II. Monetary policy design and criteria for assessing monetary policy rules

In this chapter, I provide a more general perspective to the main theoretical and practical issues in monetary policy design, which are relevant for the assessment of the several interest rate rule specifications in the subsequent parts. The issues covered in Section 1 include the advantages and implications of systematic policy behaviour (as opposed to discretionary measures) and choice of instruments/target variables that enter the rule specification. In addition, Section 2 presents the main criteria that will be used in the subsequent determinacy and impulse response analysis in Chapters III and IV. The Taylor principle, which forms the basis for the classification of monetary policy rules in terms of the degree of their “activeness” (measured by the size of the inflation response coefficient), is presented formally in the last subsection. Later on, in Section 4 in the subsequent chapter the main findings will be centred on the question whether adherence to the Taylor principle guarantees a determinate rational-expectations equilibrium when endogenous capital with adjustment costs is introduced to a New Keynesian model with staggered price-and wage-setting.

1. Monetary policy issues

In the 1960s and 1970s “activist” monetary policies, aimed at achieving “full employment” have been widely discussed and implemented\(^5\). The rise of such policies has been motivated by the conviction that there exists a stable long-run trade-off between inflation and unemployment, captured by the Phillips curve\(^6\). According to this view, in the long run the monetary authority can attain a permanent reduction in the unemployment rate by allowing for a higher rate of inflation. At the same time, estimates of these (allegedly) stable relations between inflation and unemployment have been computed by using large econometric models that assigned precise quantitative dimensions to the policy trade-off. The actual experience with the activist pursuit of full employment by monetary policy means has contradicted the policy-makers’ anticipated outcome. Not only did the business cycle fluctuations not disappear in the 1970s, but the worldwide recessions of 1973-74 and 1981-82 were among the most severe in the second half of the twentieth century, characterised by high unemployment and inflation (“stagflation”). Thus, in spite of not attaining the aspired policy objective, the “sacrifice” in terms of higher inflation rate has still been realised: the late 1960s and most of the 1970s were characterised by rising and variable rates of inflation in many countries.

\(^5\) For a more detailed discussion of monetary policy strategies in the 1960s and 1970s, see Mishkin (2006).

\(^6\) See Phillips (1958) and Samuelson and Solow (1960).
Parallel to the practical experience with activist policies, there has also been an academic critique of using monetary policy as a tool to obtain full employment at the expense of a higher inflation rate. Among the most influential arguments are Milton Friedman’s monetary critique concerning the uncertain outcomes of monetary policy interventions\(^7\), the Lucas critique of the optimal control paradigm for monetary policy\(^8\), the conclusion reached by Friedman (1968) and Phelps (1968) that there is no long-run trade-off between inflation and unemployment, as well as the warning against the perils of time inconsistency under discretionary policy delivered by Kydland and Prescott (1977), Calvo (1978) and Barro and Gordon (1983).

Without denying the significant impact of monetary policy on the economy, Friedman argued that monetary policy is a tool that cannot be used with precision for stabilisation purposes. In “The Role of Monetary Policy” he explicitly warns against “the belief that the state of employment itself should be the proximate criterion of policy”, adding that

\[
\ldots\text{I fear that... the pendulum may well have swung too far, that... we are in danger of assigning to monetary policy a larger role than it can perform, in danger of asking it to accomplish tasks that it cannot achieve, and, as a result, in danger of preventing it from making the contribution that it is capable of making (Friedman, 1968, p. 5).}
\]

Friedman emphasised that, due to long and variable lags of monetary policy, a too strong policy response might have a destabilising effect on the economy. This forms the basis for the subsequent discussion on the appropriate degree of activism of monetary policy. As argued by Blanchard and Fischer (1993), under long and variable lags very strong policy responses to shocks could create instrument instability. Instrument instability arises when the current effects of changes in the monetary policy instrument are small and the lagged effects large, so that large changes in the policy instrument are required to offset the effects of a recent shock, creating the need for even larger changes later on. An even more powerful argument for more moderate policy responses has to do with uncertainty about the structural coefficients in the model, i.e. to what extent the variability of the instrument increases the variability of the target variables.

Although Friedman’s criticism emphasises the technical difficulties in controlling the policy outcomes, it does not fundamentally rule out activist central bank behaviour. If the pitfalls of the active pursuit of short-run output stabilisation had been predominately of instrumental nature, implementing more elaborate methods such as the (at that time increasingly popular) techniques of optimal control would have been sufficient to compensate for lags between policy measures and their effects. Thus, for policy activism to be ruled out as an appropriate central bank strategy, a formal methodological critique of the proposed

---

7 See Friedman and Schwartz (1963).
8 See Lucas (1976).
techniques of optimal control or a substantial re-evaluation of the implied stable relation between inflation and unemployment were needed.

The formal methodological critique of optimal control has been put forward by Lucas (1976) who argues that macroeconomic models that are not based on consistent microeconomic underpinning are non-structural and cannot be useful for policy evaluation. The underlying reason for that finding is that the estimated coefficients of such models’ equations include both structural and policy parameters and are therefore not invariant to the choice of monetary policy regime.

1.1. The case for rules rather than discretion

The general equilibrium framework adopted in recent research permits explicit utility-based welfare analysis by introducing a quadratic central bank loss function that involves stabilizing inflation around an inflation target and stabilizing the real economy, represented by the output gap. Some examples of research incorporating such a loss function include Clarida et al. (1999), McCallum et al. (1999, 2000), Svensson et al. (2000), Woodford (2001).

One of the main issues in monetary policy research in recent years has been whether central banks should commit themselves to a systematic approach to monetary policy that involves an explicit framework for decision-making and is communicated to the public.

1.1.1. Analytical distinction between rules and discretion

For the subsequent analysis, it is necessary to introduce an analytical distinction between the two main strategies of monetary policy conduct - discretionary and rule-based monetary policy. In an argument on rule—based monetary policy Friedman (1962) notes that under a policy rule decisions are made by following a procedure applicable to many distinct cases and not on a case-by case basis, which has favourable effects on expectations. He notes that, under discretionary policy, wrong decisions are likely to be made in a large fraction of cases because the decision-makers are not taking into account the cumulative consequences of the policy as a whole. By contrast, adopting a general rule is adopted for a group of cases as a bundle would have favourable effects on people’s attitudes and expectations that would not follow even from the discretionary adoption of precisely the same actions on a series of separate occasions.

Taylor (1993) emphasises that under pure discretion, “the settings for the instruments of policy are determined from scratch each period with no attempt to follow a reasonably well-defined contingency plan for the future.” Alternatively, rule-based behaviour is systematic, or in other words “methodical, according to a plan, and not casual or random.” McCallum (1993) argues that although this condition is necessary, it is not sufficient for a rule-based policy. Under rational expectations, in order for rule-like behaviour to be at place, the central bank should not only be systematic in the sense of applying the same type of response
each period, but should also design the systematic response pattern taking into account the private sector’s expectational behaviour. Under a theoretical point of view the distinction is between: (i) responding to existing conditions as prescribed by a prearranged formula specifying instrument settings. The formula could be derived as a result of optimisation analysis, but is not influenced by current conditions in each period; and (ii) period-by-period optimisation based on current conditions while treating past experiences and policies as irrelevant bygones.

Last but not least, a rule-based monetary policy procedure should rule out the temptation to exploit existing expectations for temporary output gains by creating an inflationary bias as in the baseline framework on dynamic inconsistency developed by Kydland and Prescott (1977).

1.1.2. The problem of dynamic inconsistency

According to the definition of Blanchard and Fischer (1993) “a policy is dynamically inconsistent when a future policy decision that forms part of an optimal plan formulated at an initial date is no longer optimal from the viewpoint of a later date, even if no relevant new information has appeared in the meantime”. Extensive theoretical research has been devoted to this subject since Kydland and Prescott (1977) first argued that optimal macroeconomic policies could be dynamically inconsistent. The basic question refers to the costs of a government not being able to commit itself to implementing announced policy actions or, equivalently, of the benefits of policy rules over discretion. Under rational expectations, a policy commitment (such as following a rule) means carrying out the policy that is optimal and expected. By contrast, under discretionary policy the private sector in each period may anticipate that the government will opt for the short-run optimal decision and react accordingly.

