# Open Economy Inflation Targeting

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**Preliminary and incomplete**

**Abstract**

The purpose of this compendium is to show how some of the models in Rødseth: *Open Economy Macroeconomics*, Cambridge University Press 2000 can be adapted and applied to discuss inflation targeting. All conclusions are contingent on the models presented.

# Chapter 1

# Introduction

The purpose of this compendium is to show how some of the models in Rødseth (2000) can be adapted and applied to discuss the case of inflation targeting. Inflation targeting is discussed in Section 10.1 of the book. However, had the book been written today the widespread adoption of inflation targeting would have warranted an integration of inflation targeting in several of the chapters and in models that are richer than the one in Section 10.1. As in the book, focus will be on open economy issues, exchange rates, current accounts and capital movements.

Writing the supplement is challenging for a number of reasons:

1. Inflation targeting is not a single, precisely defined policy. In fact it is often defined as a framework for conducting a rather flexible monetary policy. Any framework that gives sufficient priority to meeting an explicit target for the inflation rate over some time horizon may qualify. Usually the interest rate is seen as the main or the only instrument to achieve the target.

2. Traditionally text-books (and economic research) concentrated on two main types of monetary policy, one where the central bank targeted the money supply and one where it targeted the exchange rate. Rødseth (2000) is no exception. Monetary policy has a more immediate effect on the exchange rate and the money supply than on the inflation rate. Hence, time lags become more prominent in discussions of inflation targeting. For technical reasons economists have preferred to handle these issues in discrete-time models, while the main parts of Rødseth (2000) uses continuous time. The complexity of the lag structure in

commonly used models means that numerical simulations often have to be used to get conclusions. This is less attractive in a text-book, where transparency is paramount.

3. In the literature there are two different approaches to describing how central banks set interest rates under inflation targeting. One models central banks as maximizing a preference function over inflation and output (and possibly other variables) given the structure of the economy. The other starts directly with a relationship that purports to the describe how the interest rate setting depends on the state of the economy. The Taylor rule is a prominent example of the latter. The first approach has an obvious advantage when it comes to producing good ideas for how to conduct policy. However, the second approach may sometimes be more illuminating in a pedagogical setting.

4. Model-consistent (rational) expectations are always an important benchmark for assessing policies. The book shows in Sections 4.1 and 6.7 how one can form unique model-consistent expectations when the money supply is fixed, and how these expectations determine the future path of the price level. However, having an inflation target is not, by itself, sufficient to produce unique solutions for the price level. There may turn out to be a whole set of (non-explosive) rational expectations paths for the price level. This paradox is discussed further in Section 2 below.

In the present compendium we stick as close as possible to the book but take an ad hoc approach to expectations. They are assumed to display some degree of rationality but are not always fully consistent with the model we discuss. We emphasize the consequences of pursuing the inflation target without regard for the other aims that often are part of actual policy frameworks. We downplay the policy lags and the difficulty of forecasting inflation. This means that one should not jump to strong conclusion about how policies are or should be conducted. In actual policy making there are more variables to consider, more lags, more information problems, a more complicated structure of the economy etc. Remember that all conclusions are contingent on the models presented.

# Chapter 2

# Targeting inflation in the simple monetary model of Chapter 4

Recall that in this model there is a single good which costs the same abroad and at home when prices are measured in the same currency. Prices are fully flexible. The output level is determined from the supply side. There is uncovered interest rate parity and the money supply is exogenous. Hence, money demand plays a crucial role in the determination of the price level.

With an inflation target the money supply become endogenous, and the model has to be supplemented with a new relation that describes how the interest rate is related to the inflation target, to the state of the economy and to expectations of the future state. Suppose the inflation target is $\bar{\pi}$. Inflation-targeting central banks often claim to be forward looking, meaning that they are concentrating on hitting the target in the future and not just responding to past deviations in inflation. This is also often recommended in the theoretical literature. Inspired by Taylor-rules we may first try out the assumption that central bank behavior can be described by the function:

$$i = i_0 + \phi(\pi_e - \bar{\pi}) \tag{2.1}$$

where $i$ is the interest rate, $\pi_e$ is the expected inflation rate, $\phi$ a positive constant and $i_0$ the interest rate that will be set when expected inflation is equal to the target.

The rule for setting the interest rate has to be consistent with the interest rate parity condition

$$i = i_* + e_e \tag{2.2}$$

where $i_*$ is the foreign interest rate and $e_e$ is the expected rate of depreciation. Furthermore, it seems reasonable to require that the expectations of inflation and depreciation are consistent with each other, which, in view of that the model assumes purchasing power parity, means

$$\pi_e = e_e + \pi_{*e} \tag{2.3}$$

where $\pi_{*e}$ is the expected rate of inflation abroad. Combining the last two equation yields real interest rate parity:

$$i = i_* - \pi_{*e} + \pi_e \tag{2.4}$$

For arbitrary levels of $\pi_e$ equations (1) and (4) are inconsistent. The interest rate cannot both be determined by the central bank and by the expectations that prevail in the markets. This means that in the extremely open economy with perfect capital mobility the central bank is able to affect the nominal interest rate only if it can affect expectations. Expectations have to be endogenous and monetary policy is all about managing expectations.

Consistency between the two equations require that benchmark interest rate $i_0$ is set in accordance with the interest rate parity condition. Suppose $\pi_e - \bar{\pi}$. Then according to (1) $i = i_0$. However, for this to be consistent with equation (4), we have to have

$$i_0 = i_* - \pi_{*e} + \bar{\pi} \tag{2.5}$$

In words, the benchmark interest rate has to be equal to the foreign *real* interest rate plus the domestic inflation target. Hence, the interest setting rule can be reformulated as

$$i = i_* - \pi_{*e} + \bar{\pi} + \phi(\pi_e - \bar{\pi}) \tag{2.6}$$

Still this is not consistent with (4) except in the special case that $\pi_e = \bar{\pi}$. The implication is that the only inflation expectations that are consistent with the model are $\pi_e = \bar{\pi}$. Indeed, if we set $\pi_e = \pi$ ($\pi$ being the actual inflation rate) and $e_e = e$ the only solution to equations (2), (3) and (6) is $\pi = \bar{\pi}$, $i = i_* - \pi_{*e} + \bar{\pi}$ and $e = \bar{\pi} - \pi_{*e}$. Inflation targeting in this economy seems miraculously simple! Just set the domestic interest rate equal to the foreign interest rate plus the target inflation rate and inflation becomes equal to the target.

Alas, this is too good to bee true. The exchange rate is free to jump at any time, and, hence, the price level is free to jump too. The most we can get from the reasoning above is the expected future inflation rate. It tells us nothing about what the price level will be now. When the money supply was exogenous we could use this as a nominal anchor determining where the price level ends up in the long run. Then we could reason backwards to what the present price level should be. No such nominal anchor is available here. The absolute price level plays no role in the model above, and, hence, there is no way in which it can be used to determine the present price level.

The solution for the inflation rate is illusory. Future price levels are as indeterminate as the present. Given the model there is really no rational way to form expectations about the inflation rate. With fully flexible prices and perfect capital mobility a simple forward-looking rule for interest rate setting like (1) cannot provide a sufficient nominal anchor for the economy. This problem is not confined to extremely open economies.

Before we discuss ways to get around the problem, it is useful to take a look at price level targeting which is an alternative to inflation targeting. Suppose the target for the price level is $\bar{P}$. For simplicity assume that the foreign price level, $P_*$, is constant. Assume that the central bank raises the interest rate when the price level is above the target, lowers it when it is below, according to

$$i = i_* + \phi(P - \bar{P}), \qquad \phi > 0 \tag{2.7}$$

Given that $P = EP_*$ this is the same as

$$i - i_* = \phi(EP_* - \bar{P})$$

Assuming interest rate parity and model consistent expectations the left hand side can be replaced by the rate of depreciation:

$$\frac{d\dot{E}}{E} = \phi(EP_* - \bar{P}) \tag{2.8}$$

This is a differential equation for $E$. It is unstable, but has a unique stable saddle path which is given by $EP_* = \bar{P}$ or $P = \bar{P}$. The solution method is the same as was used for the case with exogenous money supply in the book (and subject to the same criticism). Here, there is a nominal anchor that helps pin down the price level, provided that people believe in the long-run stability of the system. Note that targeting the price level in this case is similar to targeting the exchange rate. Differences appear only if the foreign price level is changing.

