output) \( \Rightarrow \downarrow u'(c_0) \) (lower marginal utility of consumption)
- Therefore:

\[
\uparrow \frac{\nu'(l)}{A u'(c)}
\]

Real marginal costs increase!
- So \( p^F_0 \) rises!

Interpretation

- By lowering interest rates, the policy induces an increase in consumption
- This increases the demand faced by each producer
- In order to satisfy this demand, it is necessary to work harder
- Therefore marginal costs increase
Therefore producers who have flexible prices will choose higher prices in order to maintain markups

• Overall, an increase in the money supply will lead to
  – Fixed-price producers keep prices fixed and produce more output
  – Flexible-price households raise prices and produce more output, but not as much
  – Inflation (because the average price is higher than the pre-set prices)
  – Lower nominal interest rates
  – Higher output

• Many concluded that there was a fundamental tradeoff between:
  – More employment but higher inflation
  – Less employment but lower inflation

• This became known as the “Phillips Curve”

• You can find an explicit expression for the Phillips Curve by replacing (13) into (14) and using \( Y_0 = AL_0 \)

\[
P_0 = \mu p^S_0 + (1 - \mu) P_0 \frac{v' \left( 1 - \frac{Y_0}{A} \right)}{Au' (Y_0)} \frac{\eta}{\eta - 1} \]

\[
P_0 \left[ 1 - (1 - \mu) \frac{v' \left( 1 - \frac{Y_0}{A} \right)}{Au' (Y_0)} \frac{\eta}{\eta - 1} \right] = \mu p^S_0
\]

\[
P_0 = \frac{\mu p^S_0}{1 - (1 - \mu) \frac{v' \left( 1 - \frac{Y_0}{A} \right)}{Au' (Y_0)} \frac{\eta}{\eta - 1}} \tag{15}
\]

• Evidence seemed in favour of the idea until the 1970s. What happened then?