Barro and Gordon (1983) reveal the motivation behind inconsistent behaviour in monetary policy conduct. They point to two main sources of temporary benefits from inducing surprise inflation. One source of benefits can be derived from the dependence of the output gap on inflation expectations, whereby unanticipated monetary expansions lead to increases in real economic activity, lowering the unemployment rate below the natural rate. The other source of potential benefits from surprise inflation involves the reductions in real value of the government’s liabilities that are fixed in nominal terms. However, since under rational expectations the private sector is able to understand the central bank’s incentives and adjust its inflationary expectations accordingly, surprise inflation

9 The natural rate is defined by Barro and Gordon (1983) as “the value that would be ground out by the private sector in the absence of monetary disturbances”. The natural rate can shift over time because of supply shocks, demographic changes, shifts in governmental tax and transfer programs, etc. As the authors point out, the natural rate need not be optimal.
and the benefits arising from it cannot be induced systematically in equilibrium. If the private sector anticipates the potential for introducing inflationary shocks, in equilibrium the average rate of inflation and its corresponding costs will be higher than under maintained credible monetary policy commitment. Thus, under rational expectations, nothing is gained from opportunism and the outcome is in general worse compared to the commitment scenario.

1.1.3. Advantages of central bank commitment to a monetary policy rule

Based on the time-inconsistency literature findings presented in the previous subsection, two main advantages of central bank commitment to an explicit policy rule can be derived.\(^\text{10}\)

The first benefit of such an approach includes increased predictability of central bank actions, which is essential for improving policy effectiveness that depends not only on the actual measures taken, but also on the public’s expectations about future policy. This provides central banks with an important tool of stabilisation policy, as market expectations about the future path of short-run interest rates influence other financial-market prices (such as long-term interest rates, equity prices and exchange rates) that ultimately affect spending decisions. In order for this mechanism to function, the public needs to have a clear enough understanding of the rule that the central bank follows in deciding on policy actions. To this end, it could be enough that the central bank commits itself to a systematic way of determining an appropriate response to future developments, without having to explicitly specify actions under every circumstance possible.

The second main benefit from a systematic approach has to do with the optimal outcomes of a behaviour bound by past commitments. As first postulated by Kydland and Prescott (1977), even if the central bank has a correct quantitative model of the economy and of its policy trade-offs in each period and the private sector forms correct expectations about future policy, the outcome under discretion may be substantially worse than under commitment. In this line of argument, Woodford (2003) argues that the main gains from commitment in this respect are in terms of eliminating the inflation bias\(^\text{11}\) characterising sequential (discretionary) optimisation and an optimal reaction to shocks/real disturbances.\(^\text{12}\)

---

\(^\text{10}\) It should be noted that the benefits that are elaborated in this subsection are model-specific.

\(^\text{11}\) For further elaboration on inflation bias under discretion, see Kydland and Prescott (1977) and Barro and Gordon (1983).

\(^\text{12}\) Rule-based (forward-looking) decision making allows for a more persistent reaction to real disturbances over time and thus implies reducing the volatility in short-run interest rates.
An interesting new topic in the rules vs. discretion debate concerns the role of credibility. The main finding is that in the presence of a trade-off between the two policy objectives (price stability and actual output), a credible central bank commitment to a state-contingent policy results in a greater welfare gain as compared to discretionary policy. An example for this approach can be found in Woodford (1999), where the inefficiency that arises from discretionary policymaking equals the discounted present value of current and future period losses (squared deviations of inflation and output from their target levels).

1.2. Design of monetary policy rules

The issue of how a monetary policy rule should be designed has been subject to much theoretical debate in the last several decades. The discussion could be traced back to Friedman’s arguments in the 50s and 60s for a rule of constant money growth13. Apart from that particular instrument setting, in more general terms Friedman argued that monetary policy should be fixed by a rule, thus ruling out discretionary policy.

Before discussing the theoretical and practical developments concerning monetary policy design, it would be useful to identify the transmission channels of monetary impulses to the economy. Among others, Arestis and Sawyer (2002, 2003) identify six channels of monetary policy transmission: (i) the interest rate channel; (ii) the wealth effect channel; (iii) the exchange rate channel (under an open-economy perspective); (iv) the monetarist channel; (v) the narrow credit channel and (vi) the broad credit channel.

Both the narrow and the broad credit channel refer to how changes in the financial positions of borrowers and lenders affect aggregate demand in an economy with credit market frictions. The narrow credit channel emphasised by Hall (2001)14 and Bernanke and Blinder (1988) concerns the role of the banking sector as lender. When monetary policy induces changes of banking sector’s total reserves, the supply of loans to the private sector will be affected. Given the fact that normally a significant number of producers and consumers depend on bank lending to finance their investment and consumption spending, ultimately monetary policy interventions are bound to affect aggregate demand and inflation in the economy. In addition, the broad credit channel described by Hall (2001)15, Bernanke and Gertler (1999) and Bernanke et al. (1998) takes into consideration the effect of the monetary policy stance on the financial position of borrowers. If imperfect information in terms of the supply of external finance to the private

---

13 See Friedman (1960, 1962).
14 Hall (2001) originally refers to the narrow credit channel as “bank lending channel”.
15 The broad credit channel is called “balance sheet channel” in the Hall (2001) classification.
sector is assumed, lenders charge a (risk) premium\textsuperscript{16} on loans dependent on the borrower’s financial position. Generally, low gearing\textsuperscript{17} implies small external finance premium and vice versa. In this setting, the monetary policy stance affects aggregate demand through corporate cash flows and asset price developments. As to the former mechanism, a policy-induced increase in the interest rate raises the individual firm’s gearing ratio, thereby boosting the required premium on external finance. The second effect of policy-induced interest rate hikes pertains to asset prices that determine the value of loan collateral. According to this “financial accelerator” effect, higher interest rates may lead to falling asset prices and consequently a decline in the value of the collateral, thus leading to an increase in the borrower premium. On a broader scale, monetary impulses channelled through the financial sector by means of the narrow or broad credit channel affect investment and consumption decisions and consequently aggregate demand in the economy.

Apart from the importance for gaining access to external finance, asset prices affect aggregate demand through the wealth effect channel. If the consumption function is constructed to depend on consumer wealth, consumption expenditure is affected by the value of real consumer wealth (i.e. by asset prices).

Next, the distinction between the interest rate and the monetarist channels is explained by the choice of a monetary aggregate or the interest rate as a monetary policy instrument. If the nominal interest rate is the policy instrument, the money supply is endogenous and vice versa. The choice between both instruments determines the particular type of the initial monetary impulse; still, if the degree of substitutability between money and financial (especially short-term liquid) assets is very high, changes in money supply have a significant impact on interest rates. Under a sufficient degree of price stickiness, the real interest rate and the return on capital will also be affected. As a result, as long as consumption and investment decisions are interest-rate sensitive, the interest rate changes influence aggregate demand. Of course, the transmission of the monetary policy impulse to the economy is to a great extent dependent on the functioning of the financial sector. Instead of symmetrically adjusting their interest rates in response to the policy-induced interest rate changes, financial institutions may choose to perform some type of credit rationing\textsuperscript{18}. In the context of the interest and the monetary transmission channels, a broader perspective to the implications of money supply as a policy instrument beyond the effect on interest rates may also be relevant. In case a high degree of substitutability between money

\textsuperscript{16} In this context, Arestis and Sawyer (2003) mention a “premium to cover monitoring costs” charged by lenders.

\textsuperscript{17} I.e. a low debt-to-equity ratio.

\textsuperscript{18} For a thorough study of the determinants and forms of credit rationing, see Jaffee and Modigliani (1969), Stiglitz and Weiss (1981) and Blinder and Stiglitz (1983).
and real assets is assumed, the impact of money supply changes would also depend on relative price changes. In this case, apart from interest rates, asset prices also affect aggregate demand and should be considered by the monetary authority.

The last monetary policy transmission channel, the exchange rate channel, concerns the open economy and links monetary policy to inflation through several effects. One of them pertains to aggregate demand and functions through the uncovered interest rate parity condition, matching interest rate differentials to expected exchange rate changes. Another type of effect works through import prices.

