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# Monetary Policy under Inflation Targeting\*

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## Abstract

Monetary policy plays a central role in modern macroeconomics and many countries around the world has adopted inflation targeting as a guideline for policy. We emphasize and explain policy *goals* and then we assume that the central bank sets interest rates to ensure that these goals are met. We start with a simple model for a closed economy, where we briefly also discuss financial stability. We then expand the model and consider open economies. We develop the analytical results, but we focus on graphical discussions. Effects of various disturbances are analyzed using comparative statics.

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# 1 Introduction

Monetary policy plays a central role in modern macroeconomics. An important reason is the international trend over the past decades, where monetary policy has gained an ever-increasing role in macroeconomic stabilization policy—at the expense of fiscal policy. Many central banks have abandoned fixed exchange rates in favor of flexible inflation targeting to stabilize the domestic economy more directly.

New Zealand was the first country to introduce an explicit inflation target for monetary policy in 1990. Since then, countries like Canada, Australia, the UK and Sweden have followed. Today, nearly 40 countries have explicit inflation targets. The Federal Reserve Bank in the United States and the European Central Bank do not have explicit inflation targets, but the principle of interest rate setting is not significantly different from countries with inflation targets. In Norway, the Government introduced an explicit inflation target for monetary policy in March 2001.

Although many countries currently have inflation targets for monetary policy, most textbooks in macroeconomics, especially at bachelor level, use models that are not suitable for analyzing monetary policy under an inflation target.<sup>1</sup> We hope this article can help fill this gap.

Traditional textbooks at this level are largely based on the IS-LM model. The IS curve is a traditional Keynesian demand function, where demand depends negatively on the real interest rate and positively on current disposable income. In modern macroeconomics, the traditional IS equation is often replaced by a so-called Euler equation for optimal consumption over time. The main difference is that in the Keynesian IS equation, consumption depends on *current* disposable income, while the Euler equation is based on the permanent income hypothesis, where current income only affects consumption to the extent that it affects permanent income. Empirical studies indicate, however, that both current and permanent income affect

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<sup>1</sup>The textbooks of Galí (2015), Romer (2012) and Walsh (2017) cover this for more advanced students.

consumption so that the difference between the traditional IS equation and a more modern variant based on intertemporal optimization is not crucial when analyzing monetary policy. The central feature of the IS equation is that there is a negative relationship between real interest rates and demand.

The LM curve, however, is more problematic. In the traditional IS-LM model, it is assumed that the money supply is the central bank's instrument, and it is treated as an exogenous variable. The institutional interpretation of this is that the central bank has a monetary target, which does not give a good description of how central banks implement monetary policy in practice. In recent years, however, the traditional LM curve has typically been replaced with an interest rate rule (an MP curve), where the nominal interest rate is either a constant or described by a rule that depends on other macroeconomic variables—typically the rate of inflation or some measure of economic activity (output or unemployment).

To discuss price developments—which became a hot topic after the 1970s oil price shocks—the traditional IS-LM model was expanded with a supply dimension, resulting in the so-called aggregate demand-aggregate supply (AD-AS) model. A more recent treatment instead expands the model with a Phillips curve, i.e. a relationship between economic activity and the rate of inflation (see, e.g., Burda and Wyplosz 2017 and Blanchard et al. 2017).

A weakness of most of the different versions of the modern IS-LM model is that, in general, the simple rule does not result in the central bank setting an optimal interest rate. We will come back to this issue in section 2.3. For some purposes it may be appropriate with a simple description of monetary policy, especially if there are other conditions besides monetary policy itself that are the focus of the analysis. When focusing on monetary policy, however, it may be more fruitful to focus on the policy *goals* and to assume that the central bank sets interest rates to ensure that these goals are met. Lars Svensson is the main contributor behind the theory of this approach.<sup>2</sup> Most of his articles, however, have a technical level that is not suitable

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<sup>2</sup>See, e.g., Svensson (1997, 1999a,b, 2000). For further references, see Svensson (2010).

for students at bachelor level or even economists without specialization in monetary policy. Walsh (2002) presents the main principles in Svensson's theories with this target group in mind.

This article takes the same starting point as Walsh, but also briefly discusses financial stability and eventually expands to analyze a small open economy. Furthermore, we discuss the alternative approach where interest rates are based on a simple rule, as in Romer (2000), and compare the two approaches. In particular, we will show that by expanding the simple rule in order to take more information into account, we can find a policy rule that is identical to the optimal monetary policy, that is the policy that best meets the monetary policy objectives.

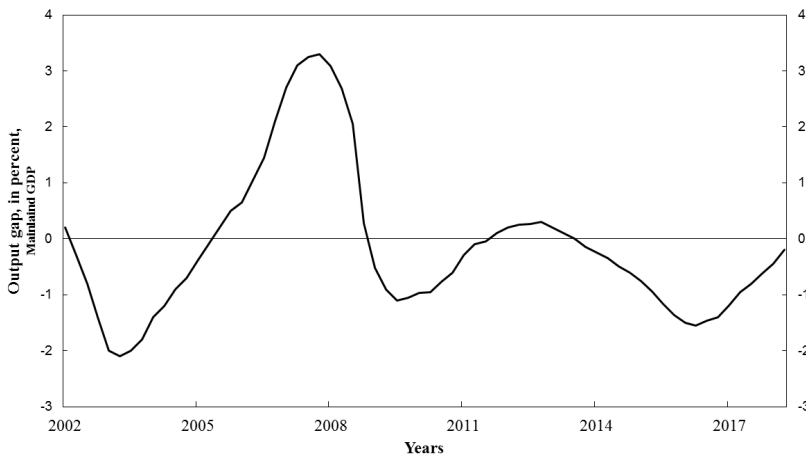
The model we use is suitable for graphical discussions. Effects of various disturbances are analyzed using comparative statics. While such graphical discussions provide the main principles of inflation targeting as well as the economic intuition behind these results, such static analysis do have certain limitations. For example, the model does not take into account that monetary policy in practice works with a time lag. Hence, discussing the appropriate time horizons, for example, for achieving the inflation target, cannot be done within such a static framework.

## **2 Inflation targeting in a closed economy**

We begin our analysis with the simplest possible model for a closed economy. Although the model is simple, it illustrates the most important monetary policy principles under an inflation target. The model consists of three components: A demand curve, a supply curve represented by a Phillips curve and, finally, an equation describing monetary policy. The model is static and shows the result after monetary policy has worked through the economy, for example, a period of 1–3 years.

It is a common opinion among researchers and practitioners that monetary policy has only a temporary effect on the real economy; monetary policy is neutral in the long run. In the long run, output is a function of technology, preferences and access





Source: Norges Bank (Monetary policy report 2/2018)

Figure 1: The output gap in Norway

to factors of production. What monetary policy can do is to try to stabilize overall demand around the level that is consistent with normal utilization of resources—what is often referred to as potential output. If  $Y$  and  $Y^*$  denote actual (GDP) and potential output, respectively, then  $\frac{Y - Y^*}{Y^*}$  measures the *output gap*; how much actual output (demand) differs in percent from potential output. Figure 1 shows developments in the output gap according to Norges Bank estimates. An economic boom is characterized by a positive output gap, while a negative gap defines a recession.

Potential output cannot be observed directly and must therefore be estimated. There are considerable uncertainties associated with such estimates. Although uncertain, the central bank’s output gap estimates do provide information about whether the central bank considers there to be either pressures in the economy, or under-utilization of resources. A goal of stability in the real economy can be translated into a goal of keeping the output gap as close to zero as possible.

## 2.1 Optimal monetary policy in a closed economy

Aggregate demand is represented by the following equation (the IS curve):

$$y = -\alpha(i - \pi^e - \rho) + \nu \tag{1}$$

where  $y$  represents the output gap and  $(i - \pi^e)$  is the real interest rate, which we denote  $r$ . Furthermore,  $i$  and  $\pi^e$  denote the nominal interest rate and expected inflation, respectively, and  $\rho$  is the long-term equilibrium real interest rate, that is the level at which real interest rates tend towards over time. Last,  $\nu$  is a demand shock, representing conditions such as surprising changes in fiscal policy, household saving behavior or firms' investments. The equation states that a higher real interest rate will, altogether, reduce demand and lower the output gap, while a lower interest rate will be expansionary and lead to a higher output gap. There may be many reasons why higher interest rates lead to lower demand. First, incentives to save increase—an effect commonly referred to as the intertemporal substitution effect—and the number of profitable investments is reduced. Moreover, increased interest rates will give a negative income effect on indebted households, which in experience have had high marginal propensity to consume. Additionally, increased interest rates can contribute to lower house prices and, consequently, a decline in households' housing wealth that will result in poorer access to credit.

If demand is largely forward-looking, as it often is in the “New-Keynesian” micro-based models,<sup>3</sup> demand is affected by expectations of next period's demand, as well as today's short-term interest rates.<sup>4</sup> By assuming rational expectations, we can solve such an equation forward so that one obtains a relation between the level of activity today and the expectations of future interest rates. If the expectation

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<sup>3</sup>See, for example, Clarida, Gali and Gertler (1999).

<sup>4</sup>In that case, our IS equation can be written as

$$y = y^e - \alpha(i - \pi^e - \rho) + \nu,$$

where  $y^e$  denotes the expected output gap.

hypothesis holds—long-term interest rates reflect expectations of future short-term interest rates—the modern variant of the IS equation, often called the Euler equation, implies that demand depends on the long-term and not the short-term interest rate. However, if demand is not particularly forward-looking, or if credit markets are imperfect, short-term interest rates may be most important for demand. At this point, however, we do not need to determine if the variable  $i$  represents short- or long-term interest rates. The main idea is that the central bank can affect market interest rates and hence demand through changes in the signal rate (loan rate) in particular and through its communication with the market in general. In what way and how effectively the central bank influences market interest rates is an important topic for understanding how monetary policy works, but there is no room for an in-depth discussion of that in this article.

Alternatively, equation (1) can be written as

$$y = -\alpha(r - \bar{r}), \quad (2)$$

where the short-run neutral real interest rate, i.e. the real rate that closes the output gap,  $\bar{r}$ , is given by

$$\bar{r} = \rho + \frac{1}{\alpha}v. \quad (3)$$

We see that output will be higher than potential, i.e. the economy will be in a boom when the actual real interest rate is lower than the neutral real rate. If the actual rate is higher than the neutral rate, the economy will be in a recession. We also see that the short-run neutral rate vary over time. The actual rate will have to be relatively high in order to close the output gap when the economy is hit by a positive demand shock and relatively low when it is hit by a negative demand shock.