There are different ways of getting around the problem with the indeterminacy of the absolute price level with exchange rate targeting. One obvious way is to introduce a backward looking term in the interest setting rule. This is a bit like introducing a moving price-level target linked to the price level in the recent past. With the right parameters in the interest rate rule this can give a unique saddle path for prices. Another escape route is to drop the assumption of fully flexible prices. Price rigidities creates a tie between past and future prices. If this link is sufficiently strong, the future price level can be 'anchored' by the present price level. This route is often taken in the literature. However, it may fail to work in highly open economies where the flexibility of the exchange rate weakens the anchoring effects of eventual price rigidities. In the literature one can also see cases where elements of exchange-rate targeting is brought in explicitly or implicitly. However, it should be obvious that if prices are fully flexible, a central bank with an inflation target cannot just look to future inflation. It must also to some degree respond to recently observed jumps in the levels of flexible prices unless these are expected to be temporary blips. The inflation target would loose credibility if big one-time jumps in the price level were allowed to happen without response. Further discussions of this matter can be technically demanding and is outside the scope of this compendium.

> *Technical note.* Some care is needed when defining the inflation rate in economies where the price level is free to jump. In the model above the price level, $P$, is the product of the exchange rate and the foreign price level, $P = EP_*$. All three variables in this equation are in principle free to jump at any time. In continuous time models the inflation rate is defined as the, $\pi = (dP(t)/dt)/P$. The derivative $dP(t)/dt$ does not exist at points where there are jumps in the price level. However, as explained in Section 4.2 in the book, we cannot have expected jumps in the exchange rate. The expected future path of the exchange rate must be continuous, and the same argument can be made for expected future price levels. Hence, we can define $\pi_e(t)$ as the expected slope of $P(t)$ when we look towards the future.

# Chapter 3

# Targeting Inflation in a Mundell-Fleming Setting

*This chapter is related to sections 6.1-6.5 and 6.7 in OEM*

This chapter starts the discussion of how the central bank in a small open economy will respond to different types of exogenous disturbances when aggregate output may deviate from equilibrium for shorter or longer periods. Central to the discussion is how the end results of exogenous impulses are modified by the response of the central bank. The impulses may come from abroad, from government policy or from changes in private sector behavior. The main emphasis is on temporary disturbances and business cycles, but the chapter ends with a brief section on the effects of permanent shocks.

The setting is the traditional one from Mundell-Fleming- models where there are home and foreign goods with prices $P$ and $P_*$ respectively. The prices are set in the producer's currency. They change only gradually over time. Hence, at any point in time their levels are predetermined and output is determined by demand. The exchange rate is floating freely, capital mobility is perfect and the central bank uses the interest rate as its instrument. The model can be compressed into an $IS$-equation describing how aggregate demand depends on the interest rate and other variables, an equilibrium condition for the foreign exchange market ($FX$-equation) and a price setting equation (Phillips-curve).

Because of the focus on inflation in a setting where prices are rigid in the short run, we need a dynamic model that can describe the evolution of prices over time. We shall discuss how the economy moves from short run to "long run equilibrium". The latter is a state where the inflation rate is constant, output, $Y$, is equal to capacity, $\bar{y}$, and domestic and foreign real interest rates, $\rho$ and $\rho_*$ are equal to a common long-run value $\bar{\rho}$. We disregard the changes over time in asset stocks. Hence, our "long run" should not be too far away. It is more like an intermediate state. We shall also ignore the wealth effects of jumps in the exchange rate, although these can easily be added in.

In sections 3.1-3.3 we take the values of all real variables in the long-run equilibrium as given. Then we can conduct the major part of our discussion in a model formulated in terms of relative deviations from long-run equilibrium. In section 3.4 we will come back to what happens when the long-run equilibrium changes.

**The IS-curve** We assume that the demand for home goods is a function of the real interest rate $\rho$, the real exchange rate $R$ and foreign output $Y_*$. We can then write the $IS$-equation in terms of deviations from long-run equilibrium as

$$y - \bar{y} = -\alpha_\rho(\rho - \bar{\rho}) + \alpha_r(r - \bar{r}) + \alpha_* u_{y*} + u_d \tag{3.1}$$

We use the convention that $x = \ln X$, $\bar{x}$ is the value of $x$ in long-run equilibrium and $\dot{x} = dx/dt = \dot{X}/X$ (the relative rate of change in $X$ over time). Hence, $y - \bar{y}$ can be interpreted as the output gap measured in percentage points. $u_d$ is a temporary demand disturbance. It may for instance represent temporarily high government expenditures. Demand disturbances that come from varying levels of economic activity abroad, $u_{y*} = y_* - \bar{y}_*$, are singled out for specific attention.

The real exchange rate is defined as $R = EP_*/P$ where $E$ is the nominal exchange rate. In logs:

$$r = e + p_* - p \tag{3.2}$$

The real interest rate is by definition

$$\rho = i - p_e \tag{3.3}$$

where $i$, is the nominal interest rate and $p_e$ the expected rate of inflation.

**The FX-curve** Turning to the foreign exchange market, uncovered interest rate parity means that

$$i = i_* + \dot{e}_e \tag{3.4}$$

Here $i_*$ is the foreign interest rate and $\dot{e}_e$ is the expected rate of depreciation. We need to be a bit more specific about exchange rate expectations than in OEM 6.2-6.4 [1]. Since $i_*$ is exogenous, any change that the central bank makes in $i$ has to result in an equal change in the expected rate of depreciation. Hence, how we model expected depreciation is crucial for what the model says about the effects of monetary policy. In the first part of this section we look only at temporary disturbances. Then we can assume that the real exchange rate in long-run equilibrium, $\bar{R}$, is constant and use this as an anchor for exchange rate expectations. If the actual real exchange rate, $R$, is depreciated relative to $\bar{R}$, it seems reasonable to expect it to return gradually towards $\bar{R}$. In particular we assume that the agents expect that

$$\dot{r_e} = -\epsilon(r - \bar{r}) + u_r, \qquad \epsilon > 0 \tag{3.5}$$

where $u_r$ is an exchange rate disturbance representing exogenous noise in expectations[2] and a high $\epsilon$ means that the approach to equilibrium is expected to be fast. Obviously the actual speed of convergence and the whole time profile of $r - \bar{r}$ will depend on the time profile of the disturbances that brought $r$ away from long-run equilibrium in the first place. Later we shall see that the expectations that come out of (3.5)will be the same as those that come out of the whole model if all disturbances have an expected path of the form $\dot{u} = -\epsilon u$. This is a restrictive assumption, but it serves as a benchmark case.

Recall that by definition $r = e + p_* - p$. In a long run equilibrium, where $r = \bar{r}$, the nominal exchange rate then moves according to $\dot{e}{=}\dot{p}{-}\dot{p}_*$. Exchange rate movements will compensate fully for any discrepancy between foreign and domestic inflation. Temporary disturbances will,as we shall see, make the nominal exchange rate jump and move $r$ away from equilibrium. The expected gradual return of $r$ to equilibrium must then take place through gradual changes in the nominal exchange rate and / or the price of home

[1] Finding a good way of representing exchange rate expectations under inflation targeting in short-run models has been a difficult problem and there may be better solutions than the one offered here. Purist would argue that one should only work with full dynamic models integrating the short and long run and having model-consistent expectations. However, there are insights to be gained also from focusing on the short run and from discussing the effects of exogenous variations in expectations.

[2] Usually a disturbance also is added to (3.4) and interpreted as a stochastic risk premium. Disturbances added to (3.4) and (3.5) will in most cases have the same effects.

goods. Consistency between the different expectations then requires that

$$\dot{e}_e = \dot{p}_e - \dot{p}_* + \dot{r}_e = \dot{p}_e - \dot{p}_* - \epsilon(r - \bar{r}) + u_r \tag{3.6}$$

This is the way that $\bar{r}$ provides the anchor for exchange rate expectations. The expectations are regressive in the sense used in OEM. If we insert the expected depreciation from (3.6) in the interest parity condition (3.4) and solve for $r$ we get the equilibrium condition for the foreign exchange market or $FX$-equation

$$r - \bar{r} = -\frac{1}{\epsilon}(i - \dot{p}_e - i_* + \dot{p}_* - u_r) = -\frac{1}{\epsilon}(\rho - \rho_* - u_r) \tag{3.7}$$

This says that the real exchange rate will deviate from long-run equilibrium when the real interest rates at home and abroad are different. A high $\epsilon$ means that interest rates have a small effect on the real exchange rate, because it is expected to return quickly to equilibrium.

**The Phillips-curve** As price-setting equation we use an expectations-augmented Phillips-curve:

$$\dot{p} = \dot{p}_e + \gamma(y - \bar{y}) + u_s, \qquad \gamma > 0, \tag{3.8}$$

Here inflation depends one for one on expected inflation. It also increases with the output gap. $u_s$ is a cost-push shock. It may reflect factors such as union militancy, deviations from trend productivity growth or reduced competition in product markets.