The six transmission channels identified by Arestis and Sawyer (2002, 2003) all describe variations of aggregate demand channel. Thus, from a broader perspective, monetary policy transmission can be classified as giving an initial impulse either to aggregate demand or to aggregate supply. In this context, Taylor (2000) speaks of “aggregate demand” and “staggered price adjustment” component of the monetary transmission mechanism. As far as monetary policy transmission from the aggregate demand perspective is concerned, Taylor (2000) identifies the “financial market price view” and the “credit view”. The former emphasizes the impact of monetary policy on the prices and rates of return on financial assets (e.g. bonds prices, interest and exchange rates) and consequently on firm and household spending decisions. The credit view stresses the impact of monetary policy on lending by banks or other financial institutions as alternative to internal finance. The “staggered price adjustment” channel (denoted “expectations channel” in Svensson (1999b)) allows monetary policy to affect inflation expectations which, in turn, affect inflation with a lag via the wage- and price-setting decisions of economic agents.

Last but not least, incorporating an aggregate supply transmission channel of monetary policy allows for a more thorough analysis of monetary policy outcomes. The framework with endogenous capital presented in the next chapter enables tracking the supply-side response to shocks induced under several rule specifications, thus offering a broader insight into medium- to long-run adjustments in the economy.

1.2.1. Rules, instruments and targets

In the recent decades interest-rate rules have attracted much theoretical attention. Despite the fact that central banks have been reluctant to publicly commit to an interest-rate rule of a specific form, there is some evidence that past behav-

---

19 For a closed-economy setting, building blocks, micro-foundations and different specifications of these two general transmission mechanism channels are modeled by King and Wolman (1996), Woodford (1996), Yun (1996), Goodfriend and King (1997), Rotemberg and Woodford (1998), McCallum and Nelson (1999) and Clarida et al. (1999).
The behavior of some monetary authorities can be described by an explicit rule, the central banks of some major economies nowadays apply explicit inflation targets (inter alia, the ECB, the Bank of England and Bank of Canada).

In the subsequent exposition, I will concentrate on interest-rate rules for conducting monetary policy. Although other definitions of a monetary policy rule could be possible, for the purpose of this work I adopt the definition of Taylor (1998):

"...a monetary policy rule is defined as a description—expressed algebraically, numerically or graphically—of how the instruments of policy, such as the monetary base or the federal funds rate, change in response to economic variables" (Taylor, 1998, p.3).

Furthermore, for the subsequent analysis it is necessary to provide a definition of instruments, targets, goals/objectives and indicators of monetary policy. From a practical perspective, Borio (1997) and Ho (2008) distinguish between the strategic and tactical level of the monetary authorities’ pursuit of policy goals (see Figure 2.1). At the strategic level, certain macroeconomic goals or final objectives are pursued, such as price stability, long-term growth or employment. By contrast, the tactical (operating) level covers the choice of instruments and operating objectives/targets. The latter are variables which can be influenced quite fast and closely by the central bank. Examples of monetary policy instruments include the official interest rates (e.g. on standing facilities), market operations (e.g. repo tenders, FX operations), reserve requirements and, in the past, direct controls (e.g. ceilings on loans or on bank depositor loan rates).

According to McCallum (2001b), instruments are variables that the central bank can control quickly and directly or at least accurately, the usual contenders being short-term interest rates, the monetary base or a measure of bank reserves. Goals/Objectives are variables that enter the central bank objective function. In case the ultimate goals are not promptly observable, the central bank employs a two-step procedure, attempting to hit target variables that are treated as surrogates for the ultimate objectives. Examples for target variables are the monetary aggregates M1, M2 and nominal GDP. Indicators are information variables, for which the central bank does not try to hit specified paths.

---

20 For example, the Taylor rule (Taylor (1993)) seems to have described the actions of the Fed remarkably accurately during most of the 80s and 90s of the past century.

21 For example, short-term financial market interest rates, exchange rates, etc.
1.2.2. Choice of instruments

A long-standing discussion in monetary policy research has concentrated on the issue whether the monetary authority should use money or the interest rate to target inflation and/or output. Money supply as a policy instrument gained increasing popularity in the 1960s and 1970s. In fact, in his policy proposals Friedman went even further and argued for a rule involving money supply not only as an instrument, but as a policy target as well. Actually, Friedman (1960) acknowledged that a constant money growth rule does not correspond to optimal policy. Still, arguments such as imperfect knowledge about the “true” objectives inflation and output, the possibly inaccurate estimation of the unobserved natu-

---

22 In the form of a monetary aggregate.
ral rates of interest, output or employment and their dynamics, as well as the difficulties with obtaining real-time measures of policy objectives seemed to support choosing a rule expressed in terms of money supply only.

Of course, the above arguments to a greater extent address the question whether the central bank should target an intermediate variable or its final objectives directly and provides less insight to the choice of instruments. A further contribution by Poole (1970) analyses the conditions under which pegging money or interest rates are appropriate. For a static IS-LM framework, Poole suggested that if disturbances originate primarily in the money demand, fixing the level of the interest rates is appropriate. For the case of goods market shocks, the money stock should be pegged. Despite the simplicity of the framework and the lack of supply side in particular, the Poole model provides an essential insight to understanding the choice between money and interest rates as monetary policy instruments.

Taylor (1995, 1998) suggests that a constant money growth rule will generally induce an interest rate response to inflation and output similar in form as in the case of interest rate policy rules, but not necessarily similar in size. For example, for very high or negative inflation rate, the resulting variability of inflation expectations can render interest rate rules less efficient than controlling the money supply23. That is why, even when pursuing an interest rate rule, it is advisable for the central bank to still monitor money supply.

Recent models, such as Casares and McCallum (2006), McCallum and Nelson (1999b) and Rotemberg and Woodford (1998a) all include an interest rate instrument, whereby the money supply is endogenous since the central bank must vary it in order to sustain its desired interest rate level. In these models the path for money growth followed by the monetary authority in the long run under an interest rate instrument exactly coincides with the one that would be followed under a money supply instrument. In line with the choice of instrument in these studies and the recent central bank practice, the monetary policy rules that I introduce in the next chapter include the nominal interest rate as a policy instrument.

1.2.3. Choice of target variables

A second issue in policy design (apart from the choice of the instrument) concerns the choice of target variables. In this subsection, the variables entering the rule specifications in Chapter III (inflation, the output gap and the lagged interest rate) will be briefly discussed from a theoretical point of view.

---

23 As Taylor (1995) shows, in such circumstances interest rate rules can break down completely.
**Inflation-targeting**

There has been consensus in the literature on the fact that in the recent years a growing number of countries has opted for some form of inflation targeting\(^{24}\) combined with central bank independence\(^{25}\). Inflation-targeting is subject to differing definitions in the literature. For example, according to Svensson (2002) inflation targeting involves stabilizing inflation around an inflation target\(^{26}\). With respect to the target variables selected, it could be distinguished between inflation targeting in a narrower sense\(^{27}\) (involving a central bank reaction to inflation deviations from a target level only) and a broader definition where inflation and a measure of real economic activity are both considered. Adhering to the former perspective, Bernanke \textit{et al.} (1999) define inflation-targeting as a framework, rather than a rule for monetary policy\(^{28}\). According to them, inflation-targeting is characterised by public announcement of official quantitative targets (or target ranges) for the inflation rate over one or more time horizons, and by explicit acknowledgement that low, stable inflation is monetary policy’s primary long-run goal.

Arestis and Sawyer (2003)\(^{29}\) offer a definition of inflation targeting complemented by certain institutional requirements. Thus, inflation targeting involves more than just targeting the rate of inflation as an objective of economic policy and implies: (i) setting a numerical target range for the inflation objective; (ii) using monetary policy as an instrument to achieve the target by adjusting the nominal interest rate; (iii) central bank independence; and (iv) monetary policy only targeting the inflation rate with the possible effects of monetary policy on other objectives ignored, with the exception of short-term effects.

