Information Asymmetries, Transparency, and Monetary Policy

Inaugural-Dissertation
zur Erlangung der Würde eines Doktors
der Wirtschaftswissenschaften
der Wirtschaftswissenschaftlichen Fakultät
der Ruprecht-Karls-Universität Heidelberg

vorgelegt von
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aus Hamburg

Heidelberg, Dezember 2001

Vorwort

Die vorliegende Arbeit wurde im Wintersemester 2001/2002 an der Wirtschaftswissenschaftlichen Fakultät der Universität Heidelberg als Dissertation eingereicht. Sie entstand während meiner Tätigkeit als wissenschaftlicher Mitarbeiter am Lehrstuhl für Wirtschaftspolitik I der Wirtschaftswissenschaftlichen Fakultät der Universität Heidelberg.

Mein besonderer Dank gilt Herrn Prof. Dr. Hans Gersbach, der mich mit großem Einsatz betreute, mir unzählige konstruktive Anregungen gab und stets Zeit fand, mit mir über Fragen, die sich aus meiner Arbeit ergaben, zu diskutieren. Des Weiteren danke ich Herrn Prof. Dr. Christoph Schmidt dafür, dass er so freundlich war, das Koreferat zu übernehmen. Ebenso gilt mein herzlicher Dank Hans-Jörg Beilharz, Verena Liessem, Bernhard Pachl und Lars Siemers, die jeweils Teile meiner Arbeit gelesen haben und es mir durch wertvolle Hinweise ermöglichten, einige Fehler zu verbessern.

Volker Hahn

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Chapter 1

Introduction

1.1 Overview

Information asymmetries seem to play an important role in monetary economics. A large group of central-bank watchers attempts to predict the monetary-policy stance of major central banks such as the Federal Reserve or the European Central Bank (ECB).[1] The careful observation of central banks suggests that substantial information asymmetries exist and that there are large potential benefits to be gained from reducing them.[2] The importance of information asymmetries is also indicated by the ongoing debate on the transparency of the ECB[3] and by the fact that central bankers value transparency as one of the three most important features of a monetary policy framework.[4]

Information asymmetries can be alleviated by information transmission. We consider three forms of information transmission. First, if information is verifiable or the publication of information is in the central bank's interest, it is possible for the central bank to alleviate information asymmetries by simply publishing information. This raises the question of the socially optimal degree of transparency in monetary policy. We will label these parts of the thesis "*transparency*".

Second, much of the literature on monetary economics is based on the time-inconsistency framework developed by Kydland and Prescott (1977) and Barro and Gordon (1983), where the central bank would profit from reducing inflation expectations below actual inflation rates and there are thus incentives to misrepresent private information.

[1] Note that in this thesis we exclude central banks where monetary policy is fixed exogenously, e.g. by a fixed exchange rate.

[2] Cf. Goodfriend (1986).

[3] Cf. e.g. Buiter (1999) and Issing (1999).

[4] Cf. Fry, Julius, Roger, Mahadeva, and Sterne (2000).

Therefore, information may not always be credible if it is not verifiable. From a normative viewpoint, this raises the question of the means best suited for information transmission in these cases. These parts of the thesis are labeled "*signaling*".

Third, it is also possible that central banks may be less well-informed than other economic agents. Then one has to examine the reverse information-transmission process from these economic agents to the central bank. Whether the central bank should rely on information transmitted by economic agents or should itself invest in information aggregation is then an interesting question from a social perspective. The parts concerned with this question are labeled "*reverse signaling*".

1.2 The Structure of the Thesis

1.2.1 Reverse Signaling

Information Content of Wages (Chapter 2)

The thesis is organized as follows. In chapter 2, which is based on Gersbach and Hahn (2001b), we examine how much information central banks should collect if other agents, such as unions, are likely to try to signal their private information to the central bank ("reverse signaling"). We are interested in the question of whether it is sufficient from a social perspective that central banks consider data on nominal variables alone or whether they in addition should draw upon information about real shocks.

More specifically, we examine the strategic interaction between a number of unions and a central bank. We present a model where inflation and unemployment are a major concern for the central bank. Additionally, we assume that unions not only maximize the real wages of their members but also take unemployment and direct costs of inflation into account. When the unions observe the realization of a real shock, they set nominal wages for their members. Subsequently, the central bank opts for a monetary policy. In this model we consider two scenarios. First, the central bank is aware of the size of the real shock from independent information aggregation through its own research department. In the second scenario, the central bank has no independent source and relies on the unions' estimate of the shock, which the latter signal by their wage setting.

The model identifies the following causal link: If central banks have no independent means of information collection about real shocks in the economy, unions have an incentive to choose quite high nominal wages in an attempt to signal positive shocks and to induce the central bank to pursue a low-inflation policy. Since high nominal

wages are only partly compensated by a more expansionist monetary policy, the unions' signaling incentives lead to large real wages and thus to fairly high unemployment. We conclude that independent information collection by central banks is socially beneficial since it eliminates the unions' signaling incentives. It is, however, unclear whether, given that it leads to lower real wages, the independent collection of information about real shocks is also in the unions' interest. The causal link described above is only relevant if wage setting is largely centralized. If many unions are involved, individual unions will not take the impact of their decisions on monetary policy into account and signaling incentives are rather small.

In the current restructuring phase of the national central banks in Europe the model is of importance in that it stresses the significance of independent information aggregation by central banks. Since the beneficial impact of direct information aggregation by central banks is only effective if there are a small number of unions, our findings suggest that the capacities for information collection at the disposal of the European System of Central Banks (ESCB) should depend on the process of union formation in Europe. If unions manage to coordinate their actions across national borders, then it may even be advisable for the ESCB to invest more in independent information collection to counteract strong signaling incentives. If wage setting is highly decentralized, independent information collection by central banks is much less important.

In contrast to chapter 2, we assume for the remainder of the thesis that the central bank may have information about shocks in the economy that is superior to that of other economic agents. The information can either be transmitted through signaling by the central bank ("*signaling*") or publication ("*transparency*") if it can be credibly published.

1.2.2 Signaling

Signaling Private Information (Chapter 3)

In chapter 3 we examine how central banks should signal private non-verifiable information on shocks to money demand. We consider monetary targeting and inflation targeting as signaling devices and evaluate their relative merits with respect to welfare. Before inflation expectations are formed, central banks announce either a monetary target or an inflation target. Subsequently, the central bank opts for a monetary policy, which involves costs if there are deviations between announced targets and targeted variables.

We show that under monetary targeting the public can infer the central bank's private information from targeted money growth rates. In equilibrium, a change in the

announced monetary target does not affect inflation expectations, it merely changes expectations about the shock. This implies that monetary targets cannot be used to commit the central bank to low-inflation policy if the time-inconsistency problem is severe. Under inflation targeting, the announced target is independent of the central bank's private information and the public cannot derive the size of the shock to money demand from the announced target. This, however, is not problematic since in our model the central bank can precisely control inflation. Therefore, by announcing target inflation rates, it can commit itself to low inflation, thus alleviating to some extent the problem inherent in the time-inconsistency framework. The conclusion we draw from this is that, if the time-inconsistency problem is severe, inflation targeting performs better than monetary targeting. We also conclude that inflation targeting is better, the larger the costs of deviations from announced targets are for the central bank. Under monetary targeting, social losses are not affected by the size of deviation costs. Taking possible extensions of our model into account, we argue that a socially optimal choice of deviation costs would be very small under monetary targeting, since low deviation costs enable the central bank to react flexibly to unexpected economic conditions. Anecdotal evidence seems to support the view that deviation costs are generally much larger for inflation-targeting central banks than for monetary-targeting central banks.

Signaling Competence (Chapter 4)

In chapter 4, which is based on Gersbach and Hahn (1999), we re-examine the issues of the previous chapter to allow for the eventuality that the central bank may not always be better informed. It is probably more realistic to assume that the central bank sometimes has superior information and that sometimes both the public and the central bank may be uncertain about the realization of shocks in the economy. Thus we consider a model where the central bank has private non-verifiable information about monetary disturbances only with a positive probability. In this case, there are two information asymmetries. First, the public is unsure about the accuracy of the central bank's knowledge about the shock. Second, the public is unaware of the information that the central bank may have. In this framework, we again ask whether monetary targeting or inflation targeting is superior in signaling private information. In the basic model of chapter 4, we consider only two possible realizations of the shock. In chapter B of the appendix we show that our results are also valid for shocks drawn from a fairly general class of distributions.

We obtain results similar to those obtained in chapter 3. But in the case of two-fold information asymmetries, both monetary targeting and inflation targeting involve

substantially higher losses compared to the benchmark case of transparency. The reasoning is rather subtle. There are three types of central banks: a central bank with a negative signal about the shock, a central bank with a positive signal, and a central bank that has no signal. The public's inflation expectations depend on the announced target and on its expectations about the type of central bank. Central banks that have observed positive shocks will wish to imitate the behavior of central banks that have not observed a signal or have observed a negative shock to money demand. Successful imitation would reduce the public's inflation expectations, thereby enabling the central bank that has observed a positive shock to achieve a lower rate of unemployment. Successful imitation, however, would harm the other types of central banks by increasing inflation expectations. This induces them to choose an inflationary policy as a signal about their own types and thus prevent imitation, as this would inflict losses on them. This effect causes both monetary targeting and inflation targeting to perform less efficiently than the first-best case. But we also show that monetary targeting leads to even worse outcomes than inflation targeting. Monetary targeting invites attempts by uninformed central banks to imitate the behavior of central banks with negative observations of the shock, causing the latter to choose a larger inflation rate than they would under inflation targeting. Under inflation targeting it is not possible for uninformed central banks to boost employment by imitating other types of central banks. This means that inflation targeting performs better than monetary targeting.

1.2.3 Transparency

Transparency of Central Banks: A Survey (Chapter 5)

In the following chapters we consider verifiable information implying that a transparency requirement is sufficient to force the central bank to reveal its private information truthfully. Besides, the central bank could choose to publicize data voluntarily if this were in its own interest. Since there is a rapidly growing literature on the transparency of central banks, chapter 5 reviews the existing literature. We distinguish three different dimensions of transparency, namely goal transparency, knowledge transparency, and operational transparency. Most authors are convinced that transparency about the objectives of monetary policy, i.e. goal transparency, is socially beneficial, although no formal model is available confirming this conviction except for the model presented in chapter 9, where goal transparency may be beneficial for some parameter values.

The various contributions to the literature on knowledge transparency, i.e. on the publication of models and forecasts used inside the central bank, come to extremely controversial conclusions. One effect figuring very frequently in formal models is that transparency can help alleviate the problem of time-inconsistency inherent in the standard monetary-policy framework by Kydland and Prescott (1977) and Barro and Gordon (1983). Knowledge transparency enables the public to identify the intended outcomes of monetary policy more easily. This deters futile attempts of central banks to surprise-inflate and thus reduces the inflation bias. On the other hand, by making the effects of monetary policy more predictable and thus inflationary surprises impossible, knowledge transparency may also hinder the central bank from increasing output when this is most valuable. These and other arguments in favor of, or against, knowledge transparency are discussed in more detail in chapter 5.

Very little theoretical work has been done on operational transparency, although there is a lively ongoing debate between policy-makers and economists on its desirability. Operational transparency involves the publication of voting records and of the minutes of meetings of the central bank's decision-making bodies.

Voting Transparency, Competence, and Simultaneous Voting (Chapter 6)

In the three following chapters, we propose different models for evaluating the social desirability of the publication of the voting records of the monetary authority's decision-making bodies.[5] In chapter 6, which is based on Gersbach and Hahn (2001c), we assume that heterogeneity between central bankers arises from different degrees of competence. Voting takes place simultaneously, i.e., central bankers do not know how their colleagues have voted. We assume that holding office brings central bankers substantial private benefits. As a consequence, central bankers will maximize their re-election chances. Under transparency, however, this makes less efficient central bankers behave inefficiently by randomizing between potentially correct interest rates since they do not want to be detected as less efficient and therefore dismissed. Under opacity, less efficient central bankers abstain in order to ensure optimal monetary policy outcomes, which in turn maximizes their chances of getting re-elected as their re-election chances coincide with those of the council. Hence, voting transparency creates costs by inducing less efficient central-bank council members to vote in a socially inefficient way in their bid to get re-elected. Transparency, however, also has a beneficial impact since it is easier for the government to distinguish highly efficient from somewhat less efficient

[5]This question cannot be fully examined in isolation from the related question of whether the minutes of the meetings should be published.

central bankers. This creates the possibility of re-electing or dismissing individual central bankers which over time improves the overall competence of the central-bank council more quickly than under opacity, where only the entire council can be dismissed or re-elected. We show that overall social losses are invariably lower under opacity.

Our conclusion hinges on the assumption that under opacity less efficient central bankers will abstain from voting. It may, however, be regarded as questionable whether actual abstention is an acceptable course of behavior for a monetary-policy committee member. In a more sophisticated framework, one might expect less efficient central bankers to wait and observe the discussion among more efficient central bankers before making a statement. However, abstention can be interpreted as waiting and following the majority. Therefore, allowing for more sophisticated abstention behavior does not affect our results. If the minutes of the meetings and the voting behavior are publicized, less efficient central banks will not dare to wait for the opinions of other central bankers since the government would detect them as being less efficient. But under opacity, waiting is optimal. To evaluate the argument against voting transparency, the next chapter discusses sequential voting procedures, which come closest to the actual discussion procedure among central bankers.

Voting Transparency, Competence, and Sequential Voting (Chapter 7)

In chapter 7, central bankers vote sequentially, which implies that the decision of a central banker may be influenced by the decisions of colleagues who have already voted. Under transparency, the individual voting behavior and the sequence of votes is published. Under opacity, this information is withheld from the public. We also exclude abstention by less efficient central bankers, thus intentionally favoring transparency by eliminating one of the potential advantages of opacity, under which abstention will not be detected. Within this framework, we obtain results similar to those achieved in the previous chapter. Voting transparency induces socially inefficient attempts to get re-elected by less efficient central bankers, thus hindering efficient aggregation of the central bankers' information. Voting transparency, on the other hand, enables the government to improve the overall quality of the central-bank council more quickly. Overall social losses are shown to be lower under opacity. Another prediction of the model is that transparency makes controversial election results, i.e., only small majorities for proposals, more likely. This is a finding that seems to be supported by anecdotal evidence. Decisions in the Governing Council of the ECB[6] are generally reached by consensus, whereas decisions of the Monetary Policy Committee (MPC) of

[6]The Governing Council is the highest decision-making body of the ECB.

the Bank of England are often reached by controversial elections. We also argue in this chapter that intermediate transparency, i.e., the publication of individual voting behavior without the sequence of votes, may be socially detrimental since it creates incentives for highly efficient central bankers to herd, i.e., to follow a majority.

Voting Transparency and Different Preferences (Chapter 8)

In chapter 8, which is based on Gersbach and Hahn (2001a), we take account of the fact that heterogeneity between central bankers might also stem from different preferences on the part of central bankers. In a model with simultaneous voting, we again analyze the question whether voting records should be published.

We show that incentives for central bankers with views differing from those of the public are not sufficiently strong to induce them to vote strategically (rather than in accordance with their preferences) in order to be re-elected and be able to influence future monetary policy. Thus, only the positive effect of transparency is at work. The government is able to re-elect or dismiss individual central bankers depending on whether they have shown favorable or less favorable voting behavior as defined by the government. This makes the average number of central bankers with the same preferences as society increase faster under transparency than under opacity. Hence overall social losses are lower under transparency.

Goal Transparency (Chapter 9)

In our evaluation of the performance of goal transparency in chapter 9, we proceed on the basis of a relatively simple one-period model in the spirit of Kydland and Prescott (1977) and Barro and Gordon (1983) without any real or monetary disturbances. The significance the central bank attaches to the output target is stochastic. Under opacity, it is the private information of the central bank but publicly known under goal transparency. The social loss function is assumed to be non-stochastic.

We find that goal transparency may involve social costs by creating larger inflation rates. But goal transparency also reduces the variance of output by making monetary policy more predictable and inflation expectations more accurate. This has a beneficial impact on social losses. Whether or not the net effect of goal transparency is positive depends on the relative significance society attaches to deviations of output from target over and against deviations of inflation from target. If society assigns sufficient importance to the inflation target, then goal transparency is not beneficial. But if society places sufficient emphasis on the output target, then it will profit from

	information is credible if published[7]	information is not credible if published[8]
central bank has superior information	chapters 5, 6, 7, 8, 9 (*"Transparency"*)	chapters 3, 4 (*"Signaling"*: signaling by central banks)
central bank has inferior information compared to other economic agents	chapter 2 (*"Reverse Signaling"*: information acquisition by central banks, signaling by other economic agents)	

Table 1.1: Structure of the thesis

goal transparency. This conclusion should, however, be handled with caution as the robustness of the findings generated by our model requires further examination.

1.3 Summary

Table 1.1 gives an overview over the main chapters. The first column shows the type of information asymmetry assumed in the respective chapters, and the top row indicates whether we consider information which could be credibly revealed or information where credible revelation is not possible, e.g. because information is non-verifiable and truthful revelation is not in the central bank's interests. Our analyses have illuminated the rich pattern of costs and benefits arising when central banks and the public communicate with each other directly or by signaling. However, future research is needed to draw more precise policy conclusions.

[7]This is the case if the information is verifiable or if the truthful release of information is always in the sender's interest.

[8]This means that the information is not verifiable and truthful release is not necessarily in the sender's interest.

Chapter 2

Information Content of Wages

2.1 Introduction

In the course of conducting monetary policy, the central bank observes and forecasts a variety of real and nominal variables such as order inflows in firms, wages, and asset prizes. In this chapter we ask whether it is sufficient for central banks to observe and forecast nominal variables only. We examine the interplay between wage setting by sectoral labor unions and monetary policy. Our major conclusion is that although central banks may not gain more information by directly acquiring data about indicators of real shocks in the economy, such activities are nevertheless beneficial for central banks and yield lower social losses.

Our main argument runs as follows. Suppose a central bank estimates shocks to labor demand independently of labor unions. The central bank will counteract nominal wage increases by inflationary policy in order to moderate unemployment. The situation changes when the central bank does not observe shocks to labor demand independently but has to rely on the inference of real shocks from the unions' wage setting. If unions choose high nominal wages, the central bank will still want to increase inflation in order to achieve a lower level of unemployment. On the other hand, the central bank will expect a favorable real shock when it observes high nominal wages. This will lower its willingness to increase inflation. Overall, without independent information acquisition, the central bank will react less strongly to an increase in nominal wages.

Since the central bank does not react strongly to increases in nominal wages when it does not observe real shocks directly, unions will choose higher nominal wages. Due to increasing marginal costs of inflation for the central bank, it does not compensate the high level of nominal wages completely by a correspondingly high rate of inflation. This leads to high real wages and unemployment despite high inflation rates.

In summary, although the central bank can infer real shocks from the unions' wage setting, unions' incentives to signal favorable labor supply shocks lead to higher nominal and real wages when the central bank has no independent sources about the shocks. Higher real wages will create more unemployment. Hence, social welfare as determined by unemployment and inflation is better if the central bank does not base policy on nominal wages alone.

The conclusions in this chapter suggest that central banks should have independent research capabilities enabling them to identify real shocks if the costs for information acquisition are not too large. Our analysis may also have some bearings on the institutional design of the European Central Bank (ECB) and the National Central Banks (NCBs) in Europe. Our analysis can be interpreted as an interplay between a central bank and many regional unions. If unions are to play an important role in Europe, our result suggests that a strong regional presence of the ECB through the NCBs will be beneficial since information acquisition can then be done independently from observing nominal variables. If, however, traditional national unions are unable to coordinate wage setting across national boundaries in the future, the ECB may need fewer independent research capabilities since in the case of a large number of small unions, the value of direct observation of shocks disappears. Our analysis suggests that the extent of research activities of the ECB should depend on the process of unions formation in Europe.

2.2 Relation to the Literature

The consequences of the interaction between central banks and a number of sectoral unions for monetary policy have recently been fleshed out in several important contributions.[1] In this chapter, we examine whether the central bank should use real variables as indicators for monetary policy even if their information content could precisely be inferred from nominal wages.

While there are no other contributions directly dealing with the issues addressed in this chapter, there is one article that is complementary to our analysis. Woodford (1994) has recently examined the general question of the indicators to be used for monetary policy. He shows that one cannot judge the usefulness of indicators by merely looking at econometric data to the exclusion of a structural model.

[1] Cf. Agell and Isander (1993), Bleany (1996), Bruno and Sachs (1985), Calmfors and Driffill (1998), Cubitt (1995), Cukierman (1992), Cukierman and Lippi (1998), Forteza (1998), Grüner and Hefeker (1998), Guzzo and Velasco (1999), Herrendorf and Lockwood (1997), and Skott (1997).

Our chapter suggests that an indicator which does not improve the central bank's information set if it is observed directly cannot be neglected without the danger of impairing the performance of monetary policy.

2.3 Model

We take our bearings from the models of Cukierman and Lippi (1998), Grüner and Hefeker (1998), and Herrendorf and Lockwood (1997) and consider information asymmetries between unions and the central bank. These information asymmetries can be mitigated either by inference from observed wages or by an independent information acquisition process.

There are a central bank, which controls inflation, and $n \geq 1$ identical unions, each of them representing a different industry. Unions are monopolists in their industries and choose wages for their members.

The loss function of the central bank is given by the standard view that the central bank is concerned about inflation and unemployment:

$$L_{CB} = p^2 + a\overline{u}^2 \tag{2.1}$$

where p is the log of the inflation rate plus one. p equals the log of the prize level if we normalize the log of the initial prize level to zero. Aggregate unemployment is denoted by $\overline{u}$ and $a > 0$ is the relative weight of the employment target.