When $u_s = 0$, it appears from (3.8) that model consistent expectations are possible only when the output gap is zero. However, $\dot{p}_e$, should not be interpreted literally as the expected inflation rate at a specific moment. Since there is some degree of short-run price rigidity, we can think of $\dot{p}_e$ as a measure of what price and wage setters think is the normal rate of inflation around this time.[3]

[3]The details of the price-setting relation are controversial. The most popular version today is perhaps the so-called new-Keynesian Phillips-curve where there is a coefficient $\beta$ less than, but close to, one in front of $\dot{p}_e$, which is then interpreted as the mathematical expectation of $\dot{p}$. That $\beta < 1$ opens the possibility for this type of fully model consistent expectation with output gaps different from zero. The reason given for preferring the new-Keynesian Phillips-curve is that it has "proper micro foundations" based on what is called Calvo pricing. However, this argument is based only on a convention to limit the

The consumer price index, $p_c$, is a weighted average of the two goods prices, $P_c = P^{1-\phi}(EP_*)^\phi$ with $0 < \phi < 1$. Hence, consumer price inflation is

$$\dot{p}_c = (1-\phi)\dot{p} + \alpha(\dot{e} + \dot{p}_*) = \dot{p} + \phi\dot{r} \tag{3.9}$$

Often $\dot{p}$ is called the domestic component of inflation while $(\dot{e} + \dot{p}_*)$ is called the imported or foreign component.

**Solution** So far we have not discussed how $i$ and $\dot{p}_e$ are determined. In the case of $i$ we leave it to the coming sections to discuss how the central bank should set $i$ in response to different disturbances. In the meantime we will be satisfied if the model can tell us the effects of $i$ on the rest of the economy.

The central bank has to consider how to respond to the actual inflation expectations that exist in the economy. Hence, it is useful to start the discussion with exogenous inflation expectations. Model consistent expectations are by definition a kind of self-fulfilling prophesies[4]. There is a danger to basing monetary policy exclusively on model consistent expectations. By constructions these models usually tend to make inflation converge quickly to target as the result of a self-fulfilling prophesy. This seems to understates the problems actual central banks have in reaching their targets. However, central banks and political authorities do influence inflation expectations in several ways. We will touch on this in the sequel, but mostly we shall treat $\dot{p}_e$ as given.

The $u$s and the stared and bared variables are exogenous. For given levels of $i$ and $\dot{p}_e$ it is easy to solve the model for the remaining variables, which are endogenous. Together $i$ and $\dot{p}_e$ give us the real interest rate $\rho$. The $FX$-equation (3.7) then gives us the real exchange rate $r$. Next we get the output level from the $IS$-equation (3.1). All real variables have then been determined. The rate of producer price inflation follows from the Phillips-curve (3.8). Other nominal variables are easily winded up. As an example, since $P$ and $P_*$ are predetermined, the nominal exchange rate moves one for one with the real exchange rate.

competition of ideas in economics. Empirically the matter is not settled, although there is some indication that the relation between expected and actual inflation may be non-linear with the marginal effect of expectations being smaller than one when inflation is close to zero and equal to one when inflation is high.

[4]This holds in expectation or on average. Shocks happen of course, and actual outcomes always differ from expectations.

Monetary policy in this model works through three channels:

1. The interest rate channel: An increase in the nominal interest rate, raises the real interest rate, lowers demand for home goods, lowers the output gap and reduces inflation.

2. The exchange rate channel: An increase in the nominal interest rate, raises the real interest rate, which increases the demand for the domestic currency. This appreciates both the real and the nominal exchange rate, lowering demand for home goods, lowering the output gap and lowering inflation.

3. The expectations channel: If central bank actions or communication reduces $\dot{p}_e$, this reduces inflation directly and through raising the real interest rate.

The plan for the remaining sections of the chapter is: In sections 3.1 and 3.2 we discuss how a central bank with an inflation target should respond to the types of temporary disturbances that can occur in the model. In section 3.1 the discussion is based on that the inflation target relates to the domestic component of inflation only. In section 3.2 we discuss how conclusions change if the target is instead for consumer prices. In 3.3 we discuss how the central bank should respond when its policy lacks credibility. In 3.4 we discuss policy responses to permanent shocks.

## 3.1 Targeting the domestic component of inflation. The case with full credibility

In section 6.4 of OEM, which discusses short-run equilibrium with floating exchange rates, the $ISFX$-curve describes the relationship between output and the interest rate given that there is short-run equilibrium in the goods market and the foreign exchange market. Monetary policy is described by a $LM$-curve, and the short-run equilibrium is found at the intersection between the $ISFX$- and the $LM$-curve. We can discuss inflation targeting within a similar framework where we keep the $ISFX$-curve, but replace the $LM$-curve with an $IT$-curve ($IT$ for inflation target) that describes the relation between $i$ and $Y$ that follows from that the central bank is pursuing an inflation target, see figure 3.1.

If we insert for $r$ from $FX$-equation (3.7) in the $IS$-equation (3.1), we get the $ISFX$-curve

$$y - \bar{y} = -(\alpha_\rho + \alpha_r/\epsilon)(\rho - \bar{\rho}) + (\alpha_r/\epsilon)(\rho_* - \bar{\rho} + u_r) + \alpha_* u_{y*} + u_d \quad (3.10)$$

This tells us the combinations of output and interest rate that are compatible with joint equilibrium in the markets for goods and for foreign exchange. The effect of an increase in $\rho$ (or in $i$) on output is the sum of the effects through the interest rate channel and the exchange rate channel. The semi-elasticity of output with respect to the real interest rate when both channels are taken account of, $\alpha = \alpha_\rho + \alpha_r/\epsilon$ plays an important role in the sequel. The more open the economy is, the higher is $\alpha_r$ and $\alpha$. Thus, a more open economy is expected to have a flatter $ISFX$-curve. [5] If in addition the exchange rate is expected to return only slowly to equilibrium ($\epsilon$ low) this makes the $ISFX$ -curve even flatter. The same two factors also increases the effect of disturbances from the international capital markets on domestic output.

Suppose the inflation target is $\bar{\pi}$ and that it is fully credible in the sense that $p_e = \bar{\pi}$. Then the Phillips-curve becomes

$$\dot{p} = \bar{\pi} + \gamma(y - \bar{y}) + u_s \quad (3.11)$$

and, unless there is a cost-push shock, all the central bank has to do is to set the interest rate at the level that makes $Y = \bar{Y}$. In figure 3.1 this monetary policy is represented by the vertical $IT$-curve. The equilibrium is where the $IT$-curve intersects with the $ISFX$-curve.

**Demand disturbances** If figure 3.1 gives the correct picture, the implication is that under inflation targeting shocks to aggregate demand and shocks to the foreign exchange market have no effect on output. Expansionary demand shocks shifts the $ISFX$-curve to the right, raises the interest rate and, thus, leads to an immediate appreciation of the currency. A depreciation shock (an increase in $u_e$) also shifts the $ISFX$-curve to the right and will be met by an increase in the central bank's interest rate. This will dampen the depreciation and neutralize the effect on aggregate demand.

Figure 3.2 gives an alternative illustration. The $FX$-curve defined in (3.7) shows the combinations of interest rate and exchange rate that yield

[5] It may appear that a low $\epsilon$ also increases the relative importance of the exchange rate channel. However, if a disturbance is expected to last, one can argue that this is bound to increase the effects of both channels. Perhaps we should divide $\alpha_\rho$by $\epsilon$.

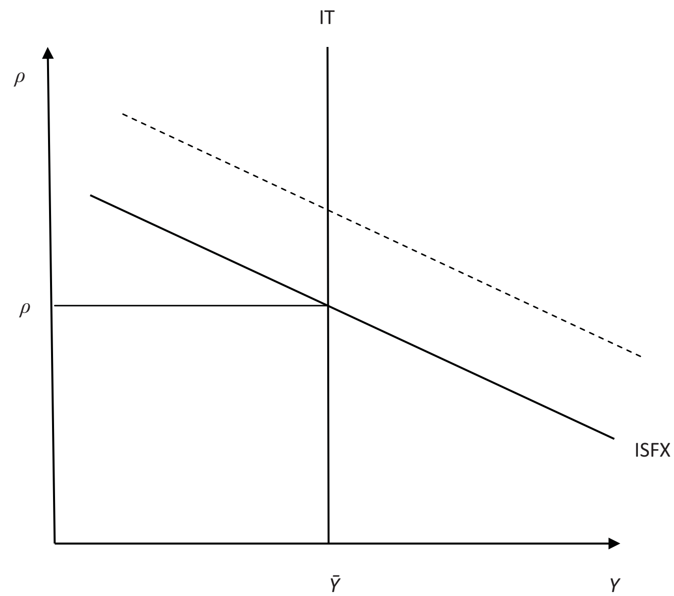


Figure 3.1: Goods market equilibrium

equilibrium in the foreign exchange market. Its slope is $-1/\epsilon$. The $MP$-curve shows the combinations of exchange rate and interest rate that yields $Y = \bar{Y}$. It is derived from the $IS$-curve (3.1) with $y = \bar{y}$ which yields

$$r - \bar{r} = \frac{1}{\alpha_r}[\alpha_\rho(\rho - \bar{\rho}) - \alpha_* u_{y*} - u_d] \tag{3.12}$$

and has slope $\alpha_\rho/\alpha_r$. A more depreciated exchange rate means that the central bank has to set a higher interests rate in order to close the output gap and keep inflation on target. Hence, the $MP$-curve slopes upward [6]. A positive demand shock means that for a given exchange rate a higher interest rate is needed in order to keep aggregate demand at $\bar{Y}$ and inflation in check. Hence, the $MP$-curve shifts to the right. The distance from a to b tells how much the interest rate would have to increase if the exchange rate did not respond. However, an increased interest rate induces an appreciation which

[6] The overall strictness of monetary policy is sometimes measured by a *monetary condition index* that is a weighted average of the relative deviation of the interest rate and the exchange rate from their reference or equilibrium levels. The weights are then $\alpha_r/(\alpha_r+\alpha_g)$ and $\alpha_\rho/(\alpha_\rho + \alpha_r)$.