---

24 Snowdon and Vane (2005) distinguish between four types of monetary regimes that have been implemented since the middle of the 20th century: exchange rate targeting (e.g. in the UK, 1990-1992), monetary targeting (e.g. in the UK, 1976-1987), explicit inflation targeting (UK, 1992-to date) and implicit inflation targeting (USA). The difference between explicit and implicit inflation targeting pertains to whether the central bank announces an exact inflation target. In this sense, the ECB policy would qualify as “explicit inflation targeting”.


26 P. 6.

27 The inflation-targeting rules referred to in Chapter IV abide by this narrower definition of the term.

28 In the terms of Bernanke \textit{et al.} (1999) inflation-targeting as a framework for monetary policy implies that the inherent discipline of a rule is extended by maintaining some degree of flexibility.

29 See p. 2.
The broader definition of inflation targeting with reference to the target variables entering the central bank’s loss function (or monetary policy rule) is denoted as “flexible” inflation targeting. Svensson (1997b, 2002) argues that in the central bank practice inflation targeting is flexible, as it also involves some concern about the stability of the real economy. The latter means that monetary policy should contribute to the welfare of the representative citizen. However, as this objective is not operational, stabilising output around potential output is included in the central bank reaction function.

There exists a general consensus in the recent empirical literature that maintaining a low and stable rate of inflation is an appropriate monetary policy objective. Yet the justification of such a policy emphasis from a theoretical point of view may not be straightforward. According to the real-business-cycle models of the 1980s relative prices rather than the absolute level of prices are relevant for the allocation of resources in the economy. Traditional Keynesian models, by contrast, postulate that variations in the growth rates of prices and wages induce variations in output and employment. However, this inflation-output relation has typically been considered as an argument in favour of achieving output and employment goals rather than a justification for establishing price stability as a primary objective of monetary policy.

With the introduction of rational expectations to a framework with nominal rigidities, keeping inflation low and less volatile “locks in” expectations about future inflation and helps to contain the possible inflationary impact of macroeconomic shocks. Furthermore, in the short run and with sluggish price adjustment inflationary impulses can have a destabilising impact on output and employment. In this line, Woodford (2003) argues that, since instability of the general level of prices causes substantial real distortions – leading to inefficient variation both in aggregate employment and output and in the sectoral composition of economic activity – price stability is important and should therefore be the primary aim of monetary policy.

In addition, the theoretical literature so far suggests a distinction between the costs of anticipated and unanticipated inflation. Anticipated inflation causes loss of social welfare because it promotes economising on real money balances, generates costs for frequent price adjustments and increases relative price uncertainty.}

30 As opposed to “strict” inflation targeting, with low and stable inflation being the only goal of monetary policy (i.e. when the reaction coefficient to inflation solely is different from zero).
31 See pp. 6-7.
32 For further analysis of the output target, see Subsection 3.2.3.2.
33 See, for example, Fischer (1996) and Mishkin (2000).
34 Real business cycle authors support “real” as opposed to “monetary” theories of fluctuations. For example, Kydland and Prescott (1982) and Prescott (1986) construct models that include real variables only.
35 For a thorough discussion, see Leeson (1994, 1997a, 1997b).
Uncertainty. Unanticipated inflation, on the other hand, increases relative price variability and costs of information gathering and leads to income redistribution. Finally, as Blanchard and Fischer (1993)\(^{36}\) put it: “Its presence as the only macroeconomic variable in addition to output in the loss function reflects in part the fact that, right or wrong, inflation is perceived as costly by people and is costly for policymakers to ignore.”

An essential practical issue in policy design concerns the specification of the inflation target. Commonly under inflation-targeting the rule followed by the monetary authority includes a weighted measure of the deviation of the inflation rate from its target value. Concerning the choice of an appropriate target, Taylor (1986) emphasises that the policy objective is to minimize fluctuations around the target, regardless of what the actual value of the target is.

**Output-targeting**

Svensson (1997a) and Rudebusch and Svensson (1998) show that it is advisable that the monetary policy instrument responds to the determinants of the target variables rather than the target variables themselves. Thus, even under a primary price stability goal, it is generally appropriate to respond to both current inflation and the output gap, since both are determinants of future inflation. The relevance of simple policy rules that, as proposed by Taylor (1993), include both an inflation and an output target for recent central bank practice can be substantiated by the following statement by Federal Reserve Board Governor Yellen, made in January 1995:

> “Now, if you take the case of the FOMC, it seems to me that a reaction function in which the real funds rate changes by roughly equal amounts in response to deviations of inflation from a target of 2 percent and to deviations of actual from potential output describes tolerably well what this Committee has done since 1986. This policy, which fits the behavior of this Committee, is an example of the type of hybrid rule that would be preferable in my view, if we wanted a rule. I think the Greenspan Fed has done very well by following such a rule, and I think that is what sensible central banks do.” (Federal Reserve Board, 1995, pp. 43-44)

Different definitions of the output gap with respect to the reference term are common in the literature. According to Galí (2002) the output gap is defined as “the deviation of output from its equilibrium level in the absence of nominal rigidities”. Woodford (1999) on the other hand, distinguishes in his proposed model between “potential output” and “natural rate of output” as reference values for the deviation of actual output. The former term represents steady state (or long-term equilibrium) output in the presence of nominal rigidities and market frictions, while the second term denotes the “equilibrium level of output under perfectly flexible prices”. The natural rate of output can be relatively time-

---

36 Chapter 11, p.569.
invariant and, at least in the short run, cannot be influenced by economic policy actions.

Walsh (2003) provides an alternative definition of the output policy objective - a “speed-limit policy” that targets growth in demand relative to growth in potential, i.e. output gap changes. He finds that targeting the change in the output gap introduces inertia into monetary policy under central bank discretion, as the lagged output gap becomes an endogenous state variable. The final outcome is that targeting the output gap change is superior to inflation targeting unless inflation adjustment is prevailing backward-looking. In contrast, McCallum (2001a) argues that the output gap is unobservable and instead assesses the implications of using a trend-type measure. His results show that highly undesirable consequences in terms of higher inflation variability arise in case policy responds strongly to the measured gap. However, this result is obtained in a framework with constant capital. By contrast, the results obtained in Chapter IV in a model with endogenous capital and adjustment costs reveal that including the output gap in the monetary policy rule plays an important stabilising role in the occurrence of shocks.

The central bank’s output objective is often included as a quadratic term on output deviations in the loss function, so that deviations of output from the target (natural or potential) level are symmetrically penalised. This feature is subject to critique by some authors who argue that in sticky-prices Keynesian models in the presence of market frictions (e.g. monopoly power by firms), the equilibrium level of output is too low, in which case a negative output gap should be penalised more heavily by the central bank. Whereas this argument rests on the subtleties of defining target output, a more general critique point could be elaborated in terms of whether a positive and a negative gap actually impose the same welfare loss to the economy.

Another critique on interest rate rules including an output gap target (such as, for instance, the Taylor rule as in Taylor (1993)) arises from measurement difficulties. In the first place, no real-time data on the value of current output are available to policy-makers. Thus, the operational usefulness of the output gap target is limited by the availability of timely and reliable estimates. This shortcoming can be alleviated to a certain extend by assuming that the current output gap is equal to the expectation in the previous period. Secondly, as McCallum and Nelson (1999b) point out, “…there is considerable uncertainty regarding

---

37 See Blanchard and Fischer (1993), Chapter 11.
38 In Blanchard and Fischer (1993) the full-employment level of output denotes potential level of output when certain distortions have been taken account of, instead of the level of output under flexible prices and perfect competition.
39 This argument has been used by Orphanides and van Norden (2004) to describe the difficulties when using the output gap to predict inflation within the Phillips curve relation.
40 P. 5.
the realised value of real GDP even at the end of the quarter in actual economies”. The reason is that empirical estimates of the output gap are in general subject to significant and highly persistent revisions. The third source of practical difficulties when measuring the output gap target pertains to correctly estimating the value of potential output. Kuttner (1994) and McCallum (1997) argue that monetary policy decisions are in practice complicated by the risk of output gap mismeasurement. Smets (1998) analyses the effect of measurement error in the output gap on efficient policy rules in a simple estimated model of the US economy. The conclusion is that output gap uncertainty can have a significant impact on the efficient response coefficients in instrument rules (such as the Taylor rule) by reducing the response to the current estimated output gap relative to current inflation. Orphanides (1998) shows that output gap real-time measurement errors “lead to a significant deterioration of feasible policy outcomes and cause efficient policies to be less activist”.