Following al Nowaihi and Levine (1994), Cukierman and Lippi (1998), and Grüner and Hefeker (1998), the loss function of union j is given by

$$L_j = -2(w_j - p) + Au_j^2 + Bp^2 \tag{2.2}$$

where w_j is the log nominal wage chosen by union j. The log real wage for the union's members amounts to $w_j^r := w_j - p$. Unemployment among the union's members is denoted by u_j. The positive parameters A and B stand for the importance of the employment and inflation target, respectively. The unions may dislike inflation because of its negative impact on member's saving accounts, pensions, and other nominal assets which cannot be indexed on inflation (as developed by al Nowaihi and Levine (1994)). To offer empirical evidence for the unions' dislike of inflation, Grüner and Hefeker (1998) report that German labor unions urged the ECB to keep inflation low under EMU.

The demand for the labor of union j is assumed to be:

$$l_j^d = \alpha\big(d - (w_j - p) + \epsilon\big)\frac{l}{n} \tag{2.3}$$

where ϵ is a macroeconomic shock which affects labor demand in all industries in the same way.[2] We assume that ϵ is normally distributed with mean zero and standard deviation σ_ϵ. α and d are positive parameters. Labor is supplied completely inelastically. Aggregate labor supply of all unions is given by l. Since unions are assumed to be identical in size, labor supply for each industry equals $l_j^s := l/n$. The unemployment rate among the members of union j is defined as:

$$u_j := \frac{l_j^s - l_j^d}{l_j^s} \tag{2.4}$$

Using the labor demand function in equation (2.3) we obtain:

$$\begin{aligned} u_j &= \alpha(w_j - p - d + \alpha^{-1} - \epsilon) \\ &= \alpha(w_j - p - w_r^c - \epsilon) \end{aligned} \tag{2.5}$$

Additionally, we have introduced the market clearing real wage $w_r^c := d - \alpha^{-1}$ which would equalize labor supply and demand if no shocks ϵ were present. The mean unemployment rate, defined as the average over all industries, amounts to:

$$\overline{u} = \alpha(\overline{w} - p - w_r^c - \epsilon) \tag{2.6}$$

where $\overline{w}$ denotes the mean wage across all unions, i.e. $\overline{w} := 1/n \sum_{i=1}^n w_i$.

The sequence of events is as follows:

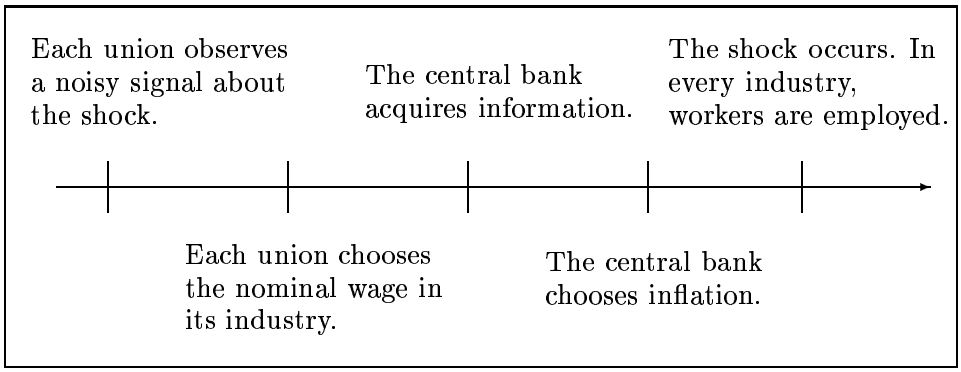
1. The shock ϵ is drawn from a normal distribution, i.e. $\epsilon \sim N(0, \sigma_\epsilon^2)$. The shock cannot be observed by the central bank and the unions. Instead, each union receives noisy information about the macroeconomic shock ϵ, i.e. it draws a sample x from a normal distribution with unknown mean ϵ and a specified value of the variance σ_x^2: $x \sim N(\epsilon, \sigma_x^2)$. For simplicity's sake, we assume that every union observes the same sample.[3] Based on the sample, each union forms a posterior distribution about the shock. The posterior distribution is again a normal distribution (cf. DeGroot (1970), p. 167) with mean:

$$E[\epsilon|x] = \frac{\frac{1}{\sigma_x^2}}{\frac{1}{\sigma_\epsilon^2} + \frac{1}{\sigma_x^2}} x \tag{2.7}$$

[2] Cukierman and Lippi (1998) use a labor demand function that depends on the difference between the wage set by the union and the average wage across all industries. This term is meant to capture a competition effect which we have omitted for convenience. But our main result appears to be robust to the introduction of this effect since the incentives to signal shocks remain, only the unions' wage responses to observations of shocks become less elastic. However, our finding that the results of proposition 2.2 do not depend on the number of unions then no longer holds.

[3] An alternative assumption would be that each union draws a different sample and therefore must estimate the mean of the other unions' posterior distribution, which differs from the mean of its own posterior distribution. In this context, the analysis becomes much more complex. But at least proposition 2.1 still holds with slight modifications, a proof is available upon request. The current assumption appears to be a plausible and the most tractable way to examine our question.

Figure 2.1: Sequence of events



and variance:

$$\sigma^2 = \frac{1}{\frac{1}{\sigma_\epsilon^2} + \frac{1}{\sigma_x^2}} \tag{2.8}$$

2. Each union chooses the nominal wage w_j in the respective industry.

3. The central bank observes the mean nominal wage and may or may not observe the unions' information about the shock,i.e. the sample x.

4. Given its information set, the central bank chooses the inflation rate.

5. The shock occurs and in every industry unemployment ensues.

We summarize the sequence of events in figure 2.1.

The use of normal distributions can be problematic because these distributions imply that shocks can be arbitrarily large. The problem can be largely avoided if the variance of the shock is rather small and thus the likelihood that labor supply will exceed labor demand can be neglected. More importantly, our results do not hinge on the distribution of shocks. Since only expected values matter in all proofs, our analysis will hold for any pair of conjugate prior and posterior distributions when the prior distribution has mean zero and a bounded variance. In particular, we could choose a prior distribution of the shock with sufficiently bounded support.[4]

[4]In proposition 2.2 we show that without independent information accumulating, the central bank's expectation of the real shock is a linear function of the observed wage level. If shocks were bounded, the central bank's expectations could not exceed the maximum possible shock but would be constant if very high wages were chosen. Similarly, the central bank's expectations about the shock would remain constant for very low wages. For intermediate wage levels, the expectations given by proposition 2.2 would still be valid. One can readily verify that this modified expectation schedule of the central bank about the shock leaves all main features of the equilibrium unchanged.

2.4 The Central Bank's Best Response

We first derive the central bank's reaction to unions' wage setting given its knowledge or assessment of the macroeconomic shock. Inserting equation (2.6) into equation (2.1) yields:

$$L_{CB} = p^2 + a\alpha^2(\overline{w} - p - w_r^c - \epsilon)^2 \tag{2.9}$$

By differentiating the central bank's expected losses with respect to p we obtain the central bank's monetary policy reaction function

$$p = \frac{a\alpha^2}{1 + a\alpha^2}\big(\overline{w} - w_r^c - E_{CB}[\epsilon]\big) \tag{2.10}$$

where E_{CB} denotes the expectation depending on the central bank's information set. The central bank's monetary policy reaction function is fairly general, since we have not yet specified how the expectations of the central bank concerning the size of the shock are formed.

The reaction function implies that the optimal rate of inflation increases with the expected mean nominal wage, but decreases with the central bank's expectation of the shock. If the nominal wages are set very high, the central bank favors larger inflation rates to reduce real wages and to prevent unemployment. If the central bank expects a large shock, which is beneficial for employment, then the desire to establish a high level of inflation is smaller. For $a = 0$, i.e. if the central bank does not care about employment at all, the optimal inflation rate is always given by $p = 0$.

2.5 Direct Acquisition of Information about Real Variables by Central Banks

In the first scenario, we assume that the central bank does not only know the mean wage $\overline{w}$, but is additionally able to gather the unions' information about the shock x. For instance, the central bank may have invested in a large information gathering process to obtain the same information as the unions. Inserting $E_{CB}[\epsilon] = E[\epsilon|x]$ into the expression for the central bank's reaction function embodied in equation (2.10) yields:

$$p = \frac{a\alpha^2}{1 + a\alpha^2}\left(\overline{w} - w_r^c - E[\epsilon|x]\right) \tag{2.11}$$

Each union minimizes its expected losses taking the central bank's reaction into account. In the appendix we show that the following equilibrium exists using superscripts NR to denote the equilibrium values if the central bank has information about nominal and real variables:

Proposition 2.1
Suppose the central bank knows the information of unions about the shock x. Then, a unique perfect Bayesian equilibrium exists where unions choose the following nominal wages:

$$\overline{w}^{NR} = w_r^c + E[\epsilon|x] + \frac{1}{A + \frac{a^2\alpha^2}{n+(n-1)a\alpha^2}B}\left(a + \frac{1}{\alpha^2}\right) \tag{2.12}$$

The central bank chooses the inflation rate:

$$p^{NR} = \frac{1}{A + \frac{a^2\alpha^2}{n+(n-1)a\alpha^2}B}\, a \tag{2.13}$$

Proposition 2.1 implies that the equilibrium real wage given by:

$$\overline{w}^{NR,r} = w_r^c + E[\epsilon|x] + \frac{1}{A + \frac{a^2\alpha^2}{n+(n-1)a\alpha^2}B}\,\frac{1}{\alpha^2} \tag{2.14}$$

and unemployment amounts to:

$$\overline{u}^{NR} = \frac{1}{A + \frac{a^2\alpha^2}{n+(n-1)a\alpha^2}B}\,\frac{1}{\alpha} + \alpha\left(E[\epsilon|x] - \epsilon\right) \tag{2.15}$$

The real wage is always above $w_r^c + E[\epsilon|x]$ which is the unions' best estimate of the market-clearing real wage. Hence, expected unemployment is always positive. Unions are willing to trade off a moderate rise in unemployment against an increase in real wages.

The prediction error of unions $E[\epsilon|x] - \epsilon$ has the following impact on unemployment. If $E[\epsilon|x] - \epsilon$ is positive, then unions expect the shock to be more favorable than it actually is. This induces them to choose rather high wages, implying high unemployment. But if $E[\epsilon|x] - \epsilon$ is negative, then unions' estimate of the shock was too pessimistic, resulting in cautious wage setting and lower unemployment.[5]

2.6 Inferring Real Variables from Nominal Variables

In this section we assume that the central bank has no direct means of gathering information about the shock or about unions' expectations about the shock. Then the only information available to the central bank is the mean wage. The central bank will

[5]Proposition 2.1 could be used to establish comparative-static results with respect to changes in the number of unions n and of the other parameters. These results, however, are omitted here since they essentially reproduce those in Cukierman and Lippi (1998) in the absence of the competition effect.

therefore try to derive unions' information about the shock from the observed nominal wages. This implies that we can rewrite equation (2.10) as

$$p = \frac{a\alpha^2}{1+a\alpha^2}\Big(\overline{w} - w_r^c - E_{CB}[\epsilon|\overline{w}]\Big) \tag{2.16}$$

where $E_{CB}[\epsilon|\overline{w}]$ denotes the central bank's expectation about the shock conditional on the observed mean wage $\overline{w}$. The crucial question is how the central bank estimates the realization of the macroeconomic shock from the aggregate nominal wage. We will only consider fully separating equilibria, i.e. for any two different expectations $E[\epsilon|x]$, different wages $\overline{w}$ are chosen.[6] Hence, the central bank can always infer the information of the unions from the observed mean wage.

Proposition 2.2
Suppose the central bank only observes the mean wage. Then a fully separating perfect Bayesian equilibrium exists.[7] *Each union sets the nominal wage according to:*

$$\overline{w}^N = E[\epsilon|x] + w_r^c + \frac{1}{A}\left(a + \frac{1}{\alpha^2}\right) \tag{2.17}$$

The central bank's choice of inflation amounts to:

$$p^N = \frac{1}{A}\,a \tag{2.18}$$

The central bank's expectation about the shock is given as:

$$E_{CB}[\epsilon|\overline{w}] = \overline{w} - w_r^c - \frac{1}{A}\left(a + \frac{1}{\alpha^2}\right) \tag{2.19}$$

From proposition 2.2, we immediately obtain the equilibrium real wage

$$\overline{w}^{N,r} = w_r^c + E[\epsilon|x] + \frac{1}{A}\,\frac{1}{\alpha^2} \tag{2.20}$$

and the unemployment rate:

$$\overline{u}^N = \frac{1}{A\alpha} + \alpha\left(E[\epsilon|x] - \epsilon\right) \tag{2.21}$$

It appears counter-intuitive for the equilibrium values of the endogenous variables to be independent of the number of unions. One would expect single unions to take the

[6] In our setup, pooling equilibria do not exist. Due to the assumption that shocks are normally distributed, it is possible that arbitrarily large shocks may occur. Intuitively, it cannot be optimal for the unions to always choose the same wage, no matter how large the expected shock. If, however, we assumed that the shocks were bounded, pooling equilibria, in which any union would always choose the same wage, could exist. The existence of pooling equilibria would not conflict with our central finding. The case for information collection would be even stronger in a pooling equilibrium since the central bank could no longer infer the size of the shock from wages.

[7] For $n \neq 1$, the proposed equilibrium is unique, i.e. no other separating equilibrium exists.

strength of their impact on the central bank's behavior into account; the strength of this impact is determined by the overall number of unions. The strategic power of any single union should become smaller in proportion to the number of unions populating the economy. So why do the equilibrium values not depend on the number of unions n?

In our model, the central bank still chooses the equilibrium inflation rate when a union deviates by choosing a different wage. This is due to two offsetting effects. If a union deviates in its wage policy, it affects both the central bank's estimate of the shock and the expected unemployment rate. Both effects increase with the size of the union. The larger the union is, the more strongly a high wage affects the central bank's estimate of the shock and the more willing the central bank is to react to a high wage with strictly anti-inflationary monetary policy. On the other hand, the larger the union is, the more it will increase aggregate unemployment with a high wage and the more likely the central bank is to pursue rather lax inflationary policy in order to reduce real wages. Thus, the strength of these two isolated effects does depend on the number of unions, while the net effect is always zero and independent of n.

While both effects always work in opposite directions, it is clear that the independence of the equilibrium values of proposition 2.2 is not robust to changes in the specification of our model with respect to the functional form of labor demand.

2.7 The Value of Direct Observations for Society, the Central Bank, and Unions

In this section we compare proposition 2.1 and proposition 2.2 in order to obtain the major conclusions of our paper.

If the central bank does not know the information of the unions, an increase in nominal wages has two effects on the central bank's reaction function. Firstly, an increase in wages should increase the optimal inflation rate because the central bank wants to reduce the unemployment created by high wages. Secondly, an increase in wages should have a positive impact on the central bank's expectation of the labor demand shock. This effect should lower the optimal inflation rate. Therefore, if the central bank does know unions' expectation about the shock, it will increase inflation more strongly as a reaction to higher nominal wages. Especially when the value of B is large, this makes high nominal wages less attractive for unions. Thus, equilibrium nominal wages are higher if the central bank does not know unions' expectation about the shock. But the higher equilibrium nominal wages are, the higher the equilibrium inflation rate must

be. And due to the increasing marginal costs of inflation for the central bank, higher equilibrium nominal wages imply higher real wages, which in turn create additional unemployment.

Proposition 2.1 and proposition 2.2 have important implications for the central bank's value of direct information about real variables. Since both inflation and unemployment are lower if the central bank can observe the information of the unions about the shock, the central bank will always prefer to have direct information on $E[\epsilon|x]$ over inferring the correct value of $E[\epsilon|x]$ from nominal variables, i.e. the value of information is larger than zero. Social losses, which we assume to increase in aggregate unemployment and inflation and which do not necessarily coincide with the central bank's losses, are higher if the central bank does not independently acquire information on real variables as well.

Having established the positive value of a direct forecast of real variables for the central bank, we now discuss whether unions also benefit from the direct observation of real variables by central banks.

In order to answer this question we compare the losses for unions if the central bank observes information about real shocks directly (cf. section 2.5) with the losses if the central bank has to derive the information observed by unions from the nominal wages (cf. section 2.6). The direct observation of real variables by the central bank is beneficial for the unions if the difference in these losses is positive. In the appendix we show:

Proposition 2.3

1. *For $B > 0$, unions benefit from the direct observation of real variables by the central bank if and only if*

$$\frac{1}{2}\alpha^2\left(\frac{1}{A}+\frac{1}{A+\frac{a^2\alpha^2}{n+(n-1)a\alpha^2}B}\right)\left(A+Ba^2\right)>1 \tag{2.22}$$

   holds.

2. *For $B = 0$, unions are always indifferent.*

The direct observation of real variables by the central bank has ambiguous effects on unions' losses. If the central bank observes the information of the unions directly, real wages are smaller. This has a negative impact on unions' profits. But on the other hand, unemployment and inflation are lower, which is beneficial for unions. Proposition 2.3 implies that it is not clear which effect is stronger. Unions may or may not benefit from the direct acquisition of information about real variables by central banks.

From our major conclusion that research activities about real shocks can be beneficial although the information gained by these activities could be obtained from observing nominal variables, we have established a new point of direct relevance for monetary policy. But our analysis also points to new insights at the conceptual level. While it is known that signaling incentives by an informed party can distort allocations even if the receiver of prize signals can precisely infer the information in equilibrium (cf. Kreps and Sobel (1994) for a survey), there are no general results for the case where an uninformed player faces a number of informed parties. We show that the central bank benefits from direct information acquisition even if a multitude of unions are trying to signal their estimate of the shock.

Two additional results are of general interest for signaling games and for agency relationships. Firstly, the more informed parties (i.e. unions) there are trying to signal shocks, the fewer the distortions there are for the uninformed party (i.e. the central bank). Indeed for n towards infinity, the value of direct observation of shocks for the central bank disappears, since if the number of unions goes to infinity, the equilibrium values are identical under both scenarios. A second, rather surprising result is that the informed players (i.e. the unions) can be better off or worse off when the uninformed player (i.e. the central bank) becomes informed. Usually, in agency relationships the uninformed agent has to give some rent to the informed agent. In our context, where the central bank can infer the shock from prizes in the labor market, the informed players may benefit when the uninformed central bank is equally well informed. Furthermore, a new finding emerging from the condition in proposition 2.3 is that unions are more likely to benefit from an informed central bank if the number of unions is large.

2.8 Conclusion

The main message of the paper is support for an independent role of central banks in the acquisition of information about real shocks in the economy. Although central banks can infer private information precisely from nominal variables such as wages, unions' incentives to signal a positive shock will lead to high unemployment and inflation.

Our analysis can be reinterpreted and applied to the European System of Central Banks (ESCB) if we consider regional instead of sectoral unions. In a first step, our results seem to stress the importance of the NCBs' role in the information acquisition process about real shocks, which should be independent of the wage-setting process.

However, caution may be advisable in two respects. Firstly, the difference between the two scenarios we have considered vanishes if a large number of unions are present and

if single unions have only a marginal impact on the central bank's policy. Therefore, the direct acquisition of information about real variables will only be important if the number of unions in Europe is not too large. An interesting corollary is that the ECB may need to increase its capacity for collecting information if traditional national unions manage to coordinate wage bargaining across national boundaries. Secondly, we have deliberately disregarded direct costs of information collection for the central bank. In reality, the staff and the resources needed to gather information represent an opportunity cost which has to be subtracted from the positive value of information in order to judge how much in the way of resources should be devoted to independent research about macroeconomic shocks.

Chapter 3

Signaling Private Information: Monetary Targeting or Inflation Targeting?

3.1 Introduction

During the last decade, inflation targeting has been adopted in many countries, including New Zealand, England, Sweden, and Canada. While it is of course too early to draw any final conclusions about the performance of inflation targeting, the experience of the last few years indicates that inflation targeting has been relatively successful. On the other hand, the German Bundesbank[1] and the Swiss National Bank have always refused to implement inflation targeting, preferring to rely on monetary targeting. Both banks have also been successful in their attempt to achieve price stability and low inflation rates. Thus, deciding which monetary policy regime central banks should adopt is an important question. For instance, in the light of the start-up phase of the European Monetary Union it is crucial to determine which monetary policy framework the ECB should choose. And some authors have argued that the Federal Reserve, which has been said to follow a "just do it" approach, should adopt inflation targeting as well (see Bernanke, Laubach, Mishkin, and Posen (1999)).

3.2 Review of the Literature

The pros and cons of monetary targeting versus inflation targeting and the historical performance of these two targeting regimes have been discussed in many important

[1]The Bundesbank, a central bank that has officially claimed to pursue monetary targeting, has recently been discussed as pursuing a hybrid strategy, i.e. a mixture of inflation targeting and monetary targeting (see Bernanke, Laubach, Mishkin, and Posen (1999)).

contributions in the last decade.[2] The main advantages of inflation targeting have been identified as the use of all available information and the promotion of transparency and credibility. First, inflation targets are easily understandable for the public. Second, inflation targeting implies accountability to the public and thus can help to discipline monetary policy (see, among others, Bernanke, Laubach, Mishkin, and Posen (1999), Mishkin (1999), and Svensson (1997, 1999)).

Inflation targeting, by contrast, has been criticized as not being operational since the central bank's control of the inflation rate is relatively tenuous and only takes effect after long time lags. Moreover, in the event of large supply-side shocks an exclusive focus of policy on inflation could lead to an unstable economy (see e.g. McCallum (1999) and Mishkin (1999)).

