

The effect of monetary shocks

# Outline

- Monetary policy decisions
- Money market
- Goods market
- Equilibrium
- Summary

- Exchange rates are adjusting to changes in the macroeconomic environment. With prices in an economy only adjusting slowly to changed conditions, it will be generally be the interest rate and the exchange rate that adjust quickly.
- While the interest rate parity would capture the effect through the impact any such changes have on the interest rate, it would be interesting to look at the implications on the exchange rate directly.
- We will therefore look at the impact money supply has on exchange rates
- The money supply might change as a result of monetary policy and thus we indirectly assess the impact monetary policy has on exchange rates.

- We will look at the equilibria in the money market and then the goods market, where prices adjust slowly. Bringing these two markets together will then allow us to assess how exchange rates adjust to any change in the money supply.

## ■ Monetary policy decisions

■ Money market

■ Goods market

■ Equilibrium

■ Summary

- We initially start by looking at monetary policy decisions and what impact we should expect on exchange rates, before we then continue with a more detailed analysis.

# Changes in money supply

- ▶ Monetary policy decisions by the central bank encompass decisions on interest rates and money supply
- ▶ If money supply is increased, the price level should increase if the output is given
- ▶ From purchasing power parity, the exchange should adjust as well
- ▶ However, prices will generally not adjust quickly

# Changes in money supply

- We will now, at a very basic level, assess the impact an increase in the money has on exchange rates.
- - The monetary policy tool of central banks encompasses, simplified decisions on the interest rates at which commercial banks can borrow funds from the central and the interest the central bank pays commercial banks if they deposit funds with the central bank.
  - In addition, they can also affect the amount they lend to commercial banks. This will affect the money available in an economy and it is hence indirectly a decision on the money supply.
- - A common consequence of increasing the money supply, with which we are concerned here, is that the larger amount of money available will increase the prices in an economy, thus increase inflation.
  - This result depends on the assumption that the output produced is constant, at least in the short term.
- With inflation increasing, we can then use the purchasing power parity to see that the exchange rate should adjust to this increased inflation.
- In reality, prices are not adjusting quickly, so-called 'sticky prices', and the main adjustment in the economy will have to be conducted through other channels that are quicker to adjust than prices. This would then ensure that despite prices adjusting slowly, the economy remains in equilibrium.
- We will now look in more detail at the adjustment process to the new equilibrium.

## Responses to changes in the money supply

- ▶ Changing the money supply changes price levels if there is full employment as output is given
- ▶ As prices only adjust slowly, the economy will not be in equilibrium immediately
- ▶ To ensure markets clear, other adjustments are needed
- ▶ The exchange rate is a variable that can adjust quickly

## Responses to changes in the money supply

- We will now look at what impact a change in the money supply has on exchange rates.
- If we assume that output is given, for example due to full employment, then an increase in the money supply will increase price levels, thus cause inflation.
- However, prices only adjust slowly and this adjustment will not be instant, while the money supply can increase very quickly. If prices do not adjust instantly, the economy would not be in equilibrium as the larger money supply would increase demand in nominal terms, and there are not enough goods that can be purchased at the stated prices. This leads to excess demand.
- If we want to ensure that markets clear and hence the economy is in equilibrium, we need to look at other variables in the economy that can adjust.
- The exchange rate is one variable that could adjust quickly and we will now consider how the exchange rate would adjust to ensure the economy is in equilibrium.
- In order to conduct this analysis we need to build a basic macroeconomic model of the money and goods market.

■ Monetary policy decisions

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- We will first consider the money market.