The supply side of the economy is represented by the following Phillips curve:

$$\pi = \pi^e + \gamma y + u \quad (4)$$

where  $u$  represents an inflation shock, for example a surprising increase in energy prices or in wages. The Phillips curve is based on the assumption of rigidity in prices and wages, so demand pressures bring gradual increases in prices. A similar Phillips curve is central within the area of New Keynesian theory. Increased inflation expectations are assumed to be fully impounded in inflation. This implies that the long-term Phillips curve, characterized by  $\pi = \pi^e$ ,  $y = 0$ , and  $u = 0$ , is vertical. Thus, it is not possible to achieve higher production in the long term by allowing higher inflation.

Pressures in the economy—a positive output gap—lead to increased inflation. First, high demand for goods and services will allow many companies to increase their profit margins by raising prices for their goods and services. Second, increased activity will normally increase the cost level—not least because low unemployment will put pressure on wages. The latter is due to the fact that unions will demand higher wage increases and that employers will try to outbid each other competing for labor.

Before specifying the monetary policy regime, we will have a look at the so-called monetary policy transmission mechanism, that is how changes in the policy rate affects macroeconomic variables. Even though the central bank has no direct control of market rates, as mentioned above, it can affect these through its signal rate and through its communication with the market. For simplicity, we assume that the central bank sets  $i$  directly.

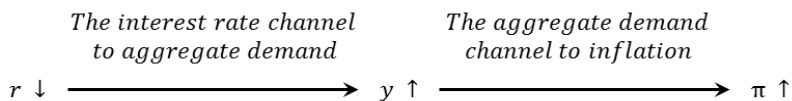


Figure 2: The monetary policy transmission mechanism

In our closed economy model, monetary operates through two different channels: (i) the interest rate channel to aggregate demand and (ii) the demand channel to inflation. Figure 2 illustrates the transmission channels. When the central bank lowers the nominal interest rate, the real interest rate also falls. This is due to the fact that inflation and inflation expectations are sticky. In our model, we keep inflation expectations constant and therefore there is a one-to-one relationship between nominal and real interest rates. The reduction in real interest rates will increase demand for goods and services. This is the interest rate channel to aggregate demand and it follows from the IS equation. The increase in demand implies an increase in the rate of inflation. This is the demand channel to inflation.

Describing monetary policy still remains. We focus on a monetary policy regime where the central bank has an inflation target but, as mentioned in the introduction, the difference between central banks with explicit inflation targets and those with less explicit targets is probably small in practice.

An inflation target is often specified in the form of a loss function:

$$L = \frac{1}{2} [(\pi - \pi^*)^2 + \lambda y^2] \quad (5)$$

where parameter  $\lambda$  measures how much weight the central bank assigns to production stability relative to price stability. The central bank's task is to minimize this loss function, which depends on the difference between actual inflation and the inflation target—the inflation gap—and the output gap. In addition to stabilizing inflation around the target, the central bank wishes to stabilize production around potential production. Why potential production and not a production level that gives full employment? The reason for this is the long-run neutrality of monetary policy; it cannot affect long-run unemployment, or structural unemployment. Structural unemployment is determined by structural conditions in the labor market. An attempt to increase output and employment to a level that gives less unemployment than structural unemployment will, over time, not give rise to lower unemployment,

but significantly higher wage and price growth. Moreover, both theory and experience from the 1970s suggest that this is not a wise strategy. When inflation has been allowed to increase, it will normally take a period of high unemployment to bring it back down.

The quadratic form implies, among other things, that it is equally “costly” when inflation is higher than the inflation target,  $\pi^*$ , as when inflation is lower. In addition, the quadratic form will imply that the central bank will prefer a balanced development of the inflation and output gaps, since large gaps result in proportionally much larger losses.

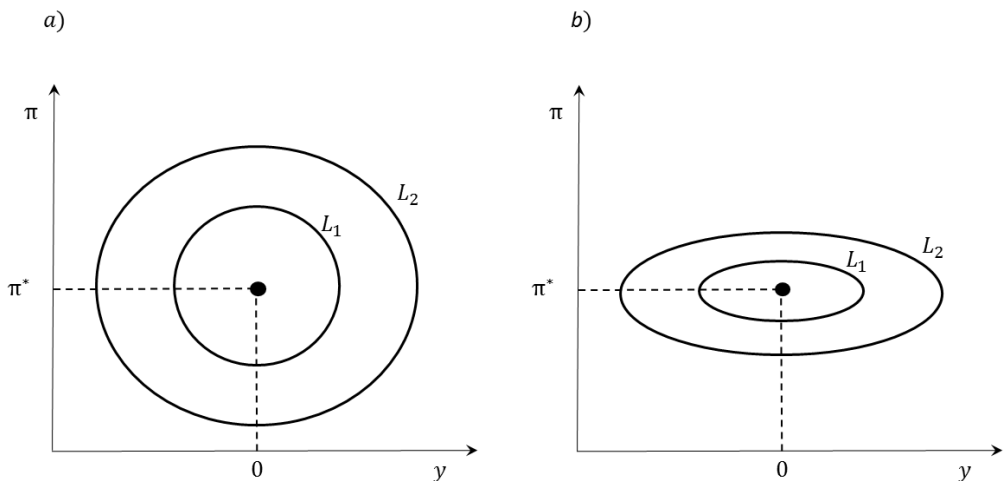


Figure 3: The loss function

A positive  $\lambda$  is often referred to as “flexible inflation targeting”. If  $\lambda = 0$  we have “strict inflation targeting” and the central bank can be characterized as an “inflation nutter” (King, 1998). Under strict inflation targeting, the central bank is concerned only with reaching the inflation target, no matter how large imbalances in the real economy this may cause. In practice, no central banks with inflation targets pursue

such a policy. In some countries, the political authorities have left the central bank to “determine” the size of  $\lambda$ . In Norway, the authorities have instructed Norges Bank to take into account developments in the real economy.

The loss function is illustrated in Figure 3a. Indifference curves show combinations of inflation and output gap that yield unchanged losses. The loss is higher the farther the indifference curves are from the target  $(0, \pi^*)$ . A lower  $\lambda$  gives “flatter” indifference curves, as indicated in Figure 3b. In this case, variations in inflation are more costly.

Often, central banks have interpreted a positive  $\lambda$  as related to the time horizon within which to achieve the target. Under “strict inflation targeting”, the central bank aims to achieve the target quickly and sets interest rates accordingly. This may require large and frequent changes in interest rates and hence large fluctuations in the real economy. Under “flexible inflation targeting”, the central bank is moving more gradually to avoid excessive fluctuations in output and employment.

Describing monetary policy in terms of minimizing the loss function does not only apply to central banks with explicit inflation targets. For example, Romer writes (2000, p.155): “In the United States, the Federal Reserve chooses the federal funds rate to try to achieve its objectives for inflation and output [...]” It is also common in theoretical work to describe the monetary policy of the European Central Bank (ECB) in the form of a similar loss function.<sup>5</sup>

The interest rate is set so that the loss function (5) is minimized given the economic mechanisms described in the model. Since  $r = i - \pi^e$ , where  $\pi^e$  is exogenous, we work with the real interest rate for simplicity. The first order condition for minimum loss is

$$(\pi - \pi^*) \frac{d\pi}{dr} + \lambda y \frac{dy}{dr} = 0 \tag{6}$$

From equations (1) and (4) we have that  $\frac{dy}{dr} = -\alpha$  and  $\frac{d\pi}{dr} = -\alpha\gamma$ . These two deriva-

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<sup>5</sup>See, for example, Aksoy, De Grauwe and Dewachter (2002).

tives summarize the transmission mechanism. Parameter  $\alpha$  measures the strength of the interest rate channel, while parameter  $\gamma$  is the strength of the demand channel.

We can now write the first order condition as

$$\pi - \pi^* = -\frac{\lambda}{\gamma}y \quad (7)$$

Equation (7) states that monetary policy is optimally aligned if both the inflation gap and the output gap are zero (the ideal situation) or there is a negative relationship between the inflation gap and the output gap. It is not optimal when both gaps are positive (or negative) at the same time because raising (or lowering) interest rates would help close both gaps and thus reduce the loss. The first order condition (7) implies a trade-off between price stability and stability in the real economy.

Alternatively, we can solve the optimality condition (7) with respect to the output gap. Then we obtain

$$y = -\frac{\gamma}{\lambda}(\pi - \pi^*), \quad (8)$$

which shows the extent to which the central bank is willing to drive the economy into a recession when inflation is above the target. The willingness depends on the weight put on avoiding fluctuations in the real economy and on the strength of the demand channel to inflation. The reason for the former is straightforward. If the central bank puts a large weight on avoiding fluctuations in the real economy, it will be less willing to bring the economy into a recession when inflation increases due to a cost-push shock. If the demand channel becomes stronger, this will make it easier to control inflation by changing the output gap. Therefore the central bank will be more willing to use the output gap to control inflation. Let us also note that the strength of the interest rate channel does not influence the optimality condition. The reason is simple. If parameter  $a$  is low, the central bank will just have to change interest rates more to achieve a change in demand.

Before we move on to graphical analysis, it is useful to take a look at the equi-



librium values of inflation and the output gap, and the nominal interest rate. We start with solving for the rate of inflation and the output gap using equations (4) and (8). This gives

$$\pi = \pi^* + \frac{\lambda}{\lambda + \gamma^2} [(\pi^e - \pi^*) + u], \quad (9)$$

$$y = -\frac{\gamma}{\lambda + \gamma^2} [(\pi^e - \pi^*) + u]. \quad (10)$$

Let us also give a brief interpretation of equations (9) and (10). We see that the cost-push shock increases the rate of inflation, while it lowers the output gap. The same is true for the term  $(\pi^e - \pi^*)$ , which can be interpreted as a “confidence” shock, that is lack of credibility that the central bank meets the inflation target. We see how the central bank trades off an increase in the rate of inflation against a lower output gap. We also see that an increase in the weight on the output gap makes the output gap fall less and the rate of inflation increase more following a positive cost-push shock (or a confidence shock). An increase in the strength of the demand channel has the opposite effect on the rate of inflation, while the effect on the output gap is ambiguous. The reason for the latter is that an increase in parameter  $\gamma$  will make the central bank want to stabilize inflation more at the expense of more fluctuations in the output gap, as we explained above. But it also becomes easier to control the rate of inflation, which implies that less variations in the output gap are needed. The former effect leads to a larger drop in the output gap (following an increase in  $u$ ), while the latter effect to a lower drop.