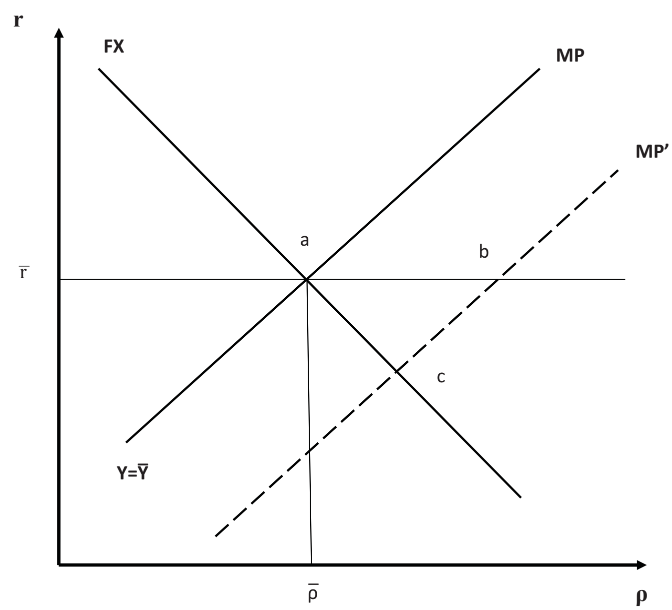


Figure 3.2: Effect of a positive demand shock

brings the economy to c. This reduces the necessary increase in the interest rate.

Figure 3.3 shows the effect of a depreciation shock. The $FX$-curve shifts up and if the interest rate were kept constant, the new equilibrium would be in b. However, a depreciated exchange rate is equivalent to a looser monetary policy and the central bank needs to tighten. It will raise the interest rate until we get to c, where the overall stance of monetary policy is again consistent with keeping inflation on target. In this way inflation targeting also makes a contribution towards stabilizing the exchange rate. The more open the economy is, the higher is $\alpha_r$ likely to be and the flatter will the $MP$-curve be. As we can see from the graph, this means that the more open the economy, the more will monetary policy stabilize the exchange rate when there are foreign exchange shocks.

Impulses from the business cycle abroad are transmitted through the two variables $Y_*$ and $\rho_*$. The former works like a demand shock, the latter like an exchange rate shock. The central bank will respond accordingly and keep the output gap equal to zero. In a highly open economy with a relatively flat $MP$-curve, changes in interest rates abroad have a strong impact on the

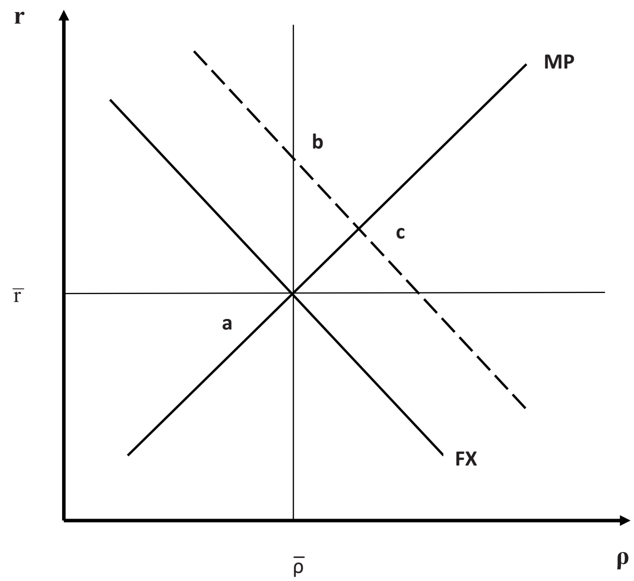


Figure 3.3: Effect of a depreciation shock

home interest rate, but always less than one for one.

A high $Y_*$ may be accompanied by a high or low $\rho_*$ depending on whether the high output is caused by an expansionary monetary policy or by an expansionary demand shock that the foreign central bank tries to counter with a tight monetary policy. Note that foreign inflation in itself has no effect on aggregate demand or on domestic producer price inflation as long as the foreign real interest rate is constant. This can be seen from equations (3.1) and (3.7) and is is a consequence of the assumption that agents expect exchange rate movements to neutralize foreign inflation.

That inflation targeting insulates completely both output and inflation against impulses from abroad may seem to be at odds with recent experiences. Two factors to consider are :

- If inflation is generally low and the world is in recession, every country may have an incentive to reduce interest rates. However, every currency cannot depreciate at the same time. For the world as a whole the expansion of aggregate demand depends on the interest rate effect alone. This may not be sufficient to close the output gap. Just like there may be competitive devaluations there may be competitive cuts in interest rates. In a serious international recession the result could easily be that most countries end up having nominal interest rates close to the lower bound at zero (or slightly below). With perfect capital mobility there is then not much more the central bank can do.

- Small countries are often specialized in exporting a small number of goods which are exported in volumes many times larger than the domestic economy can ever absorb. If in addition labor and capital are not very mobile, a negative output gap may remain in the export industries no matter what the central bank does.

Figures 3.4 illustrates how the economy may develop after a demand shock. Figure 3.4-a shows the assumed time path for the disturbance itself. Graph b says that the policy is to close the output gap. Graph c illustrates that this is accomplished by an upward jump in the interest rate. Since the value of the disturbance declines over time, the interest rate can then be reduced gradually towards its old level. The high initial interest rate induces an immediate appreciation. As the interest rate is reduced, the real exchange rate depreciates towards its old level (graph d). Throughout the price of home goods is kept at its original path (graph e). The nominal exchange rate then follows the same path as the real exchange rate (graph f).

Graph g shows that the consumer price index makes a downward leap when the currency appreciates. Then it returns gradually to its old path as the currency depreciates back to its old level. Seen over the whole period, the average rate of consumer price inflation is equal to the inflation target. If we look at shorter periods, however, the deviation may be considerable. We return to this in section 3.2 where we discuss targeting the consumer price index.

**Supply shocks** The shocks we have discussed so far have in common that they do not create any conflicts between keeping inflation on target and keeping output equal to capacity. A cost-push shock is different. As can be seen from the Phillips-curve (3.11), when $u_s > 0$ the central bank has to aim for an output level

$$y_A = \bar{y} - \frac{1}{\gamma} u_s \tag{3.13}$$

below $\bar{y}$ in order to keep $\dot{p} = \bar{\pi}$. This means raising the interest rate and accepting that the currency appreciates. As the disturbance tapers off, the central bank can reduce interest rates and allow demand for home goods to increase. This policy is illustrated with the unbroken curves in figure 3.5. In the end the exchange rate and consumer prices will be back to where they would have been without the shock. That the graphs for interest rates and exchange rates have the same shape as in figure 3.4 is no surprise. This is because in both cases the central bank raises interest rates to curb demand. Note that the monetary policy suggested here means that initially the consumer price index falls in response to a positive cost push shock. Adherence to *strict inflation targeting,* as the policy just described is called, raises the output costs of cost-push shocks relatively to what they would be under fixed exchange rates.