# Money demand

- ▶ Real money demand depends on the interest rate and output, with their respective elasticities
- ▶  $\frac{M}{P} = (1 + r)^{\varepsilon_r} Y^{\varepsilon_Y}$
- ▶ Interest rate parity holds and the exchange rate change is the difference between domestic and foreign interest rates:  $\Delta e = r - r^*$
- ⇒  $\ln M - \ln P = \varepsilon_r r + \varepsilon_Y \ln Y$
- ⇒  $\ln P - \ln M = \varepsilon_r (\Delta e + r^*) - \varepsilon_Y \ln Y$

- We first have to determine how the demand for money is determined. In an equilibrium, this demand will then have to be equal to the supply of money as set by the central bank.
- - As is common in macroeconomics, we assume that the demand for money is increasing in the interest rate. The higher the interest that is paid on money, the more individuals are willing to hold money and postpone consumption in favour of later and larger consumption.
  - The money demand will also be increasing in the output of the economy as a larger output would require larger amounts of money to purchase the goods produced.
  - The strengths of these two factors are given by their elasticities and we assume the demand for real money, that is after adjusting for the price level, is given by a Cobb-Douglas function.
- *Formula*
- We now assume that interest rate parity holds and the exchange rate changes in line with the interest rate differential to the interest rate in a foreign country.
- ⇒ From our money demand, we can now take the logarithm and make the approximation that  $\ln(1 + r) \approx r$ .
- ⇒ We can now insert the interest rate parity by solving it for  $r$ .
- We can establish how a change in the money demand will affect exchange rates.

# Exchange rate change

- ▶ The equilibrium requires that exchange rates are stable,  $\Delta e = 0$ , at some price level  $\bar{P}$
- ▶ The output we assume to be fixed due to full employment
- ▶ Money demand:  $\ln \bar{P} - \ln M = \varepsilon_r r^* - \varepsilon_Y \ln Y$
- ⇒  $\ln P - \ln \bar{P} = \varepsilon_r \Delta e$
- ⇒  $\Delta e = \frac{\ln P - \ln \bar{P}}{\varepsilon_r}$
- ▶ The exchange rate decreases if the current prices are below their equilibrium level

- We can now look at how the exchange rate will adjust if the prices cannot adjust instantly.
  - ▶ • We have an equilibrium if no variables change, that is we would require here that the exchange rate remains stable.
  - This will be require prices to adjust such that the equilibrium from above is achieved.
- ▶ We here assume that the output cannot adjust due to full employment, and a reduction in output is also not possible.
- ▶ At the price level at which the exchange does not change, we can determine the equilibrium by setting  $\Delta e = 0$ .
- ⇒ We can now eliminate  $\ln M + \varepsilon_Y \ln Y$  by combining the money demand in the long-term equilibrium after the prices have adjusted and the short-term equilibrium where prices are constant and the exchange rate adjusts.
- ⇒ This expression can now be solved for the change in the exchange we should observe.
- ▶ We this see that the exchange rate decreases if the current prices  $P$  are below the long-term equilibrium price level  $\bar{P}$ . Thus if the prices cannot adjust, the exchange rate will. Where prices are fully flexible and adjust instantly we have  $P = \bar{P}$  and the exchange rate does not change.
- This establishes the equilibrium in the money market, here the money demand equal the money supply.

■ Monetary policy decisions

■ Money market

■ Goods market

■ Equilibrium

■ Summary

- We now turn to the goods market and will seek to determine the equilibrium there and see how much the price level will adjust in the long-term. This will then allow us to assess the impact monetary policy has on exchange rates.

# Demand in goods markets

- ▶ Demand depends on the relative prices of goods, output, and interest rates, with their respective elasticities
- ▶ 
$$D = \left(\frac{eP^*}{P}\right)^{\hat{\varepsilon}_P} Y^{\hat{\varepsilon}_Y} (1 + r)^{\hat{\varepsilon}_r}$$
- ⇒ 
$$\ln D = \hat{\varepsilon}_P (\ln e - \ln P + \ln P^*) + \hat{\varepsilon}_Y \ln Y + \hat{\varepsilon}_r r$$
- ▶ Prices adjust slowly to excess demand:  $\Delta P = \lambda (\ln D - \ln Y)$
- ▶ For simplicity we normalise the foreign price level such that  $\ln P^* = 0$

# Demand in goods markets

→ We will first look at how the demand in goods markets is determined.

- We assume that the total demand for goods in a country depends on the price of the goods when compared to the price of such goods in another country. The more expensive the goods in the own country are (high  $P$  compared to a low  $P^*$ ), adjusted by the exchange rate, the lower the demand will be.
- It will also depend on the total output the country produces, as that will in turn determine the amount of funds available to purchase goods.
- A higher interest rate will reduce the demand as more funds are saved.
- The importance of these three factors is determined by there elasticities and we again assume the the demand is determined by a Cobb-Douglas function.