Next, we find the equilibrium value of the nominal interest rate. This can be done combining the IS equation (2) with (10):

$$i = \bar{r} + \pi^e + \frac{\gamma}{\alpha(\gamma^2 + \lambda)}u + \frac{\gamma}{\alpha(\gamma^2 + \lambda)}(\pi^e - \pi^*) \quad (11)$$

The term  $(\bar{r} + \pi^e)$  is the short-run neutral nominal interest rate, that is the short-

run neutral real rate plus expected inflation. Equation (11) states that the central bank should raise the nominal interest rate one-for-one with changes in the neutral nominal interest rate. This implies that demand shocks should be neutralized. We will come back to this point below. The interest rate is also raised if a positive inflation shock,  $u$ , occurs. By how much it is raised depends on factors such as how much weight, measured by  $\lambda$ , the central bank attaches to the real economy. We also see that following a “confidence” shock, that is if agents in the economy expect inflation above the inflation target, interest rates are raised. We see from the equation that such a confidence shock results in the same type of reaction as an inflation shock. The reason is that both shocks have the same effect on inflation. In this way, it is not necessary for the central bank to decide whether, for example, a surprisingly high wage growth, is due to a random deviation in wage formation (i.e. an inflation shock) or whether the inflation target is not sufficiently anchored by the labor market parties (i.e. a confidence shock). Such a conclusion, however, may be premature. Confidence is not purely exogenous, but is influenced by the central bank’s reaction pattern and communication. There are therefore arguments for responding more firmly to confidence shocks than to pure inflation shocks. By showing the outside world that it is serious about reaching the inflation target in periods with low confidence, the central bank may help prevent future confidence shocks. In that case, it will also contribute to a more stable real economy over time. The design of monetary policy in practice is dependent on how trust is built up or torn down. This model does not capture such conditions, nor do most other models.

## 2.2 Graphical analysis

We will present monetary policy in a diagram of inflation and the output gap. The economy is described by the Phillips curve (PC) in equation (4). In addition we will draw the first order condition, equation (7), which shows how the central bank weighs the inflation gap against the output gap. We call it monetary policy (MP).

Equilibrium is illustrated in Figure 4, where we assume that all shocks are equal to zero and that expected inflation equals the inflation target. PC has a positive slope because higher economic activity—an increase in the output gap—gives rise to inflation. MP has a negative slope because the central bank trades off a larger positive output gap against a more negative inflation gap.

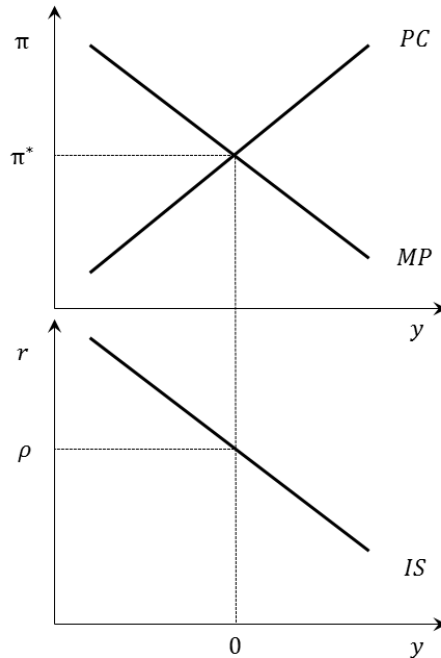


Figure 4: The PC-MP-IS chart

Let us take a detailed look at the impact of three types of shocks: a demand shock, an inflation shock and a change in the inflation target. In order to show the effect these shocks have on the interest rate, we have included an IS diagram below the PC-MP diagrams. Although not required to find equilibrium, it provides more intuition. The IS curve is given by:

$$r = \rho + \frac{1}{\alpha}v - \frac{1}{\alpha}y = \bar{r} - \frac{1}{\alpha}y, \quad (12)$$

where we have solved equations (1) and (2) with respect to the real interest rate.

Note that the shocks considered here, with the exception of changes in the inflation target, are temporary shocks. Permanent shocks can be interpreted as changes in equilibrium values of the real economy. In the model above this is a change in  $Y^*$ . Thus, deviations in inflation and output from the inflation target and potential output, will only be temporary deviations. How long these deviations last depends on the structure of the economy as well as the size and duration of the shocks.

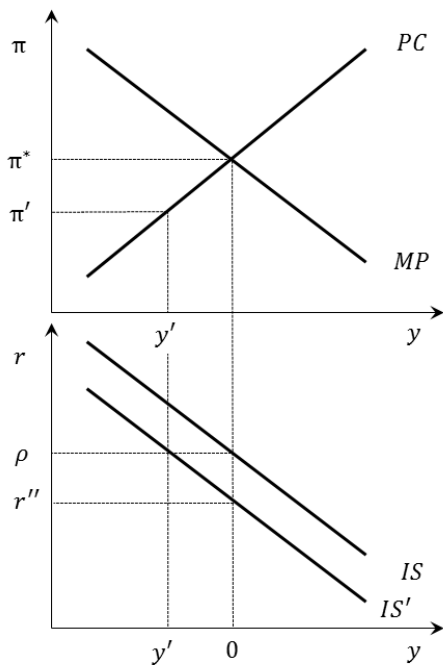


Figure 5: Negative demand shock

### 2.2.1 Negative demand shock: $\nu < 0$

Assume that there is a negative demand shock ( $\nu < 0$ ), for example in the form of tighter fiscal policy or a temporary increase in savings. The demand shock, however,

is not included in either PC or MP, and hence there will be no shifts in these curves. The IS curve, on the other hand, shifts to the left as a result of the negative shock. Since the MP curve and PC curve do not change, the result will be unchanged inflation and output gap. The intuition is as follows: First, assume that the central bank does *not* respond with an expansionary monetary policy, but keeps the real interest rate equal to the long-run level  $\rho$ , so that the demand shock is fully reflected in  $y$ . A decrease in  $y$  will reduce the rate of inflation, and the result would be the combination  $y'$  and  $\pi'$  in Figure 5. However, by implementing a more expansionary monetary policy, the central bank would bring both inflation closer to the target and output closer to potential output. Hence, the loss, measured by the loss function (5), would decrease. By lowering interest rates so much that the negative demand shock will be completely neutralized—that is by choosing  $r''$ —output, and thus inflation, will remain unchanged. *Under inflation targeting in a closed economy, aiming at neutralizing the demand shocks is therefore optimal.*

### 2.2.2 Negative inflation shock: $u < 0$

A negative inflation shock, for example in the form of an unexpected moderate wage settlement, will lead to lower inflation. We can see from equation (4) that the Phillips curve shifts downwards, as shown in Figure 6. The IS curve remains unchanged, since  $u$  is not part of the IS equation. If the central bank does not reduce the real interest rate but keeps it equal to the long-run real rate—neutral monetary policy—the result will be  $\pi'$  and 0. However, this point is not on the MP curve and, consequently, does not reflect an optimal balance between reaching the inflation target and the consideration of stability in the real economy. By lowering interest rates, the output gap will be positive, but the resulting loss will be more than offset by inflation moving closer to the target. In other words, we end up on an indifference curve that is closer to the target,  $(0, \pi^*)$ , as shown in the figure.

Why is reducing interest rates resulting in a positive output gap optimal? Assume the central bank keeps demand unchanged, so that  $y = 0$ . A reduction in

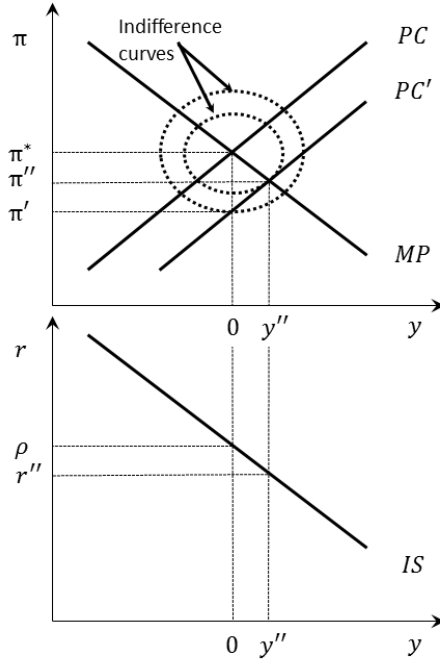


Figure 6: Negative inflation shock

the interest rate will yield a negligible loss in the form of overproduction, since the output gap is still close to zero. However, since inflation is too low at  $y = 0$  when  $u < 0$ , what we gain by bringing inflation closer to the target will not be negligible. This is because deviation from inflation target enters the loss function squared. Therefore, reducing the interest rate will generally result in a lower loss. The optimal adjustment will therefore be where the output gap is  $y''$ , inflation is  $\pi''$  and the real interest rate is  $r''$ . Therefore we see that, contrary to demand shocks, inflation shocks do entail a conflict between price stability and stability in the real economy.

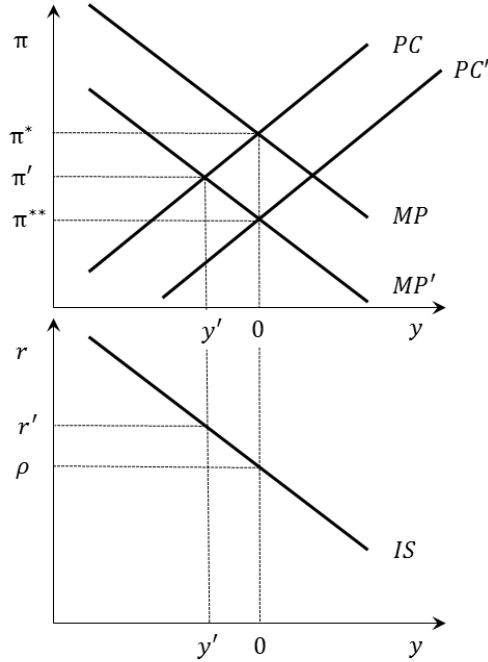


Figure 7: Lower inflation target

### 2.2.3 Lower inflation target: $\pi^{**} < \pi^*$

Assume that the central bank is given a new and lower inflation target  $\pi^{**}$  in a situation where the output gap is zero and inflation equals the old target  $\pi^*$ . Suppose, first, that inflation expectations do not change. This means that the new target lacks credibility. The central bank needs to conduct a contractionary monetary policy in order to bring down the rate of inflation and sets the real rate to  $r'$ . The central bank does not reduce inflation all the way to  $\pi^{**}$ , since this would be too costly in terms of low output and high unemployment. The optimal trade-off between achieving the new inflation target and stable output implies that the interest rate is set such that the output gap equals  $y'$  and inflation  $\pi'$ . This is shown in Figure 7.