**Interest-rate smoothing**

A policy rule with the short-term interest rate as instrument can be designed to involve interest-rate smoothing. Here it should be differentiated between smoothing in the sense of lowering the variance of the level of interest rates, as opposed to lowering the variability of interest-rate changes. According to Woodford (1999) reducing short-term interest rate level variability can be justified under the assumption that the distortions associated with positive nominal interest rates are described by a convex function of the interest rate. In this case, for any average level of nominal interest rates, a lower variance in them will reduce the size of the distortions. The case for lowering interest rate level variability could easily be illustrated by analysing the implications of significant interest rate changes in the two extreme scenarios of a low and a high average level of nominal interest rates respectively. A policy consistent with a low average rate of inflation and nominal interest rates faces the zero nominal interest rate bound and therefore cannot apply large interest rate reductions to combat deflationary shocks. On the other hand, when the levels of inflation and nominal interest rates are already relative high, in order to avoid distortions (as private sector’s resources are wasted on attempts to economise on cash balances), the monetary authority should avoid significant further increases in interest rates in response to inflationary shocks.

Interest-rate smoothing in the sense of seeking to minimise the variability of interest rate changes is a widely observed phenomenon in actual central bank

---

41 The difficulties associated with measurement of potential (and, by analogy, the natural rate of) output and resource utilization and their implications for monetary policy and macroeconomic stabilization have a long tradition in modern economic literature, beginning with Friedman (1947, 1953).

42 See also Orphanides et al. (2000).
practice. From a theoretical point of view, minimising the variability of interest-rate changes by adjusting official interest rates in a sequence of relatively small steps in the same direction means that central bank behaviour depends not only on current states and current forecasts of future conditions, but also on past conditions and commitments. Sack (1998), for example, estimates the optimal federal funds rate policy given the structural form of the US economy and compares it to actual historical data. He finds that in the absence of parameter uncertainty, the calculated optimal policy responds more aggressively to changes in the economy than the observed policy, resulting in a substantially higher volatility of the funds rate than observed. He explains lower variability of interest rates in actual policy with the existence of parameter uncertainty, which limits the willingness of the Fed to deviate from the policy rule that has been previously implemented.

There are several possible explanations of interest-rate smoothing that have been discussed in the recent literature on central bank practice. First, as Lowe and Ellis (1997) point out, policy-makers are averse to frequent changes in the direction of interest rate movements as it may undermine confidence in the central bank and therefore its ability to influence private sector expectations and behaviour in a desirable manner. Second, it can be argued that the nature of the decision-making process on monetary policy leads to conservatism that is at the heart of interest-rate smoothing. According to this line of argument, central banks are not able to gain broad political support for prospective interest rate changes until sufficient evidence has been gathered. Because the evidence needed accumulates slowly, interest rates tend to be changed gradually. A third motive for interest-rate smoothing, as discussed by Sellon and Roley (1995), concerns the fact that a predictable path for short-term interest rates confers the central bank greater influence over long-term bond yields, and consequently over future output and inflation. Similarly, Lowe and Ellis (1997) provide the explanation that central banks tend to modify interest rates gradually in order to be able to assess the policy impact on longer rates and adjust the direction and pace of changes accordingly.

2. Criteria for assessing monetary policy rules

After having presented some main theoretical insights concerning monetary policy design (which are taken into account when specifying the policy rules to be assessed in the next two chapters), I will discuss several criteria for assessing rule-based monetary policy performance, including operationality/simplicity, local determinacy of rational expectations equilibrium and its implications for response to shocks, as well as adherence to the Taylor principle. In the next

---

43 For further empirical evidence of interest-rate smoothing, see Clarida et al. (1998) and Rudebusch (1995).
44 Also in Lowe and Ellis (1997).
chapters, I will assess several interest-rate rule specifications in terms of whether they induce a locally determinate rational expectations equilibrium and desirable responses to a number of shocks. By definition, the operationality/simplicity criterion is fulfilled for all the interest-rate rule specifications assessed in Chapters III and IV. In the next parts, adherence to the Taylor principle is discussed from a broader perspective in terms of critically examining whether within the model chosen fulfilling this criterion actually guarantees local determinacy of rational expectations equilibrium.

2.1. Operationality/Simplicity

In a series of studies on monetary policy rules, McCallum (1988, 1989, 1993, 1994) has emphasised operationality as a crucial property when deciding on a policy strategy. The operationality criterion limits consideration to policy rules (i) that are expressed in terms of instrument variables that could be controlled on a high-frequency basis by the monetary authority and (ii) that require only information that could actually be possessed by this authority.

The use of simple instrument rules to specify rule-based monetary policy behaviour has a long tradition in the literature. Wicksell (1898) and Henderson and McKibbin (1993) suggested simple instrument rules with the interest rate as the instrument. Meltzer (1987) and McCallum (1988) proposed simple instrument rules with the monetary base as the instrument. The most prominent simple instrument rule is the Taylor rule (Taylor (1993)), incorporating an interest-rate instrument responding to the inflation and output gaps. Recent discussions of Taylor rules include Clarida et al. (1999), Hetzel (2000), Kozicki (1999), Woodford (2001b).

A certain degree of disaccord pertains to the definition of a simple rule in the existing literature. Earlier contributions, such as Blanchard and Fischer (1993) use the term “simple rules” to refer to non-activist rules. Schmitt-Grohe and Uribe (2004) define simple rules in terms of restricting attention to rules whereby policy variables are set as a function of a small number of easily observable macroeconomic indicators. In compliance with this criterion they propose studying central bank interest-rate feedback rules that include measures of inflation and output.

Svensson (1997b, 1999a, 2002) offers a more detailed classification of monetary policy rules. According to him, a rule-based monetary policy procedure could take the form of either an instrument or a targeting rule. An instru-

---

45 “Desirable responses to shocks” here refers to quantitatively modest and short-lived model variable deviations from steady state as a result of a shock.
46 This means that solely the fact that a policy rule is active is not seen as a positive trait. The determinacy results in Section 4 in Chapter III support this critical perspective.
47 In the studies mentioned, McCallum treats simple rules as being operational as well.
48 See pp. 581-583.
ment rule expresses the central bank’s instrument (e.g. the short-term nominal interest rate) as an explicit function of information available to the monetary authority. In particular, in the case of a simple instrument rule (such as the Taylor rule, for instance) the monetary policy instrument is a function of a small subset of the information available and no optimal reaction function is derived. Apart from the simple type, instrument rules (at least in theory) can be designed to involve optimisation, whereby the monetary policy problem is solved once-and-for-all for the central bank’s optimal reaction function. After the optimal explicit reaction function is determined, the central bank makes a commitment and follows it ever after.

However methodically appealing the optimal-control approach may seem, it is hardly practicable. Its complexity renders it unverifiable, i.e. it cannot be objectively and unambiguously determined whether monetary policy actions diverge from the prescriptions of the underlying reaction function. In addition, it cannot be expected that every possible circumstance be anticipated as required by the optimal reaction function. What is more, even if the perspective is limited to a certain number of realistic assumptions, the complexity of the optimal reaction function is still exuberant.

Targeting rules are designed by presenting a central bank loss function whose arguments are the monetary policy targets. The loss function is then minimised subject to aggregate demand and aggregate supply equations describing the model of the economy. Thus, the monetary policy rule is an implicit reaction function and can be written as the optimal response of the monetary policy instrument to current and/or expected values of state variables. A general targeting rule is a high-level specification of a monetary-policy rule that specifies operational objectives, the targets and the loss function to be minimised. A “specific targeting rule” is instead expressed directly as an operational condition for the target variables (or their forecasts).