The advantages of monetary targeting are therefore associated with two main arguments. First, monetary growth rates are closely related to the instruments of monetary policy and thus more easily controllable than inflation itself. Second, monetary targets may be more transparent to the public than inflation targets because only one indicator is used (cf. e.g. Mishkin (1999) and von Hagen (1995, 1999)).

In this chapter, we examine the case where the relationship between money growth and inflation is affected by shocks. We show that the costs associated with monetary targeting are higher than those associated with inflation targeting.

A different set of communication problems has been examined by Laubach (1999). He considers asymmetric information in terms of the degree of commitment of central banks, concluding that inflation targeting is not inferior for communicating the central bank's objectives. This chapter suggests that under inflation targeting the costs of communicating competence are lower than under monetary targeting.

3.3 Model

We consider a one-period model based on the well-known framework by Kydland and Prescott (1977) and Barro and Gordon (1983). Let π denote inflation realized at the end of the period, π^e the private sector's expectation of inflation, and l the log employment. The natural rate of log employment is denoted by l_0. The private sector's behavior is

[2] See Bernanke, Laubach, Mishkin, and Posen (1999), Cabos, Funke, and Siegfried (1998), Cukierman (1995, 1996), Friedman and Kuttner (1996), Goodhart and Viñals (1994), Laubach (1999), Leiderman and Svensson (1995), McCallum (1999), Mishkin (1999), Svensson (1997, 1999), Taylor (1996), von Hagen (1995, 1999), and Wagner (1998)).

summarized by a standard Phillips curve:

$$l = l_0 + (\pi - \pi^e) \tag{3.1}$$

The relation between inflation π and the monetary growth rate m chosen by the central bank is:

$$\pi = m + \epsilon \tag{3.2}$$

ϵ is a normally distributed shock with zero mean and variance σ_ϵ^2.

The shock to money demand ϵ can be observed by the central bank but not by the public. This assumption is discussed in more detail in the next chapter.

Social losses are assumed to be:

$$L = \pi^2 + a(l - l^*)^2 \tag{3.3}$$

a is a positive parameter which determines the relative importance of deviations of employment from its target l^*.

The central bank's loss function under inflation targeting is assumed to be:[3]

$$\begin{aligned} L_{IT} &= \pi^2 + a(l - l^*)^2 + b_{IT}(\pi - \pi_t)^2 \\ &= \pi^2 + a(\pi - \pi^e - \Delta)^2 + b_{IT}(\pi - \pi_t)^2 \end{aligned} \tag{3.4}$$

The subscript IT stands for inflation targeting. b_{IT} is a positive parameter which determines the relative importance of the inflation target π_t. We have used the definition $\Delta := l^* - l_0$. The employment target l^* is assumed to be larger than l_0, i.e. $\Delta > 0$. This could be interpreted as labor-market distortions lowering competitive unemployment below the socially optimal level. π_t represents the inflation target that the central bank can announce at its discretion.

The central bank's loss function under monetary targeting is given by:

$$\begin{aligned} L_{MT} &= \pi^2 + a(l - l^*)^2 + b_{MT}(m - m_t)^2 \\ &= \pi^2 + a(\pi - \pi^e - \Delta)^2 + b_{MT}(m - m_t)^2 \end{aligned} \tag{3.5}$$

m_t is the monetary target that is announced by the central bank. The subscript MT stands for monetary targeting. The parameter $b_{MT} > 0$ measures the weight put on the deviation of the monetary target from monetary growth. By distinguishing between b_{IT} and b_{MT}, we explicitly allow for the costs of deviations from targets to differ under both scenarios. We will show later that the size of b_{MT} and of b_{IT} is not crucial for our main results.

[3]This kind of loss function can also be found in Rogoff (1985).

The new ingredient of our model compared to the standard framework are the costs of deviations from target values. These costs could either stem from pressure by the government, which punishes the central bank if it does not fulfill its promises[4] or it could be caused by the central bankers' inherent aversion to lie or the central bankers' dislike to appear incompetent or less credible. Any model that tries to describe the effect of announced targets must model some mechanism that commits the central bank to its announcements. Our assumption is comparably weak since b_{MT} and b_{IT} can be rather small.

The sequence of events is given as follows:

1. The central bank observes the shock to money demand ϵ.[5]
2. The central bank announces an inflation target π_t or a monetary target m_t respectively.
3. The public forms its inflation expectations.
4. The central bank chooses its instrument, i.e. the money growth rate m.
5. The shock realizes, determining inflation and employment.

For this game, we will derive a perfect Bayesian Nash equilibrium.

3.4 Inflation Targeting

We solve the model by backwards induction. Since the central bank can control inflation exactly in our simple model, we can neglect the choice of m and compute the optimal choice of π as a function of π^e and π_t by the respective first-order condition:

$$\pi - a(\Delta - \pi + \pi^e) + b_{IT}(\pi - \pi_t) = 0 \tag{3.6}$$

In a rational-expectations equilibrium we must have $\pi = \pi^e$. Hence, we obtain:

$$\pi = \frac{a\Delta + b_{IT}\pi_t}{1 + b_{IT}} \tag{3.7}$$

[4] Also confer the next chapter.

[5] It is not necessary for the central bank to be able to predict the shock exactly. It is sufficient for the central bank to have some private information. In the next chapter we describe a model where there is only a positive probability that the central bank has superior knowledge on money-demand shocks. The assumption about central banks having superior information will be discussed in more detail in the next chapter.

The inflation target π_t the central bank announces after observing the shock can be derived from the respective first-order condition:

$$0 = \frac{1}{2}\frac{dL_{IT}}{d\pi_t} = \pi\frac{\partial\pi}{\partial\pi_t} + b_{IT}(\pi - \pi_t)\left(\frac{\partial\pi}{\partial\pi_t} - 1\right) \tag{3.8}$$

Solving for π_t we obtain:

$$\pi_t = 0 \tag{3.9}$$

Thus the equilibrium inflation rate amounts to:

$$\pi = \frac{a\Delta}{1 + b_{IT}} \tag{3.10}$$

We summarize our observations by the following proposition:

Proposition 3.1
Under inflation targeting, the following perfect Bayesian Nash equilibrium exists. Independently of the observed shock, the central bank announces an inflation target of $\pi_t = 0$. *The public expects an inflation rate of* $\pi^e = \frac{a\Delta}{1+b_{IT}}$. *The central bank chooses a monetary growth rate of* $m = \frac{a\Delta}{1+b_{IT}} - \epsilon$. *Thus, inflation amounts to* $\pi = \frac{a\Delta}{1+b_{IT}}$.

There should be systematic deviation of inflation from its target, the size depends on the severity of the incentive for surprise inflation, which can be quantified by $a\Delta$. Inflation targeting helps reduce the inflation bias. The larger the costs of deviations of inflation from target, which are proportional to b_{IT}, the better is the improvement over the discretionary solution where the inflation bias is given by $\pi = a\Delta$. This can be confirmed by setting $b_{IT} = 0$ which represents the discretionary case. Inflation targeting performs better, the larger b_{IT} is. For infinitely large costs of deviations of the announced target from actual inflation, i.e. for $b_{IT} \to \infty$, we obtain the first-best solution, which could be achieved by committing the central bank to a strict rule. The optimal strict rule would guarantee no inflation bias at all, i.e. $m = -\epsilon$ and $\pi = 0$.

3.5 Monetary Targeting

In order to compute a perfect Bayesian Nash equilibrium, we solve the model by backwards induction. The optimal choice of m depending on the inflation expectations π^e, the size of the shock ϵ, and the announced monetary target m_t can be derived from the respective first-order condition:

$$0 = m + \epsilon - a(\Delta - m - \epsilon + \pi^e) + b_{MT}(m - m_t) \tag{3.11}$$

$$m = \frac{-\epsilon(1+a) + a(\Delta + \pi^e) + b_{MT}m_t}{1 + a + b} \tag{3.12}$$

Now we compute the optimal monetary target:

$$\begin{aligned} 0 &= \frac{dL_{MT}}{dm_t} \\ &= (m+\epsilon)m'(m_t) + a\Delta\left(-\pi^{e\prime}(m_t) - m'(m_t)\right) + b_{MT}(m-m_t)(m'(m_t)-1) \end{aligned} \tag{3.13}$$

We assume that inflation expectations depend linearly on the announced monetary target. Thus we can write:

$$\pi^e = \alpha m_t + \beta \tag{3.14}$$

where α and β are coefficients that are left to be determined. Later one can verify that this assumption is consistent with a rational-expectations equilibrium. Straightforward calculations yield:

$$m_t + \epsilon = a\Delta + \frac{1+b_{MT}}{b_{MT}}\alpha a\Delta \tag{3.15}$$

If we guess that the central bank chooses different monetary growth targets for different observed shocks, which can be verified later, we can conclude that in equilibrium we must have:

$$m + \epsilon = \pi^e = \alpha m_t + \beta \tag{3.16}$$

Inserting $m + \epsilon = \pi^e$ into (3.12) yields:

$$m = \frac{-\epsilon + a\Delta + b_{MT}m_t}{1+b_{MT}} \tag{3.17}$$

Combining this equation with (3.15) and (3.16) we obtain:

$$\alpha m_t + \beta = (1+\alpha)a\Delta \tag{3.18}$$

Since this equation must hold for any m_t, we obtain $\alpha = 0$ and $\beta = a\Delta$. This implies that inflation expectations do not depend on the announced monetary target and are given by:

$$\pi^e = a\Delta \tag{3.19}$$

Thus we have:

$$m_t = a\Delta - \epsilon \tag{3.20}$$

$$m = a\Delta - \epsilon \tag{3.21}$$

$$\pi = a\Delta \tag{3.22}$$

We summarize our observations by the following proposition:

Proposition 3.2

Under monetary targeting, the following perfect Bayesian Nash equilibrium exists. Having observed the shock, the central bank announces a monetary target of $m_t = a\Delta - \epsilon$. *The public expects an inflation rate of* $\pi^e = a\Delta$. *The central bank chooses a monetary growth rate of* $m = a\Delta - \epsilon$. *Thus, inflation amounts to:* $\pi = a\Delta$.

Interestingly, under monetary targeting there is no systematic deviation of the announced target from the actual monetary growth rate, which is in contrast to our finding in the last section where the inflation target was systematically smaller than inflation.

By comparing propositions 3.1 and 3.2, we obtain the following proposition about the relative performance of inflation targeting and monetary targeting:

Proposition 3.3
For all values of $b_{IT} > 0$ and all values of $b_{MT} > 0$, social losses are always lower under inflation targeting.

The proof is straightforward. Employment is the same under both scenarios but the inflation rate is always larger under monetary targeting. Thus, social losses understood to be determined by employment and inflation are lower under inflation targeting.

Under monetary targeting, the public can always infer the size of the shock from the central bank's target which is not possible under inflation targeting since the inflation target does not depend on the observed shock. As under inflation targeting, the shock is completely stabilized under monetary targeting, i.e. inflation does not depend on the size of the shock. This, however, would no longer hold if the central bank obtained only an imprecise signal about the shock before announcing the target and some new information afterwards. Then monetary targeting would lead to less stabilization of money-demand shocks due to the central bank's aversion to deviate from its announcements. Inflation variability would be larger under monetary targeting than under inflation targeting. Therefore, the performance of monetary targeting is decreasing with the central bank's costs of missing their targets, i.e. under monetary targeting b_{MT} should be rather small to guarantee satisfactory results. This seems to have been the case for the Bundesbank before the EMU since actual money growth was out of the target range very often which indicates that losses from deviations of monetary aggregates from targeted values were small. Monetary targeting is optimal if $a\Delta$ is very small i.e. the time-inconsistency problem is negligible. Then a monetary target reveals more information to the public than an inflation target since the public cannot infer the size of the shock from the inflation target which is possible for a monetary target. This increased knowledge, however, does not have a beneficial impact in our model as inflation targeting would lead to the optimal solution as well.

Why are monetary targets less efficient in overcoming the time-inconsistency problem? The reason is that monetary targets can only be used to signal the central bank's private information. The central bank cannot commit itself to anti-inflationary policy by announcing low monetary targets and thus reduce inflation expectations since low

monetary targets are understood to signal positive monetary shocks. This means that inflation expectations do not depend on the monetary target. Therefore monetary targets cannot reduce the inflation bias whereas inflation targets can. Several countries which suffered from large inflation rates have introduced inflation targets, which seems to stress the validity of our result that inflation targets are better tools to reduce the inflation bias than monetary targets.

3.6 Conclusion

The main message of this chapter is that if a targeting procedure is used as a device to alleviate the time-inconsistency problem inherent in the framework by Kydland and Prescott (1977) and Barro and Gordon (1983), then inflation targeting is superior to monetary targeting. Inflation is lower under monetary targeting, but output is the same under both regimes. If more information becomes available to the central bank after the announcement of the target, inflation targeting also leads to a better stabilization of the money demand shocks and to lower variance of inflation. If the public is unsure about the central bank's incentives for creating surprise inflation and the central bank could choose either inflation targeting or monetary targeting, then it could be beneficial to choose monetary targeting in order to signal that the central bank is not interested in surprise inflation, i.e. that $a\Delta$ is very small.

In the next chapter, we will reach a similar conclusion about the advantages of inflation targeting over monetary targeting for the case where the central bank may be more or less competent, i.e. there is only a positive probability that the central bank has superior information on shocks to money demand. The implications of our main result will be discussed in more detail in the next chapter.

Chapter 4

Signaling Competence: Monetary Targeting or Inflation Targeting?

4.1 Introduction

The purpose of this chapter is to compare the social efficiency of inflation targeting with that of monetary targeting when central banks wish to signal their competence and the nature of their private information about future money demand shocks.

We consider a model in which inflation is affected by money growth and by other factors about which the central bank may have only incomplete knowledge. Here, the public faces two kinds of information asymmetries. First, it is unsure about the precision of the central bank's information on future inflation. In other words, the public faces the risk that the central bank may not be fully competent to predict money demand. Second, if the central bank does in fact possess that competence, the public is unsure about the nature of the central bank's information on the future link between money growth and inflation.

In our model, a transparency requirement would yield the socially efficient monetary policy. Therefore publication is beneficial, if the central bank's private information is verifiable. If, on the other hand, information is non-verifiable, which is one of our key assumptions, truthful revelation may not be in the interest of the central bank. If the central bank has no incentive to truthfully reveal its private information, non-verifiable information can only be communicated through signaling.

We consider two kinds of monetary policy rules: monetary targeting, which is an instrument rule, and inflation targeting, which does not rely on an intermediate target. These two monetary policy frameworks involve two different communication or signaling problems.

An informed or competent central bank is able to control inflation exactly, something which is impossible for an uninformed central bank. Therefore a competent central bank may want to imitate the behavior of an uninformed central bank under inflation targeting. By imitating an uninformed central bank the informed central bank can deliberately achieve inflation rates that differ from the announced target with impunity. Such attempts by informed central banks to create surprise inflation and employment gains would push up inflation expectations. Thus there may be an incentive for an uninformed central bank to signal its lack of competence.

Under monetary targeting, central banks must stick to their targets because money growth is assumed to be fully controllable and is observable by the public. Central banks, however, may want to signal the nature and the precision of their information by a certain money growth rate to influence the public's inflation expectations. For instance, an uninformed central bank may want to signal its lack of competence in order to prevent imitation by a central bank which has observed a positive shock. Since successful imitation would push up inflation expectations and lead to high unemployment, an uninformed central bank could benefit from separating itself from a central bank that has observed a positive shock by choosing a different monetary target.

We show that under both policy regimes, a unique separating equilibrium will occur while pooling equilibria can be eliminated by the intuitive criterion. Our major finding is that in social terms inflation targeting is superior or at least equivalent to monetary targeting.

Why is monetary targeting inferior to inflation targeting? Under monetary targeting, an incompetent central bank imitating a central bank that has observed a negative shock, has the potential to create surprise inflation without being detected. This induces central banks that have observed a negative shock to choose high inflation rates in order to deter imitation. This effect involves high social losses. Under inflation targeting, inflation expectations are always larger or equal to the inflation announcement by an incompetent central bank, which implies that an incompetent central bank can never achieve surprise inflation. Therefore, a competent central bank with a negative shock has no reason to deter imitation and to choose a higher inflation target than the incompetent central bank. This lowers social losses relative to monetary targeting.

Our major finding implies an interesting corollary. If central banks put large emphasis on employment and are accordingly weak on inflation, central banks will choose inflation targeting when they have the choice between inflation targeting or monetary targeting.

The chapter is organized as follows: In the next section we review the related literature, proceeding in section 4.2 to develop the model. A benchmark solution is proposed in

section 4.3, while the results for inflation targeting and monetary targeting are derived in sections 4.4 and 4.5 respectively. In section 4.6 we compare the results for monetary targeting and inflation targeting. Section 4.7 discusses the underlying assumptions of our model and the implications for the robustness of the results. Section 4.8 presents our conclusions.

4.2 Model

We consider a simple one-period model with two players, a central bank and the public. The government acts as a delegated monitor for the public. The public is unsure about the precision and the nature of the central bank's information about future inflation.

Let π denote inflation realized at the end of the period, π^e the private sector's expectation of inflation, and l the log employment. The natural rate of log employment is denoted by l_0. The private sector's behavior is summarized by a standard Phillips curve:

$$l = l_0 + (\pi - \pi^e) \tag{4.1}$$

The relation between inflation π and the monetary growth rate m chosen by the central bank is:

$$\pi = m + \epsilon \tag{4.2}$$

where ϵ denotes shocks to money demand.

$$\epsilon = \begin{cases} +\delta & \text{w.p. } \frac{1}{2} \\ -\delta & \text{w.p. } \frac{1}{2} \end{cases} \tag{4.3}$$

Equation (4.2) takes into account that inflation is determined by money growth as well as temporarily by other factors beyond the central bank's control (see also Laubach (1999)). Note that the choice of m can be observed by the public.

We assume that the private sector's expectations are rational, that is, π^e is the correct expectation of the public, given its information set.

The central bank observes a signal of the demand shock with probability $\lambda \in]0, 1[$. For simplicity's sake we assume that this signal is not noisy, i.e. if the central bank recognizes the signal, it is able to completely determine inflation by choosing the appropriate value for m. Thus, with probability λ, the central bank becomes fully informed about the value of ϵ and, with probability $1 - \lambda$, the central bank will remain ignorant and there is nothing it can do to achieve its preferred rate of inflation with certainty.

The public therefore faces three types of central banks:

$$\begin{array}{lll} CB^+ & \rightarrow & \text{CB has observed } \epsilon = +\delta \qquad (\text{prob. } \frac{1}{2}\lambda) \\ CB^- & \rightarrow & \text{CB has observed } \epsilon = -\delta \qquad (\text{prob. } \frac{1}{2}\lambda) \\ CB^0 & \rightarrow & \text{CB has not observed the signal} \quad (\text{prob. } 1-\lambda) \end{array}$$

We assume that the signal is private information available only to the central bank and not verifiable for the public. The central bank's assessments about the future developments in an economy may involve a certain amount of judgment and experience of the decision-making body and may thus be unverifiable private information.

Our central assumption is that there is a chance that central banks have superior information. There is a large literature suggesting that central banks obtain information about the future course of the economy earlier than the public.[1] The assumption has recently received empirical support by Peek, Rosengreen, and Tootell (1998) and Romer and Romer (2000). Our assumption is weaker since we consider a case when there is only a positive probability that at some time the central bank will have more accurate forecasts than the public. Moreover, some recent arguments support the view that there is a positive chance that central banks may temporarily have more information than the public. We will review these arguments in detail in section 4.7 when we discuss the significance of our assumptions.

The central bank's loss function is given by

$$L = E[\pi^2 + a(l - l^*)^2] + \mathcal{P} \tag{4.4}$$

where l^* is the log employment target. It is above the natural level l_0 and given by $l^* = l_0 + \Delta$ with $\Delta > 0$.[2] E denotes the expectation given the information set of the central bank and $\mathcal{P}$ a possible penalization. The cost function builds on the natural rate model introduced by Barro and Gordon (1983) and Kydland and Prescott (1977). These preferences represent an explicit zero inflation target and an employment target. There is a trade-off between the desire for low inflation and the incentive to create higher employment by surprise inflation. The weight on the employment target is given by $a \in [0, \infty]$. Hence, the higher a, the more relevant the employment target is. We assume that the central bank's objectives are representative of the public's preferences. The central bank's loss function minus the possible punishment $\mathcal{P}$ stands for social losses.

[1] The idea has been introduced by Canzoneri (1985) and also by Goodfriend (1986). For extensive discussion see Cukierman (1992) and Romer and Romer (1997). Recent examinations of central banks with private information include Berger and Thum (2000), Garfinkel and Oh (1995), Laubach (1999), and Schaling (1995). A survey has been conducted by Prast (1996).

[2] Additionally, we assume that $\Delta > 2\delta$ which will guarantee that realized employment l is always smaller than the target l^*.

$\mathcal{P}$ represents a penalty imposed by the government if it can verify that the central bank has not attempted to meet its target levels.[3] Let the announced targets of the central bank under inflation targeting and monetary targeting be denoted by π_t and by m_t respectively. We will use additional indices to specify the type of bank that announces the target. E.g. π_t^+ represents an inflation target announced by a central bank of type CB^+. Since the central bank can completely control its target under monetary targeting, the punishment rule is simply given by:

$$\mathcal{P} = \begin{cases} 0 & \text{if } m = m_t \\ \infty & \text{otherwise} \end{cases} \tag{4.5}$$

Under inflation targeting, the penalty rule is only slightly more complicated since an incompetent bank cannot control inflation exactly. But m is observable by the government and can be used to control the behavior of the central bank. Thus, under inflation targeting $\mathcal{P}$ is given by:

$$\mathcal{P} = \begin{cases} 0 & \text{if } m = \pi_t \text{ or } \pi = \pi_t \\ \infty & \text{otherwise} \end{cases} \tag{4.6}$$

An incompetent central bank must choose $m = \pi_t$ which means that its best estimate of inflation equals the target. A competent central bank can control inflation exactly and therefore achieve $\pi = \pi_t$ or it can mimic an incompetent bank and choose $m = \pi_t$ which implies an inflation rate of $\pi_t - \delta$ or $\pi_t + \delta$ respectively. All other choices imply that the central bank has tried to deceive the public and will therefore lead to severe punishment.