Due to the fact that actual inflation will remain below inflation expectations, it is reasonable to expect that inflation expectations will fall. Over time it seems natural that we will obtain  $\pi^e = \pi^{**}$  and that the output gap will be zero. The choice of inflation target will therefore not matter for output and employment in the long run.

If we, instead, assume that monetary policy is credible and that there is transparency about the inflation target, inflation expectations will change immediately when the new target is announced. PC will then move together with MP. In this case, the economy will move to the new long-run equilibrium immediately and the central bank will not need to bring the economy into a recession in order to bring the rate of inflation to its new target level.

## 2.3 Simple rules

In the analysis above, monetary policy is represented by monetary policy goals: to stabilize inflation around the inflation target and to stabilize real economic activity, which we measured by the output gap. More specifically, we assumed that the central bank sets interest rates in order to minimize a loss function which depends on the inflation gap and the output gap.

In much of the existing textbooks monetary policy is instead represented by a constant nominal (or real) interest rate or as an interest rate rule (see, e.g., Blanchard et al. 2017 and Burda and Wyplosz 2017). Romer (2000) specifies the rule as follows:

$$r = \rho + \theta (\pi - \pi^*), \quad (13)$$

where  $\theta$  is a positive constant. In nominal terms, the rule becomes

$$i = \rho + \pi^e + \theta (\pi - \pi^*), \quad (14)$$

where the first two terms represents the long-run nominal interest rate. The rule



prescribes that the central bank should engineer an increase in the real interest rate when the rate of inflation increases. This is in accordance with the so-called Taylor principle, according to which the nominal interest rate should increase by more than one-to-one with increases in inflation. The parameter  $\theta$  then indicates by how much the central bank should increase the real interest rate when inflation increases. If we, in addition, add an additional term that penalizes deviations from the output gap, the rule would resemble the classic Taylor (1993) rule. In our simple set-up, this would only complicate the algebra, without adding any insight, so we will stick to the rule above.

We can use the rule above to eliminate the real interest rate in the IS equation (2). Solving the resulting equation with respect to the inflation gap gives:

$$\pi - \pi^* = -\frac{1}{\alpha\theta} (y - \nu). \quad (15)$$

We see that monetary policy also in this case will imply a downward sloping schedule. In this sense, the two approaches—optimal policy and simple rules—are similar. There are, however, two important differences between the equation above and the optimality condition in equation (7). First, the parameter in front of the output gap will in general be different across the two models and they will be equal only if the central bank choose  $\theta = \frac{\gamma}{\alpha\lambda}$ . Second, and more importantly, the demand shock influences the trade-off. This implies that even if  $\theta = \frac{\gamma}{\alpha\lambda}$ , the rule above will not imply optimal policy following a demand shock. More precisely, a demand shock will shift the monetary policy schedule above upwards implying that both the output gap and the inflation gap are positive. We therefore know that increasing the nominal interest further would bring both the output gap closer to zero and inflation closer to the inflation target.

Simple rules like the Taylor rule and our interest rate rule in equation (13 or 14) are often criticized for being a too mechanical description of monetary policy. Svensson (2003), in particular, has been very critical about describing monetary policy

in this simple way. He questions the fact that our models often assume optimizing households and firms, while the central bank, with a big staff of economists, does not optimize in order to best achieve their goals.

As it turns out, there exists an intuitive way to adjust the rule above to make it replicate optimal policy. Consider the following rule:

$$i = \bar{r} + \pi^e + \frac{1}{\alpha} \frac{\gamma}{\lambda} (\pi - \pi^*) \quad (16)$$

The first two terms on the right hand side are the neutral short-run nominal interest rate. The rule thus indicates that the central bank should set interest rates equal to the neutral nominal rate if inflation is on target and not equal to the long-run nominal rate as in the rule suggested by Romer (2000). If inflation is above target, the central bank should increase rates above the neutral rate and thus bring the economy into a recession. This will, according to the Phillips curve, bring inflation closer to the target. And the extent to which the central bank should increase interest rates depends on how much demand responds to changes in interest rates and on the two parameters that describe the optimal trade-off in equation (7).

## 2.4 Financial stability

Since the Great Financial Crises and the Great Recession, financial stability has been high on the agenda in many central banks. In particular, so-called “leaning against the wind” (LAW) policy has been discussed among both practitioners and academics. It is fair to say that no consensus has so far emerged and LAW policy is still controversial. Some authors argue that the benefits are large (see, e.g., Gambacorta and Signoretti 2014), while others argue that the benefits do not outweigh the costs (see, e.g., Svensson 2017). We will not discuss the pros and cons of LAW policy here. Instead we will use our simple framework to discuss how financial stability could be taken into account. To this end, we assume that the central bank wants to avoid financial imbalances. Let  $q$  represent the relevant financial variable

(e.g., house prices, credit or leverage), where  $q$  is measured as deviation from its equilibrium value, i.e.  $q = 0$  in equilibrium with no shocks. Hereafter we will refer to  $q$  as the financial gap. The central bank's loss function is extended by a term representing financial imbalances, i.e.

$$L = \frac{1}{2} [(\pi - \pi^*)^2 + \lambda y^2 + \delta q^2], \quad (17)$$

where  $\delta$  is the weight placed on the financial gap. There are several reasons why  $q$  may enter the loss function as a separate term. First, Schularick and Taylor (2012) show that credit growth is a significant predictor of financial crises. And the cost of those crises goes beyond the effect on inflation and the output gap, since a financial turmoil will imply that profitable investment opportunities will not be financed. Moreover, Jordá et al. (2013) show that high credit growth in expansions tend to result in deeper and more long-lasting recessions. In addition, too low values of the financial variable will make it harder for firms to finance investment since the value of their collateral will be low. For simplicity we therefore assume that the central bank wishes to limit the variations in the financial gap.

Next, we need to consider how the financial gap depends on macroeconomic variables. We start by assuming that the real interest rate influences the financial gap, since it is often argued that financial imbalances increase when real interest rates fall.<sup>6</sup> We assume that the financial gap is given by:

$$q = -\phi (r - \rho) + w, \quad (18)$$

where  $w$  is a “financial shock”, that is a change in the financial variable that is unrelated to changes in the real interest rate. For example, several authors argue

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<sup>6</sup>Svensson (2017) argues that this relationship is weak and that  $\phi$  might even be negative in the short run. To see why, consider the debt-to-GDP ratio, which is a key variable that many central banks focus on. If debt reacts little to changes in the the interest rate in the short run while the effect on GDP is more pronounced, the debt-to-GDP ratio will increase when real rates increase since GDP falls more than debt.

that there are so-called financial cycles that do not correspond to business cycles (see, e.g., Borio 2012). In our model, those cycles will be captured as changes in  $w$ . Parameter  $\phi$  measures how much our financial gap variable increases when the real interest rate falls.

For now we let economic activity be independent of the financial variable, so the output gap is still given by equations (1) or (2) and the rate of inflation by equation (4).<sup>7</sup> Before we turn to the optimality condition, let us note that the financial variable can be written as:

$$q = -\phi(r - \tilde{r}) \quad (19)$$

where  $\tilde{r} = \rho + \frac{1}{\phi}w$  is the real interest rate that closes the financial gap. We will return to this real rate below.

The optimality condition becomes

$$(\pi - \pi^*) \frac{d\pi}{dr} + \lambda y \frac{dy}{dr} + \delta q \frac{dq}{dr} = 0, \quad (20)$$

which can be written as<sup>8</sup>

$$(\pi - \pi^*) = -\frac{\lambda}{\gamma}y - \frac{\phi\delta}{\alpha\gamma}q = -\frac{\lambda + \delta\left(\frac{\phi}{\alpha}\right)^2}{\gamma}y - \frac{\phi\delta}{\gamma\alpha^2}(\alpha w - \phi v) \quad (21)$$

We see that the concern for financial imbalances changes the optimality condition in two important ways. First, the central bank implicitly puts more weight on avoiding fluctuations in real economic activity, that is the MP schedule is steeper. To understand why, consider a cost-push shock that increases the rate of inflation. The central bank will react to the shock by engineering a negative output gap. This is done by increasing the real interest rate. This will also make the financial gap negative, however, which is an additional cost of high real rates. The second

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<sup>7</sup>Below we will allow the financial variable to influence the output gap. It can also be argued that the financial variable will influence the rate of inflation, see, e.g., Woodford (2012). We leave this to the interested reader.

<sup>8</sup>The second equality follows from combining (1) and (18) to write the financial gap as a function of the output gap.

change in the optimality condition is that both shocks to financial imbalances and the demand shock will shift the MP schedule. It is, therefore, no longer optimal to fully stabilize demand disturbances. Moreover, it is not necessarily optimal that the inflation gap and the output gap have opposite signs. For example, both the inflation gap and the output gap would be (optimally) negative if  $w$  is positive.

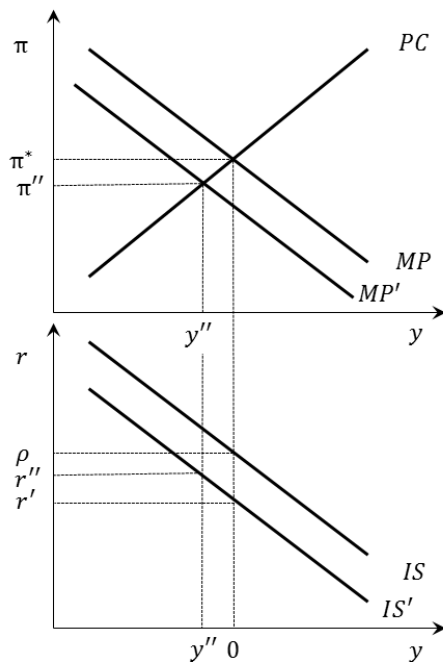


Figure 8: Negative demand shock with LAW

Assume again that there is a negative demand shock ( $\nu < 0$ ). The result is shown in Figure 8. The demand shock is not included in PC, and hence there will be no shift in this curve. Both MP and IS will shift to the left as a result of the negative shock, however. We will therefore have a new equilibrium where both the output gap and the rate of inflation are below their respective targets. The intuition is as follows: First, assume that the central bank fully neutralizes the demand shock by setting the real interest rate equal to  $r'$ . In this case the output gap will remain at

zero and the rate of inflation will equal the target. The financial gap will be positive due to the low policy rate, however. Therefore monetary policy would not be well balanced. Instead the central bank will optimally react less with the interest rate—by choosing  $r''$ —so that the financial gap increases less. The cost is a somewhat lower output gap and a rate of inflation that is somewhat below target.