**Flexible inflation targeting** As we just saw there is a conflict between the goals of keeping inflation equal to target and output equal to capacity when there are cost-push shocks. Strict inflation targeting means that the inflation target takes precedence over other goals. The actual mandates for central banks usually open for making a compromise that weighs in both goals. Standard models of *flexible inflation targeting* assume that the central bank minimizes a loss function that is a weighted sum of the squares of the output gap and the *inflation gap* $\dot{p} - \bar{\pi}$:

$$L = \frac{1}{2}(\dot{p} - \bar{\pi})^2 + \frac{\lambda}{2}(y - \bar{y})^2, \qquad \lambda > 0 \tag{3.14}$$

The weight $\lambda$ determines the relative influence of the two goals in the compromise that is to be made. In order to find the real interest rate that minimizes the loss we can first use the Phillips-curve (3.11) to substitute for $\dot{p} - \bar{\pi}$ in $L$:

$$L = \frac{1}{2}(\gamma(y - \bar{y}) + u_s)^2 + \frac{\lambda}{2}(y - \bar{y})^2$$

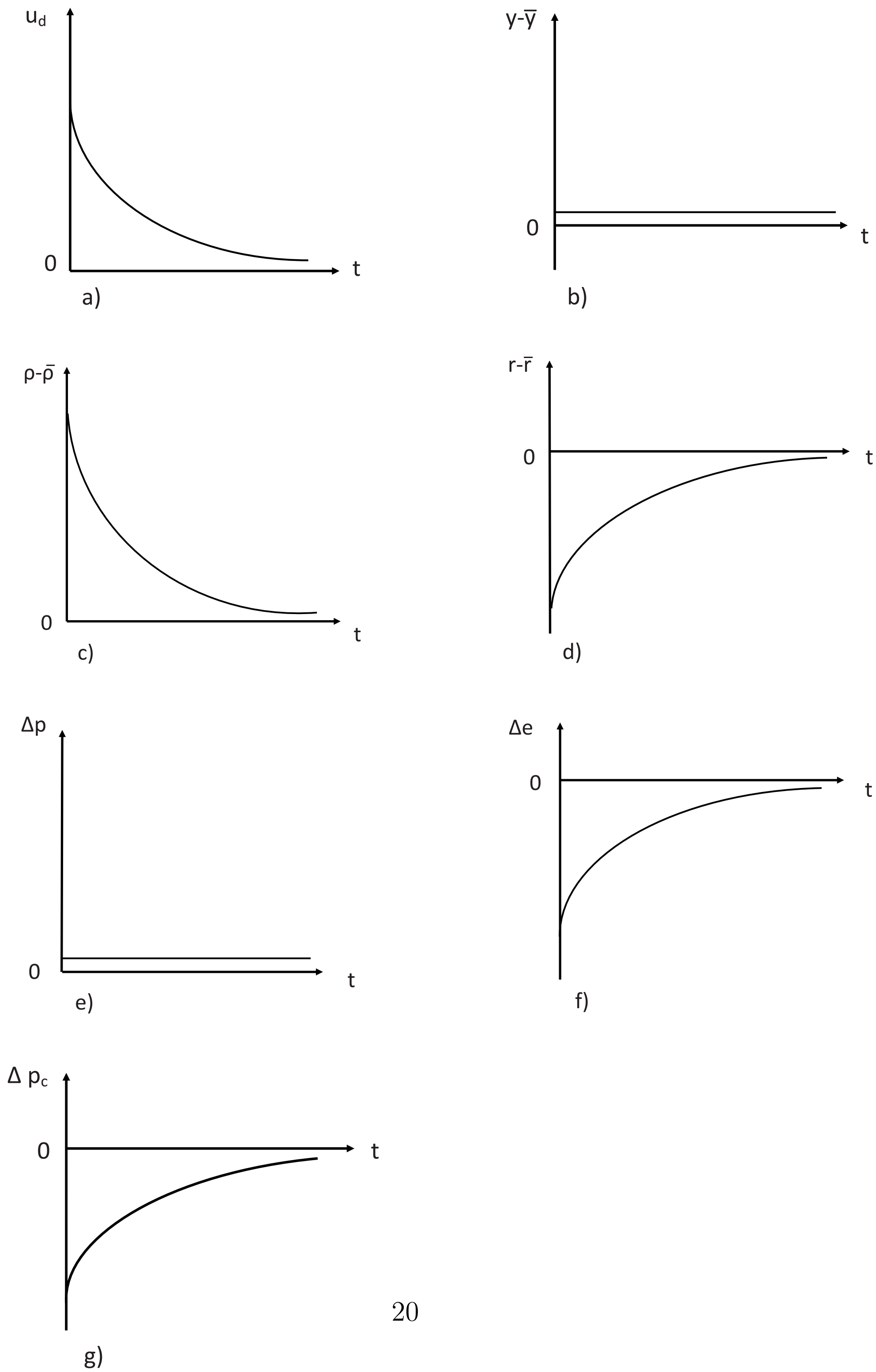


Figure 3.4: Effects of an expansionary demand shock. Deviations from equilibrium path.

For a given $\rho$, $y$ is determined by the $ISFX$-curve (3.10). Imagine that this is inserted for $y$ in the expression for $L$. The first order condition for a minimum of $L$ is then

$$\frac{dL}{d\rho} = \{\gamma[\gamma(y - \bar{y}) + u_s)] + \lambda(y - \bar{y})\}\frac{dy}{d\rho} = 0$$

It is easy to check that the second-order condition is satisfied. From before we know that $dy/d\rho = -\alpha \neq 0$. Hence, we can write the first order condition as

$$\dot{p} - \bar{\pi} = \gamma(y - \bar{y}) + u_s = -(\lambda/\gamma)(y - \bar{y}) \tag{3.15}$$

This implies that when it is not possible to make both gaps equal zero, the two should have opposite signs. Hence, *stagflation* - the combination of a positive inflation gap and a negative output gap - is acceptable. Excessive inflation combined with a booming economy is not. Conversely, deflation in a stagnating economy should be avoided, while deflation in a booming economy may be OK. A successful monetary policy may thus reverse the correlation between output gap and inflation that one would expect by just looking at the Phillips-curve in isolation. In this respect flexible inflation targeting differs from both fixed exchange rates and money supply targeting with flexible rates.

The interest rate that minimizes the loss can be found by inserting for $y$ from the $ISFX$-equation in the first-order condition (3.15) and solving for $\rho$. This yields

$$\rho - \bar{\rho} = \frac{1}{\alpha}\left[(\alpha_r/\epsilon)(\rho_* - \bar{\rho} + u_r) + \alpha_* u_{y*} + u_d + \frac{\gamma}{\gamma^2 + \lambda}u_s\right] \tag{3.16}$$

The output level the central bank should aim for can be found by inserting $\rho$ back in the $ISFX$-equation, or, more conveniently, by just solving the last equality in (3.15):

$$y_B = \bar{y} - \frac{\gamma}{\gamma^2 + \lambda}u_s \tag{3.17}$$

the resulting inflation rate is then from the Phillips-curve:

$$\dot{p_B} = \bar{\pi} + \frac{\lambda}{\gamma^2 + \lambda}u_s \tag{3.18}$$

A high weight on the output gap in the loss function reduces the absolute value of the output gap and increases the absolute value of the inflation gap.