We introduce a punishment mechanism in our model as the target announcements would otherwise be meaningless. It is not necessary for the punishment to amount to ∞, it is sufficient for the punishment to be strong enough to prevent deviations. Of course, we are using a highly stylized mechanism enabling the central bank to commit itself to targets. Weaker assumptions that would allow for small deviations from announced targets would only complicate the analysis and probably lead to similar results.[4]

[3] For a discussion of the enforcement of such arrangements and the nature of penalties see Garfinkel and Oh (1993), Persson and Tabellini (1993), Rogoff (1985), and Walsh (1995a, 1995b)). For instance, Walsh (1995a) shows how the threat of dismissal can cause the central banker to pursue a desired policy.

[4] Berger and Thum (2000) note that it may be relatively easy for a competent central bank to pretend to be incompetent. Pretending to be incompetent simply requires withholding information. On the other hand, falsely pretending to have a certain kind of information requires the faking of data, which may be much more difficult. In our model, it is never necessary for the central bank to actually forge information. Under monetary targeting, the central bank simply announces a money growth target which can be controlled exactly. The punishment is completely independent of the observed shock. Under inflation targeting, competent central banks may claim to be incompetent, but a central bank will never have to fake information.

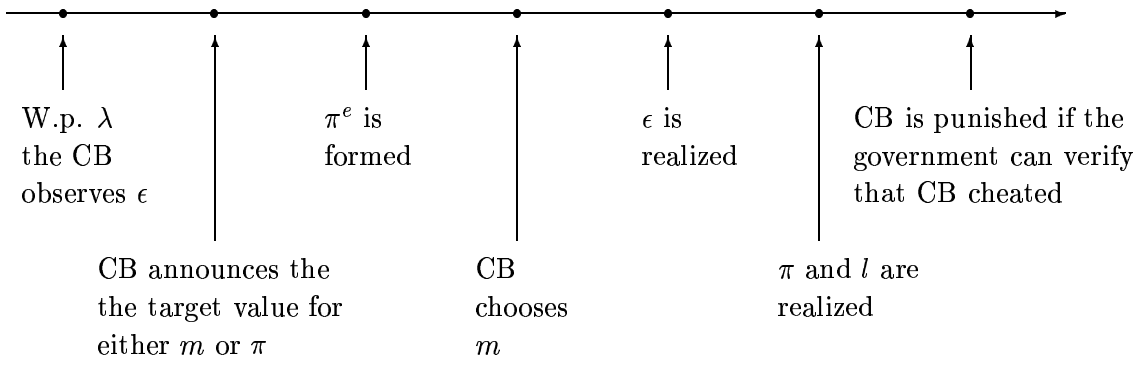


Figure 4.1: Sequence of events

Within the period in question, the sequence of events is as follows: At the beginning of the period, the central bank has the possibility of observing a signal about the monetary demand shocks occurring in this period. Subsequently, the central bank announces either an inflation target or a monetary target. Then the public forms inflation expectations based on the announcement and locks into nominal contracts for the remainder of the period. Subsequently, the central bank chooses its monetary policy. Finally, after the monetary demand shock has occurred, inflation and real output are realized. If the government is able to prove that the central bank has deliberately failed to achieve the target, it will impose major punishments on the central bank, e.g. fire the central bank manager. Thus, the central bank will never want to deviate from its announcement if the government can verify afterwards that the bank did not do its best to achieve the target. We summarize the sequence of events in figure 4.1.

The government has no possibility of observing whether the central bank was informed in the first stage of the game since the information is not verifiable. Due to the shock an uninformed bank announcing an inflation target will not be able to reach its goal with certainty. This means that an informed central bank can choose a monetary policy resulting in an inflation rate that differs from the announced target. If there is a difference between actual and announced inflation, the bank can claim that this gap occurred because it did not have information on the monetary demand shock.

Under monetary targeting, there are no discretionary powers for the central bank since the government is always able to detect whether the central bank has fulfilled its obligation and has chosen the announced rate of monetary growth m. There are however other communication problems with monetary targeting. Under the monetary targeting scenario, the public knows for sure which choice of monetary growth m the central bank will make. But the public may be unsure which inflation rate will be realized

after observing a particular money growth rate since different types of central banks may choose the same or different money growth rates.

The model will later be elaborated for two different cases: inflation targeting and monetary targeting (in sections 4.4 and 4.5 respectively). In the next section we establish a benchmark case.

4.3 Socially Efficient Monetary Policy Rules

Let us assume that a social planner exists who can verify the information of the central bank. Ex ante, the planner can impose exact rules concerning how the central bank should behave given the observed signal, i.e. in every contingency CB^-, CB^0, CB^+. Hence, problems due to information asymmetries or dynamic inconsistency cease to exist. The social planner enforces a monetary policy that guarantees expected inflation to be zero. The choice of a particular target rule is irrelevant. Hence we obtain:

Proposition 4.1
The socially efficient solutions under both monetary policy rules are given by:

$$\begin{array}{lcccccc} CB^+ & : & \pi_t^+ & = & m_t^+ + \delta & = & 0 \\ CB^- & : & \pi_t^- & = & m_t^- - \delta & = & 0 \\ CB^0 & : & \pi_t^0 & = & m_t^0 & = & 0 \end{array} \tag{4.7}$$

Thus, losses for an informed bank are given by:

$$L^I := L^+ = L^- = a\Delta^2 \tag{4.8}$$

However, expected losses for an uninformed central bank are larger, because it cannot perfectly control inflation:

$$L^0 = a\Delta^2 + (1+a)\delta^2 \tag{4.9}$$

Since a central bank is informed with probability λ and a bank of type CB^0 occurs with probability $1-\lambda$, we can now derive the expected overall losses in the benchmark case using formulas (4.8) and (4.9):

$$L = \lambda L^I + (1-\lambda)L^0 = a\Delta^2 + (1-\lambda)(1+a)\delta^2 \tag{4.10}$$

Not surprisingly, expected overall losses decrease with λ. The greater the likelihood that the central bank is informed about shocks, the smaller the expected losses are because inflation variability can be avoided by stabilizing money demand shocks.

Another way to implement the socially optimal solution is a transparency requirement which forces the central bank to truthfully reveal all private information.[5] In our model we assume that this is impossible since the public is not able to verify the central bank's private information.

4.4 Inflation Targeting

Let us first consider inflation targeting as the monetary policy rule. From the punishment scheme (equation (4.6)) it follows that CB^+ can create inflation that exceeds its target level by δ if it chooses $m = \pi_t$. But CB^- and CB^0 cannot deviate from their targets by creating larger inflation than announced. Therefore, there may be incentives for CB^+ to imitate the banks CB^- and CB^0. The latter may want to signal their types by announcing higher inflation targets than would be optimal without the risk of imitation. This can create extra losses.

The following definition will greatly simplify the analysis:

$$b := a(2\Delta/\delta - 1) \tag{4.11}$$

We will now show that both under inflation targeting and under monetary targeting the characteristics of possible equilibria crucially depend on the value of b.[6] A classification according to $b \leq 1$ and $b \geq 1$ is reasonable for both scenarios. Note that b increases in the weight a on the employment target and in Δ while it decreases in the magnitude of the shock δ.

We will now show that under inflation targeting a simple pooling equilibrium exists for $b \leq 1$. We prepare the ground for our findings with the following observation about the behavior of CB^+ in the case where the public knows the central bank's type. In the appendix we show:

Proposition 4.2
Assume the type of central bank is known to be CB^+. If the inflation target is below a critical level π_c

$$\pi_t < \pi_c := \frac{b-1}{2}\,\delta \tag{4.12}$$

then $\pi^e = \pi = \pi_t + \delta$ for a central bank of type CB^+. If $\pi^e = \pi = \pi_t$, then $\pi_t > \pi_c$ necessarily holds.

[5] Cf. section 4.7 for a more detailed discussion.
[6] Note that from $\Delta > 2\delta$ it follows that $b > 0$.

The reasoning behind proposition 4.2 is as follows: If CB^+ announces a very high inflation rate, the additional losses for choosing an inflation rate that is even higher ($\pi = \pi_t + \delta$) may outweigh the relatively small benefits from the higher employment possibly created by surprise inflation. An inflation target above the critical value is always credible. Since $\pi_c < 0$ for large values of δ, we obtain a pooling equilibrium for $b \leq 1$:

Proposition 4.3
Assume $b \leq 1$ (i.e. $\pi_c = \delta(b-1)/2 < 0$), then a pooling equilibrium exists with $\pi_t = \pi^e = 0$ for all types of banks. The beliefs of the public are given by:

$$\pi^e(\pi_t) = \begin{cases} \pi_t + \delta & \text{for } \pi_t \leq \pi_c \\ \pi_t & \text{for } \pi_t > \pi_c \end{cases} \tag{4.13}$$

Expected overall losses are the same as in the benchmark case.

It is obvious that there is no profitable deviation for either type of bank.

Intuitively, since CB^+ can only create surprise inflation by the size of the shock and since the parameter δ increases with decreasing b, $b \leq 1$ means that the possible surprise inflation is so large that the losses caused by the high inflation rate outweigh the benefits from surprise inflation.

For $b \geq 1$ we obtain the following proposition, which is proved in the appendix:

Proposition 4.4
Assume $b \geq 1$. Then a semi-separating equilibrium exists with announcements

$$\begin{aligned} \pi_t^+ &= -\delta \\ \pi_t^0 &= \pi_t^- = (\sqrt{b}-1)\delta > 0 \end{aligned} \tag{4.14}$$

The equilibrium and out-of-equilibrium beliefs of the public are given by:

$$\pi^e(\pi_t) = \begin{cases} \pi_t + \delta & \text{for } \pi_t < \pi_t^0 \\ \pi_t & \text{for } \pi_t \geq \pi_t^0 \end{cases} \tag{4.15}$$

Inflation rates amount to:

$$\pi = \begin{cases} 0 & \text{for } CB^+ \\ \pi_t^0 & \text{for } CB^- \\ \pi_t^0 \pm \delta & \text{for } CB^0 \end{cases} \tag{4.16}$$

Expected overall losses are:

$$L = a\Delta^2 + (1-\lambda)(1+a)\delta^2 + \left(1 - \frac{1}{2}\lambda\right)\left(\sqrt{b}-1\right)^2\delta^2 \tag{4.17}$$

The equilibrium satisfies the intuitive criterion.[7]

Hence, CB^0 and CB^- announce the same positive inflation rate. CB^+ is separated due to a negative inflation target.[8] The properties of the equilibrium are illustrated in figure 4.2. On the left side of figure 4.2, the equilibrium targets and the resulting inflation rates are displayed. The right side shows the inflation expectations of the public depending on the announced target.

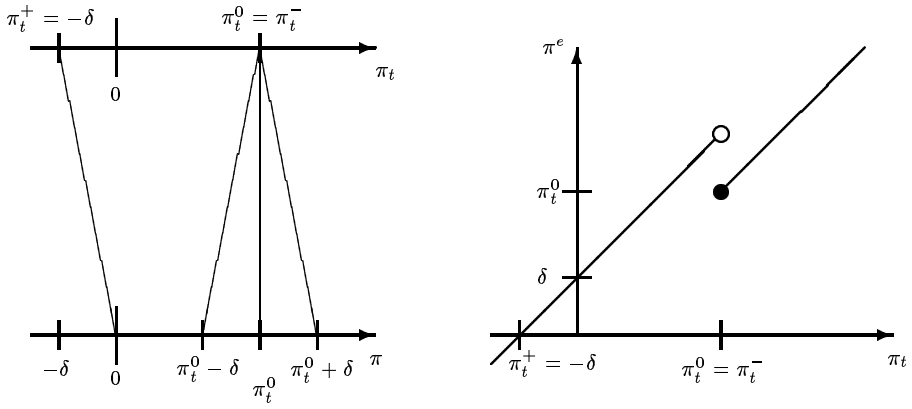


Figure 4.2: Separating equilibrium under inflation targeting for $b \geq 1$.

Let us take a close look at L in proposition 4.4. The first and second summand are precisely the losses in the benchmark case. The last summand represents positive signaling costs for CB^0 and CB^-. The probability for a bank to be either of type CB^0 or CB^- is exactly $1 - 1/2\lambda$. Overall losses are decreasing in λ, but always exceed the benchmark losses since even for $\lambda \to 1$ there are signaling costs for CB^-.

We have already noted in the proof of proposition 4.4 that in any separating equilibrium π_t^+ must be $-\delta$. Hence, if other separating equilibria exist, the difference can only be due to higher values for π_t^0. But obviously these equilibria would not satisfy the intuitive criterion since every $\pi_t > \sqrt{b} - 1$ is equilibrium dominated for CB^+ by construction. We obtain:

[7]The intuitive criterion provides a means to check the plausibility of out-of-equilibrium beliefs. Suppose a central bank were expected to be of type $T \in \{CB^-, CB^0, CB^+\}$ if it chose a certain target that is not chosen in equilibrium. If a central bank of type T would never benefit from choosing this out-of-equilibrium strategy whereas a central bank of type $T' \neq T$ would, then the out-of-equilibrium beliefs about the central bank's type can be ruled out as implausible. See Cho and Kreps (1987) for the precise definition of the intuitive criterion.

[8]Note our assumption that the government cannot penalize CB^+ for creating higher inflation than announced, even though the type of central bank becomes apparent due to the signal created by the announced target. One reason might be that the central bank has the "right to be irrational". An incompetent central bank is allowed to choose an inflation target of $-\delta$ though this would not be optimal. Another reason might be that a punishment would imply the use of the public's expectations, which might not be verifiable in court.

Proposition 4.5
The equilibrium of proposition 4.4 is the only separating equilibrium that satisfies the intuitive criterion.

We next look at pooling equilibria for $b \geq 1$. In the appendix we will prove the following proposition:

Proposition 4.6
No pooling equilibrium exists for $b \geq 1$ that satisfies the intuitive criterion.

Hence, the equilibrium in proposition 4.4 is unique if we use the intuitive criterion which is the most widely applied refinement in signaling games.

Note that for $b = 1$ the results obtained for both assumptions $b \geq 1$ and $b \leq 1$ yield the same inflation rates and social losses.

4.5 Monetary Targeting

In this section we focus on monetary targeting. The central bank announces a target value m_t. The public knows that the central bank will always choose the announced monetary growth rate since any deviation would cause punishment and infinite losses (according to equation (4.5)). But in order to predict inflation, the public must form expectations about the type of central bank announcing a particular money growth target m_t. Given the announcement m_t, any of the values $m_t - \delta$, m_t and $m_t + \delta$ might be the inflation rate expected by the central bank. Because of this uncertainty, there are several incentives for central banks to mimic other types of banks and to signal a particular type to the public. CB^0 could gain from imitating the behavior of CB^- since surprise inflation would be possible if the public believed that CB^0 was CB^-. And CB^+ might elect to imitate CB^0 and perhaps even CB^- because this would create space for moderate or even very high surprise inflation. Because the danger of being imitated pushes up inflation expectations, both CB^0 and CB^- may want to signal their types. Thus, there is the possibility of even larger signaling costs compared to the outcome under inflation targeting.

Due to the punishment scheme for monetary targeting (equation (4.5)) $m_t = m$ holds in any equilibrium. Hence, we will omit the index t in the following.

For $b \leq 1$ we obtain results that are similar to the outcomes under inflation targeting. In the appendix we prove the following proposition:

Proposition 4.7
Assume $b \leq 1$. Then the following fully separating equilibrium exists. The monetary policy chosen in equilibrium is: $m^+ = -\delta$, $m^- = +\delta$, and $m^0 = 0$. The equilibrium and out-of-equilibrium expectations of the public are given by:

$$\pi^e(m) = \begin{cases} m + \delta & \text{for } m < 0 \\ m & \text{for } 0 \leq m < \delta \\ m - \delta & \text{for } m \geq \delta \end{cases} \tag{4.18}$$

Inflation rates amount to:

$$\pi = \begin{cases} 0 & \text{for } CB^+ \text{ and } CB^- \\ \pm\delta & \text{for } CB^0 \end{cases} \tag{4.19}$$

Expected overall losses are the same as in the benchmark case.

Proposition 4.7 indicates that where b is sufficiently small, we obtain the benchmark outcome as in the case of inflation targeting.

Let us now examine the solution for $b \geq 1$. In the appendix we show:

Proposition 4.8
Assume $b \geq 1$. Then the following separating equilibrium exists. The monetary policy chosen in equilibrium is:

$$\begin{array}{lcl} m^0 & = & \left(\sqrt{b} - 1\right)\delta > 0 \\ m^- & = & \sqrt{2b - 2\sqrt{b} + 1}\;\delta > \delta \\ m^+ & = & -\delta \end{array} \tag{4.20}$$

The equilibrium and out-of-equilibrium beliefs of the public are given by:

$$\pi^e(m) = \begin{cases} m + \delta & \text{for } m < m^0 \\ m & \text{for } m^0 \leq m < m^- \\ m - \delta & \text{for } m^- \leq m \end{cases} \tag{4.21}$$

Inflation rates amount to:

$$\pi = \begin{cases} 0 & \text{for } CB^+ \\ m^0 \pm \delta & \text{for } CB^0 \\ m^- - \delta > m^0 & \text{for } CB^- \end{cases} \tag{4.22}$$

Overall expected losses are:

$$L = a\Delta^2 + (1-\lambda)(1+a)\delta^2 + (1-\lambda)\left(\sqrt{b} - 1\right)^2\delta^2 + \frac{1}{2}\lambda\left(\sqrt{2b - 2\sqrt{b} + 1} - 1\right)^2\delta^2 \tag{4.23}$$

The equilibrium for monetary targeting differs from the equilibrium for inflation targeting in one way. Under monetary targeting, there are three types of banks, whereas in the preceding section there were effectively only two types. As we will prove, this leads to increased signaling costs and therefore to higher expected overall losses. The properties of the equilibrium are illustrated in figure 4.3. On the left side of figure 4.3, the chosen equilibrium targets and the resulting inflation rates are displayed. The right side shows the inflation expectations of the public depending on the announced target.

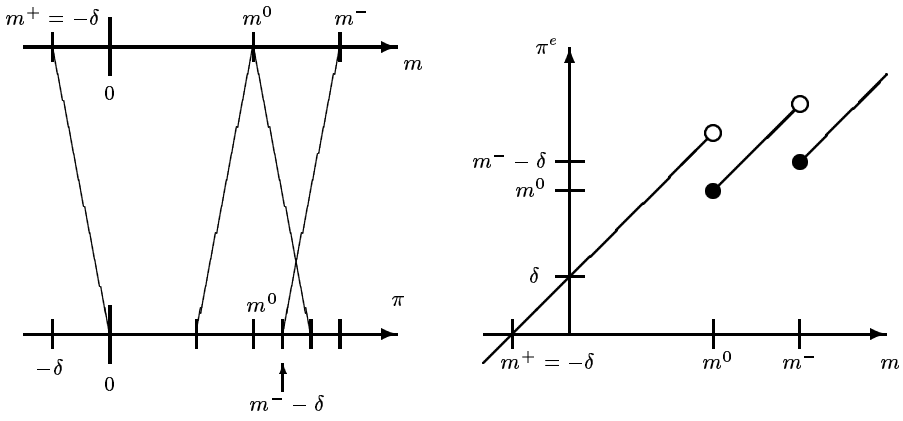


Figure 4.3: The separating equilibrium under monetary targeting for $b \geq 1$.

The expression for L in proposition 4.8 may seem rather complicated, but is in fact easy to interpret. The first and second terms are the benchmark losses, with the second term representing the losses due to the imperfect controllability of inflation for uninformed banks. Note that the probability for the emergence of an uninformed bank is $1 - \lambda$. The third and the fourth terms represent the signaling costs of banks CB^0 and CB^- respectively. Note that the probability for CB^0 is $1 - \lambda$ and $1/2\lambda$ for CB^-.

Whether losses are increasing or decreasing in λ under monetary targeting depends on the parameter values. For some parameter constellations, poor knowledge of the central bank about future shocks might be socially more beneficial than accurate forecasts.

In the appendix we show that, as with inflation targeting, pooling equilibria can be ruled out by the intuitive criterion.[9]

Proposition 4.9

Assume $b \geq 1$. No pooling equilibrium exists if we apply the intuitive criterion.

[9]It is unlikely that there are other equilibria, such as semi-separating equilibria, where two types pool while the third type of central bank chooses a different equilibrium strategy, which would satisfy the intuitive criterion.

4.6 Monetary Targeting versus Inflation Targeting

Let us compare monetary targeting and inflation targeting for $b > 1$. For both monetary policy rules CB^+ incurs no signaling costs because CB^+ would choose the same targets if the public knew the central bank's type. Under monetary targeting the signaling costs of CB^0 are exactly the same as under inflation targeting whereas the signaling costs for CB^- are higher. This is the case under monetary targeting because CB^0 could profit from imitating CB^- by creating unexpected inflation and thus employment gains. This possibility does not exist under inflation targeting since CB^0 does not want to create inflation exceeding the announced target.

Due to the increased signaling costs for CB^- overall expected losses and expected inflation rates are higher under monetary targeting.

We can thus derive:

Proposition 4.10
The social losses under inflation targeting are either lower than or equal to those incurred under monetary targeting.