It is interesting to inspect the simple rule that implements optimal monetary policy in this case. It is given by:

$$i = \mu [\bar{r} + \pi^e + \gamma (\pi - \pi^*)] + (1 - \mu) (\tilde{r} + \pi^e), \quad (22)$$

where  $\mu = \lambda / (\lambda + \delta (\frac{\phi}{\alpha})^2)$ . We recognize the term in the squared bracket as the nominal interest rate that implements flexible inflation targeting, while the last bracket is the nominal interest rate that closes the financial gap. We see that the nominal interest rate should be set as a weighted average of the two rates; and the higher the weight ( $\delta$ ) on variations in  $q$ , the higher the weight on  $\tilde{r}$ .

Next, we will extend our analysis in two interesting ways. First, we will allow the real economic activity to influence financial imbalances and, second, we will assume that the financial variable feeds back to the level of activity. The former can be motivated by the assumption that financial imbalances tend to build up in booms. We assume the following relationship

$$q = \tau y - \phi (r - \rho) + w, \quad (23)$$

where parameter  $\tau$  measures how much the financial gap increases when the output gap increases. Furthermore, we assume that the IS equation is given by:

$$y = -\alpha (r - \rho) + \chi q + \nu. \quad (24)$$

Parameter  $\chi$  measures the extent to which the financial variable affects the output gap and  $\chi > 0$  can be motivated by the assumption that a high level of  $q$  makes it

easier for firms to finance investment and households to finance consumption. These assumptions will imply that our model has a financial accelerator. Figure 9 shows the transmission mechanism in the extended model. The real interest rate affects both the output gap and the financial gap, while the two gaps mutually influence each other through the financial accelerator.

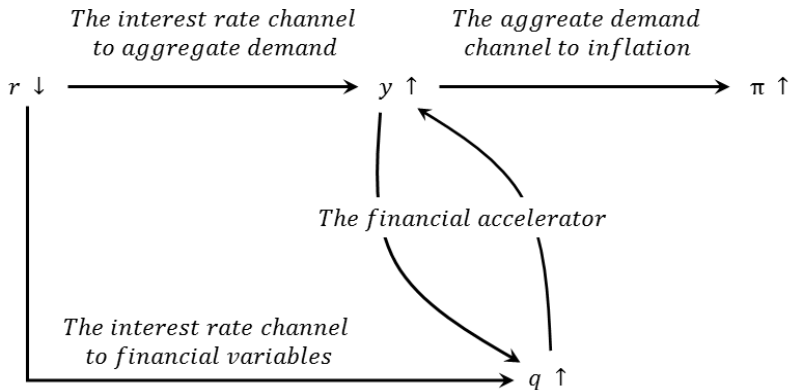


Figure 9: Transmission mechanism with financial accelerator

To see the financial accelerator more formally, it is instructive to solve for the reduced-form relationship between the output gap and the real interest rate. It is given by

$$y = -\frac{\alpha + \chi\phi}{1 - \chi\tau} (r - \bar{r}) = -\bar{\alpha} (r - \bar{r}), \quad (25)$$

where  $\bar{r} = \rho + \frac{1}{\alpha + \chi\phi}\nu + \frac{\chi}{\alpha + \chi\phi}w$  and  $\bar{\alpha} = \frac{\alpha + \chi\phi}{1 - \chi\tau}$ . Here we see the financial accelerator at work. A decrease in the real interest rate increases the output gap. This, in turn, increases  $q$ , which implies a further increase in the output gap. The strength of this multiplier is measured by  $\frac{1}{1 - \chi\tau}$ . In addition, we see that the effect on the output gap is amplified by the fact that the real interest rate affects  $q$  (the parameter  $\chi\phi$  in the nominator).

Also in this case, we can write the financial gap as a function of the real interest

rate gap:

$$q = -\frac{\tau\alpha + \phi}{1 - \chi\tau}(r - \tilde{r}) = -\bar{\phi}(r - \tilde{r}) \quad (26)$$

where  $\tilde{r} = \rho + \frac{\tau}{\tau\alpha + \phi}\nu + \frac{1}{\tau\alpha + \phi}w$  and  $\bar{\phi} = \frac{\tau\alpha + \phi}{1 - \chi\tau}$ . We see that the interest rate effect is amplified by the fact that the output gap influences  $q$  directly and by the financial accelerator. Moreover, comparing  $\tilde{r}$  with the natural real interest rate,  $\bar{r}$ , we see that the demand shock and the financial shock still influence the two rates differently. This means that both shocks will drive a wedge between the rates which will make it impossible to close both the output gap and the financial gap at the same time.

Next, we turn to optimal monetary policy. We still minimize the loss function (17), but in this case subject to equations (25) and (26), in addition to PC as before. The first-order condition in this case can be written as:

$$(\pi - \pi^*) = -\frac{\lambda}{\gamma}y - \frac{\bar{\phi}\delta}{\bar{\alpha}\gamma}q = -\frac{\lambda + \delta\left(\frac{\tau\alpha + \phi}{\alpha + \chi\phi}\right)^2}{\gamma}y - \frac{\delta}{\gamma(\alpha + \chi\phi)^2}(\alpha w - \phi\nu). \quad (27)$$

We see that optimality condition is similar to the more simple case analyzed above. The central bank implicitly puts more weight on stabilizing the output gap, that is the MP curve is steeper, and both demand shocks and financial shocks lead to shifts in MP. Importantly, this means that qualitatively our graphical analysis in Figure 8 does not change.<sup>9</sup>

### 3 Inflation targeting in a small open economy

Explicit inflation targeting is usually found in small, open economies. The countries are small in the sense that they have negligible effects on international economic developments, and open in the sense that they take part in, and are influenced by, international trade in goods, services and capital. The main difference between the open and closed model is the effects from exchange rate changes. Although the open

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<sup>9</sup>We will leave it to the reader to develop how policy can be implemented with a simple policy rule for this case.



economy is affected by international economic conditions, these effects can be seen as demand shocks and thus do not fundamentally distinguish the open-economy model from the closed-economy model.

### 3.1 The monetary policy transmission mechanism

In an open economy, domestically produced goods and services will be used for both domestic consumption and investment and exported and sold abroad to foreign households and firms. Moreover, domestic firms face international competition on the local market from imports. We therefore expand the IS curve (1) to take into account how the exchange rate affects the level of activity. We assume that the IS curve of the open economy can be written as:

$$y = -\alpha_1 (r - \rho) + \alpha_2 e + \nu, \quad (28)$$

where  $e = s + p^* - p$  is the logarithm of the real exchange rate. Here  $s$  denotes the logarithm of the nominal exchange rate (increased value represents a weaker currency, i.e., a depreciation),  $p^*$  is the logarithm of the price of foreign goods measured in foreign currency and  $p$  is the price of domestically produced goods. For simplicity, we have assumed that the purchasing power parity holds in the long run and thus that the long-run real exchange rate is one. A weaker real exchange rate (increase in  $e$ ) makes domestically produced goods and services cheaper relative to foreign goods and therefore contributes to higher demand for domestic products.

Households consume both domestically produced goods and services and imported goods. As far as rate of inflation on the former is concerned, we will assume a similar Phillips curve as for the closed economy. Domestic inflation,  $\pi_H$ , is thus given by:

$$\pi_H = \pi_H^e + \gamma_1^H y + u^H \quad (29)$$

where  $\pi_H^e$  is expected domestic inflation and  $u^H$  represents inflation shocks to domestic inflation. As in the closed economy, domestic inflation is affected by changes

in the level of activity. The reason is the same as before. An increase in the output gap increases production costs for firms and firms tend to pass some of those costs on to their customers.<sup>10</sup>

A small, open economy also imports goods and services are used for consumption. We assume that imported inflation,  $\pi_F$ , is given by:

$$\pi_F = \pi_F^e + \gamma_2^F e + u^F, \quad (30)$$

where  $\pi_F^e$  is expected imported inflation and  $u^F$  is a shock to imported inflation. We see that a imported inflation is affected by the real exchange rate. The reason is as follows. When the real exchange rate increases, the price of foreign goods in domestic currency increases (either because foreign goods prices increase or because the price of foreign currency increases). Importers of foreign goods therefore face higher costs and will want to increase their local prices. We assume that import prices are sticky and thus higher costs for importers will only gradually lead to higher domestic prices of foreign goods. In the literature, this is named “imperfect pass-through”. We have imperfect pass-through if an increase in the nominal exchange rate lead to a less than one-to-one increase in import prices, while perfect pass-through refers to the case when changes in the exchange rate lead to one-to-one changes in import prices.<sup>11</sup> The degree of pass-through is measured by parameter  $\gamma_2^F$ .

We assume that consumer price inflation is given by

$$\pi = \psi \pi_F + (1 - \psi) \pi_H \quad (31)$$

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<sup>10</sup>Domestic inflation will also be influenced by changes in the real exchange rate, since it influences the price of imported input factors. We ignore this here.

<sup>11</sup>Let us clarify with an example. Consider a product, wine say, that is imported to the domestic economy. Let us assume that the price of a bottle of wine is 10 Euro abroad, that the NOK/Euro nominal exchange rate is 10 and that the bottle costs 100 Kroner in a domestic shop. We now consider what happens to the domestic price of wine if the NOK/Euro increases to 11. Importers of wine now pays 110 Kroner per bottle and would like to increase the local price. If the price increases to 110, we have perfect pass-through, while an increase of the price to less than 110 gives imperfect pass-through.

where  $\psi$  is the share of imports in the consumption basket. Combining the three latter equations we obtain our open-economy Phillips curve

$$\pi = \pi^e + \gamma_1 y + \gamma_2 e + u, \quad (32)$$

where  $\gamma_1 = (1 - \psi) \gamma_1^H$ ,  $\gamma_2 = \psi \gamma_2^F$ , and  $u = \psi u^F + (1 - \psi) u^H$ . In the following we will use consumer price inflation, but we will come return to domestic and imported inflation when discussing the implication of optimal policy below.