## ► *Formula*

⇒ We can now take the logarithm of this expression and make the approximation  $\ln(1 + r) \approx r$ .

► Let us now assume that prices are sticky and adjust only at a slow rate to their equilibrium. We assume that the price adjustment is proportional to the difference in demand and supply (the production of goods),

► We simplify the analysis by normalising the price level in the foreign country and assume it to be constant. This allows us to set the price level to 1, ensuring that the expression can be neglected in the further analysis.

→ We can now continue by determining the equilibrium inflation.

# Inflation

- ▶ From the money demand we have  $r = \frac{\ln P - \ln M + \varepsilon_Y \ln Y}{\varepsilon_r}$
- ⇒  $\Delta P = \lambda \left( \hat{\varepsilon}_P (\ln e - \ln P) - \frac{\hat{\varepsilon}_r}{\varepsilon_r} (\ln M - \ln P) + \left( \frac{\hat{\varepsilon}_r \varepsilon_Y}{\varepsilon_r} + \hat{\varepsilon}_Y - 1 \right) \ln Y \right)$
- ▶ The equilibrium requires that prices are stable,  $\Delta P = 0$ , at some price level  $\bar{P}$  and exchange rate  $\bar{e}$
- ⇒  $0 = \lambda \left( \hat{\varepsilon}_P (\ln \bar{e} - \ln \bar{P}) - \frac{\hat{\varepsilon}_r}{\varepsilon_r} (\ln M - \ln \bar{P}) + \left( \frac{\hat{\varepsilon}_r \varepsilon_Y}{\varepsilon_r} + \hat{\varepsilon}_Y - 1 \right) \ln Y \right)$
- ⇒  $\Delta P = \lambda \hat{\varepsilon}_P (\ln e - \ln \bar{e}) + \lambda \left( \frac{\hat{\varepsilon}_r}{\varepsilon_r} - \hat{\varepsilon}_P \right) (\ln P - \ln \bar{P})$
- ▶ The price level increases if the current exchange rate is above the equilibrium and the price level is below its equilibrium

- We can now look at the implications of these relationships for the inflation in equilibrium.
- ▶ We can solve the money demand from above for the interest rate.
- ⇒ We can now insert into the price change, representing inflation from the above. We insert for the demand,  $\ln D$ , and the interest rate,  $r$ , and obtain this *formula*.
- ▶ In equilibrium, we assume that the price level and exchange rate are such that there is no inflation. We denote these variables with upper bars.
- ⇒ Replacing the variables with their equilibrium values, we then have that this *formula*.
- ⇒ using the long-run equilibrium from above and inserting this into the current inflation, gives this *formula*.
- ▶
  - We see that we have inflation if the current exchange rate is above its equilibrium value
  - and the price level is below its equilibrium value. This latter results emerges as the term in brackets will be negative because  $\hat{\epsilon}_r < 0$ .
- We have thus established the equilibrium in the goods markets, namely the equilibrium inflation.

■ Monetary policy decisions

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- We can now combine the equilibrium in the goods market and the money market.

# Relationship between price level and exchange rate

- ▶ The equilibrium requires that prices are stable,  $\Delta P = 0$ , at some price level  $\bar{P}$  and exchange rate  $\bar{e}$
- ▶ In equilibrium, exchange rates are also stable,  $\Delta e = 0$ , and from interest rate parity we then have  $r = r^*$
- ⇒  $\ln \bar{e} - \ln \bar{P} = \frac{-\hat{\varepsilon}_r r^* + (1 - \hat{\varepsilon}_Y) \ln Y}{\hat{\varepsilon}_P}$
- ▶ In equilibrium, there is a positive relationship between the price level and exchange rate