1. *If $b \leq 1$, monetary targeting and inflation targeting are socially equivalent.*
2. *If $b > 1$, inflation targeting is socially preferable to monetary targeting. The difference in social losses, i.e. social losses under monetary targeting minus social losses under inflation targeting, amounts to:*

$$\Delta L = \frac{1}{2}\lambda\delta^2\left(b - 2\sqrt{2b - 2\sqrt{b} + 1} + 1\right) > 0 \tag{4.24}$$

Although the possibility of creating surprise inflation exists both for $b \leq 1$ and for $b \geq 1$, condition $b \leq 1$ guarantees that the benefits of an increase in employment due to surprise inflation are smaller than the losses created by a higher inflation rate. Therefore, under both monetary policy rules there is no necessity for signaling and the socially optimal results occur for $b \leq 1$.

Interestingly, under monetary targeting the public can exactly derive the central bank's type from the announced target; this is impossible under inflation targeting. Thus, the public is informed better under monetary targeting, albeit at the expense of inefficiently high costs.

Why is monetary targeting inferior to inflation targeting? Under monetary targeting an incompetent bank has the potential to create surprise inflation; this is not possible under inflation targeting. Let us consider monetary targeting and suppose that the

central bank is incompetent. If the public expects a negative shock, then the public's inflation expectations are below the incompetent central bank's inflation expectations. This means the incompetent central bank expects beneficial employment gains. A central bank with a negative shock will, however, try to prevent imitation due to larger unemployment gains if the public's expectations are above the actual inflation rate. It will therefore choose a high inflation rate to deter imitation. Now let us consider inflation targeting and suppose that the central bank is incompetent and announces an inflation target π_t. If the public expects a positive shock, inflation expectations will be $\pi_t + \delta$. If the public expects an incompetent bank, the public's expectations will equal π_t. If the public expects a negative shock, it will expect an inflation rate of π_t since a choice of $\pi_t - \delta$ though possible is never beneficial for $b \geq 1$. All three cases imply that the public's inflation expectations are larger than or equal to the inflation rate expected by the central bank. There is no possibility for an incompetent central bank to create surprise inflation and employment gains. Therefore, a central bank with a negative shock has no reason to deter imitation at the expense of large inflation. This is why inflation targeting is superior to monetary targeting.

We will now discuss the factors determining the size of b which we have defined in equation (4.11). This is important because inflation targeting is superior to monetary targeting for $b > 1$ whereas both inflation targeting and monetary targeting yield the same social losses for $b \leq 1$. First, the parameter b is decreasing in a. Thus, for central banks that are hard on inflation, i.e. for small a, both scenarios lead to the same outcomes. But for central banks that put very high emphasis on employment targets, our model indicates that inflation targeting will be the better option. Second, b depends on the value of the quotient Δ/δ. If this quotient is above a critical level, then inflation targeting yields better outcomes; if not, the results to be expected will not differ from monetary targeting.

4.7 Discussion of Assumptions

One of our assumptions is that the government imposes infinite losses on the central bank if it can verify that the central bank has deliberately failed to achieve the target. If we were to consider a dynamic version of our model with infinitely many subsequent stages of the game we have described, then these infinite losses could be interpreted as a loss of reputation. Due to time inconsistency, it may be uncertain whether the government will actually impose the penalty if a deviation is detected. In New Zealand for instance the Governor of the Reserve Bank can be fired if the inflation target is missed. In 1996, inflation exceeded the upper ceiling of the target range, but the

Governor stayed in office (cf. e.g. Bernanke, Laubach, Mishkin, and Posen (1999)). For our results to hold it is not necessary for the central bank manager to be actually fired, it is sufficient for the central bank manager to estimate the likelihood of dismissal high enough to deter any detectable deviations.

Note how our results change if we assume transparency, i.e. if the public is able to independently observe the signal about shocks to money demand as well. In such a case deliberate deviations from target values are not feasible for central banks. We obtain the benchmark results under monetary targeting and inflation targeting, no matter how large b is. But often the information is not verifiable, so transparency, though desirable, may be impossible (see e.g. Goodfriend (1986)). If only a part of the whole shock is known to the public, our model can still be applied. If shocks to money demand can be divided into a commonly known component and a component that is only known to the central bank, the shock ϵ in our model represents the latter part of the whole shock.

Our results strengthen if we change the sequence of events. If the central bank chooses m before the public forms its inflation expectations π^e, nothing changes under monetary targeting since due to our punishment scheme m_t and m are always equal.[10] Thus m does not reveal any new information to the public. But under inflation targeting the situation is different. Since the public observes both m and π_t, this means that CB^- can signal its type without cost. This further improves the performance of inflation targeting. The same arguments imply that compared to losses under inflation targeting and monetary targeting the central bank's expected losses will be lower if it announces two targets simultaneously. If the central bank announces both a monetary target and an inflation target, then the central bank that observes a negative shock can signal its type without cost. The incompetent bank, however, can still be imitated by CB^+ and will signal its type by choosing the same targets as under inflation and monetary targeting.

If we neglect the assumption that the loss function of the central bank is representative of social losses, the conclusion that inflation targeting will perform either as well as or even better than monetary targeting still remains valid. Even if social losses were represented by a loss function with a different weight on the employment goal $a' \neq a$, society should still prefer inflation targeting for $b > 1$. This follows from the fact that surprise inflation can never be achieved in equilibrium. But of course a central bank

[10] There is usually a long time lag between the monetary policy measure and its maximum effect. So there is a chance that the central bank may have already chosen a monetary policy but that at the time when e.g. wages are determined, the monetary policy has not yet become effective (for a discussion of the transmission channels of monetary policy and the respective time lags see e.g. Svensson (1999)).

with a very low weight on the employment target, a, is most desirable in our model, since $a = 0$ will always guarantee the benchmark outcomes.[11]

Let us now discuss the special form of loss function we are considering here. One might argue that no central bank in industrial countries has recently tried to stimulate economy by creating surprise inflation. Hence, the employment goal in the loss function might seem artificial. But this observation does not contradict our model since the model predicts that surprise inflation does not occur in equilibrium. Another form of loss function often encountered in the literature (e.g. in Laubach (1999)), is linear in the employment goal and not quadratic as is assumed in our model. One can show that the results essentially stay the same for this modified loss function.

We have derived our results assuming a very simple distribution of shocks. In the appendix we illustrate for completeness that our results would still hold if we considered a richer set-up in which shocks are equally distributed on a symmetric interval around zero.

One important assumption is that there is a positive chance that central banks will have superior information. Apart from the reasoning in the literature mentioned in section 3.2, there are complementary arguments that central banks may have superior information. Wieland (1999) notes that under model uncertainty central banks may be inclined to change their instruments slightly in order to obtain information about the way the transmission channel works. Since only the central bank knows whether certain effects are due to exogenous shocks or due to its own experimenting, this may be a source of superior information. Goodfriend (1986) suggests that the widespread use of "fed watchers" is an indication that the Federal Reserve has private information about monetary relationships. But obviously, this could also be information about preferences or the intended path of future monetary policy. Recent claims that the ECB should publish internal forecasts (see Buiter (1999), among others) may also indicate that central banks have private information that is not available to outsiders. Peek, Rosengreen, and Tootell (1998) identify a possible source of superior information. They convincingly argue that part of the Fed's informational advantage stems from confidential data gained by banking supervision. Moreover, both the US Federal Reserve System and the ECB through the eleven National Central Banks have large research departments and a strong regional presence and may be privy to information on aggregate or regional monetary shocks that are not readily available to outsiders.

[11] Similarly, if the employment target equals the natural level of employment, i.e. $\Delta = 0$, we obtain the benchmark outcomes.

4.8 Conclusions

Let us briefly review why our model suggests that inflation targeting might perform better than monetary targeting. Under monetary targeting there are no deviations of m from m_t, i.e. the target variable can be controlled perfectly. Under inflation targeting, deviations of π_t from π will occur. But this reduced controllability of the target variable does not lead to increased social losses. This is due to the fact that under monetary targeting although the public knows the exact future monetary growth rate given the announced target, it is not a priori able to derive the inflation rate because it has no access to the information of the central bank. Therefore, under monetary targeting, the central bank incurs increased signaling costs, thus leading to higher social losses. According to our model, the costs of making the consequences of inflation targets visible for the public are lower than for monetary targets. This supports the view that inflation targets provide more visibility for the public than monetary targets (see e.g. Cabos, Funke, and Siegfried (1998)).

An interesting implication of our model is that transparency, i.e. the publication of central banks' private information concerning macroeconomic shocks, is beneficial if the private information can be verified by the public. In brief, this model's recommendation for central banks is to publish all verifiable information concerning macroeconomic shocks. For non-verifiable information transparency, though desirable, is not feasible because truthful revelation is not in the central bank's interest.[12]

Let us now discuss what would happen if the central bank could choose freely whether to adopt inflation or monetary targeting as its monetary policy framework. This is an important issue in the current start-up phase of the European Central Bank (ECB). Our results indicate the following choices. If the central bank were able to choose its target variable ex ante, i.e. before it realizes the shock, it would prefer inflation targeting for $b > 1$ because this implies lower expected losses. For any of the three contingencies CB^+, CB^0 and CB^-, losses under inflation targeting are either as large as under monetary targeting or smaller. But for $b \leq 1$ the central bank would be indifferent since expected losses and inflation rates are the same for both monetary policy rules. Inflation targeting is thus especially attractive for countries where credibility is a major issue, i.e. where the value of b is relatively high, which implies that the temptation for surprise inflation is large.

This implies an interesting corollary. Our model might provide an argument why many countries suffering from rather large inflation rates in the past have adopted inflation

[12] Cf. section 4.7 for a discussion.

targeting. According to our model, inflation targeting enables central banks to commit themselves to low inflation rates more easily than with monetary targeting.[13] The countries that have adopted inflation targeting may have had considerable deficiencies with respect to credibility, which is reflected by a high value of b in our model. They may have used inflation targeting as a device to surmount these problems.

On the other hand, a similar argument might explain why the central banks in Germany and Switzerland did not switch policies from monetary to inflation targeting. Both central banks can be thought of as hard on inflation. This implies small weights a on employment targets and therefore comparably small values for b. Hence, there have been smaller incentives to implement inflation targeting compared to other central banks.[14]

But if we assume that the ECB starts with a higher value of a than the Bundesbank and the Swiss National Bank, or at least the public assumes that a is larger, then inflation targeting should be the policy of choice (see also Illing (1998)).

[13] In a dynamic context with many periods, it might be possible for central banks to gain a reputation for being tough on inflation and thus solve the credibility problem inherent in the framework of Barro and Gordon (1983). But building reputation by keeping inflation low may take time and is often costly at the outset.

[14] Clearly, there are other potential explanations why different countries have adopted different targeting approaches for central banks. For instance, the decision for monetary targeting could be interpreted as an attempt to signal a small value of a since according to our model only central banks with a small value of a would choose monetary targeting.

Chapter 5

Transparency of Central Banks: A Survey

No-one would dare say that they were against transparency (...): It would be like saying you were against motherhood or apple pie.

Joseph Stiglitz[1]

5.1 Introduction

As the above quote highlights most people engaged in monetary economics claim to be in favor of central-bank transparency. So why is there such a ferocious controversy in the recent academic literature and in the newspapers about the transparency of monetary policy?

In fact, almost no one involved in the political discussion about the transparency of the European Central Bank (ECB) actually denies that transparency is socially beneficial. Although the ECB has been accused of being opaque,[2] it claims to be open and transparent.[3]

One reason for the controversial debate about transparency, despite the seemingly wide-spread consensus that transparency is desirable, is that people have different

[1] Quoted in Financial Times 5 October 1998.

[2] Cf. e.g. Buiter (1999), who accuses Issing to be "the enforcer for the ECB Opaqueness Squad". A commentary in The Financial Times of 15 October 1998 said: "The ECB intends to make decisions in secret, using forecasts it will not reveal, to achieve objectives it does not need to justify."

[3] Cf. e.g. Duisenberg (1999). Issing (1999) writes that "transparency - appropriately defined - is absolutely crucial for the effectiveness of monetary policy".

views as to what transparency of monetary policy is.[4] Central bankers often stress that the publication of data requires careful comments and explanations by the central bank for the public to be able to make correct use of it.[5] Winkler (2000) criticizes that transparency is understood too narrowly in the academic literature where it is seen as the mere release of information. He emphasizes the importance of "common understanding". People need to share a "common language". In his opinion it is problematic that communication issues arising from inefficiencies of information processing, inefficient information transmission or the bounded validity of the common-knowledge assumption are neglected in formal economic models.

Although the concerns of Winkler (2000) are certainly of some significance, I will nevertheless abstract from these difficulties and will identify transparency as the alleviation of information asymmetries by the publication of private information of the central bank which is relevant for the policy-making process.[6] The antipodes of transparency are "opacity" and "secrecy".

Political considerations are often thought to strongly support transparency. As central banks have become increasingly independent, mainly to protect them from politicians aiming at very short-term benefits of monetary policy, it is viewed to be of increasing importance for democratic legitimacy that central banks are made transparent.[7] Central banks must give more detailed accounts on their views on monetary policy, thus enabling the public to evaluate their performance.[8] Whether transparency is desirable from an economic perspective is not so clear-cut. In this chapter we will mainly focus on economic reasons in favor of or against central-bank transparency.

We distinguish between three types of transparency,[9] namely:

- goal transparency
- knowledge transparency
- operational transparency

Goal transparency means transparency about the central bank's objectives. We can distinguish between the transparency of short-term goals such as short-term interest-rate objectives or long-term goals such as the long-term inflation target or the long-term output objective or the relative significance the central bank attributes to these targets.

[4] Cf. Winkler (2000).
[5] Cf. Remsperger and Worms (1999).
[6] Cf. Geraats (2001a) for a similar definition.
[7] Cf. Briault, Haldane, and King (1996).
[8] Cf. e.g. Buiter (1999) or Geraats (2001a).
[9] Cf. Gersbach and Hahn (2001c), a more detailed distinction can be found in Geraats (2001b).

We use the term knowledge transparency to describe the publication of economic data or economic models used inside the central bank. These pieces of information include forecasts about future inflation, information from banking supervision, data on the real economy, and the whole model which is used for predicting future inflation.

Operational transparency concerns the publication of the procedures used to determine monetary policy. This type of transparency is concerned with the publication of the voting records of the decision-making bodies and the publication of the minutes of the meetings.

5.2 Literature Overview

5.2.1 Goal Transparency

5.2.1.1 Long-Term Objectives

There is a reasonably robust conviction about the desirability of transparency about long-term objectives,[10] which is especially pronounced in the inflation-targeting literature. As we have already noted, from a political viewpoint, a clear specification of what goals central banks should aim at seems essential for democratic accountability. Transparency about objectives is an important prerequisite for the evaluation of the performance of central banks.

Despite this conviction, only a few articles addressing this topic in a formal model have been published. One of these, Geraats (2000), examines a standard one-period model in the spirit of Kydland and Prescott (1977) and Barro and Gordon (1983). Social losses are assumed to be linear in output. The public forms its inflation expectations after the central bank has chosen its instrument namely money growth. The public is unsure both about the central bank's inflation target and about a velocity shock which is perfectly known to the central bank. Money growth affects the public's expectations about the velocity shock and, under opacity, also affects the public's estimate of the central bank's inflation target. If central-bank preferences are not perfectly known to the public, then money growth affects the public's expectations about the inflation target. This makes large money growth rates costly, because large money growth rates raise inflation expectations in the next period, which implies output losses. Overall, opacity, by making large money growth rates undesirable and thus large inflation rates less likely, is socially beneficial.

[10] See e.g. Nolan and Schaling (1996).

The timing of events in Geraats (2000) is rather unusual, in most models central banks choose monetary policy after the public has formed its inflation expectations. This case is examined in chapter 9. There a more standard framework with the modification that there may be uncertainty about the attention central banks pay to the output target is examined to evaluate the relative performance of goal transparency and the opacity of objectives. Our findings are ambiguous. Goal transparency may lead to larger losses in terms of inflation, i.e. may increase the costs stemming from deviations of inflation from its socially optimal value. Hence society prefers opacity if it estimates inflation as sufficiently important. On the other hand, goal transparency reduces losses in terms of output. Therefore society would prefer transparency if it values the output target sufficiently. Nevertheless, the robustness of this model needs further examination, as is detailed in section 9.6.

Although future research on this topic seems necessary, one might advise goal transparency due to the positive effects discussed in chapter 9. Goal transparency may, according to our model, lower losses in terms of output, albeit at the cost of larger deviations of inflation from its socially optimal value. In addition, goal transparency may be accompanied by a change in central-bank objectives, guaranteeing that the central bank pursues socially optimal goals.

5.2.1.2 Short-Term Objectives

In a classic paper Goodfriend (1986) surveys the literature on transparency available at that time and reviews the arguments given by the Federal Open Market Committee (FOMC)[11] in support of secrecy. In a court trial, the FOMC, which was demanded to publicize the so-called Directive immediately, had to justify the delay of 90 days for the publication. The Directive contains instructions to the Manager of the System Open Market Account on the conduct of open market operations for the interim-period between FOMC meetings including short-term objectives for Federal Funds Rate (FFR)[12] tolerance ranges and money-stock growth. Goodfriend (1986) dismisses several arguments of the FOMC as implausible and requires further research about the validity of some arguments. With hindsight, it is interesting to note that in 1994, the FOMC decided voluntarily to publish the FFR target directly after the meetings, which represents a complete reversal of opinion.

One controversial topic of the debate on the publication of the Directive is whether transparency would lead to more variability in interest rates. To answer this question

[11]The FOMC is the decision-making body of the Federal Reserve System.
[12]The FFR is the over-night interest rate for reserves on the US inter-bank market.

Dotsey (1987) presents a model where the Fed is assumed to follow a feedback rule that links the supply of non-borrowed reserves with the deviation of money demand from a monetary target. The monetary target is private information of the Fed and affected by policy shocks. The Fed's monetary target is published under transparency, but remains secret under opacity.

Dotsey (1987) shows that the conditional variance, i.e. the forecasting error of banks for the future FFR given their knowledge of all past variables and the present FFR, decreases if the short-term monetary target is publicized. This is rather plausible as better informed banks should produce better forecasts. For banks the disclosure of the Fed's monetary target is beneficial for two reasons. First, it reduces the costs of information collection. Second, it improves the banks' information set, leading to better decisions.

The unconditional, i.e. ex ante, variance of the FFR, however, is generally higher under transparency. The unconditional variance is affected through two channels. First, under transparency, the FFR responds more strongly to changes in the monetary target, the public being better informed about these changes. The second channel involves that borrowing responds less to policy shocks when banks are better informed. This reduces the variability of borrowing, which reduces the FFR variance. Overall, the unconditional variance of the FFR will most likely be increased by the publication of information about policy shocks for reasonable parameter values.

In my opinion it has not been satisfactorily clarified what the benefits of a low interest rate variance are if simultaneously the forecasting error of financial intermediaries, i.e. the conditional variance, is comparably large. Thus, it is hard to draw a normative conclusion from Dotsey (1987). It would also be interesting to know how results would be affected by different operating procedures. Perhaps the Fed could change to a better procedure if it had to release private information since the optimal procedure may depend on the level of transparency.

Rudin (1988) examines a model that is very similar to Dotsey (1987), but considers different degrees of transparency associated with different costs of Fed watching. The lower the fixed costs of Fed watching are, the larger is the fraction of market participants that invest in Fed watching and becomes informed.

For the polar cases where all banks are informed or all banks are uninformed, the same results as in Dotsey (1987) hold. For marginal increases of the fraction of informed banks, i.e. marginal decreases of the costs of Fed watching, the already informed banks are worse off since they do not gain new information and are harmed by the larger unconditional variance of interest rates. The larger variability of interest rates also

affects uninformed banks, but they gain from the more precise information that can be derived from the FFR. Whether the overall effect for uninformed banks is positive or negative is unclear, hence for marginal increases of transparency all market participants including the central bank may be worse off.

In my opinion, it is not very realistic that banks can only decide to either invest a fixed amount in Fed watching or not invest at all. I consider it would be more reasonable that in equilibrium all banks should be approximately equally well informed, which would imply that the main contribution of Rudin (1988) is theoretically interesting but does not grant new insights for the question of the desirability of transparency when compared to Dotsey (1987). Another paper in the spirit of Dotsey (1987) has been written by Cosimano and van Huyck (1993). It reaches very similar conclusions.

Tabellini (1987) presents a model that is interesting since, contradicting Dotsey (1987), Rudin (1988), and Cosimano and van Huyck (1993), he concludes that the variability of interest rates is lower under transparency. The model is similar to Dotsey (1987) and Rudin (1988), but the monetary objective is constant over the period of time between FOMC meetings. Then, for the interim periods, monetary-policy actions under secrecy give rise to parameter learning, i.e. Bayesian updating. If the present FFR is positively affected by expectations of future FFR, which results from increasing marginal costs of discount-window borrowing,[13] then the variability of interest rates is higher under opacity.

The intuition for this result is as follows. Assume a positive shock to the demand for reserves raises the FFR, then banks will assume that the central bank possibly has a lower target for non-borrowed reserves than they previously thought and therefore expect future FFRs to increase as well. Then they reduce borrowed reserves today due to increasing marginal costs of discount-window borrowing, which puts further upward pressure on the current equilibrium value of the FFR.

Overall one might conclude from the theoretical literature on the relation between transparency and the variability of interest rates we have discussed in this section that secrecy reduces interest-rate variability if the monetary target changes very often. Transparency raises interest-rate variability if the objective is constant over time and banks constantly update their beliefs about the monetary target. As we have already discussed, it is hard to draw a normative conclusion since the relative size of the costs and benefits of the potentially higher variability of interest rates and of the costs and benefits of the reduced forecasting error of financial-market participants are not clear.