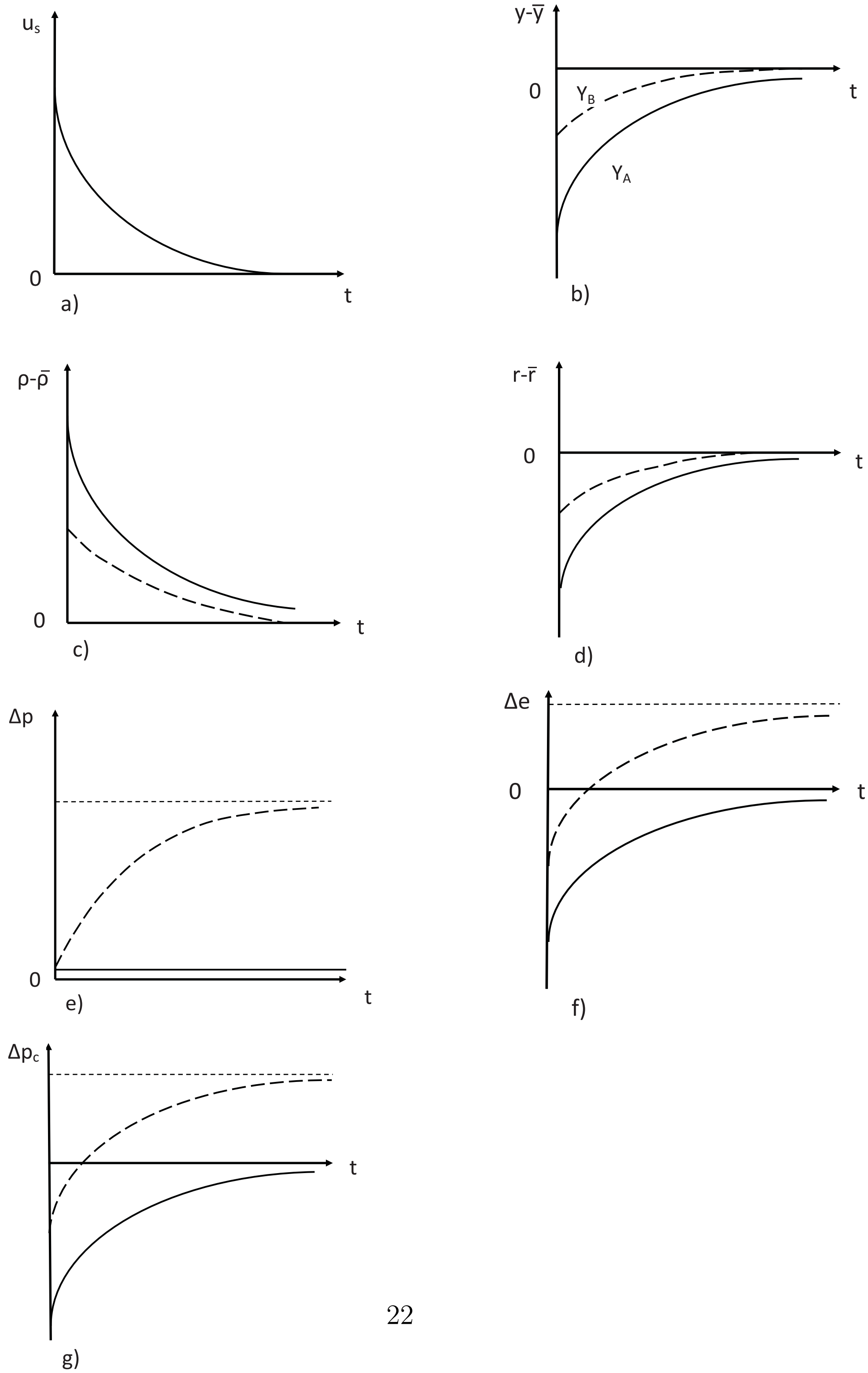


Figure 3.5: Effects of a positive cost-push shock

When $u_s > 0$, $\dot{p_B} > \bar{\pi}$ and $y_A < y_B < \bar{y}$. Output is between capacity and the level that makes inflation equal to target. The higher the weight on output stabilization, $\lambda$, the less will the central bank raise the interest rate. The symmetry of the loss function means that when competition between firms is increasing and productivity growth is rapid (negative cost-push) one should expect to see inflation below target and a positive output gap.

It remains to find the solution for the exchange rate. This follows easily by inserting the solution for $\rho$ in the $FX$-equation (3.7). The result is

$$r - \bar{r} = \frac{-1}{\alpha\epsilon}\left[-\alpha_\rho(\rho_* - \bar{\rho} + u_r) + \alpha_* u_{y*} + u_d + \frac{\gamma}{\gamma^2 + \lambda} u_s\right] \tag{3.19}$$

The broken curves in figure 3.5 illustrate the effects of a positive cost-push shock under flexible inflation targeting. Notice that the policy means that $P$ is bound to end up higher than if the central bank had stuck to the inflation target[7]. Since the real exchange rate should end up the same as before, the nominal exchange rate must then have depreciated proportionally with the increase in $P$. This means that the when we look at the whole adjustment period, both inflation and output has been higher than when the central bank kept strictly to the output target. Since the initial increase in the interest rate is lower, the initial appreciation is also smaller. The real exchange rate will then depreciate gradually as the central bank reduces the interest rate. At the same time the prices of home goods will be going up. This combination is possible only if the nominal depreciation is faster than the real depreciation, as by definition $\dot{e} = \dot{p} - \dot{p_*} + \dot{r}$.

One possible objection to the loss function (3.14) is that positive and negative output gaps are treated symmetrically. Implicitly extraordinary low unemployment is as bad as extraordinary high unemployment. However, the loss function should not be read as a direct statement about the underlying political preferences. It should rather be seen as a tool for coming up with suggestions for a reasonably good policy given the constraints that the structure of the economy places on what the central bank can achieve. With the assumed Phillips-curve being symmetric and linear around $\bar{y}$, it is not possible for the central bank to keep the average output level above $\bar{y}$ without

[7]Since the nominal price level in long-run equilibrium are determined by the historical path that led to the equilibrium, we measure the effects on $p$, $p_C$ and $e$ as changes relative to the path if the shock had not occurred. Hence the $\Delta$in the graphs.

inflation being over target on average[8]. This would destroy the confidence in the inflation target. Rebuilding confidence will require high unemployment. In these circumstances monetary policy is best conducted if it starts from the premise that it cannot affect the average output level. Then the choice is not between different average levels of output and inflation, but between different degrees of variability in the two. The loss function is about finding a reasonable compromise between a high volatility of output and a high volatility of inflation.

Since in the examples discussed so far inflation eventually comes back to target, it may be tempting to set $\lambda$ high. What harm can it do? The usual answer is that high volatility of inflation means poor resource allocation at the micro level because relative prices deviate more from their flex-price levels and perhaps because people get confused about the value of money. These are valid arguments, but it may be more important that a too high $\lambda$ risks undermining the credibility of the target as people observe larger deviations. In the model it is the belief that inflation will on average be $\bar{\pi}$ that makes inflation return there once the disturbances are over. It is just an assumption that these beliefs stay in place. If everybody sticks to them, then they are self-fulfilling prophesies[9] just like any other type of rational expectations will be within their models.

One implication of the view just expounded is that if confidence in the policy is strong and well established, the central bank may be able to conduct a more flexible policy, as if having a higher $\lambda$.

**Other supply shocks** Supply shocks may also be shocks to $\bar{Y}$. A positive shock of this kind will be fully accommodated by a central bank adhering to an inflation target, meaning it will lower interest rates in order that aggregate demand can increase to the same level as supply. The result will be a depreciation that makes home goods relatively cheaper both at home and abroad.

[8]Note that this argument applies to the output levels measured in logs. The (arithmetic) average of the absolute output levels can actually be reduced without increasing average inflation if we reduce the variance of output. With a loglinear Phillips-curve this is an additional argument for valuing a low variance of the output gap. The same argument can be made for any concave relationship between the output gap and inflation.

[9]In expectations and on average, new disturbances will of course occur.

**Practical considerations** Carrying out the policies discussed in this section will hit a number of practical problems. Among these are:

1. It takes time from a shock occurs until it is recognized by the central bank and interest rate decisions can be made. In the meantime there will be no interest rate response, Hence. the immediate effects of a shock will be better described by a model where the interest rate is fixed, e.g. the one in OEM section 6.4.

2. The nature of the disturbance (supply or demand) is often unknown. The central bank may observe that output and inflation have increased, but need time to identify the source.

3. The further development of the disturbance (expected time profile) is uncertain.

4. Changing the interest rate for a brief period has limited direct effect on demand for home goods, especially on long-term investments and investments requiring long construction periods. Even if we count in the exchange rate channel the short-run effect can be limited due to short-run constraints in logistics etc. Countering short-lived disturbances are likely to be infeasible, or require unpleasantly large movements in real interest rates.

5. Even short lived changes in interest rates may have lagged effects on aggregate demand that last beyond the life of the disturbances, e.g. through construction starts,

6. When demand is low, even a zero interest rate may be too low to create sufficient aggregate demand.

The upshot is that inflation will deviate from target and output from capacity even in the absence of cost-push shocks.

## 3.2 Targeting consumer price inflation

Actual inflation targets usually refer to the overall consumer price index rather than just the domestic component or, what amounts to the same in the present model, they refer to consumer prices rather than producer prices. Above we saw that consumer price inflation can be calculated as

$$\dot{p}_c = \dot{p} + \phi\dot{r} \tag{3.20}$$

We also saw that foreign inflation alone does not affect domestic inflation as long as the foreign real interest rate is constant.. Foreign inflation is neutralized by an opposing change in the nominal exchange rate.

Targeting the consumer price index creates a dilemma. While the prices $P$ and $P_*$ change only gradually, the exchange rate can jump instantaneously. The consumer price index then jumps too, as illustrated in figures 3.4 and 3.5. This means that keeping the rate of increase in consumer prices on target continuously is difficult if not impossible. If the interest rate is used to avoid jumps in the exchange rate, it cannot at the same time be used to keep output equal to capacity[10]. If there is a positive demand shock, raising the interest rate will lead to a one-shot fall in import prices measured in domestic currency. The initial appreciation can be avoided by not raising the interest rate, but prices of home goods will then start to increase. Consumer price inflation is bound to vary around the target. With only one instrument at disposal there is no escape.

In section 3,1 we saw that with strict targeting of the domestic component the average increase in the overall index over a full cycle would be equal to the target. Since relative prices in long run equilibrium are given, the same result can be obtained with strict targeting of the imported component. This would be a kind of crawling peg where the exchange rate is managed to compensate for variations in the foreign currency prices of imports. Aside from these two alternatives, strategies that ensure that disturbances do not affect the average inflation rate over their life-time are bound to be complicated.