The use of simple monetary policy rules has both practical advantages and disadvantages. According to Rotemberg and Woodford (1998a), the simplicity of such rules makes them more easily understandable, so that the central bank should have less difficulties in explaining its course of action. Indeed, once the decision to adopt a simple rule is made and announced to the general public, the decision process of the monetary authority becomes exceedingly transparent and simple. Based on the data on the target variables available, the instrument-setting can be calculated. As a result, the public is to a greater extent able to monitor the monetary authority’s compliance with the adopted rule. Taylor (1998a) summarises simulation results on simple policy rules and concludes that

49 Taylor-like specifications of the monetary policy rule enter the analysis in Chapter IV.
50 According to Svensson (2002) this can be called a commitment to an optimal instrument rule.
they seem to be “a surprisingly good approximation to fully optimal policy.” He also states a further advantage of this type of rules, namely their greater robustness in comparison with complex rules across a variety of models. The idea has been recently restated by McCallum (1997) and supported by the results of Levin et al. (1999) who find that simple monetary policy rules may be robust across a set of models of the U.S. economy. In a later study, Levin and Williams (2003) offer a more sophisticated analysis of the robustness property of simple rules and conclude that a robust outcome is attainable only when the objective function places substantial weight on stabilising not only inflation, but output as well52.

As far as the disadvantages of adopting a simple monetary policy rule are concerned, Svensson (1999a, 1999c) argues that a commitment to a simple instrument rule does not leave any possibility for judgmental adjustments and extra-model information. He concludes that for both of these reasons, a commitment to an instrument rule would be inefficient. An interesting example for practical difficulties with implementing the theoretically much appealing concept of a simple Taylor rule refers to the inclusion of the output gap as a target variable, to which nominal interest rates respond. As McCallum (2000b) points out, various measures of potential or natural-rate output levels differ widely and there is no professional consensus regarding the most appropriate measure or even concept to be used. Furthermore, McCallum and Nelson (1999b) argue that most detrending procedures in use inappropriately attribute the effects of technology shocks to the output gap, instead to the reference value of potential output itself. A more general critique refers to the real-time availability and reliability of output gap data. Orphanides (2001) provides real-time non-revised data series for 1987-1992 on macroeconomic indicators available for the Federal Open Market Committee’s decisions on the federal funds rate. In this respect, potential output estimates are particularly problematical. Data revisions had such a decisive magnitude that, as a result policy recommendations based on real-time data might differ widely from those obtained with the revised published data employed later on. Lastly, Svensson (1999a) emphasises the fact that, however appealing the idea of a simple monetary policy rule might seem, no central bank has yet actually committed to such a rule, as this would mean that “Monetary policy could be delegated to the staff, or even to a computer, and it would be completely static and mechanical... Such a degradation of the decision-making process would naturally be strongly resisted by any central bank and, I believe, arguments about its inefficiency would also easily convince legislators to reject it”.

---

52 For the case when the monetary policy objective is to stabilize inflation only, the authors are unable to find a robust simple rule.
2.2. Local determinacy of a rational-expectations equilibrium and monetary policy analysis

2.2.1. An overview

A central issue when evaluating alternative monetary policy rules is whether they can induce a determinate rational expectations equilibrium. A vast literature starting with Sargent and Wallace (1975) and McCallum (1981) has considered the fact that certain types of monetary policy rules may be associated with multiple rational expectations equilibria, some of which involving fluctuations of inflation and output as a result of self-fulfilling expectations. Such rules should clearly be avoided if the monetary authority aims at stabilising the variables previously mentioned. Giannoni and Woodford (2002) define determinacy of a rational-expectations equilibrium as “A unique equilibrium with the property that bounded disturbance processes result in bounded fluctuations in the endogenous variables”.

Blanchard and Fischer (1993) offer a classification of various types of multiplicity of equilibria, such as bubbles, “components that explode in expected value over time” and equilibria that exhibit sunspots. As McCallum (2004, 2003b) emphasizes, apart from finding a unique determinate equilibrium, a well-defined policy rule should lead to a bubble-free solution.

A related issue often consistent with the existence of a rational expectations equilibrium is what is called a “sunspot equilibrium”, i.e. endogenous variables changing according to random states that are not associated with any changes in economic fundamentals. This is the case of changes in equilibrium resulting from self-fulfilling expectations. Such self-fulfilling arbitrary changes in expectations introduce endogenous instability. Therefore, the design of a set-up that

---

53 Here a steady-state equilibrium (also known as a stationary equilibrium, a rest point, an equilibrium point, or a fixed point) is referred to. According to Galor (2007), a steady-state equilibrium of a n-dimensional system is a value of the n-dimensional vector of the state variables that is invariant under further iterations to the dynamic system. Thus, once each of the state variables reaches its steady-state level, the system will not evolve in the absence of exogenous disturbances.


55 In the subsequent exposition only real determinacy is being considered.

56 In other words, a solution reflecting only “market fundamentals”, as specified in the model. For a detailed definition of a bubble, see Burmeister, Flood and Garber (1983).
does not allow multiplicity of equilibria is of very important practical significance for the design of macroeconomic policies\textsuperscript{57}.

2.2.2. Presenting the criterion

In order to assess in terms of determinacy the implications of different model settings with forward-looking elements, it is important to specify how individuals form expectations. In the subsequent analysis I assume rational expectations consistent with the definition of Muth (1961), that is, expectations equal to the mathematical expectation of the variable in \(t+1\) based on information at time \(t\). For simplicity, I further assume that individuals know the underlying model and its parameters and all have the same information set at time \(t\)\textsuperscript{58}. In the next chapter, the assessment of monetary policy alternatives regarding determinacy of rational-expectations equilibrium will be based on the formal setting provided by Blanchard and Kahn (1980). The structural model is described by:

\[
\begin{bmatrix}
X_{t+1} \\
E[Y_{t+1}]
\end{bmatrix}
= A \begin{bmatrix}
X_t \\
Y_t
\end{bmatrix} + \gamma Z_t
\]  
(2.1)

where \(X\) is an \((n \times 1)\) vector of variables predetermined at time \(t\); \(Y\) is an \((m \times 1)\) vector of variables non-predetermined at time \(t\); \(Z\) is a \((k \times 1)\) vector of exogenous variables; \(E[Y_{t+1}]\) is the expectation of \(Y_{t+1}\) at time \(t\); \(A\) and \(\gamma\) are \((n+m) \times (n+m)\) and \((n+m) \times k\) matrices, respectively. Rational expectations are formalised by

\[
E[Y_{t+1}] = E[Y_{t+1} | \Omega_t]
\]  
(2.2)

where \(E\) is the expectation operator; \(\Omega_t\) is the information set at \(t\), such that

\[
\Omega_t = \{X_{t-i}, Y_{t-i}, Z_{t-i} ; i = 0, \ldots, \infty\}.
\]  
(2.3)

The above specification of the information set implies no loss of memory, as all the information known at time \(t\) is still known at time \(t+1\). In order to rule out exponential growth of \(E[Z_{t+i}]\), the following condition needs to be met:

\[
-(1+i)^\Theta \bar{Z}_t \leq E[Z_{t+i} | \Omega_t] \leq (1+i)^\Theta \bar{Z}_t,
\]  
(2.4)

\(t \geq 0\), \(\bar{Z}_t \in \mathbb{R}^t\), \(\Theta_t \in \mathbb{R}\).

\textsuperscript{57} An exception to this consensus opinion in the literature is expressed by McCallum (2003b), who argues that in the case of multiple equilibria only fundamental, minimal state variable solutions are likely to be observed in practice, and therefore the existence of a number of non-fundamental equilibria should be granted less attention in the literature.