[13]Banks can borrow limited amounts of reserves from the Fed at the discount window. The associated interest rate is the discount rate. There are implicit costs of discount-window borrowing for banks, often associated with 'moral suasion' by the Fed, implying that the FFR is usually larger than the interest rate charged on discount-window borrowing (cf. e.g. Woodford (2000)).

In recent years, with the popularity of central-bank transparency increasing rapidly, many central bankers and academics have suggested that transparency enhances the efficiency of monetary policy. Among them Blinder, Goodhart, Hildebrand, Lipton, and Wyplosz (2001) argue that monetary policy can only affect very short-term interest rates directly. But monetary policy can only exert a powerful influence through long-term interest rates, asset prices or exchange rates. The link between short-term interest rates and the latter variables involves expectations of future monetary policy decisions. The authors argue that transparency enables the central bank to influence the public's expectations, which in turn makes monetary policy more effective. However, this reasoning may be doubted on the grounds that the central bank can and, in fact, will always influence expectations. If it is not through transparency, then financial market will derive the likely future monetary-policy stance from today's and past actions, which implies that expectations are affected by signaling.

5.2.2 Knowledge Transparency

There is a vast amount of literature reaching very controversial conclusions about the desirability of knowledge transparency. In a seminal paper Cukierman and Meltzer (1986) consider an infinite-horizon variant of the standard Kydland and Prescott (1977) and Barro and Gordon (1983) model. Central banks seek to stabilize inflation around a target. Inflation surprises are valued since they increase output. The authors also introduce the assumption that the central bank's marginal value of inflation surprises cannot be observed directly by the public and is given by an AR(1) process with positive autocorrelation coefficient. The central bank controls money growth imperfectly and the size of the control error of money growth is associated with different degrees of transparency. Thus the absence of control errors corresponds to a maximum level of transparency. Since the public cannot observe the central bank's marginal value of surprise inflation directly, it tries to infer it from the monetary target. Under maximum transparency, this is perfectly feasible. It is, however, beneficial to the central bank if the public is unaware of the value of surprise inflation. Then the central bank can create surprise inflation, i.e. larger than expected inflation, when it esteems surprise inflation very much. When the marginal value of inflationary surprises is low for the central bank, then the central bank chooses inflation to be lower than inflation expectations. On average, inflation expectations equal actual inflation, thus the assumption of rational expectations is not violated. The paper rationalizes why central banks might prefer a certain degree of ambiguity and opaqueness but does not reach a normative conclusion.

Lewis (1991) examines a model that is rather similar to the one used by Cukierman and Meltzer (1986). Lewis (1991) identifies two reasons why society constrains central-bank secrecy. First, if due to shifting powers of interest groups, the central bank's preference for surprise inflation varies over time, central banks prefer secrecy to transparency. The reasoning is identical to the one in Cukierman and Meltzer (1986). If society tried to minimize central-bank secrecy, central bankers would choose other forms of secrecy which would imply higher costs.[14] Since central bankers will be able to achieve opacity anyhow, society tries to make opaqueness available at low costs. Second, due to the varying importance of the output-inflation trade-off, society may sometimes want to be surprised by inflationary policy. This, however, only works if society is unaware of its own loss function, which is a rather problematic assumption.

The paper by Cukierman and Meltzer (1986) has some disadvantages.[15] One disadvantage is that issues of transparency and the control of money growth are jointly examined. This problem is solved by Faust and Svensson (2000). Assuming the variance of the shocks to the relationship between money growth and inflation to be independent of the transparency regime, Faust and Svensson (2000) explicitly distinguish between monetary control and transparency. In their model, monetary shocks are always perfectly known to the central bank, but only partly known to the public. The more informed the public is about these shocks, the more transparent monetary policy is. As is standard in the literature, losses depend quadratically on output. Moreover, social losses are assumed to be static, whereas the central bank's employment target follows an AR(1) process, which is a similar behavior as in Cukierman and Meltzer (1986).

The findings are as follows: Under transparency, the public's expectations about the employment target are more sensitive to the central bank's actions which has a moderating effect on the central bank's choice of money growth. E.g. even if the central bank would profit very much from surprise inflation, it would nevertheless refrain from inflationary policy. Inflationary policy would increase the public's expectation of the present employment target and thereby would also increase the public's expectation of the target in the future since the values of the employment target are correlated for subsequent periods. This in turn would increase inflation expectations for future periods drastically. Thus transparency raises the costs of inflationary policy, and thereby is generally socially beneficial. But transparency is not always in the central bank's interest since the preferences of the central bank and of the public generally do not coincide.[16]

[14] Lewis (1991) reports that when there were attempts to force the Fed to publish the minutes of FOMC meetings, the Fed tried to abolish the minutes altogether.

[15] Cf. Goodfriend (1986).

[16] If the central bank's preferences were public, the central bank would no longer take into account

Jensen (2001) presents a model which uses the same information asymmetries and formal description of transparency as Faust and Svensson (2000). The public does not know the central bank's output target, which varies over time, and it does not know the control error of monetary policy. The (partial) release of this control error is associated with different degrees of transparency. In contrast to Faust and Svensson (2000), the author applies a Neo-Keynesian model, which comprises two periods. Inflation is determined by expectations about future inflation and the output gap, which can be chosen at the discretion of the central bank.

Similar to Faust and Svensson (2000) transparency has a positive effect since it disciplines monetary policy if the central bank does not enjoy a large amount of initial low-inflation credibility, i.e. the public's estimate of the central bank's output-gap target is very large. On the other hand, if initial credibility is high, transparency may be bad. When transparency is increased, private-sector inflation expectations react more strongly to monetary-policy changes since the public can infer the preferences of the central bank more easily. Since present inflation depends on expectations of future inflation, a certain change in the monetary-policy instrument affects present inflation more strongly under transparency compared to opacity. Thus transparency increases the costs of demand stabilization in terms of inflation. Hence there are ambiguous effects of transparency which the author associates with the trade-off of credibility gains by more transparency vs. the losses of flexibility by more transparency.

I think it is a disadvantage that the model comprises only two periods. In a forward-looking model like the one the author considers, inflation depends on expected future inflation. Thus inflation expectations in the last period concern a period that is not captured by the model and must be determined by a border condition, which is not justified. I am not sure how the results would be affected by the introduction of an infinite horizon.

In a note Jensen (2000) presents a variant of the model in Jensen (2001), which I have just described. Having examined monetary shocks in Jensen (2001), he now considers the case where the central bank has private information on cost-push shocks, i.e. real shocks, prior to the setting of monetary policy. The publication of this private information leads to excess sensitivity of expectations making shock stabilization less efficient. It may, however, be questionable whether central banks have superior information on cost-push shocks. The author notes that firms may be well-informed about their own

the effects of its policy on the public's expectations of its employment goal. Reputation would be independent of the central bank's actions. This would yield socially a very bad result. According to the authors, the result, however, would no longer hold in a richer version of the model where the public could better enforce its preferred monetary policy under transparency.

costs but less informed about aggregate cost-push shocks. It nevertheless seems more likely that central banks have superior information about monetary disturbances than about real shocks.

The paper by Geraats (2000) has already been studied in subsection 5.2.2 since it also deals with goal transparency. The public is unsure about the inflation target and about the size of monetary shocks but observes money growth before forming inflation expectations. If the central bank releases its information about the velocity shock completely, then the public knows exactly how large inflation will be. Since knowledge transparency enables the central bank to commit itself to zero inflation, it is socially optimal.[17]

Geraats (2001b) examines a standard two-period model with losses linear in output.[18] There are demand shocks and supply shocks, which the public cannot observe but the central bank can observe perfectly. Under transparency, the central bank reveals the size of the shocks to the public. The central bank's inflation target is static and private information of the central bank. Information about first-period inflation and output is not available to the public when forming expectations about second-period inflation. Under opacity, the monetary-policy instrument is used both for conferring information about the central bank's inflation target and about the economic shocks. The public's inflation expectations are therefore less responsive to interest-rate changes. This makes reputation-building less attractive and the inflation bias is higher compared to transparency. Opacity is beneficial to weak central banks since it obfuscates their preferences, making inflationary surprises possible, but it is detrimental for hard central banks. Overall social losses, understood to be determined by inflation and output, are always lower under transparency.

Geraats (2001b) also considers another version of the model in which losses depend quadratically on output and in which the central bank does not want to push output above the level that is sustainable in the long run. Under opacity interest rates, i.e. the central bank's instruments, are used for both signaling the inflation target and for shock stabilization. Since, under opacity, interest-rate changes affect the public's perception of the interest target, the central bank uses its instrument more carefully and shocks are not sufficiently stabilized. Thus opacity is detrimental to welfare, hindering the central bank from stabilizing shocks optimally. But Geraats (2001b) also argues that greater variations in interest rates might be a disadvantage of transparency, which would be especially severe if the financial sector were structurally weak. This argument is not completely convincing since the costs of interest-rate variations could be considered by

[17] The result of this model is also one of our conclusions in chapter 4.

[18] A very similar model is also examined in Geraats (2001a) where it is labeled treasury model.

the central bank and incorporated into the central-bank loss function. Then socially inefficiently large interest rate changes would not occur.

Gersbach (1998) examines the benefits and costs of knowledge transparency in a standard one-period model. The central bank may possess knowledge on monetary shocks affecting the relation between money growth and inflation or real shocks to the Phillips' curve respectively. The central bank always stabilizes monetary shocks perfectly. Hence these shocks do not affect inflation and the publication of forecasts of monetary shocks has no impact on inflation expectations and thus does not change social losses. The case is different for real shocks. A negative real shock moves output away from its target which makes surprise inflation, i.e. inflation rates which are larger than inflation expectations, very attractive due to increasing marginal costs of deviations of output from its target. A positive shock moves output ceteris paribus closer to its target, which makes surprise inflation comparably unattractive. If the central bank's information on real shocks is not published, the central bank can create surprise inflation if the real shock is negative and create surprise deflation if the real shock is positive. On average, inflation expectations are correct, thus the assumption of rational expectations is not violated. Since at times when shocks move output away from its target the central bank cannot counteract by inflationary surprises, transparency may be detrimental.

There is one drawback of the approach mentioned in the paper, which applies to many other models as well. It may be possible that real shocks influence the output objective as well. E.g. in Real-Business-Cycle models, varying output represents the Pareto-efficient allocation. Then output stabilization would not be beneficial. Another point is that uncertainty about inflation may be bad since it lowers investment. Then less public uncertainty about inflation would be an advantage of transparency.

In a recent paper Cukierman (2000a) presents two models in which the desirability of the publication of central-bank forecasts is evaluated. The first model is almost identical to the model in Gersbach (1998) and the author obtains the result that transparency may be harmful.[19] The second model considered by Cukierman (2000a) is of the New-Keynesian type. The central bank cares about three objectives, namely stabilizing inflation and output around their targets and minimizing interest-rate variability. Inflation depends on lagged output and a velocity shock. Output depends on the expected future real rate of interest and on a non-monetary shock to aggregate demand. Within this model it is shown that the publication of central-bank forecasts is detrimental to welfare. Transparency leads to larger changes in interest rates, which are assumed to cause costs, e.g. because they endanger the stability of financial in-

[19]Since monetary shocks are assumed to have a direct effect on output, Cukierman (2000a), in contrast to Gersbach (1998), also obtains that transparency about monetary shocks is bad.

stitutions. Again, it would be interesting to assess the costs of large interest changes which are foreseen by market participants.

In the model presented by Tarkka and Mayes (1999) the central bank has only one objective which is an inflation target that is not known to the public. The economy is characterized by a standard Lucas supply curve and a quantity equation, which describes demand. The central bank has private information on shocks to the velocity of money in the quantity equation. The central bank is not able to observe the public's inflation expectations, which implies that its expectation of the public's inflation expectation and the public's inflation expectation are usually different. The authors are, however, not clear about why the central bank cannot compute the public's inflation forecast. This should always possible if all information available to the public is also available to the central bank. Most likely, the authors have in mind that the public's estimate of the central bank's inflation target is unknown to the central bank.

Their findings are the following: The structure of the model implies that the central bank reveals both its inflation target and its estimate of private-sector inflation expectations by publishing its output forecast and by setting its instrument.[20] The improved information set reduces the public's error in predicting inflation. Therefore, since output in the Lucas' supply function depends on the private sector's prediction error for inflation, output volatility is reduced under transparency. Since the central bank has no incentive to misrepresent its information, the disclosed information is always credible.

The model hinges on the assumption that the central bank cannot observe private-sector inflation forecasts. This may, however, be doubtful. Usually inflation forecasts are assumed to have an effect on monetary-policy outcomes since they are incorporated into nominal contracts such as wage contracts. It is hard to think of a reason why central banks should not be able to observe wages or similar variables. Many inflation forecasts formed outside the central bank stem from research institutes which make their predictions publicly available. Hence, the validity of the results of Tarkka and Mayes (1999) seems restricted.

Geraats (2001a) attempts a theoretical analysis of the relation between the institutional framework and the desirable level of transparency of monetary policy. She presents a model with the possibility for the government to override the decisions of the central

[20] Alternatively the central bank can publish its inflation target. But, the authors being employed at the Bank of Finland, which is part of the European System of Central Banks, they probably want to show that the ECB's practice to publish output forecasts is beneficial.

bank at some fixed cost.[21] [22] If the central bank does not publish private information on velocity shocks, the government, which would like to boost output above the natural level, does not know when to intervene. This increases the effective independence of the central bank, which means that the central bank can choose its instrument from a larger range without government interference. Hence secrecy may lower the inflation bias and thus in turn social losses.

Apart from the reasoning given by formal models, there are also some verbal arguments in favor of or against the publication of inflation forecasts which I will briefly review. Buiter (1999) thinks that the publication of inflation forecasts would allow market participants a more informed view about the performance of the ECB council. The ECB is, at the present state, not ready to fulfill the request to regularly publish inflation forecasts. This decision is justified by the following arguments: As Issing (1999) notes, the Eurosystem should not be judged on the accuracy of its internal forecasts. The role of forecasts is quite different and less ambitious in the ECB compared to inflation-targeting central banks. A publication would be misleading since the public would attach a significance to the forecast which would not conform with the minor role it plays in the monetary-policy-making process.

Remsperger and Worms (1999) are of a view similar to Issing (1999), claiming that especially in the start-up phase of the Euro, discretional intervention is inevitable in the economic models of the ECB to incorporate expected structural changes. Assumptions being necessary regarding exogenous variables, the forecasts are inherently opaque and their relevance for monetary policy is constrained. The public could also misinterpret the inflation forecast since it may not understand the contingency on an assumption about future monetary-policy interventions.[23] In my opinion, it may, however, seem doubtful whether the public actually cannot grasp the contingency of forecasts, especially when the central bank carefully explains under which assumptions the forecasts are formed. In addition, the relevant public in this case comprises mainly financial-market participants, who are familiar with highly sophisticated financial-market instruments with a complex contingent structure of payments.

[21] The idea of central-bank decisions being overridden by the government at some costs can also be found in Eijffinger and Hoeberichts (2000). They obtains similar conclusions like Geraats (2001a). Their paper has the disadvantage that transparency is identified with the variance of the normal distribution from which the inflation target of the central bank is drawn.

[22] The model we discuss here is labeled the political-central-bank model by Geraats (2001a). Another model presented in the paper is very similar to Geraats (2001b) and is therefore not separately discussed.

[23] E.g. the Bank of England publishes the inflation forecast assuming constant short-term interest rates. If the inflation forecast is above target, economic agents might expect large inflation rates. This may not be correct since the central bank will react with increases in short-term interest rates and thus will reduce future inflation.

I now attempt an overall conclusion about the merits of knowledge transparency. Some models predict that knowledge transparency, by making it easier for the public to identify intended policy outcomes, can help central banks to commit to low inflation if the central banks are tempted to boost output above the long-run sustainable level.[24] This effect seems rather robust across different models and might be a reason why central banks without a very good performance of low-inflation history would be well-advised to adopt more knowledge transparency. Examples might include the Bank of England or the Reserve Bank of New Zealand; both had an unsatisfactory history of high inflation and adopted inflation targeting and a high degree of transparency in order to commit the central bank to low inflation.

Another strand of the literature concludes that transparency may be bad for the central bank or for society when it is beneficial that the central bank can influence output. The reason is the following. A Lucas-type transmission mechanism implies that only unexpected monetary policy can affect output. Hence transparency is detrimental since it makes monetary policy predictable and thus in turn inflationary surprises impossible.[25] Although this literature is certainly interesting, there are also some possible objections.

First, surprises may be beneficial to society if the central bank has superior information about real shocks,[26] which, however, may seem less likely than superior information about monetary shocks. Especially, one has to consider that in order for inflationary surprises to be beneficial, the central bank needs information approximately one year in advance, the period which roughly represents the lags with which monetary policy is usually thought to have an effect on output. Alternatively, surprises may be beneficial if the central bank knows that the public would like to be surprised but the public is unaware of it.[27] This does not seem very plausible.

Second, one might wonder whether output stabilization is indeed beneficial. In Real-Business Cycles models e.g., it would be clearly detrimental as the Pareto-efficient output varies over time. One might also argue that the significance central banks assign to output stabilization has been decreasing over the last decades. E.g. the ECB's primary goal is price stability whereas the ranking of objectives was not so clearly defined for the Bundesbank. The case is even stronger for other NCBs (national central banks) who are now part of the ESCB. Also the popularity of inflation targeting

[24] This effect occurs in Faust and Svensson (2000), Jensen (2001), Geraats (2000), Geraats (2001b).

[25] This effect occurs in Cukierman and Meltzer (1986) and Lewis (1991) where the society's or central bank's preferences for the employment goal change. In Gersbach (1998) and Cukierman (2000a), shocks may move output away from its target.

[26] Cf. Gersbach (1998) and Cukierman (2000a).

[27] See Lewis (1991). Cukierman and Meltzer (1986) do not reach a normative conclusion.

might indicate a vanishing importance central banks attach to output goals. There are also large uncertainties associated with estimates of the output gap, which may lead some central bankers to focus more strongly on inflation than on output.[28] These changes in central bank objectives may also reflect changes in the preferences of society.

Third, one might doubt whether the Lucas-curve mechanism is an appropriate description of the monetary transmission mechanism or the only way the central bank can affect output.

In Geraats (2001a), central banks confronted with potential government interference adopt secrecy in order to improve their effective independence. By enhancing the independence of central banks and thus reducing the inflation bias, secrecy could be socially beneficial if the intervention of a government that aims at very short-term employment gains seems likely. This scenario, however, is clearly of no great significance to the ECB and the Fed.

Another aspect is that knowledge transparency may foster the dialogue between outside academics and the central bank, thereby improving models and forecasts used inside the central bank. This might lead to more efficient monetary-policy making in the long run.

In Neo-Keynesian frameworks, transparency leads to inefficient output stabilization[29] or large interest-rate changes.[30] In a more conventional model Geraats (2001b) obtains that transparency leads to improved stabilization of shocks and thus more flexibility but at the same time causes larger interest rate variability. The costs of short-term interest rate variability should be examined more carefully in order to be able to evaluate the importance of these effects. Whether transparency hinders or improves the flexibility to respond optimally to shocks seems not satisfactorily clarified yet.

Overall, one might advocate knowledge transparency if building a reputation for low-inflation policy is an important issue. If the time-inconsistency problem plays no major role, then transparency about economic data may be less important from an economic viewpoint but nevertheless may be desirable for political reasons.[31]

With respect to the ECB, it may be recommendable to issue forecasts of inflation and other economic variables and publish details about the models used to generate these

[28] However, most central banks would claim that they also take output growth into account.

[29] Cf. Jensen (2000) and Jensen (2001).

[30] Cf. Cukierman (2000a).

[31] Nevertheless there are sometimes limits to transparency if information is confidential, e.g. information from private communications with other central banks, governments or international institutions such as the IMF (see Blinder, Goodhart, Hildebrand, Lipton, and Wyplosz (2001)). Also information from banking supervision that is available to some central banks must be kept secret.

forecasts. Recently the ECB moved in that direction as it started to publish macroeconomic projections on a biannual basis in December 2000. These macroeconomic projections include forecasts of real GDP growth and inflation over a two-year horizon. Nevertheless, the forecasts have been criticized for being too imprecise to be of any use and for being the staff's forecast and not the Governing Council's forecast.[32]

5.2.3 Operational Transparency

5.2.3.1 Collective vs. Individual Responsibility

The issue of collective vs. individual responsibility comprises the publication of minutes and voting records on a more abstract layer.[33] It concerns the question of whether it is better that individuals build reputation and credibility or whether the institution as a whole should strive for these goals.

Buiter (1999) states that it is important for the public to know whether there is disagreement on facts and data. An expert who finds himself in the minority can argue, publicly, his case for a different monetary policy and thus engage a wider community in this debate. This improves the quality of policy-making in the long run. Individual responsibility also implies that individual competence can be assessed. This is important for re-appointments and for further employment of former central bankers outside the central bank.[34]

Issing (1999) contradicts and claims that the excessive focus on personalities complicates the public's signal extraction problem. Developing a common culture is vital for a new institution and under the conditions of a multi-country monetary union.

5.2.3.2 Voting Records

The debate by Buiter (1999) and Issing (1999) on the transparency of the ECB has also stirred the question of whether the voting records of the Governing Council, which is the highest decision-making body of the ECB and sets the ECB's instruments, should be published.

It is the concern of Issing (1999) that national political authorities would be able to put more pressure on the members of the Governing Council if voting records were

[32] See Blinder, Goodhart, Hildebrand, Lipton, and Wyplosz (2001).