Finally, we need an equation to determine the exchange rate. We start with the uncovered interest rate parity equation:

$$s = s^e - (i - i^*) + z \quad (33)$$

where  $s^e$  is the expected nominal exchange rate for the next period,  $i^*$  the interest rate abroad and  $z$  is a currency shock (shock to the risk premium). Uncovered interest rate parity states that the expected return should be the same in different currencies. The shock variable  $z$  thus represents a deviation from uncovered interest rate parity, and a positive shock means that domestic yields must be higher than foreign yields.

Note that the uncovered interest rate parity equation can be rewritten into real form, that is

$$e = e^e - (r - r^*) + z \quad (34)$$

where  $r^* = i^* - \pi^{*,e}$  is the foreign real interest rate and  $\pi^{*,e} = p^{*,e} - p^*$  is expected foreign inflation. We will use this specification later on.

Figure 10 gives an overview of the different channels through which monetary policy influences real economic activity and the rate of inflation. As in the closed economy, a decrease in the nominal interest rate, which lowers the real rate, increases  $y$ , and, in turn, increases the rate of inflation. These channels are the interest

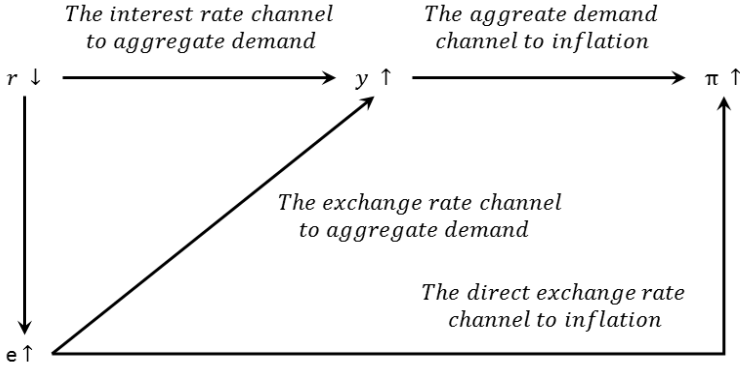


Figure 10: The monetary policy transmission mechanism in an open economy

rate channel to aggregate demand and the demand channel to inflation, and their strengths are measured by parameters  $\alpha_1$  and  $\gamma_1$ , respectively. When the real interest rate falls, the real exchange rate depreciates. The depreciation increases inflation since imported goods become more expensive, and this we call the direct exchange rate channel to inflation. The strength of that channel is measured by  $\gamma_2$ . The depreciation also improves competitiveness, which increases demand for goods and services produced in the domestic economy. We call this the exchange rate channel to aggregate demand and measure its strength by  $\alpha_2$ .

It is useful to rewrite the IS equation using the uncovered interest rate parity. This gives

$$y = -(\alpha_1 + \alpha_2)(r - \bar{r}) \quad (35)$$

where

$$\bar{r} = \rho + \frac{1}{\alpha_1 + \alpha_2}\nu + \frac{\alpha_2}{\alpha_1 + \alpha_2}((r^* - \rho) + e^e + z) \quad (36)$$

is the neutral real rate in the open economy. Compared to the closed economy, we see that the neutral real rate depends on the strength of both the interest rate channel and the exchange rate channel, in addition to exogenous variables that influence the

real exchange rate. For example, we see that the domestic neutral real rate increases when the foreign interest rate increases.

Below we will also need the reduced-form inflation equation, where inflation is only a function of the output gap. We find this equation by combining the open-economy Phillips curve (32) with the uncovered interest rate parity (34) and the IS equation (28). This gives

$$\pi = \pi^e + \left( \gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2} \right) y + u^{open}, \quad (37)$$

where

$$u^{open} = u + \frac{\gamma_2}{\alpha_1 + \alpha_2} [\alpha_1 ((r^* - \rho) + e^e + z) - \nu]. \quad (38)$$

Compared with the closed economy, the output gap affects the rate of inflation through two channels, the demand channel and indirectly through the exchange rate channel. These two channels corresponds to the two (combined) parameters inside the bracket in front of the output gap. First, an increase in the output gap increases demand for domestically produced goods. This is measured by  $\gamma_1$ . Second, in order for the output gap to increase (without any change in the shocks), the central bank needs to lower the real interest rate by  $\frac{1}{\alpha_1 + \alpha_2}$  (see equation 35). From the UIP this leads to an increase in the real exchange rate of the same order, which in turn increases inflation further.

### 3.2 Optimal monetary policy in an open economy

We assume the same loss function as in equation (5). It may be argued that the exchange rate should be included in the loss function for a small, open economy. On the other hand, unstable exchange rates result in instability in output, employment and prices. Stability in the exchange rate is therefore indirectly taken into account in the traditional loss function by including output and inflation stability.<sup>12</sup>

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<sup>12</sup>However, assigning different weights to domestic and imported inflation might be appropriate. If, for instance, there is more price rigidity in domestically produced goods than imported goods,

The first order condition for minimizing the loss function is still given by equation (6), but we now have

$$\frac{d\pi}{di} = -(\gamma_1(\alpha_1 + \alpha_2) + \gamma_2), \quad \frac{dy}{di} = -(\alpha_1 + \alpha_2).$$

We can therefore write the first order condition as

$$\pi - \pi^* = -\frac{\lambda}{\gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2}} y \quad (39)$$

Comparing equation (39) and (7), we see that the optimal trade-off now depends on the strength of the interest rate channel (and the exchange rate channel to demand). The reason is the direct exchange rate channel to inflation. We see that  $(\alpha_1 + \alpha_2)$  would disappear from the equation if  $\gamma_2$  was equal to zero. This would be the case if there is zero pass-through from exchange rates to imported inflation or that the fraction of imported goods in the consumption basket is zero. In both cases, consumer price inflation would be disconnected from exchange rate movements.<sup>13</sup>

### 3.3 Graphical analysis

To present the Phillips curve and the IS equation of an open economy, we must first take into account the exchange rate, which is an endogenous variable. We do this by using equations (37) and (35), where we have expressed inflation as a function of the output gap and the output gap as a function of the real interest rate.

We will now look at the impact of an inflation shock, a demand shock and a risk premium shock (an exchange rate shock) on inflation, output and the real interest rate. The effects of a change in the inflation target are qualitatively the same as in a

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imported inflation would have a lower weight in the loss function (see Aoki, 2001).

<sup>13</sup>We also see that the MP curve seems to be less steep in an open economy compared with a closed economy. This would be so if the coefficients are the same in open and closed economies, which obviously need not be the case. For example, when domestic consumption and investment increase after a reduction in the real interest rate, part of the increase in demand will fall on imported goods. We would therefore expect that  $\gamma_1$  is lower than the closed-economy parameter  $\gamma$ .

closed economy. These effects and the effects of changes in other exogenous variables included in (37) are left to the reader. However, it should be noted that the effects of a shock to the foreign interest rate are similar to those of a risk premium shock. As before, we use an IS diagram to provide intuition.

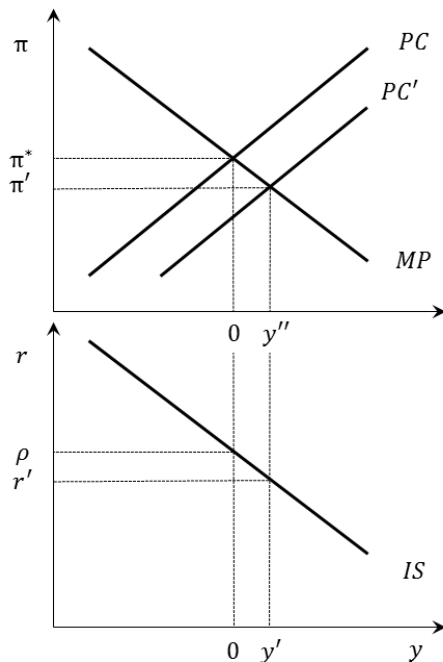


Figure 11: Negative inflation shock in an open economy

### 3.3.1 Negative inflation shock: $u < 0$

In equations (29) and (30) we see that in the open economy, the inflation shock might be due to a shock to domestic inflation ( $u^H$ ) or imported inflation ( $u^F$ ), or both. We will analyze the case where  $u^H < 0$  and we leave it to the reader to analyze the effects when there is a shock to imported inflation.

We see from equation (37) that a negative domestic inflation shock results in a

negative vertical shift in the Phillips curve, as shown in Figure 11. This is similar to the closed economy. Optimal policy will imply that the central bank lowers the real interest rate (to the new level  $r'$ ) to counteract the drop in inflation, as shown in Figure 10. This implies that the real exchange rate increases, that is we get a real depreciation. The output gap increases (to  $y'$ ), both due to lower real rates and the fact that a weaker currency increases demand for domestically produced goods and services. What about domestic and imported inflation? Domestic inflation will decrease even though the central bank partly counteracts this by increasing the output gap. Imported inflation increases due to the depreciation of the currency.

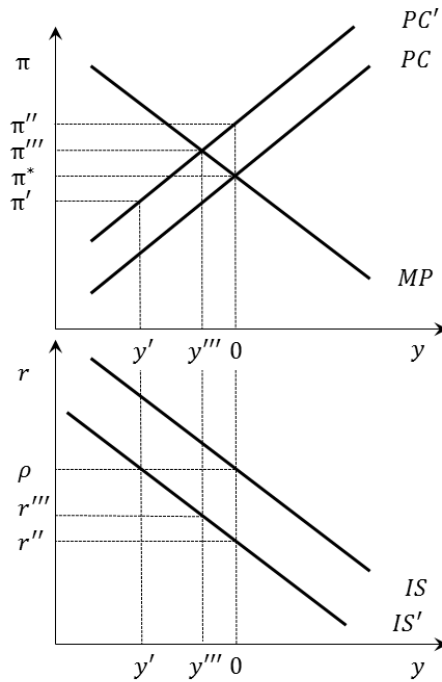


Figure 12: Negative demand shock in an open economy



### 3.3.2 Negative demand shock: $\nu < 0$

As in the closed economy, the negative demand shock implies that the IS curve shifts inward. We see from equations (37) and (38) that a negative demand shock gives a positive vertical shift in the Phillips curve of size  $\frac{\gamma_2}{\alpha_1 + \alpha_2}\nu$ , as shown in Figure 12. The reason why the Phillips curve shifts upwards is that a negative demand shock must, for a given  $y$ , lead to a weaker real exchange rate for demand to remain unchanged. The depreciating exchange rate, on the other hand, increases imported inflation.