# Relationship between price level and exchange rate

- We will first establish the relationship between price levels and exchange rates in the long-term equilibrium before then considering the way this equilibrium is reached.
- ▶ In the long-run equilibrium we assume that there is no inflation at the relevant equilibrium price level and exchange rate.
- ▶ In the long-run equilibrium we assume that the exchange rate does not change at the relevant equilibrium price level and exchange rate. We also assume that interest parity holds and hence the domestic and foreign interest rates are identical in the long-run equilibrium.
- ⇒ Using the expression from  $\ln M - \ln \bar{P}$  from the long-run money market equilibrium and the expression for the long-run goods market equilibrium, we get this *formula*.
- ▶ As the (log-) differences between the exchange rate and price level are some constant, we see that there is a positive relationship between these two long-run variables; a higher price level would require a higher exchange rate.
- We can now use these relationship to asses how this equilibrium will be reached over time as prices adjust slowly.

# Out-of equilibrium dynamics

- ▶ The evolution of the exchange rate and price level is given by

$$\Delta e = \frac{\ln P - \ln \bar{P}}{\varepsilon_r}$$

$$\Delta P = \lambda \hat{\varepsilon}_P (\ln e - \ln \bar{e}) + \lambda \left( \frac{\hat{\varepsilon}_r}{\varepsilon_r} - \hat{\varepsilon}_P \right) (\ln P - \ln \bar{P})$$

- ▶ These equations characterise the relationship between price levels and exchange rates outside of the equilibrium
- ▶ The solution shows that the equilibrium is only reached if

$$\ln e - \ln \bar{e} = \frac{\xi + \lambda \left( \hat{\varepsilon}_P - \frac{\hat{\varepsilon}_r}{\varepsilon_r} \right)}{\hat{\varepsilon}_P} (\ln P - \ln \bar{P})$$
$$\ln e - \ln \bar{e} = \underbrace{\frac{\xi + \lambda \left( \hat{\varepsilon}_P - \frac{\hat{\varepsilon}_r}{\varepsilon_r} \right)}{\hat{\varepsilon}_P}}_{<0} (\ln P - \ln \bar{P})$$

- ▶ The adjustment towards the equilibrium has a negative slope

# Out-of equilibrium dynamics

- We will now consider the dynamics that will lead to the long-run equilibrium. Strictly speaking this is not out-of-equilibrium as an equilibrium is obtained by adjusting the exchange rate, but this will not be the long-term equilibrium.
- ▶ From the previous money market equilibrium we had the conditions as shown in the *formulae*, reproduced here.
- ▶ These two equations show the relationships between the exchange rate and the price level. They together form a system of difference equations that can be solved.
  - We can solve these difference equations and obtain the result shown in the *formula*, where  $\xi$  summarises some other variables. We thus see that the difference of the exchange rate to its long-run average is related to the difference of the price level to its long-term average.
  - We can show that the coefficient is negative.
- ▶ We thus have a negative relationship between exchange rate and price level, as the price level increases, the exchange rate will reduce.
- Thus far we have analysed how an economy adjusts to a situation where the long-run equilibrium is different to the current state of the economy, we will now see how a new long-run equilibrium can be determined.