[33] Our discussion is of course irrelevant for central banks where only one individual is responsible for monetary policy, e.g. the Reserve Bank of New Zealand where the governor alone is responsible for setting interest rates.

[34] The models presented in chapters 6, 7, and 8 take this into account.

published.[35] Buiter (1999) strongly disagrees. He even thinks that national political authorities are able to put more pressure on members if voting records are not published, arguing that due to unavoidable leaks the national political authorities will know the voting behavior of central bankers no matter whether it is published officially or not. But this information will not be formally available to bodies charged with supervising the ESCB. However, I do not think that this argument by Buiter (1999) is very plausible, since it relies on the assumption that bodies charged with supervising the ECB, which have no legal possibility of sanctioning central bankers, need formally available and verifiable information to put pressure on the ECB, whereas it is sufficient for national political authorities to have informal information to put pressure on central bankers.

Cukierman (2000a) thinks that the publication of voting records does not necessarily induce members to vote more strongly in the interest of their countries. It could equally well be possible that central bankers do not wish to be detected pursuing a nationally oriented monetary policy. Whether the publication of voting records leads to more "European" oriented voting behavior or not depends on whether the position central bankers aspire after their office at the central bank is in a European institution or in a national institution.[36]

While it is less likely that the six members of the Executive Board, who are in addition part of the Governing Council, face serious national political pressure since they are not accountable to any national institution and their term in office is not renewable, it is well conceivable for the twelve governors of the NCBs, who are also members of the Governing Council, that the case is different. Although it is forbidden for national or European institutions to seek to influence them, their term in office must be at least five years and they cannot be relieved unless they are guilty of serious misconduct or do no longer fulfill the requirements necessary for their positions, governors of the NCBs may nevertheless face national pressure under transparency if economic conditions or preferences about monetary policy are very different across countries. In particular at the end of their office, national governors may try to satisfy national authorities in order to be re-elected or in order to get other prestigious positions.

Whilst he thinks that costs of voting transparency are likely, Issing (1999) also asserts that the potential benefits from publishing voting records are rather small. The

[35] Remsperger and Worms (1999) have a similar view, expressing their concerns that the publication of voting records would reduce the efficiency of monetary policy.

[36] Cukierman (2000a) nevertheless expresses his concerns that, when votes are published, decisions depend more on political and personal considerations and less on professional considerations. The models presented in chapter 6 and 7 allow similar conclusions.

publication of the voting records is not sufficient for substantive individual accountability without the publication of arguments, underlying assumptions et cetera. And the validity of dissenting views cannot be assessed even ex post. Empirical literature, however, seems to indicate that the release of voting records (and minutes) by the Bank of England has an informational value for financial markets and thus might involve benefits.[37]

Apart from the analysis presented in chapters 6, 7, and 8 I know of only one formal model examining the publication of voting records or minutes of the meetings. Sibert (1999) presents a model of overlapping generations of central bankers. In each period, the central-bank council comprises one old and one young central banker. Central bankers can either be hawks or doves; their type is private information. Hawks, in contrast to doves, do not want to surprise-inflate. The author shows the following: In their second term in office, doves always choose a large inflation rate, no matter whether votes are published or not. However, it may be profitable for doves in their first period in office to appear as hawks by voting for low inflation. This reduces inflation expectations for the next period, thus enabling doves to boost output in the next period. The incentives for doves to vote for low-inflation policy when they are young are larger under transparency since the public can more easily assess how the young central banker has voted. Under opacity, these incentives are lower since there is a chance that a young central banker's vote for a low interest rate is attributed to the old central banker. Hence transparency increases incentives for doves to vote for low inflation in their first period in office, which is beneficial, yielding a lower inflation bias.

The formal analysis has two flaws, which, however, probably could be remedied without changing the conclusions of the paper. The assumption that hawks always vote for low inflation is not motivated by their loss function but simply assumed as hawks vote for low inflation even if this makes them worse-off. Another problem stems from the assumption that the average of the two interest rates for which the central bankers have voted is adopted. Given this assumption and dissenting interests in the central-bank council, it is definitely not optimal for both central bankers to vote for the interest rate that they individually estimate to be optimal. In this model with incentives to vote strategically even the existence of an equilibrium cannot be guaranteed.

In chapters 6, 7, and 8 we will present three formal models to evaluate the impact of voting transparency on the voting behavior of the members of the decision-making bodies of central banks and to assess whether voting transparency or the opacity of voting records yield lower social losses.

[37] See Clare and Courtenay (2000) and Gerlach-Kristen (2001).

In chapters 6 and 7 we show that transparency may be harmful if central bankers differ in their efficiency to identify shocks in the economy. Their individual voting behavior being published, less efficient central bankers try to imitate highly efficient central bankers under transparency in order to appear efficient and thus be re-elected. This is socially inefficient and reduces the likelihood of beneficial monetary policy. Overall, despite the advantage of transparency of revealing inefficiencies a bit more successfully than opacity, transparency may yield higher social losses.

In chapter 8 we assume that central bankers differ in preferences. We show that voting strategically in order to be re-elected and be able to influence future monetary policy is not optimal for central bankers with preferences differing from those of the public. Transparency is beneficial, enabling the government to re-elect only individuals with favorable voting behavior. This increases the likelihood of the central bank choosing monetary policy that conforms with social preferences.

Our findings in chapters 6, 7, and 8 seem to be comparably robust (cf. e.g. section 6.10), but there is one effect we do not discuss there. There may be costs of dismissing and replacing central bankers, which might increase with the number of dismissed and replaced central bankers. There are probably not infinitely many appropriate new candidates available[38] or central bankers' experience from holding office may be valuable, thus it may be valuable to leave at least a few central bankers in office. This should make opacity perform less well compared to our models. Under opacity, if monetary policy is unsatisfactory, the whole council is replaced since the government has no means to distinguish the individual behavior of central bankers. But if the replacement of the whole council involved some costs, the government would replace only part of the council on a random basis. This would make the overall competence of the council under opacity increase very slowly over time. This argument may also be of some significance for real-life central-bank councils. Transparency enables the government to assess individual behavior, thus the replacement of fewer central bankers than under opacity may be necessary if monetary policy is not satisfactory.

There are some complementary arguments in favor of or against the publication of voting records. If the central bankers' competence is endogenous and central bankers can affect their probability of being informed by choosing more or less effort, then transparency is most likely to be beneficial since the individual competence of single members can be assessed more easily. This should increase incentives to invest in effort, thereby increasing the competence of central bankers. Under opacity, there

[38]Hence, the likelihood of a newly appointed central banker being efficient may decrease with the number of appointed central bankers, whereas we assume this likelihood to be constant in our analysis in chapters 6 and 7.

are incentives to free-ride on other central banker's effort. This should be especially significant if the council is very large as with the ECB, where the Governing Council comprises 18 members at the moment.

Although being not very competent, central bankers may be appointed for political reasons. Politicians may be tempted to nominate friends or members of their own political party. If the central bankers' individual competence could be assessed, appointments of less efficient candidates would occur more seldom since politicians would dislike being detected as appointing candidates due to personal relationships. Hence the transparency of voting records could have a beneficial impact.

Under transparency, the desire of central bankers to appear competent in every decision and in every topic, might deter socially beneficial specialization. E.g. a central banker who could specialize in lender-of-last-resort policy might be concerned to appear as less competent if his special knowledge were not needed at the moment. The deterioration of specialization could be detrimental to welfare.

Buiter (1999) states that voting transparency is important because it reveals to the public the amount of disagreement in the central-bank council. It is interesting to examine why this could be important for the public. First, if the amount of disagreement is correlated with the amount of uncertainty central bankers expect for economic conditions, then financial-market participants may learn something about the riskiness of economic conditions from the voting records. Second, if the majority for a certain proposal is rather small, the interest rate that a large minority has voted for may be comparably likely to be adopted in the next meeting of the council.[39] E.g. if a large minority is in favor of interest-rate cuts, but the majority wants to leave interest rates unchanged at the present state, then interest-rate cuts may be more likely in the near future than increases in interest rates. Thus, the publication of voting records may inform the public about likely future interest rate changes, thus making monetary policy more predictable. Examining these potential benefits of the publication voting records might be an interesting topic for future research.

Overall, balancing the positive and negative effects of voting transparency, one might cautiously advocate the publication of attributed voting records. Voting transparency is beneficial if central bankers may have preferences differing from those of the public, transparency may increase incentives to appoint highly efficient central bankers, and transparency may also induce central bankers to invest more effort into becoming more competent. Nevertheless there remains a significant concern that under voting transparency central bankers focus too much on appearing as competent individuals and less

[39] Also cf. Gerlach-Kristen (2001).

on the overall outcome. It is interesting to note that in the last years many influential central banks decided to publish voting records. E.g. the Federal Reserve, the Bank of Japan, and the Bank of England publish voting records after several weeks, providing full details of individuals' votes.[40] Thus the traditional reservations of central bankers about operational transparency seem to be shrinking.

At the time being, voting transparency cannot be advised for the ECB since the danger that governors of NCBs face political heat from their nations seems severe. However, it appears rather likely that at some point in time the composition of the Governing Council will be changed. As more countries become members of the EMU (European Monetary Union), the size of the council is constantly increasing since all governors of the NCBs are members of the Governing Council. Since its initial meeting it has already grown from 17 to 18 members as Greece joined the EMU at the beginning of 2001, despite 17 members being thought too much for an efficient policy making by some observers.[41] If, in the future, a restructuring takes place such that national governors are no longer part of the Governing Council, then the issue of publishing voting records should be reconsidered.

5.2.3.3 Minutes of the Meeting

Another aspect of the debate about operational transparency concerns the publication of the minutes of the meetings of the decision-making bodies. Buiter (1999) demands the ECB to make the minutes available on a non-attributed basis as attributed opinions would prevent open-minded discussions. In his view the minutes should be published because all information should automatically be in the public domain.

Issing[42] claims that to publish as much as possible does not necessarily improve the public's understanding. The public can never be sure that no information is withheld and no motives are hidden.[43] Issing (1999) argues that the ECB President's monthly press conferences immediately after the meetings come very close to providing "summary minutes". Duisenberg[44] states that the publication of the minutes of the meetings would give false and confusing signals to financial markets and would influence the expectations of the markets ahead of the meetings. Buiter (1999) dismisses this argument as implausible and claims that publishing the minutes replaces misinformed by informed speculation.

[40] Cf. Blinder, Goodhart, Hildebrand, Lipton, and Wyplosz (2001).
[41] Cf. Buiter (1999).
[42] Quoted in Buiter (1999).
[43] Cf. also Remsperger and Worms (1999).
[44] Quoted in Buiter (1999).

Overall, one might advocate the publication of a summary of the meetings. This may be similar to the introductory statement given at the press conference held by the President of the ECB immediately after the meetings, but should be more detailed and should also refer to dissenting opinions. An immediate non-edited publication of the minutes on an attributed basis might deter open-minded discussion in the central-bank council and might lead to costly substitution when central-bankers circumvent transparency requirements. If voting records are published (which, however, as detailed above may not seem recommendable for the ECB at the present state), then one should also publish statements of individual council members in which they could justify their decisions. This may enhance the public's understanding of dissenting views, may make it easier to evaluate their validity ex post and may foster the debate between central bankers and economists outside the central bank.

5.3 Open Issues

Despite the large amount of literature on transparency in monetary policy, there are still several open issues left for future research. Sometimes the merits of transparency depend on the model applied (cf. the section on knowledge transparency). Thus it is important to study the effects of transparency in a broader set of models in order to obtain robust conclusions. There are only very few papers considering the benefits and costs of goal transparency in formal models. Hence, more formal analyses on this topic seem to be desirable.

It would also be interesting to study the impact of transparency on financial markets and on the stability of the banking system in more detail. It seems conceivable that information about a possible crisis might trigger a crisis which otherwise could be avoided.

To my knowledge, one issue that has not been challenged by a formal model so far is whether transparency about exchange-rate interventions can be shown to be detrimental, which is argued by many academics and central bankers.[45] Duisenberg has been criticized harshly by financial-market analysts for saying too much when he admitted that he thought it unlikely that central banks including the ECB would engage in strengthening the Euro exchange rate if it should continue to fall.[46] A theoretical foundation of this critique might be illuminating. In addition to these avenues for future research, more empirical work on the effects of transparency seems recommendable.

[45] See Blinder, Goodhart, Hildebrand, Lipton, and Wyplosz (2001).
[46] See e.g. The Financial Times, October 17, 2000.

Chapter 6

Voting Transparency, Competence, and Simultaneous Voting

6.1 Introduction

In this chapter, we identify the costs and benefits of voting transparency in a simple model in which central bankers differ in their efficiency and derive utility from being central bankers. We consider a standard aggregate demand and supply framework over two periods. The central bank sets short-term interest rates. Each member of the central bank proposes an interest-rate policy for each period. The interest-rate policy of the central bank is determined by majority voting. Voting transparency means that individual interest-rate proposals and voting records are published, hence enabling the government to verify how each single central banker has voted.[1] The absence of voting transparency implies that only the adopted interest-rate policy is made known, while both individual voting behavior and the proportion of votes for different interest rates remain the private information of the central bankers.

The benefits of voting transparency arise from the way it enables the government to distinguish the highly efficient from the somewhat less efficient central bankers more easily. The government can thus improve the overall competence of the central-bank council over time by re-electing only manifestly highly efficient central bankers. But there is a serious disadvantage to transparency. To avoid being dismissed, less efficient central bankers will try to give the impression of expertise whenever their individual behavior can be observed. They propose the interest policies which a highly efficient central banker would vote for. But since they do not know whether interest rates should

[1]Note, however, that many supporters of voting transparency favor the publication of non-attributed voting records (see e.g. Buiter (1999)).

be raised or lowered, the probability of them erring is fifty percent. The likelihood that the central bank will adopt the appropriate interest-rate policy decreases and social losses are higher than they would be in the absence of transparency, as this enables less efficient central bankers to abstain. We show that these costs exceed the benefits of transparency gained by assembling a highly efficient central-bank council.

However, it is premature at this stage to advocate non-transparency for voting records. Apart from the issue of the robustness of our model, the main reason for caution is that the transparency of voting records can be beneficial if central bankers differ with respect to preferences, i.e. with respect to different emphases on inflation and output stabilization. In this case transparency can help to change the median central banker's preferences in the direction of the socially desirable preferences faster than would be the case with non-transparency.[2]

Our model also implies that both less efficient central bankers and highly efficient central bankers prefer opacity to transparency. This implication might explain why central bankers may sometimes be reluctant to publish voting records. We extend our analysis to longer time horizons, where the advantage of transparency is preserved for reasonable parameter values.

Are our findings applicable to the ECB?[3] The ECB does not publish voting records. During the press conferences after the General Council meetings, the President, Mr. Duisenberg, gives only a summary of the discussion among the members. However, one member of the European Commission (EC) attends the meetings of the General Council without the right to vote. Since secrecy is required from the EC observer and the members of the General Council, we may assume that it is possible to describe the ECB using the opacity case which figures in our model.

Though it is conceivable for secrecy might be violated and information about the meetings might leak out to governments (again, cf. Buiter (1999)), the ECB's voting procedure can still be regarded as relatively opaque. Duisenberg has often stressed that decisions are reached by consensus, not by formal voting (cf. e.g. the ECB press conference by Duisenberg and Noyer (2000)). Thus, even with an outside observer present, the General Council can achieve voting opacity.

This chapter is organized as follows: In the next section, we describe the model. In section 6.3, we simplify the social loss function. The reappointment scheme is derived

[2]A formal treatment of this case is set out in Gersbach and Hahn (2001a).

[3]However, the debate about transparency is not limited to the ECB. A number of studies have examined the transparency of the Federal Open Market Committee's (FOMC) decisions. Most recently, Lapp, Pearce, and Laksanasut (2000) show that monetary policy was less transparent in the Greenspan era than under the Volcker chairmanship.

in section 6.4. In the following two sections, the results for the first and the second period are derived. Then we will attempt an overall comparison between transparency and opacity in section 6.7. Since the equilibria for opacity and transparency are not unique, we proceed in section 6.8 to discuss the refinements that could be used for choosing unique equilibria and the results to be expected under these refinements. In section 6.9 we present an extension of our model with more than two periods. The robustness of our argument is discussed in section 6.10. Section 6.11 presents our major conclusions.

6.2 Model

We examine a two-period model in which the government can re-elect or dismiss members of the central-bank council after the first period.

Consider the following standard aggregate demand and aggregate supply equations, which hold in any period:[4]

$$y^d = \alpha\big(r - (i - \pi)\big) \tag{6.1}$$

$$y^s = \beta(\pi - \pi^e) + \varepsilon \tag{6.2}$$

α and β are positive parameters, r is the natural real rate of interest, i the short-term nominal interest rate and the central bank's instrument variable. Inflation is denoted by π and expected inflation by π^e. To simplify the exposition, we assume only two possible realizations for the supply shock $\varepsilon \in \{-s, s\}$. y^d and y^s are measured as deviations from the natural rate of output.

Social losses in any period are given by:

$$l = \pi^2 + ay^2 \tag{6.3}$$

$a > 0$ denotes the weight on output stabilization. Since there is no output target above the natural level, there will be no inflation bias in our model.

A crucial issue is the utility gained by central bankers when in office. There are two possible motives. Central bankers can be motivated by certain policies, i.e. they would like to minimize their individual loss function depending only on inflation and output.[5] Or they may derive additional private benefits from being a central banker, i.e. from the prestige and the satisfaction of the work on the council. Both approaches

[4] We will omit the subscripts denoting the period whenever possible.

[5] The case where central bankers want to minimize the social loss function is a special case.

to the formulation of utilities for central bankers are equally plausible and give rise to transparency issues. In this paper, we follow the latter approach; each central banker is assumed to draw large private benefits from being on the council. For simplicity, these benefits are assumed to be so large that a central banker will always prefer any situation where he is a member of the council over any situation where he is not. A central banker's losses are given by:

$$l^{CB} = \pi^2 + ay^2 - B \tag{6.4}$$

B denotes private benefits emanating from being a member of the central-bank council. These benefits are zero if not a member and large otherwise.

It is obvious that the publication of voting records can only have a differential impact if there is some heterogeneity among central bankers.[6] There are two possibilities for differences among central bankers to emerge:

- central bankers may have different preferences, e.g. put different emphasis on output stabilization;
- central bankers may have different degrees of knowledge concerning the way the economy works.

In this paper, we will explore the second avenue and distinguish between highly efficient and less efficient central bankers.[7] A highly efficient central banker will have more accurate judgments about the magnitude of shocks in the economy. We assume that the judgment of a highly efficient central banker will be correct with probability p $(1/2 < p \leq 1)$, and wrong with probability $1 - p$. Probability p is the same for all highly efficient central bankers and is commonly known. Less efficient central bankers have a lower ability to judge the future course of the economy and we assume that the probability of their predicting shocks correctly amounts to $1/2$. In other words, a less efficient central banker does not have any informative indications about the magnitude of shocks.

We will consider a two-period model, with the periods denoted by $t = 1$ and $t = 2$. Overall social losses are given by:

$$L = (\pi_1^2 + ay_1^2) + \delta(\pi_2^2 + ay_2^2) \tag{6.5}$$

δ $(0 < \delta < 1)$ denotes the discount factor. The subscripts denote the period.

[6] The heterogeneity could also be caused by identical central bankers belonging to different generations. A model of overlapping generations of central bankers is examined in Sibert (1999).

[7] An analysis of the first case is conducted in Gersbach and Hahn (2001a).

Accordingly, a central banker's losses amount to:

$$L^{CB} = (\pi_1^2 + ay_1^2 - B_1) + \delta(\pi_2^2 + ay_2^2 - B_2) \tag{6.6}$$

Monetary policy is in the hands of the council of the central bank, which decides by majority rule which short-term interest rate will be set.

The sequence of events is as follows:

- **1st Period**
  - At the beginning of the first period, the council is formed, comprising N central bankers ($N \geq 1$, N odd). There is equal probability of any member being highly efficient or less so. The efficiency of each member is private information.
  - The public forms expectations about inflation.
  - Highly efficient central bankers observe a signal indicating the magnitude of the shock. The probability of a highly efficient central banker's judgment being correct is p.
  - Members simultaneously vote for their preferred interest rate i. Members are allowed to abstain.
  - The interest rate preferred by the median central banker is set by the central bank. In the case of several median positions, each of the median positions is equally likely to win.
  - The shock materializes and is observed by the central bankers and the government. Inflation and output are determined accordingly.
  - Voting records are either published under a transparency requirement or remain secret for all outsiders under opacity.
- **2nd Period**
  - At the beginning of the second period, the re-election of the members of the central-bank council takes place. The government can dismiss any central banker and replace him by another central banker from a pool of candidates. The probability of newly elected central bankers being highly efficient is 1/2.
  - The public forms expectations about inflation.
  - Highly efficient central bankers observe a signal indicating the magnitude of the shock. The probability of their judgment being correct is p.

- Members simultaneously vote for their preferred interest rate i. Members may abstain.
- The interest rate of the median voter is set by the central bank. In the case of a draw, the interest rate is set to the value that would be optimal if no shocks were present.[8]
- The shock materializes. Inflation and output are determined accordingly.