First, suppose that the central bank does not respond with expansionary monetary policy, and the reduced demand is realized. This leads to lower output, illustrated at point  $y'$ , and lower inflation, illustrated by  $\pi'$ . However, such an adjustment by the central bank cannot be optimal—if the central bank lowers the interest rate, both inflation and output will come closer to their respective targets. By how much, then, should the central bank lower the interest rate? Assume that it lowers the interest rate so that the demand shock is completely neutralized—that is the demand shock does not affect  $y$ . In the figure, this corresponds to setting the real interest rate equal to  $r''$ . With  $y = 0$  there is no downward pressure on domestic prices and domestic inflation will be neutralized. This would have been the optimal response in a closed economy. However, the low interest rate that neutralizes the demand shock will depreciate the exchange rate, contributing to higher imported inflation. Thus, a policy that neutralizes the demand shock in an open economy will result in too high inflation (equal to  $\pi''$ ). An optimal decision allows for a slightly lower output and an inflation rate slightly higher than the target. This is illustrated in the point  $(y''', \pi''')$ , where the interest rate is reduced to  $r'''$ . The central bank thus reduces the interest rate, which implies that the exchange rate depreciates. This implies that imported inflation increases. At the same time, the output gap has fallen, which puts a downward pressure on domestic inflation.

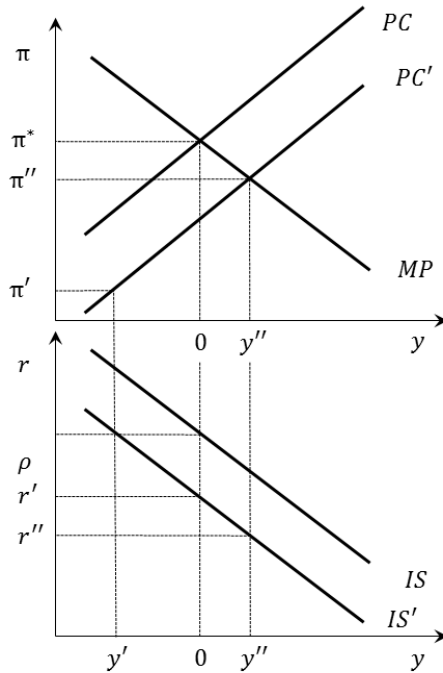


Figure 13: Negative risk premium shock

### 3.3.3 Negative risk premium shock: $z < 0$

A negative risk premium shock, that is a decreased return requirement from foreign investors on domestic securities results in a currency appreciation (for a given interest rate differential). A stronger currency, in isolation, contributes to lower imported inflation, a lower activity level in the economy, and due to the latter, lower domestic inflation. We see from equation (37) that this causes an downward shift in the rate of inflation, as shown in Figure 13. The IS curve also shifts down, since a negative risk premium shock provides, for a given interest rate differential, a stronger exchange rate and thus lower demand. If the central bank does not decrease the interest rate, both inflation and output will be lower, as in the point  $(y', \pi')$ . However, this will not be an optimal adjustment from the central bank, as decreasing the interest rate

will bring both inflation and production closer to their respective goals. It will not be possible to reach both targets, however. Having  $y = 0$  will imply a lower real interest rate and a somewhat appreciated currency, which will give a rate of inflation lower than the target. To understand why, think about what happens if the central bank completely neutralizes the effect on the exchange rate. This would imply  $y > 0$ , since  $r < \rho$  and  $e = 0$ . The optimal decision implies decreasing the interest rate below what will result in a zero output gap, in the figure to  $r''$ , so inflation will come closer to the target, at the expense of a positive output gap, represented by the point  $(y'', \pi'')$  in the figure. As far as domestic and imported inflation is concerned, the currency appreciates, which pulls imported inflation down. The output gap increases, which pulls domestic inflation up.

### 3.4 Simple rules in the open economy

We will end this section by analyzing simple rules, as we did for the closed economy. We start by assuming that the central bank sets real interest rates according to equation (13) above, which we repeat here:

$$i = \rho + \pi^e + \theta (\pi - \pi^*).$$

If we once again use this equation to replace the real interest rate in the IS equation, we obtain:

$$\pi - \pi^* = -\frac{1}{\theta} \frac{1}{\alpha_1 + \alpha_2} (y - \nu - \alpha_2 ((r^* - \rho) + e^e + z)). \quad (40)$$

Let us compare this equation with the optimal trade-off in the open economy in equation (39). First, as in the closed economy, we see that the monetary policy schedule would have the right slope if  $\theta$  takes a particular value. Furthermore, we see that the demand shock still distorts the monetary policy trade-off. In addition, the policy rule in equation (13) also implies distorted reactions to changes in foreign

interest rates, to changes in the expected real exchange rate and to risk premium shocks.

The next task is to analyze how the policy rule in equation (40) needs to be changed in order to replicate optimal policy as in the closed economy. To this end, we solve the MP schedule in equation (39) with respect to the output gap and use it to replace the output gap in equation (35). The latter is the IS equation where we have used the UIP condition to replace the real exchange rate. Solving the resulting equation with respect to the nominal interest rate gives:

$$i = \bar{r} + \pi^e + \frac{1}{\alpha_1 + \alpha_2} \frac{\gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2}}{\lambda} (\pi - \pi^*).$$

This rule is remarkably similar to the one for the closed economy. As in that case, the central bank should set the nominal interest rate equal to the short-run neutral nominal rate if the inflation gap is zero. Of course, the neutral nominal rate will depend on open-economy variables, as we discussed above. If inflation is higher than the target, the central bank should increase the nominal interest rate. And compared with the closed economy, the central bank should take into account the exchange rate channel ( $\frac{1}{\alpha_1 + \alpha_2}$  versus  $\frac{1}{\alpha}$ ) and the fact that the policy trade-off is different in an open economy ( $\frac{\gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2}}{\lambda}$  versus  $\frac{\gamma}{\lambda}$ ).

## 4 Conclusion

We have presented a simple model for monetary policy under an inflation target. The strength of the model is that it focuses on the objective of monetary policy and describes how the interest rate is set to achieve the monetary policy goals. It thus gives a more realistic description of monetary policy as it is conducted in most countries than traditional textbook models like the IS-LM model, even if the LM curve is replaced by a constant nominal (or real) interest rate or a simple policy rule.

The model is particularly well-suited for graphical studies of various shocks in diagrams with inflation and the output gap. A key model assumption is that the central bank seeks to balance achieving the inflation target on the one hand while taking into account real economic stability on the other hand. In response to shocks which cause short-term conflicts between these considerations, the central bank will set interest rates so that the inflation gap and the output gap have opposite signs.

In a closed economy, the central bank will seek to neutralize demand shocks, and target levels for both inflation and output will be achieved. In an open economy, on the other hand, this is not feasible as the exchange rate directly affects inflation. With a positive demand shock, it will be optimal to set interest rates so that inflation will be somewhat lower than the target and the output gap will be positive. An open economy will generally experience more shocks causing short-term conflicts between the inflation target and the goal of a stable real economy than will a closed economy. In isolation, inflation targeting is more demanding in an open economy. On the other hand, monetary policy might be more effective in influencing inflation in an open economy as it has an extra transmission channel; the exchange rate channel.

Under inflation targeting, although the exchange rate might not be included directly in the function for setting interest rates, the central bank will respond to exchange rate movements when setting optimal interest rates. The reason for this is that changes in the exchange rate affect both inflation and output. Some exchange rate movements will be optimal, however, as they will contribute to more stability in inflation and the real economy when shocks occur.

The static model is appropriate for describing the main principles of inflation targeting in a pedagogical way. The model does not capture the time lag in the monetary policy transmission mechanism and the dynamics of the economy, however.

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## Appendix: Some algebra

*The neutral short-run real interest rate:* We get the neutral short-run rate by using equation (1):

$$0 = -\alpha(\bar{r} - \rho) + \nu, \quad (\text{A.1})$$

where we have used that  $r = i - \pi^e$ . We get equation (3) by solving (A1) with respect  $\bar{r}$  and equation (2) by subtracting (A1) from (1).

*Equilibrium inflation, output gap and nominal interest rate in the closed economy:*

We start by substituting for the output gap in equation (4) using equation (8):

$$\pi = \pi^e - \frac{\gamma^2}{\lambda} (\pi - \pi^*) + u,$$

and then we solve this equation with respect to the rate of inflation. This gives

$$\pi - \pi^* = \frac{\lambda}{\lambda + \gamma^2} [(\pi^e - \pi^*) + u], \quad (\text{A.2})$$

which is the equilibrium solution for the rate of inflation. Next, we combine (A.2) with (8)

$$\begin{aligned} -\frac{\lambda}{\gamma} y &= \frac{\lambda}{\lambda + \gamma^2} [(\pi^e - \pi^*) + u] \\ y &= -\frac{\gamma}{\lambda + \gamma^2} [(\pi^e - \pi^*) + u]. \end{aligned} \quad (\text{A.3})$$

This gives equation (10) in the text. Last, we find the equilibrium interest rate. To this end, we use equation (12) and substitute for the output gap using equation (10):

$$i = \bar{r} + \pi^e + \frac{1}{\alpha} \frac{\gamma}{\lambda + \gamma^2} [(\pi^e - \pi^*) + u]. \quad (\text{A.4})$$

Rewriting gives the equation (11) in the text.

*Simple rules in the closed economy:* We want to derive a monetary policy schedule given the interest rate rule in equation (14). We do this by using the rule to remove



the interest rate in the IS equation (1):

$$\begin{aligned}
 y &= -\alpha(\rho + \pi^e + \theta(\pi - \pi^*) - \pi^e - \rho) + \nu \\
 &= -\alpha\theta(\pi - \pi^*) + \nu.
 \end{aligned}
 \tag{A.5}$$

Solving this equation with respect to the inflation gap gives the equation in the text.

To develop the simple rule that implements optimal policy, we do the reverse. We start with equation (8) and use the IS equation (2) to substitute for the output gap. This gives

$$\begin{aligned}
 -\alpha(r - \bar{r}) &= -\frac{\gamma}{\lambda}(\pi - \pi^*) \\
 r &= \bar{r} + \frac{\gamma}{\alpha\lambda}(\pi - \pi^*).
 \end{aligned}
 \tag{A.6}$$

Using the fact that  $r = i - \pi^e$  we obtain equation (16) in the text.