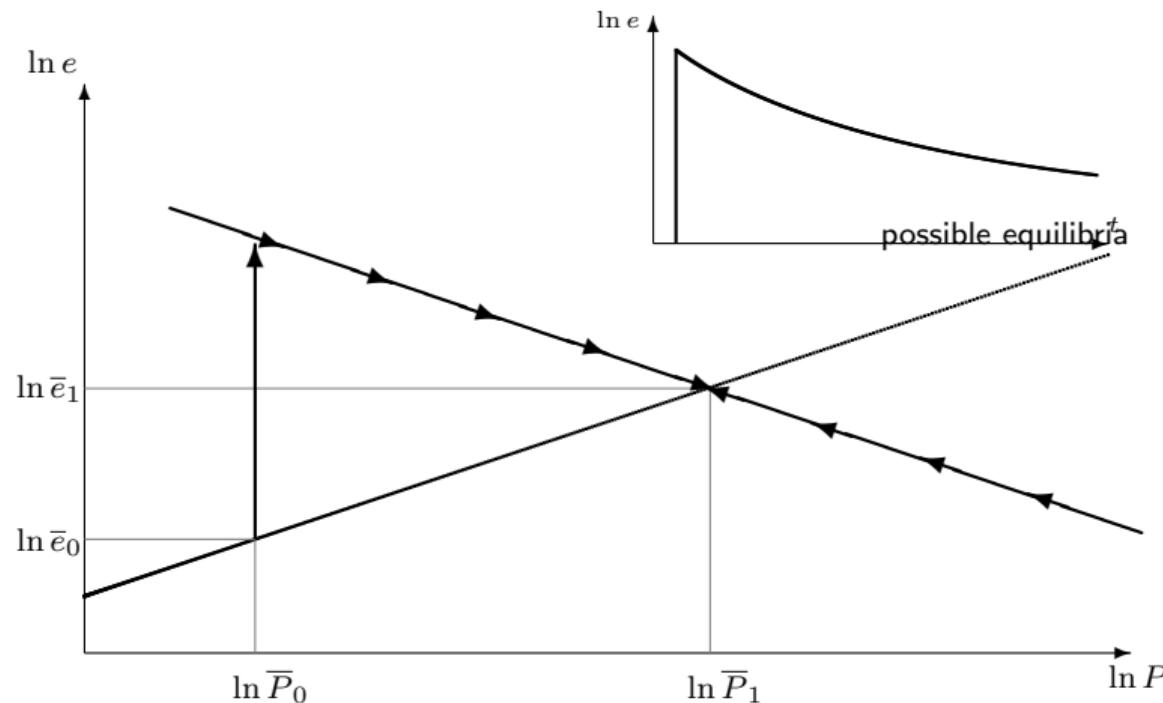
# Impact of monetary policy

- ▶ From the money demand we had  $\ln \bar{P} - \ln M = \varepsilon_r r^* - \varepsilon_Y \ln Y$
- ▶ An increase in the money supply will increase the price level due to the output being given
- ▶ From the relationship of exchange rates and price levels in equilibrium, this implies a higher exchange rate

# Impact of monetary policy

- We will look at the impact of monetary policy on shifting the long-run equilibrium of an economy. We start with the economy being in a long-run equilibrium.
- ▶ We know that the long-run equilibrium in the money market is given by this *formula*, using that in this long-run equilibrium the exchange rate change is zero.
- ▶ The right-hand side is given with our assumption that output cannot increase and hence an increase in the money supply,  $M$ , will necessitate an increase in the long-run price level  $\bar{P}$ .
- ▶ Thus we have established a new long-run price level and the long-run exchange rate will adjust accordingly to ensure that purchasing power parity is maintained and the exchange rate will increase accordingly.
- We can now analyse the adjustments the economy undergoes until reaching the new long-run equilibrium.

## Reaction to an increase in money supply



## Reaction to an increase in money supply

- We do consider the impact of a monetary shock in the form of the central bank increasing the money supply. The reasons for this decisions are outside of the scope of this model.
- ▶ We will look at the relationship between the price level and the exchange rate.
- ▶ We know that all possible long-run equilibria are on a line with a positive slope. this was the relationship  $\ln \bar{e} - \ln \bar{P} = \frac{-\hat{\varepsilon}_r r^* + (1 - \hat{\varepsilon}_Y) \ln Y}{\hat{\varepsilon}_P}$  we had before.
- ▶ Assume we are currently in a long-run equilibrium with a given price level.
- ▶ We can use this price level to determine the long-run equilibrium exchange rate.
- ▶ This exchange rate is given here.
- ▶ Let us now assume that central bank has increased its money supply and the long-run equilibrium price level has increased.
- ▶ We can use this new price level to determine the new long-run equilibrium exchange rate.
- ▶ This new exchange rate is given here.
- ▶ We can now look at the adjustment process leading to this new equilibrium. We had the dynamics written as  $\ln e - \ln \bar{e} = \frac{\xi + \lambda \left( \hat{\varepsilon}_P - \frac{\hat{\varepsilon}_r}{\hat{\varepsilon}_r} \right) \left( \ln P - \ln \bar{P} \right)}{\hat{\varepsilon}_P}$ , which is represented by this line. This represents the short-term equilibrium.
- ▶ The exchange will adjust quickly and thus jump to the short-term equilibrium.
- ▶ Then, as the prices slowly adjust the exchange rate will move slowly towards its long-term equilibrium.
- ▶ We can now look at the time series of how the exchange rate evolves over time.
- ▶ We see an initial large increase in the exchange rate, reflecting the jump from the old long-run equilibrium to the new short-run equilibrium.
- ▶ After that the exchange rate is slowly reducing again and moving towards its long-term equilibrium.
- We thus see how in response to a monetary shock, the exchange rate will quickly increase and then slowly over time fall back towards its new long-run equilibrium.