**A forward-looking policy** It is often suggested that central banks should be forward-looking in their behavior and not try to compensate for past deviations from the inflation target. Jumps in exchange rates are associated with surprising new information. Many policy proposals explicitly or implicitly suggest that central banks focus exclusively on future inflation and ignores the immediate price effects that come from jumps in the exchange rate. We

[10] In practice it takes some time before the full effect of a depreciation is transmitted to consumer prices. This may ease some of the problems discussed here, but does not remove them.

shall look at how a strict version of such a policy would work when its is fully credible in the same sense as in section 3.1.

The policy then aims at making

$$\dot{p_c} = \dot{p} + \phi\dot{r} = \overline{\pi}$$

The price increase on home goods, $\dot{p}$, is still determined by the Phillips-curve (3.11 ) and UIP makes $\dot{r}_e = \rho - \rho_*$. If we assume that the central bank has the same exchange rate expectations as the private sector, the policy will be set in such a way that

$$\bar{\pi} + \gamma(y - \bar{y}) + u_s + \phi(\rho - \rho_*) = \bar{\pi}$$

or

$$\gamma(y - \bar{y}) + u_s + \phi(\rho - \rho_*) = 0 \tag{3.21}$$

Here we are faced with yet another problem. Raising the interest rate reduces inflation through reducing $y$. The marginal effect through this channel is $\gamma\alpha$, the product of the effects of the interest rate on output and of output on inflation . However, raising the interest rate also leads to an immediate appreciation which is expected to be followed by a depreciation. Only the latter matter for a forward-looking policy. The size of the expected depreciation is measured by the interest rate differential. Through this channel an increase in the interest rate raises inflation. The marginal effect is equal to $\phi$. If $\phi > \gamma\alpha$, the overall effect on inflation will be positive! However, this is a pathological case where the short-run market dynamics become unstable. Hence, the model is interesting only if we assume $\phi < \gamma\alpha$, which will be maintained from now on.

In the absence of cost-push shocks equation (3.21) implies that the output gap and the interest rate differential should have opposite signs. A positive interest rate differential means that a real depreciation is expected. Then we need prices on home goods to increase less than the target. There are only two ways this can come about, either a negative cost-push shock or a negative output gap.

In section 3.1 shocks originating on the demand side did not create any conflict between closing the output gap and keeping inflation on target. Here it is different. Consider a positive demand shock. The recipe from section 3.1 is to raise the real interest rate, and we just made sure that this will work here too. However, it creates a positive interest rate differential which signals a coming gradual depreciation. The output gap then has to be negative to allow low price increases on home goods to compensate for the expected depreciation. Aggregate demand and output actually goes down in spite of the positive demand shock.

We can find the equilibrium interest rates by inserting for $y - \bar{y}$ from the $ISFX$ - equation in (3.21). After reorganizing this yields

$$\rho - \bar{\rho} = \frac{1}{\gamma\alpha - \phi}\left\{[\gamma(\alpha_r/\epsilon) - \phi](\rho_* - \bar{\rho}) + \gamma[(\alpha_r/\epsilon)u_r + \alpha_* u_{y*} + u_d] + u_s\right\} \tag{3.22}$$

We see that the multipliers for supply and demand shocks approach infinity when the difference between $\phi$ and $\gamma\alpha$ goes to zero, a common sign that we are approaching a region of instability. Except for the foreign interest rate, all multipliers have the same sign and are greater than in section 3.1. The reason that interest rates have to be raised more, is the need to compensate for the direct effect of the expected future exchange rate movements on consumer price inflation. The effect of the foreign interest rate on its domestic counterpart is always lower than when the domestic component is targeted. If $\phi > \gamma\alpha_r/\epsilon$, the effect even changes sign from positive to negative. In the multiplier for the foreign interest rate $\gamma(\alpha_r/\epsilon)$ represents the positive effect of on future inflation due to increased demand for home goods via the initial depreciation, while$\phi$ represents the negative effect due to the expected future appreciation reducing the foreign component of inflation.

From the $FX$-equation we know that the solution for the exchange rate is just $-1/\epsilon$ times $\rho - \rho_* - u_r$ or

$$r - \bar{r} = \frac{1/\epsilon}{\gamma\alpha - \phi}\left\{\gamma\alpha_\rho(\rho_* - \bar{\rho} + u_r) - \gamma(\alpha_* u_{y*} + u_d) - u_s\right\} \tag{3.23}$$

The output gap can be found by inserting for $\rho$ in the $ISFX$ -curve, which results in

$$y - \bar{y} = \frac{-\phi}{\gamma\alpha - \phi}\left\{-\alpha_\rho(\rho_* - \bar{\rho}) + (\alpha_r/\epsilon) - \phi)u_r + (\alpha_* u_{y*} + u_d) + u_s/\gamma\right\} \tag{3.24}$$

Unlike in section 3.1, the output gap responds to all kinds of shocks, while in section 3.1 monetary policy guided by strict inflation targeting kept the output gap equal to zero for all shocks except cost-push.

**Flexible inflation targeting (For the record only)** Since there is a conflict between variability in output and inflation, we can bring in the loss function from section 3.1 and optimize like there. It still turns out that that the inflation gap and the output gap should have opposite signs. The solution for the real interest rate is

$$\begin{aligned}\rho - \bar{\rho} &= \frac{1}{(\gamma\alpha - \phi)^2 + \lambda\alpha^2}\left\{\left[(\gamma\alpha - \phi)(\gamma\alpha_r/\epsilon - \phi) + \lambda\alpha\alpha_r/\epsilon\right](\rho_* - \bar{\rho})\right.\\ &+ \left. +((\gamma\alpha - \phi)\gamma + \lambda\alpha)\left[u_d + \alpha_{y*}u_{y*} + (\alpha_r/\epsilon)u_r\right] + (\gamma\alpha - \phi)u_s\right\}\end{aligned}$$

For disturbances coming from the demand side, a positive weight on the output gap makes the outcome closer to what it would be if the target were the domestic component. This follows from that stabilizing producer price inflation and stabilizing output are more or less the same thing. A higher $\lambda$ reduces the interest rate response to all kinds of shocks. This means that the exchange rate will jump less in response to demand and supply shocks, which also contributes to stabilize output. The response to the foreign interests rate is less than one to one.

Sometimes it is suggested that the central bank should also care about the stability of the real exchange rate. We can include $r - \bar{r}$ in the loss function in the same way as the other gaps with a weight $\psi$. This has similar effects to increasing the weight on the output gap. In fact, if we replace the output gap in the loss function with the exchange rate gap, we get the same solution for the real interest rate except that $\lambda\alpha$ is replaced by $\psi/\epsilon^2$. By varying $\psi$ it is possible to span the whole range between forward-looking targeting of the overall index and targeting of the domestic component only.

**Alternative strategies** One question that comes up when comparing the policies we have discussed is this: Suppose we want consumer price inflation to vary as little as possible around an inflation target. How do we then compare two policies when the ranking between them depends on the length of the time period over which the inflation rate is defined. Should we use the quarterly, the yearly or the five-yearly inflation rates or should we use the whole spectrum to calculate the variation? In the model we are studying there is reason to believe that targeting the domestic component gives a high degree of stability of consumer price inflation if we use a long time period, while it scores less well for short periods. The crawling peg mentioned above may score well in both ends of the specter (in the short end because it avoids jumps in the exchange rate), but perhaps less well in the middle. Anyhow, the crawling peg is a kind of fixed exchange rate, and has very different properties than floating rates when it comes to stabilizing output.

The forward-looking strategy may in this perspective look illogical. If it is important to minimize deviations from target in every short period in the future, how can one then neglect the initial jumps? It is possible to act on jumps in exchange rates before they change prices. The usual arguments for letting bygones be bygones (for example when a policy mistake has been done) does not apply here. A literal interpretation of the loss function that we have used means that discrete jumps in the price level should be avoided at any costs since it produces an infinite loss. There are probably good reasons for taking an intermediate position, accepting jumps and care about their size. Then more thought should probably be given to what the appropriate loss function is.

Most models of inflation targeting use discrete time. Then the distinction between jumps and continuous movements gets blurred. The problems we have discussed are hidden, but still there.

In practice several factors will mitigate the importance of jumps in the exchange rate. For many goods there are long lags before exchange rate changes find their way to consumer prices. There is also pricing to market. Judged from the inflation reports that central banks issue, focus in policy making is usually on the expected path of the 12 month inflation rate. This indicates that policy is forward looking, but perhaps not to the same extent as in the example above. Next months 12 month rate includes price changes eleven months back from now.

One conclusion from the above is that it is not obvious that targeting the CPI is intrinsically better than targeting its domestic component. The degree of output stability achieved may be an important criterion when choosing between different inflation targets. However, the public focus on the overall index may mean that if one wants to achieve credibility it may be necessary to keep the overall CPI close to target. Conclusions in this area also depend on exactly how expectations of consumer and producer prices enter the Phillips-curve. Our assumptions may be criticized for been too simplistic on this point.

Another conclusion may be that if one target the overall index, one should avoid an asymmetric response to exchange rates, neglecting jumps but responding to aggressively to the later movements that over time reverses the jumps.