*Financial stability:* To derive equation (21), we need to insert for the derivatives in equation (20). They are given by

$$\frac{d\pi}{dr} = -\alpha\gamma, \quad \frac{dy}{dr} = -\alpha, \quad \frac{dq}{dr} = \phi.$$

We obtain the first equality in equation (21) by solving the resulting equation with respect to the inflation gap. To get the second equality, we write the financial gap as a function of the output gap. To this end, we combine (12) and (18):

$$\begin{aligned}
 q &= -\phi\left(\rho + \frac{1}{\alpha}v - \frac{1}{\alpha}y - \rho\right) + w \\
 &= \frac{\phi}{\alpha}y + w - \frac{\phi}{\alpha}v,
 \end{aligned}
 \tag{A.7}$$

which can be used to substitute for  $q$  in the optimality condition. This gives

$$(\pi - \pi^*) = -\frac{\lambda}{\gamma}y - \frac{\phi\delta}{\alpha\gamma} \left( \frac{\phi}{\alpha}y + w - \frac{\phi}{\alpha}v \right) = -\frac{\lambda + \delta \left( \frac{\phi}{\alpha} \right)^2}{\gamma}y - \frac{\phi\delta}{\gamma\alpha^2}(\alpha w - \phi v). \quad (\text{A.8})$$

For completeness, we can derive equilibrium values of  $\pi$ ,  $y$  and  $q$ . First, we combine (A.8) with the Phillips curve (4):

$$(\pi^e - \pi^*) + \gamma y + u = -\frac{\lambda + \delta \left( \frac{\phi}{\alpha} \right)^2}{\gamma}y - \frac{\phi\delta}{\gamma\alpha} \left( w - \frac{\phi}{\alpha}v \right),$$

which can be solved with respect to the output gap to yield:

$$\begin{aligned} \gamma(\pi^e - \pi^*) + \gamma^2 y + \gamma u &= - \left( \lambda + \delta \left( \frac{\phi}{\alpha} \right)^2 \right) y - \frac{\phi\delta}{\alpha} \left( w - \frac{\phi}{\alpha}v \right) \\ y &= -\frac{\gamma}{\gamma^2 + \lambda + \delta \left( \frac{\phi}{\alpha} \right)^2} \left[ (\pi^e - \pi^*) + u + \frac{\phi\delta}{\alpha\gamma} \left( w - \frac{\phi}{\alpha}v \right) \right]. \end{aligned}$$

We obtain the rate of inflation by combining with (4)

$$\begin{aligned} \pi &= \pi^e + \gamma \left[ -\frac{\gamma}{\gamma^2 + \lambda + \delta \left( \frac{\phi}{\alpha} \right)^2} \left[ (\pi^e - \pi^*) + u + \frac{\phi\delta}{\alpha\gamma} \left( w - \frac{\phi}{\alpha}v \right) \right] \right] + u \\ &= \pi^* + \frac{\lambda + \delta \left( \frac{\phi}{\alpha} \right)^2}{\gamma^2 + \lambda + \delta \left( \frac{\phi}{\alpha} \right)^2} [(\pi^e - \pi^*) + u] - \frac{\frac{\gamma\phi\delta}{\alpha}}{\gamma^2 + \lambda + \delta \left( \frac{\phi}{\alpha} \right)^2} \left( w - \frac{\phi}{\alpha}v \right), \end{aligned}$$

and the financial gap by combining with (A.7)

$$q = -\frac{\frac{\gamma\phi}{\alpha}}{\gamma^2 + \lambda + \delta \left( \frac{\phi}{\alpha} \right)^2} [(\pi^e - \pi^*) + u] + \frac{\gamma^2 + \lambda}{\gamma^2 + \lambda + \delta \left( \frac{\phi}{\alpha} \right)^2} \left( w - \frac{\phi}{\alpha}v \right).$$

To find the simple policy rule (22), we solve equation (21) with respect to the output gap

$$y = -\frac{\gamma}{\lambda}(\pi - \pi^*) - \frac{\phi\delta}{\alpha\lambda}q, \quad (\text{A.9})$$

and we use this substitute for  $y$  in equation (12)

$$r = \bar{r} - \frac{1}{\alpha}y = \bar{r} + \frac{1}{\alpha} \frac{\gamma}{\lambda} (\pi - \pi^*) + \frac{\phi\delta}{\alpha^2\lambda}q.$$

Next, we use (19) to replace  $q$ . This gives

$$\begin{aligned} r &= \bar{r} + \frac{1}{\alpha} \frac{\gamma}{\lambda} (\pi - \pi^*) - \frac{\delta \left(\frac{\phi}{\alpha}\right)^2}{\lambda} (r - \tilde{r}) \\ r &= \frac{\lambda}{\lambda + \delta \left(\frac{\phi}{\alpha}\right)^2} \left[ \bar{r} + \frac{1}{\alpha} \frac{\gamma}{\lambda} (\pi - \pi^*) \right] + \frac{\delta \left(\frac{\phi}{\alpha}\right)^2}{\lambda + \delta \left(\frac{\phi}{\alpha}\right)^2} \tilde{r}. \end{aligned} \quad (\text{A.10})$$

We obtain equation (22) in the text by using  $r = i - \pi^e$ .

*Financial accelerator model:* In this case the derivatives describing the monetary policy transmission mechanism are given by:

$$\frac{d\pi}{dr} = -\bar{\alpha}\gamma, \quad \frac{dy}{dr} = -\bar{\alpha}, \quad \frac{dq}{dr} = -\bar{\phi}.$$

Combining the above with (20), we obtain

$$(\pi - \pi^*) = -\frac{\lambda}{\gamma}y - \frac{\bar{\phi}\delta}{\bar{\alpha}\gamma}q = -\frac{\lambda}{\gamma}y - \left( \frac{\tau\alpha + \phi}{\alpha + \chi\phi} \right) \frac{\delta}{\gamma}q. \quad (\text{A.11})$$

Next, we solve for the financial gap as a function of the output gap. We combine (25) and (26) to get:

$$q = \left( \frac{\tau\alpha + \phi}{\alpha + \chi\phi} \right) y + \frac{\tau\alpha + \phi}{1 - \chi\tau} (\tilde{r} - \bar{r}). \quad (\text{A.12})$$

Then we insert for  $\bar{r}$  and  $\tilde{r}$ , which gives

$$\begin{aligned} q &= \left( \frac{\tau\alpha + \phi}{\alpha + \chi\phi} \right) y + \frac{\tau\alpha + \phi}{1 - \chi\tau} \left( \left( \frac{1}{\tau\alpha + \phi} - \frac{\chi}{\alpha + \chi\phi} \right) w + \left( \frac{\tau}{\tau\alpha + \phi} - \frac{1}{\alpha + \chi\phi} \right) \nu \right) \\ &= \left( \frac{\tau\alpha + \phi}{\alpha + \chi\phi} \right) y + \frac{1}{\alpha + \chi\phi} (\alpha w - \phi\nu). \end{aligned} \quad (\text{A.13})$$

Last, we combine this with the optimality condition (A.11) above to obtain

$$(\pi - \pi^*) = -\frac{\lambda + \delta \left( \frac{\tau\alpha + \phi}{\alpha + \chi\phi} \right)^2}{\gamma} y - \frac{\delta}{\gamma} \frac{\tau\alpha + \phi}{(\alpha + \chi\phi)^2} (\alpha w - \phi\nu). \quad (\text{A.14})$$

*The open-economy IS equation:* To derive equation (35), we first use the UIP condition to substitute for the exchange rate in equation (28). This gives:

$$\begin{aligned} y &= -\alpha_1(r - \rho) + \alpha_2(e^e - (r - r^*) + z) + \nu \\ &= -(\alpha_1 + \alpha_2)(r - \rho) + \alpha_2(e^e - (r^* - \rho) + z) + \nu. \end{aligned} \quad (\text{A.15})$$

Next, we can find the natural real rate by setting the output gap equal to zero:

$$\begin{aligned} 0 &= -(\alpha_1 + \alpha_2)(\bar{r} - \rho) + \alpha_2(e^e - (r^* - \rho) + z) + \nu \\ \bar{r} &= \rho + \frac{1}{\alpha_1 + \alpha_2}\nu + \frac{\alpha_2}{\alpha_1 + \alpha_2}(e^e + (r^* - \rho) + z). \end{aligned} \quad (\text{A.16})$$

Subtracting the next to last equation above from (A.15) gives equation (35) in the text.

*The open-economy PC schedule:* First we add and subtract  $\rho$  in equation (34) and solve the resulting equation with respect to  $r - \rho$ . This gives

$$r - \rho = -(e - e^e) + (r^* - \rho) + z. \quad (\text{A.17})$$

Next, we insert this into equation (28):

$$y = \alpha_1[(e - e^e) - (r^* - \rho) - z] + \alpha_2 e + \nu,$$

which we solve with respect to  $e$ :

$$e = \frac{1}{\alpha_1 + \alpha_2} [y + \alpha_1(e^e + (r^* - \rho) + z) - \nu]. \quad (\text{A.18})$$

Last, we put this expression into the Phillips curve (32):

$$\begin{aligned}\pi &= \pi^e + \gamma_1 y + \frac{\gamma_2}{\alpha_1 + \alpha_2} [y + \alpha_1 (e^e + (r^* - \rho) + z) - \nu] + u \\ &= \pi^e + \left( \gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2} \right) y + \frac{\gamma_2}{\alpha_1 + \alpha_2} [\alpha_1 (e^e + (r^* - \rho) + z) - \nu] + u\end{aligned}\quad (\text{A.19})$$

*Simple rule in the open economy:* We derive the monetary policy schedule by eliminating the interest rate in the IS equation (35):

$$\begin{aligned}y &= -(\alpha_1 + \alpha_2) (\theta (\pi - \pi^*) - (\bar{r} - \rho)) \\ &= -(\alpha_1 + \alpha_2) \theta (\pi - \pi^*) + (\nu + \alpha_2 (e^e + (r^* - \rho) + z)),\end{aligned}\quad (\text{A.20})$$

where we have used the natural real interest rate (36) in the second equality. Solving this equation with respect to the inflation gap gives the equation in the text.

To find the optimal simple rule, we first solve the optimality condition with respect to the output gap:

$$y = -\frac{\gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2}}{\lambda} (\pi - \pi^*). \quad (\text{A.21})$$

Next, we use this to substitute for the output gap in equation (35) and solve it with respect to the nominal interest rate:

$$\begin{aligned}\frac{\gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2}}{\lambda} (\pi - \pi^*) &= (\alpha_1 + \alpha_2) (i - \pi^e - \bar{r}). \\ i &= \bar{r} + \pi^e + \frac{1}{\alpha_1 + \alpha_2} \frac{\gamma_1 + \frac{\gamma_2}{\alpha_1 + \alpha_2}}{\lambda} (\pi - \pi^*).\end{aligned}\quad (\text{A.22})$$

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