\textsuperscript{58} As opposed to the alternative assumption that individuals are learning about the model as they are forming their expectations. The issues of learning and expectational stability have been studied by several key papers in the 1980s, including Bray (1982), Evans (1985), Lucas (1987), and Marcet and Sargent (1989).
Analogously to (2.4), for a unique determinate rational expectations solution it is required that the expectations of $X_{t+1}$ and $Y_{t+1}$ at time $t$ do not explode. Thus, condition (2.4) can be applied as follows:

$$
\begin{pmatrix}
X_t \\
Y_t
\end{pmatrix} \in \mathbb{R}^{n+m}, \quad \tau_t \in \mathbb{R} \text{ such that}
$$

$$
-(1+i)^{\tau_t} \begin{pmatrix}
X_t \\
Y_t
\end{pmatrix} \leq \begin{pmatrix}
E(X_{t+1} | \Omega_t) \\
E(Y_{t+1} | \Omega_t)
\end{pmatrix} \leq (1+i)^{\tau_t} \begin{pmatrix}
X_t \\
Y_t
\end{pmatrix}, \quad \forall t \geq 0.
$$

According to Blanchard and Kahn (1980), in order to obtain a unique solution, the number of eigenvalues of $A$ outside the unit circle (denoted by $\bar{m}$) should be equal to the number of non-predetermined variables ($m$). The unique solution is “forward-looking” in the sense that the non-predetermined variables depend on the past only through its effect on current predetermined variables. The condition $\bar{m} = m$ actually states that a unique solution exists if and only if $A$ has the strict saddle point property. If $\bar{m} > m$, there is no unique non-explosive solution satisfying all necessary conditions (2.1)-(2.5). For the opposite case, $\bar{m} < m$, i.e. when the number of eigenvalues outside the unit circle is less than the number of the predetermined variables, there is an infinity of solutions. In particular, it could be the case that the non-predetermined variables depend directly on the past or that a variable not belonging to $Z$ directly affects $X$ and $Y$. By contrast, these possibilities are ruled out when $\bar{m} = m$.

2.2.3. Determinacy and reactions to shocks

When assessing the impact of shocks, the issue of dynamic stability (convergence) plays a crucial role. Stability analysis facilitates the study of the local (and sometimes the global) behaviour of a dynamic system and of the implications of disturbances occurring once the system is in the vicinity of a steady-state equilibrium. According to Heijdra and van der Ploeg (2002) a stable system is defined as “one in which the unique equilibrium (also called steady state) is eventually restored following a shock to one or more of the exogenous variables”. In case of multiple equilibria (or stationary points), there may exist stable (convergent) and unstable (divergent) equilibria. Still, even under multiple equilibria, if there is a unique stable equilibrium, the system can still be regarded as stable. The arguments in favour of using stable systems only can be traced back to the correspondence principle in Samuelson (1947). Indeed, unstable systems are not particularly useful for economic analysis. Even if one or more (unstable) equilibria exist, the system is not very likely to be at any of these at a particular point in time. Moreover, even if, by coincidence, the system is in an equilibrium, a minor shock will suffice to displace it permanently from that equilibrium.

---

59 Early applications of dynamic methods in macroeconomics can also be found in Baumol (1959) and Allen (1967).
ble systems, by contrast, converge along an adjustment path to a stable equilibrium. An additional convenient feature of stable systems is that it is often possible to derive steady-state multipliers for the impact of changes in government policy and other exogenous variables on the endogenous ones in the system. Heijdra and van der Ploeg (2002) distinguish between backward-looking and forward-looking stability. The former implies that, at a particular moment, the model determines the endogenous variables as a function of the exogenous and the predetermined state variables. Under forward-looking stability, lagged (historical) and expectational (future) values jointly determine the current situation.

A perhaps more important issue for stability analysis is the distinction between local and global stability of a dynamic system. In the mathematical literature stability refers to situations in which trajectories that are initiated from an $\epsilon$-neighbourhood of a fixed point remain sufficiently close to this fixed point subsequently. Galor (2007) defines a system as being locally (asymptotically) stable if for a sufficiently small perturbation the dynamic system converges asymptotically to the original equilibrium. In the case when, regardless of the magnitude of the perturbation, the system converges asymptotically to the original equilibrium, the system is globally (asymptotically) stable. In other words, a steady-state equilibrium is locally (asymptotically) stable if there exists an $\epsilon$-neighborhood of the steady-state equilibrium such that for every initial condition within this neighborhood the system converges to this steady-state equilibrium, whereas a steady-state equilibrium is globally (asymptotically) stable if the system converges to the steady-state equilibrium regardless of the initial condition.

Local stability of a steady-state equilibrium requires the local uniqueness of the steady-state equilibrium. Thus, if the system is characterized by a continuum of equilibria none of these steady-state equilibria is locally stable. Local stability necessitates therefore local uniqueness of the steady-state equilibrium. Global stability of a steady-state equilibrium requires global uniqueness of the steady-state equilibrium. In the case of a linear system, local uniqueness implies global uniqueness and local stability necessarily implies global stability.

In Chapter IV (Sections 2 and 3), the model variables’ responses to a number of shocks (monetary policy unit shock, technology shock and consumption preference shock) under a variety of interest-rate rule specifications are illustrated by impulse response analysis. Clearly, convergence to the steady state values is regarded as crucial when assessing the performance of different policy rule specifications. Beyond that, the existence of a monotonic convergence path

---

60 In the subsequent analysis in Chapter IV, local determinacy of rational-expectations equilibrium will be assessed.

61 I.e. the absence of any additional point in the steady-state neighbourhood from which there is no escape.

62 I.e. the absence of any additional point in the space from which there is no escape.
and relatively small and short-lived initial variable deviations from steady state values are also considered to be advantageous\textsuperscript{63}.

### 2.3. The Taylor principle

Taylor (1999) derives a relationship between the stability of inflation and the size of the interest rate coefficient on inflation in the policy rule. He shows that it is crucial to set the interest rate response coefficient on inflation above a critical “stability threshold” of one. The interest rate rule is given by\textsuperscript{64}

\[
i_t = \bar{r} + \pi_t + \lambda_\pi \left( \pi_t - \pi^* \right) + \lambda_y \hat{y}_t,
\]

where \(i_t\) is the nominal interest rate in \(t\), \(\pi_t\) denotes the inflation rate over the previous four quarters, \(\pi^*\) is the central bank’s inflation target\textsuperscript{65}, \(\hat{y}_t\) is the output gap\textsuperscript{66}, \(\bar{r}\) is the equilibrium (steady-state) real interest rate\textsuperscript{67}, \(\lambda_\pi\) and \(\lambda_y\) are policy parameters, denoting the central bank’s response to inflation and output gap deviations from target\textsuperscript{68}. The total response to inflation in (2.6) is given by

\[
\lambda_\pi^* = 1 + \lambda_\pi.
\]

It is assumed that the monetary policy stance is counter-cyclical, i.e. \(\lambda_\pi^*, \lambda_y > 0\). Taylor (1999) combines (2.6) with backward-looking IS- and AS-specifications given by

\[
\hat{y}_t = -\varphi (i_t - \pi_t - \bar{r}) + g_t,
\]

and

\[
\pi_t = \alpha \hat{y}_{t-1} + \pi_{t-1} + u_t,
\]

where \(\varphi, \alpha > 0\) are reduced-form parameters that depend on the policy parameters; \(g_t\) and \(u_t\) are serially uncorrelated stochastic shocks with zero mean. By substituting equation (2.6) in equation (2.7), an aggregate demand (AD) relation between inflation and output gap can be derived\textsuperscript{69}

\[
\hat{y}_t = -\frac{\varphi \lambda_\pi^*}{1 + \varphi \lambda_y^*} \pi_t + \frac{1}{1 + \varphi \lambda_y^*} g_t.
\]

\textsuperscript{63} The reason for this is quite straightforward: considerable deviations from the steady-state level and/or long-lasting adjustment all induce losses and uncertainty in the economy.

\textsuperscript{64} The rule specified by Taylor (1999) is a more general form of the Taylor (1993) one.

\textsuperscript{65} Taylor (1993) sets the inflation target to be equal to 2 percent per annum. In Taylor (1999) only \(\pi_t\) enters the policy rule, i.e. \(\pi^* = 0\).

\textsuperscript{66} In Taylor (1993) the output gap denotes the percent deviation of real GDP from a target (trend real GDP). Taylor (1999) defines the output gap as the percentage deviation of real GDP from potential GDP. For the purpose of this work, the latter definition will be used.

\textsuperscript{67} The steady-state real interest rate is estimated in Taylor (1993) using US data and set at 2 percent per annum.