# Overshooting exchange rates

- ▶ The exchange rate will adjust quickly to its new equilibrium path
- ▶ As price levels adjust slowly, the exchange rate then adjusts slowly towards its equilibrium
- ▶ The exchange rate initially overshoots the equilibrium exchange rate and then slowly falls back
- ▶ We have this large change in the exchange rate to compensate for the lack of price adjustment
- ▶ Only once the prices adjust does the exchange rate fall back to its equilibrium value

## Overshooting exchange rates

- We observe that the exchange rate initially adjusts too much and then reverses its movements over time.
- We have established that in order to reach the short-run equilibrium, the exchange rate will adjust by jumping to its new short-term equilibrium. This is because the prices do not adjust quickly, but we assume that exchange rates ensure that the goods and money markets are both in equilibrium.
- As the price levels increase slowly, the burden on the exchange rate to ensure an equilibrium is maintained is reduced; the exchange rate slowly falls back to its long-run equilibrium.
- We thus have a situation in which the exchange rate overshoots its long-run equilibrium and then slowly falls back over time.
- This initial large jump is the result of prices not adjusting to the larger money supply and exchange rates need to adjust more than they would if prices were fully flexible and would take their burden of the adjustment process from the start.
- It is then that once the prices adjust and hence prices take an ever increasing burden of the required adjustment that the exchange rate can approach its long-run equilibrium.
- We thus saw that exchange rates over-adjust and this is then slowly reversed over time.

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- We can now summarize the main results of this model.

# Sticky prices

- ▶ Price levels only adjust slowly to changes in the money supply
- ▶ Exchange rates will adjust instantaneously and put the economy on an equilibrium path
- ▶ The adjustment of the exchange rate is more than the new equilibrium requires
- ▶ As prices adjust slowly, the exchange rate also slowly adjusts towards its equilibrium

- A key assumption for our model was that prices only adjust slowly to new macroeconomic conditions.
- We assumed that prices only adjust gradually to any change in the money supply, while exchange rates (and through interest rate parity also interest rates) are fully flexible.
- This quick adjustment of exchange rates allows the economy to be in equilibrium at any point in time; money and goods markets both clear.
- The exchange rate adjusts more than is needed for the long-run equilibrium as in this case prices and exchange rates adjust both. It is the inflexibility of prices in the short run that require the exchange rate to change more than is justified by the long-term equilibrium.
- With prices slowly adjusting, the exchange rate will then fall back to account for the adjustment taken by prices.
- Hence, temporarily, exchange rates overshoot their 'target' (the new long-run equilibrium) and fall back over time.

## Exchange rates over-adjust

- ▶ In response to monetary policy exchange rates initially bear the full adjustments
- ▶ As the remainder of the economy adjusts, exchange rates slowly fall back
- ▶ This leads to a reversal of the initially excessive exchange rate movement

## Exchange rates over-adjust

- We can now establish some relationship between long-term and short-term exchange rates.
- Initially exchange rates bear the full adjustment to a monetary shock and will therefore move significantly.
- As the remainder of the economy adjusts to the monetary shock, such as prices changing, the exchange rate reverses some of its initial movement. In a different model we could similarly make other, slow, adjustment, for example by allowing production to increase, and obtain qualitatively similar results.
- We see a large reaction of the exchange rate to the monetary supply shock, which is then reversed over time.
- Thus in the long run interest rate parity and purchasing power parity are fulfilled, but in the short run we can see substantial deviations of the exchange rate, or the changes in the exchange rate, from these theories. This is due to exchange rates being able to adjust faster than other macroeconomic variables and hence bearing the burden of the initial adjustment alone, before then falling back.



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