## 3.3 Lack of credibility

We now go back to the case where the target is for the domestic component of inflation. It may happen that $p_e > \bar{\pi}$, meaning that the inflation target does not have full credibility. Suppose the central bank practices strict inflation targeting. It then has to aim for an output level below $Y$. If it wants

$$\dot{p} = \dot{p}_e + \gamma(y - \bar{y}) = \bar{\pi},$$

it has to aim for:

$$y_A = \bar{y} - \frac{1}{\gamma}(\dot{p}_e - \bar{\pi}) \tag{3.25}$$

Thus, excessive inflation expectations $p_e > \bar{\pi}$ results in output and employment below capacity in the same way as a cost-push disturbance does. Figure 3.3 illustrates what happens in the markets for money and for foreign currency. The $FX$-curve (3.7) does not depend on expected inflation and stays put. The $MP$-curve shifts to the right, since a tighter monetary policy is needed to bring down output. The result is a higher real interest rate and a real appreciation. Since $\rho = i - \dot{p}_e$, this means that the central bank has to raise the nominal interest with more than the increase in expected inflation. In the literature the idea that the central bank should raise the *real* interest rate when inflation goes up, is known as the *Taylor principle*.

Since prices are predetermined, the initial real appreciation implies a nominal appreciation of the same size. One might think that higher expected inflation raises the expected future rate of depreciation and, hence, leads to an immediate depreciation. The reason we get an appreciation instead, is that is that the central bank overcompensates by raising the interest more than expected inflation has gone up.

As we have seen, if the interest rate is increased sufficiently, actual inflation will stay on target. The fact that actual inflation is below expected inflation will over time bring down inflation expectations. Private agents will realize that the central bank is determined to keep inflation on target and has the power to do so. The interest rate can then gradually be reduced and the nominal exchange rate will depreciate gradually. Obviously there is a lot to gain if the authorities can convince the public about its intentions just by talking though or other symbolic means.

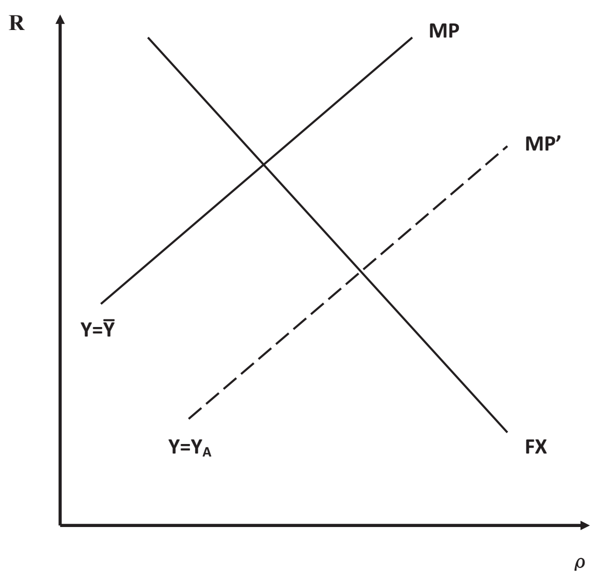


Figure 3.6: Effects of an increase in $p_e$ on real interest rates and exchange rates.

As long as the central bank sticks to the inflation target, all adjustments in the real exchange rate have to come through changes in the nominal exchange rate. This supports the assumption we made about exchange rate expectations in (4).

**Flexible inflation targeting** As with a cost-push shock, the central bank may be unwilling or unable to bring inflation down to the target at one stroke. There will then be a period of stagflation: high inflation combined with output below equilibrium. The interest rate is then set in order to achieve a level of aggregate demand somewhere between $Y_A$ and $\bar{Y}$. We may again apply the loss function from section 3.1 to find a middle way. Repeating the same procedure as there, we find that the optimal policy yields

$$y_B = \bar{y} - \frac{\gamma(\dot{p}_e - \bar{\pi})}{\gamma^2 + \lambda} \tag{3.26}$$

$$\dot{p} = \bar{\pi} + \frac{\lambda(\dot{p}_e - \bar{\pi})}{\gamma^2 + \lambda} \tag{3.27}$$

$y_B$ is between $\bar{y}$ and the $y_A$ that we found in (3.25). When $\dot{p}_e > \bar{\pi}$, $\bar{\pi} < \dot{p} < \dot{p}_e$. A high $\lambda$ means that the output gap should respond less to the gap between expected and target inflation. The higher the weight on output stabilization, $\lambda$, the less will the central bank raise the interest rate in response to expected inflation being above target. However, it should always increase the real interest rate. The argument made above can be repeated. Keeping the real interest rate constant will keep aggregate demand at $\bar{y}$. An increase in the real interest rate and a strong real exchange rate is needed to get any reduction in $y$.

The optimization approach taken here is somewhat simplistic, because it ignores the benefits that will come in later periods if expected inflation is brought down quickly. Essentially the central bank has to choose between a short and deep recession or a long and shallow one if the inflation rate is ultimately to be brought to the target. Taking account of the future gains would imply a more aggressive anti-inflation policy, but not an immediate return to the inflation target. Economic theory does not seem to have much to say about how much more convincing a deep recession is relatively to a shallow one.

So far we have been occupied with gaining credibility. There is also the issue of preventing loss. Policies that use longer time to meet the inflation target risks losing credibility. In countries that have a recent history of high inflation, central banks may have reason to be more concerned with loss of credibility than elsewhere. They may then be prone to practice less flexibility in case of e.g. supply shocks. On the other hand, if there is too little flexibility, the consequences for output and employment may seem so severe that this undermines the belief in the continuation of the policy regime from the other side. Speculative attacks on the currency may then occur.

[This section may be expanded later with paragraphs on learning models and on influencing expectations through different commitment devices.]

## 3.4 Permanent shocks

Permanent shocks would be shifts in $\bar{y}$, $\bar{y}_*$, $\bar{\rho}$ or $\bar{r}$. The first three can be seen as exogenous. In contrast $\bar{r}$ will usually change when one of the others change, but can also change for independent reasons. A true long-run equilibrium in a stationary context would have a balanced current account, zero net investment, endogenous wealth and endogenous capital stock. This goes well beyond the scope of the present chapter. Long run equilibrium in the context of the present chapter means a state where the output and inflation gaps are zero, the real exchange rate is constant, and expected and actual values are equal. We continue to focus on the case where the target is for the domestic component of inflation.

Our first example is a shift in the trade balance function that permanently shifts demand away from home goods and towards foreign goods.Equilibrium output does not change. Long run equilibrium then requires a decline in the relative price of home goods. In other words $\bar{r}$ has to go up. Assume that the economy initially is in long-run equilibrium without any disturbances. From (3.7) we see that the actual real exchange rate $r$ jumps immediately with $\bar{r}$ to its new level. Expected future depreciation causes depreciation now. This brings demand for home goods back to $\bar{y}$ and the economy remains in long-run equilibrium. No action is required from the central bank if its target is for the domestic component. The necessary change in relative prices take place through an immediate nominal depreciation. Thus, there will be a spike in consumer price inflation when the shift occurs. If consumer prices are targeted, there is the usual dilemma that the spike can be reduced but at a cost. This time the cost will be a gradual deflation, or inflation below target.

Even though the shift is in the trade balance-function, the trade surplus remains the same as before thanks to the flexibility of the exchange rate when the target is the domestic component.

How can a temporary demand shock have effects on output while a permanent demand shock has not? The reason is a that a temporary shock does not shift the $FX$-curve and therefore has no immediate impact on exchange rates.

If $\bar{y}$ goes up, long run equilibrium will require that demand is shifted towards home goods. This again requires a real depreciation. As above, this leads to an equally strong immediate depreciation. This is just what is needed to redirect enough demand to home goods to fill the new production capacity. Producer price inflation remain on target.

An increase in $\bar{\rho}$ will reduce domestic demand in the long run. This must be compensated by a real depreciation directing more demand towards home goods. Hence, $\bar{r}$ increases. To find out what happens in the short run, we can start by assuming that when the shift happens $\rho_*$increases in line with $\bar{\rho}$. If we then take a look at the $FX$-equation (3.7) we see that if the central bank makes sure that $\rho$ goes up in line with the foreign interest rates, then $r$ will jump straight to the new $\bar{r}$ when the shift happens. Since no output gap emerges, inflation then stays on target.

It is remarkable that in all cases the economy jumps immediately from one long run equilibrium to another. Floating exchange rates combined with targeting the domestic component of inflation does away with the protracted adjustment periods that one can get in comparable models with fixed exchange rates. The same is true for many types of shocks in the Dornbusch model of floating exchange rates. However, if we bring in stock-flow relationships (saving to wealth, investment to capital), prolonged adjustment periods are more difficult to avoid. This is the topic of the next chapter.