\textsuperscript{68} In Taylor (1993), \(\lambda_\pi = \lambda_y = 0.5\)

\textsuperscript{69} The stochastic term \(g_t\) is left out here.
The slope of the AD curve $-\frac{\varphi \lambda_x}{1 + \varphi \lambda_y}$ is determined by the choice of the policy parameters $\lambda_x$ and $\lambda_y$. For $\lambda_x > 0$ (i.e. $\lambda_x^* > 1$), the aggregate demand curve is downward-sloping\(^{70}\) and for $\lambda_x < 0$ it is upward-sloping. Figure 2.2 reveals graphically the stability properties of a Taylor rule for an effective inflation response coefficient greater or smaller than unity (the upper two panels) and the resulting AD relations for these two cases (the two lower panels). The horizontal lines in the two lower panels represent the aggregate supply (price adjustment) relation. The zero slope of the AS line is determined by the fact that in equation (2.8) current-period inflation depends in the previous-period output gap, rather than on the contemporaneous one. Changes in $\bar{y}_t$ are thus transmitted to the inflation dynamics with a time lag. The intersection of the two solid lines (the AS and the AD line) in the two lower panels represents a situation when $\bar{y}_t = \bar{y}$ (actual output is equal to the potential output), i.e. $\bar{y}_t = 0$. The AS line eventually moves up when the output gap is positive and vice versa. A positive supply shock also shifts the line upwards.

---

\(^{70}\) As $\lambda_y > 0$. 

---

46
The two left-hand panels in Figure 2.2 present a rule with $\lambda_s^* > 1$ and the two right-hand panels one with $\lambda_s^* < 1$. The case on the left is stable because an upward shift in the AS line (a positive inflation shock) results in a decline of the output gap below zero, which leads to a downward adjustment of the inflation rate, represented by a downward shift of the price adjustment (AS) line. The case on the right is unstable, as, by contrast to the previous case, a positively sloped AD line implies that an upward shock to inflation leads to a positive output gap and contributes to further increases in inflation. This explosive property of the system has as consequence that supply-side shocks will tend to have a permanent, self-accelerating effect on inflation, bringing the system farther away from its equilibrium.

Algebraically, the above results can be substantiated as follows. The stability question can be expressed in terms of whether shocks will have a permanent, self-accelerating effect on inflation, i.e.

$$\left| \frac{d\pi_t}{d\pi_{t-1}} \right| \leq 1 \ ? \quad (2.10)$$

whereby only under $|d\pi_t / d\pi_{t-1}| < 1$ does the system converge to steady state after a shock occurs. Equivalently, iterating (2.10) one period forward yields

$$\frac{d\pi_{t+1}}{d\pi_t} \leq 1 \ ? \quad (2.10')$$

and $|d\pi_{t+1} / d\pi_t| < 1$ as a condition for stability respectively. The policy-dependence of the stability property of the system becomes evident after one last transformation, this time of the AS relation. One period forward, equation (2.8) becomes

$$\pi_{t+1} = \alpha \hat{y}_t + \pi_t + u_{t+1} \ . \quad (2.8')$$

Then,

$$\frac{d\pi_{t+1}}{d\pi_t} = 1 + \alpha \frac{d\hat{y}_t}{d\pi_t} \ . \quad (2.8'')$$

Substituting $d\hat{y}_t / d\pi_t = -\phi\lambda_s / 1 + \phi\lambda_s$ from the AD relation (2.9) into (2.8'') yields

$$\frac{d\pi_{t+1}}{d\pi_t} = 1 - \frac{\alpha\phi\lambda_s}{1 + \phi\lambda_s} \ . \quad (2.8''')$$

Then, for stability,

$$\frac{\alpha\phi\lambda_s}{1 + \phi\lambda_s} > 1 \ . \quad (2.11)$$

Equivalently,

$$\lambda_s > 0 \ , \quad (2.11')$$
and 
\[ \lambda^* > 1. \]  \hspace{1cm} (2.11"")

The relationship between the stability of inflation and the size of the inflation response coefficient in the central bank’s monetary policy rule has been reaffirmed by empirical analysis, such as Clarida et al. (2000), Judd and Rudolph (1998) and Wright (1998). Benhabib et al. (1999) also argue that real determinacy could be attributed to the degree of activeness of monetary policy and the inflation measure that enters the central bank’s interest rule. They find that under sticky prices and an active monetary policy stance (i.e. a policy that aggressively fights inflation by raising the nominal interest rate by more than the registered increase in inflation), a forward-looking component in the intermediate target is more likely to lead to indeterminacy than a backward-looking component. The assumption that the demand for money also plays a role in the monetary-transmission mechanism and that productivity is affected by the cost of funds leads to novel results concerning equilibrium determinacy. A further point is recognising the difference between local and global determinacy of equilibrium. An active policy stance may appear to lead to macroeconomic stability as it ensures locally unique equilibrium, but in fact be destabilizing because it is associated with global indeterminacy and equilibria in which the economy converges to a cycle.

Clarida et al. (2000) provide empirical analysis of US monetary policy, based on a baseline sticky-prices model with a modified Taylor rule where the Fed responds to expected future deviations of inflation and the output from their target values, instead of to their current values. Their findings support the results of and Kerr and King (1996) concerning the destabilising impact of an excessively weak reaction of the policy instrument to an increase in expected inflation. This is the case of an effective policy reaction coefficient on the inflation gap \[ \lambda^* \leq 1. \] Values of \[ \lambda^* \] below unity lead to equilibrium indeterminacy and monotone divergence or fluctuations around the steady-state values of inflation and output, resulting from self-fulfilling changes in expectations. The rise of self-fulfilling changes in expected inflation can be explained by the fact that with \[ \lambda^* < 1, \] a rise in anticipated inflation is accompanied by a decline in the real interest rate which stimulates aggregate demand and causes a rise in inflation. Thus, due to the accommodating stance of monetary policy, the initial rise in expected inflation becomes “self-confirmed”. As shown by Clarida et al. (2000), the unity threshold value of \[ \lambda^* \] is obtained only in the absence of a systematic policy response to output variations (i.e. \[ \lambda_y = 0 \]). For values of the policy reaction coefficient on the output gap \[ \lambda_y > 0, \] the lower bound for \[ \lambda_y \] decreases be-

71 For further analysis, see Benhabib et al. (2001).
72 For similar models, see King and Wolman (1996), Woodford (1996, 1998) and Yun (1996).
low unity, although the deviation from unity is quantitatively negligible, and is independent of whether an interesting-smoothing parameter (i.e. the lagged nominal interest rate) enters the rule specification. As far as the upper bound for the unique equilibrium defined by the range of values of $\lambda^*$ is concerned, Bernanke and Woodford (1997) find that an excessive response to variations in expected inflation may also lead to indeterminacy.

3. Preliminary summary

Since the middle of the last century, the design, transmission channels and outcomes of monetary policy have been the focus of extensive research. The practical experience with “activist” monetary policies in the 1960s and 1970s, motivated by the conviction that in the long run the monetary authority can attain a permanent reduction in the unemployment rate by allowing for a higher rate of inflation, has been disappointing. Parallel to the practical experience with activist policies, there has also been an academic critique of using monetary policy as a tool to obtain full employment at the expense of a higher inflation rate. Among the most influential arguments are Milton Friedman’s monetary critique concerning the uncertain outcomes of monetary policy interventions, the Lucas critique of the optimal control paradigm for monetary policy, the conclusion reached by Friedman (1968) and Phelps (1968) that there is no long-run tradeoff between inflation and unemployment, as well as the warning against the perils of time inconsistency under discretionary policy delivered by Kydland and Prescott (1977), Calvo (1978) and Barro and Gordon (1983).

The experience with time-inconsistent discretionary policy has not only fuelled the debate on the benefits of systematic policy behaviour vs. discretion, but has also given an impetus for extensive research on how monetary policy rules should be designed and assessed. In terms of policy instrument choice, in the last two decades setting the nominal interest rate has generally prevailed over directly controlling money supply in both theory and practice. However, selecting the target variables and their response coefficients in the policy rule currently remains a controversial issue, since the estimated outcomes are to a great extent model-dependent. In order to ensure a comprehensive assessment of the different rule specifications, it is essential to consider not only the aggregate demand, but also the aggregate supply monetary transmission channel, which requires using a comprehensive macroeconomic framework incorporating endogenous capital (as the one used in Chapter III). Under such a framework, the determinacy and shock response properties of different rule specifications, as well as the relevance of the Taylor principle will be examined and assessed in the next two chapters.