6.3 The Equilibrium and the Social Loss Function

In this section, we simplify the expression of the loss function. Equilibrium requires $y^d = y^s$ in every period, which implies:

$$\alpha\big(r - (i - \pi)\big) = \beta(\pi - \pi^e) + \varepsilon \tag{6.7}$$

We immediately obtain the inflation rate:

$$\pi = \frac{-\alpha(i - r) + \beta\pi^e - \varepsilon}{\beta - \alpha} \tag{6.8}$$

Without any real shock to the economy, i.e. $\varepsilon = 0$, each central banker would choose $i = r$ to minimize social losses. Since the public does not know the magnitude of the shock when forming its expectations and there is no inflation bias, it will rationally expect $i^e = r$ and $\pi^e = r - i^e = 0$.[9] Then equation (6.8) simplifies to:

$$\pi = -\frac{\alpha(i - r) + \varepsilon}{\beta - \alpha} \tag{6.9}$$

In the following, we will assume $\beta > \alpha$. Otherwise inflation would increase if the central bank raised the interest rate, which seems less plausible.

Inserting equation (6.9) into the expression for y^d in equation (6.1) yields the equilibrium output as a function of i:

$$y = -\frac{\alpha\big(\beta(i - r) + \varepsilon\big)}{\beta - \alpha} \tag{6.10}$$

[8] Note that the assumption is slightly different from the corresponding assumption in the first period. In the first period central bankers do not want the government to believe that they are less efficient and this will prevent them from choosing the value that would be optimal if no shocks were present. The assumption, however, is not essential to our results, especially if the central bank council is a relatively large body.

[9] Obviously, $\pi^e = 0$ is part of an overall Bayesian Nash equilibrium. It can readily be verified later that $\pi^e = 0$ are the equilibrium beliefs.

Social losses for one period are therefore given by:

$$l = \frac{\big(\alpha(i-r)+\varepsilon\big)^2 + a\alpha^2\big(\beta(i-r)+\varepsilon\big)^2}{(\beta-\alpha)^2} \tag{6.11}$$

Minimizing per-period social losses with respect to i yields the optimal interest rate i^*:

$$i^* - r = -\frac{1+a\alpha\beta}{\alpha(1+a\beta^2)}\,\varepsilon \tag{6.12}$$

We can now restate the problem of minimizing social losses. If the council could observe ε without noise, the socially optimal interest rate would be given by (6.12). Any deviation from i^* creates social losses which are quadratic in $i - i^*$. Therefore, an equivalent problem for central bankers is to minimize:

$$\mathcal{L} = (I - I^*)^2 \tag{6.13}$$

where $I := i - r$ and $I^* := i^* - r$. The central bank now chooses I and faces shocks to the optimal interest rate of I^*. We normalize the two possible realizations of I^* to 1 and -1, respectively. This, of course, simplifies the analysis but is not crucial to our results.[10]

6.4 Re-election Schemes

In this section, we discuss the government's re-election procedure. While the optimal re-election procedure and the monetary policy proposed by highly efficient and less efficient central bankers interact, we simplify the analysis at this stage by assuming a certain pattern of monetary policy for different types of central banker. Later we will justify these assumptions as equilibrium strategies. It is, however, important to note that the equilibrium we are constructing is not unique. In section 6.11 we discuss the other equilibria that exist and whether our main results hold for those as well.

We assume that one out of only two different possible interest rates will be chosen in the first period of the game. Highly efficient members will either vote for a positive or for a negative interest rate I, depending on the signal they have received about the shock.

Under transparency, less efficient central bankers will randomize between the two possible positions of a highly efficient central banker. Under opacity, less efficient central

[10] Normalizing the two possible realizations of I^* to 1 and -1 is equivalent to a linear transformation of the interest rates. For our purposes it does not matter whether the central bank chooses the interest rate or the interest rate times a constant expression which is $\frac{1+a\alpha\beta}{\alpha(1+a\beta^2)}$.

bankers will abstain. For the present purpose these assumptions will help us to derive the optimal re-election scheme. Later we will show that given the government's re-election scheme the assumed behavior does indeed minimize central bankers' losses.

Under transparency, it is optimal for the government to re-elect any central banker who voted for the policy representing the position of a central banker with a correct estimate of the shock, and to dismiss all other central bankers. This strategy will minimize expected social losses in the second period. Assume the shock is positive, i.e. $I^* = 1$, then

$$\begin{array}{lcl} I_i \geq I^H & \Rightarrow & \text{member } i \text{ is re-elected} \\ I_i < I^H & \Rightarrow & \text{member } i \text{ is dismissed} \end{array}$$

I_i is the vote of member i and I^H is the interest rate a highly efficient central banker would choose in equilibrium if he gaged the sign of the shock correctly. An analogous re-election scheme holds for negative shocks.

In the absence of transparency, the government will either fire the whole council or leave them in office, since the government does not know how each single central banker has voted. If the central bank sets an interest rate I that indicates that a majority of the voting central bankers estimated the shock correctly, then the central-bank council will be left in office; otherwise it will be dismissed. The re-election scheme for $I^* = 1$ is given by:

$$\begin{array}{lcl} I \geq I^H & \Rightarrow & \text{the whole council is re-elected} \\ I < I^H & \Rightarrow & \text{the whole council is dismissed} \end{array}$$

A subgame-perfect Bayesian equilibrium consists of monetary policy votes in the first and second period, of the re-election scheme, and of the public's inflation expectations. Since first-period equilibrium monetary-policy votes are independent of second-period votes, we can examine the first period before analyzing the second.

6.5 The First Period

6.5.1 Opacity

We will first derive the interest rate I^H that a highly efficient central banker would choose if he were alone. Expected losses would be:

$$\mathcal{L}_1|_{alone} = p(1 - |I|)^2 + (1 - p)(1 + |I|)^2 \tag{6.14}$$

The first-order condition yields:

$$-p(1-|I^H|)+(1-p)(1+|I^H|)=0 \tag{6.15}$$

which implies that the optimal interest rate is given by

$$I^H=\pm(2p-1) \tag{6.16}$$

with $I^H=+(2p-1)>0$ if the signal about the shock is positive and $I^H=-(2p-1)<0$ otherwise. Not surprisingly, a highly efficient central banker would choose a more cautious policy if uncertainty is rather large; this would be reflected by a small value for p.

The following proposition holds:

Proposition 6.1
In the first period, under opacity, the following Nash equilibrium exists. Each highly efficient central banker will choose:

$$I^H=\pm\big(2p-1\big) \tag{6.17}$$

where $I^H=+(2p-1)>0$ if the central banker expects the shock to be positive and $I^H=-(2p-1)<0$ otherwise. The less efficient central bankers abstain. If no highly efficient central banker is present, the council randomizes between the two possible values of I^H.

Proof of Proposition 6.1 In the absence of transparency, less efficient members will abstain because they know that they would otherwise exacerbate the results of monetary policy and additionally lower their chances of getting re-elected.

Assume a highly efficient central banker would favor an interest rate of $|I'|>|I^H|$. He knows that his vote would not usually change the median position, unless he were the only highly efficient central banker.[11] But if that were the case, he would by definition prefer to choose I^H.

No central banker would ever choose an interest rate of $|I'|<|I^H|$ since the whole council would be dismissed if he were the median voter.

□

Assume the size of the central-bank council to be $N\geq 1$ and the number of highly efficient members to be n. Note that n is known neither to the central bankers nor

[11] Or, for completeness, he could be the median central banker with probability 1/2 if only one other central banker were efficient; this would not change the line of argument.

to the government. The probability of the median central banker's estimating the direction of the shock correctly is equal to the probability that the estimate of at least $(n+1)/2$ central bankers' is correct and is given by:

$$P(n) = \begin{cases} \sum_{i=(n+1)/2}^{n} \binom{n}{i} p^i (1-p)^{n-i} & \text{if } n \text{ odd} \\ \sum_{i=n/2+1}^{n} \binom{n}{i} p^i (1-p)^{n-i} + \frac{1}{2}\binom{n}{n/2} p^{n/2}(1-p)^{n/2} & \text{if } n \text{ even} \end{cases} \tag{6.18}$$

The last term of $P(n)$ for an even value of n gives the probability of a correct direction of the interest rate in the case of a draw. There will be a randomization between the two choices, reflected by the factor $1/2$.[12]

It is useful to define:

$$\overline{P} = \frac{1}{2^N} \sum_{n=0}^{N} \binom{N}{n} P(n) \tag{6.19}$$

which is the probability that an outside observer assigns to the eventuality of the median central banker's vote being directionally correct.

With the use of $\overline{P}$, expected losses in the first period, denoted by $\mathcal{L}_1^O$, are given by:

$$\mathcal{L}_1^O = \overline{P}(1 - |I^H|)^2 + (1 - \overline{P})(1 + |I^H|)^2$$

which together with equation (6.17) can be rewritten as:

$$\mathcal{L}_1^O = 4\big(p^2 - 2\overline{P}p + \overline{P}\big) \tag{6.20}$$

$\mathcal{L}_1^O$ depends negatively on p in two ways. If p increases, the interest rate will move closer to the optimal interest rate and the probability that the council takes a correct vote will increase additionally. As corollaries we obtain:

Corollary 6.1
If the central-bank council is very large, the median position is always directionally correct, i.e.

$$\lim_{N\to\infty} \overline{P} = 1$$

Corollary 6.2
If the central-bank council is very large and the probability of each highly efficient central banker's signal being correct is $p = 1$, then losses approach zero, i.e.

$$\lim_{N\to\infty} \mathcal{L}_1^O = 0$$

[12]Note that $P(n+1) = P(n)$ if n is odd. An increase of the number of highly efficient central bankers by one when n is odd produces more ties and more correct judgments of the interest-rate policy of the majority. The two effects cancel each other out.

The two corollaries are implications of the law of large numbers. The first corollary is a variant of the Condorcet Jury Theorem.[13]

We can now easily verify that the re-election scheme proposed in section 6.4 does indeed represent an equilibrium strategy. Since the expected overall competence of a council that has chosen a directionally correct interest rate is higher than the expected overall competence of a newly elected council, it is optimal to re-elect the original council. On the other hand, if the council has chosen a directionally wrong interest rate, its expected competence is lower than the expected competence of a newly elected council. Thus, dismissing the council will minimize expected social losses in the second period.

6.5.2 Transparency

With respect to the highly efficient central bankers' behavior the Nash equilibrium under transparency will be quite similar to the equilibrium developed in the last section. But less efficient central bankers will not abstain. The government would observe who abstained and would dismiss the respective members to improve the pool of highly efficient central bankers. Therefore, less efficient central bankers will randomize between the two possible interest rates of highly efficient central bankers in order to have a fifty percent chance of not being detected as less efficient. Compared to the case without transparency this effect will increase social losses in the first period since the probability that the median voter is correct will decrease.

The following proposition holds:

Proposition 6.2
Under transparency, the following Nash equilibrium exists in the first period. Each highly efficient central banker will choose:

$$I^H = \pm\big(2p-1\big)$$

where $I = +(2p-1) > 0$ *if the central banker expects the shock to be positive and* $I = -(2p-1) < 0$ *otherwise. Less efficient central bankers will randomize between the two possible values of* I^H *with equal probability.*

[13]The Condorcet Jury Theorem, which states that under majority voting, there is a very high probability of large electorates with diverse information reaching correct decisions, goes back to Condorcet (1785) (see Klevorick, Rothschild, and Winship (1984), Miller (1986), Grofman and Feld (1988), Young (1988), Ladha (1992), and Berg (1993)). Austen-Smith and Banks (1996), Feddersen and Pesendorfer (1996, 1997), and Myerson (1998) have shown that taking the possibility of strategic voting into account considerably restricts the potential for generalizing on the informational efficiency of majority voting.

Proof of Proposition 6.2 Under transparency, less efficient central bankers will try to make the government believe that they are highly efficient because they obtain large private benefits from being central bankers and thus want to be re-elected. This will induce them to randomize between the two possible positions of highly efficient central bankers.

No central banker could profit from choosing an interest rate I' with $|I'| > |I^H|$ since he could not change the median position of the central-bank council and would not increase the probability of getting re-elected either.

No central banker would ever choose an interest rate with $|I'| < |I^H|$ because he would not be re-elected if he did.

□

In order to derive expected losses, we will first define the probability, denoted by $Q(n)$, that if n members of the council are highly efficient the median central banker will choose the correct interest rate.

$$Q(n) = \sum_{j=(N+1)/2}^{N} \left(\sum_{i=0}^{j} \binom{n}{i} p^i (1-p)^{n-i} \binom{N-n}{j-i} \left(\frac{1}{2}\right)^{N-n} \right) \tag{6.21}$$

The index j indicates that j members of the central-bank council vote correctly. Thus, the first sum starts at $(N+1)/2$ and ends at N, which takes into account all possibilities of more than half of the members voting correctly. There are always several possibilities of j members voting correctly. The index i describes the number of highly efficient members voting correctly while $j-i$ less efficient members will choose the right interest rate.

In contrast to the case of $P(n)$, there is no necessity to consider a draw when calculating $Q(n)$. Under transparency, all members will vote and N is assumed to be odd.

Again, it is useful to define

$$\overline{Q} = \frac{1}{2^N} \sum_{n=0}^{N} \binom{N}{n} Q(n) \tag{6.22}$$

which is the probability that an outside observer assigns to the eventuality of a median central banker voting correctly.

With this definition, we immediately obtain expected losses in the first period as:

$$\mathcal{L}_1^T = 4\left(p^2 - 2\overline{Q}p + \overline{Q}\right) \tag{6.23}$$

As corollaries we observe:

Corollary 6.3
If the central-bank council is very large, the median position is always directionally correct, i.e.

$$\lim_{N\to\infty} \overline{Q} = 1$$

Corollary 6.4
If the central-bank council is very large and the probability of each highly efficient central banker's signal being correct is $p = 1$, then losses approach zero, i.e.

$$\lim_{N\to\infty} \mathcal{L}_1^T = 0$$

The corollaries are similar to corollaries 6.1 and 6.2 and again follow from the law of large numbers. In order for corollary 6.3 to hold, it is important for the likelihood of a single central banker being correct to be strictly larger than 1/2. But this likelihood amounts to $1/2 \cdot 1/2 + 1/2 \cdot p$ where we have used that the probability of central bankers being less efficient or highly efficient is 1/2, the probability of less efficient central bankers voting directionally correct is 1/2, and the probability of highly efficient central bankers being correct is p.

We will now demonstrate that the proposed re-election scheme in section 6.4 is optimal. When the government re-elects the central bankers, it will try to minimize expected second period losses. The probability of a newly elected central banker being highly efficient is one half. Thus, it is reasonable to re-elect any central banker whose probability of being highly efficient is higher than fifty percent and to dismiss the other central bankers. One can easily verify that the probability of a central banker who chose a directionally correct (wrong) interest rate being highly efficient is $q := p/(p+1/2) > 1/2$ $(1 - q < 1/2)$.[14] Therefore, the proposed re-election scheme states an equilibrium strategy.

6.5.3 Comparison

We compare first-period losses with the following proposition:

Proposition 6.3
Losses in the first period are always larger under transparency than under opacity, i.e.

$$\mathcal{L}_1^O < \mathcal{L}_1^T$$

[14] The probability of a highly efficient central banker choosing a correct interest rate is p, for a less efficient central banker it is 1/2. This means that p and 1/2 are the relative probabilities of a central banker who has chosen the correct interest rate being either highly efficient or less efficient. Thus, the probability of a central banker who has voted for a correct interest rate being highly efficient is q.

The proof is straightforward. For any n, it is easy to show that $P(n) > Q(n)$. Then one can conclude that $\overline{P} > \overline{Q}$, which implies the above proposition.

This result is quite plausible. Under transparency, no less efficient central banker will dare to abstain since he would not be re-elected if he did. This will induce less efficient central bankers to randomize between the two possible positions of highly efficient central bankers. That will decrease the probability of a correct decision being reached.

6.6 The Second Period

6.6.1 Opacity

In the second period again, only highly efficient council members will vote since less efficient central bankers would decrease the likelihood of the central bank's decision being correct. Highly efficient central bankers will choose $I = \pm|I^H|$.

It is straightforward to show:

Proposition 6.4
Under opacity, the following Nash equilibrium exists in the second period. All less efficient central bankers abstain, and all highly efficient central bankers choose $I_i = \pm(2p-1)$. *If no highly efficient central banker is present, the interest rate* $I = 0$ *will be chosen.*

To derive expected losses, we need to distinguish whether the council has been dismissed or left in office. If the central-bank council is dismissed, expected losses will differ slightly from the losses computed for the first period. If no highly efficient central bankers are present on the council, $I = 0$ minimizes social losses. In this case, the council has randomized in the first period between $I^H = \pm(2p-1)$ in order to avoid dismissal.

Thus, if the central-bank council has not been re-elected expected losses amount to:

$$\mathcal{L}_2^O|_{new\ council} = 4\big(p^2 - 2\overline{P}p + \overline{P}\big) - \frac{1}{2^N}\big(2p-1\big)^2$$

For large values of N, $\mathcal{L}_2^O|_{new\ council}$ and $\mathcal{L}_1^O$ will be identical, since it is then extremely unlikely that there will be no highly efficient central banker present.

Overall expected losses in the second period amount to:

$$\begin{aligned}\mathcal{L}_2^O =& \frac{1}{2^N}P(0) + 4\,\frac{1}{2^N}\sum_{n=1}^{N}\binom{N}{n}\left[P(n)\Big(P(n)(1-p)^2 + \big(1-P(n)\big)p^2\Big)\right] \\ &+ 4\,\frac{1}{2^N}\sum_{n=0}^{N}\binom{N}{n}\left[\big(1-P(n)\big)\Big(p^2 - 2\overline{P}p + \overline{P} - \big(1/2^N\big)\big(p-1/2\big)^2\Big)\right]\end{aligned} \tag{6.24}$$

If the central-bank council has been disbanded, expected losses will be $\mathcal{L}_2^O|_{new\ council}$, which yields the last term of equation (6.24). The first and second term correspond to the losses when the central-bank council is re-elected; the probability of this is $P(n)$. Given that the number of highly efficient central bankers is $n \geq 1$ in the second period, second-period losses amount to $4\Big(P(n)(1-p)^2 + \big(1-P(n)\big)p^2\Big)$, which is the expression appearing in the first sum.

Expression (6.24) can be simplified to:

$$\begin{aligned}\mathcal{L}_2^O =& \frac{1}{2^{N+1}} + 4\Bigg[\overline{P}p^2 - 2p\overline{P^2} + \overline{P^2} - \big(1/2^{N+1}\big)p^2 \\ &\qquad + (1-\overline{P})\left(p^2 - 2\overline{P}p + \overline{P} - \big(1/2^N\big)\big(p-1/2\big)^2\right)\Bigg] \\ =& \; 4\Big(p^2 + (2p-1)\big(\overline{P}^2 - \overline{P^2} - \overline{P}\big)\Big) - \frac{1}{2^{N+1}}(2p-1)(2p+1) - \frac{1}{2^N}\big(1-\overline{P}\big)(2p-1)^2 \\ =& \; 4p^2 + (2p-1)\left[4\big(\overline{P}^2 - \overline{P^2} - \overline{P}\big) + \frac{1}{2^N}\Big(3p - 1/2 + (2p-1)\overline{P}\Big)\right]\end{aligned}$$

where we have used:

$$\overline{P^2} := \frac{1}{2^N}\sum_{n=1}^{N}\binom{N}{n}\big(P(n)\big)^2$$

6.6.2 Transparency

In the second period, the equilibrium losses under transparency will be the same for a given number of highly efficient central bankers as under opacity. Less efficient central bankers will abstain because they can gain no benefits from making the government believe that they are highly efficient, but would exacerbate social losses if they voted. However, the probabilities that n central bankers will be highly efficient in the second period are different under transparency, thus changing expected losses in comparison to opacity. In the second period, expected losses will be smaller under transparency since the average number of highly efficient central bankers will be larger. This is due to the fact that the government is better able to distinguish highly efficient from less

efficient central bankers when each central banker can be made accountable for his preferred policy.

It is easy to show:

Proposition 6.5
In the second period, under transparency, the following Nash equilibrium exists. All less efficient central bankers abstain, and all highly efficient central bankers choose $I_i = \pm(2p-1)$. *If no highly efficient central banker is present, the interest rate* $I = 0$ *is chosen.*

If we define $\rho_N(n)$ as the probability of n highly efficient central bankers being present in the second period and the size of the council amounting to N, expected losses can be written as:

$$\mathcal{L}_2^T = \rho_N(0) + 4\sum_{n=1}^{N}\rho_N(n)\big(p^2 - 2P(n)p + P(n)\big) \tag{6.25}$$

or as

$$\mathcal{L}_2^T = \rho_N(0) + 4\Big(\big(1-\rho_N(0)\big)p^2 - 2\widetilde{P}p + \widetilde{P}\Big) \tag{6.26}$$

where we have used the following definition:

$$\widetilde{P} := \sum_{n=1}^{N}\rho_N(n)P(n) \tag{6.27}$$

$\widetilde{P}$ can be interpreted as the probability that the central-bank council will estimate the shock correctly.

To determine $\rho_N(n)$, we will first derive $\rho_1(0)$ and $\rho_1(1)$. According to figure 6.1, the probability of a single central banker being highly efficient in the second period is made up of three factors. First, nature determines whether a central banker is highly efficient in the first period. Second, re-election takes place. Third, nature determines whether a newly elected central banker is highly efficient or not. We obtain the following expression:

$$\begin{aligned}\rho_1(1) &= \frac{1}{2}\cdot p\cdot 1 + \frac{1}{2}\cdot(1-p)\cdot\frac{1}{2} + \frac{1}{2}\cdot\frac{1}{2}\cdot\frac{1}{2} && (6.28)\\ &= \frac{1}{4}p + \frac{3}{8} && (6.29)\end{aligned}$$

It is now easy to derive $\rho_1(0)$:

$$\begin{aligned}\rho_1(0) &= 1 - \rho_1(1) && (6.30)\\ &= -\frac{1}{4}p + \frac{5}{8} && (6.31)\end{aligned}$$

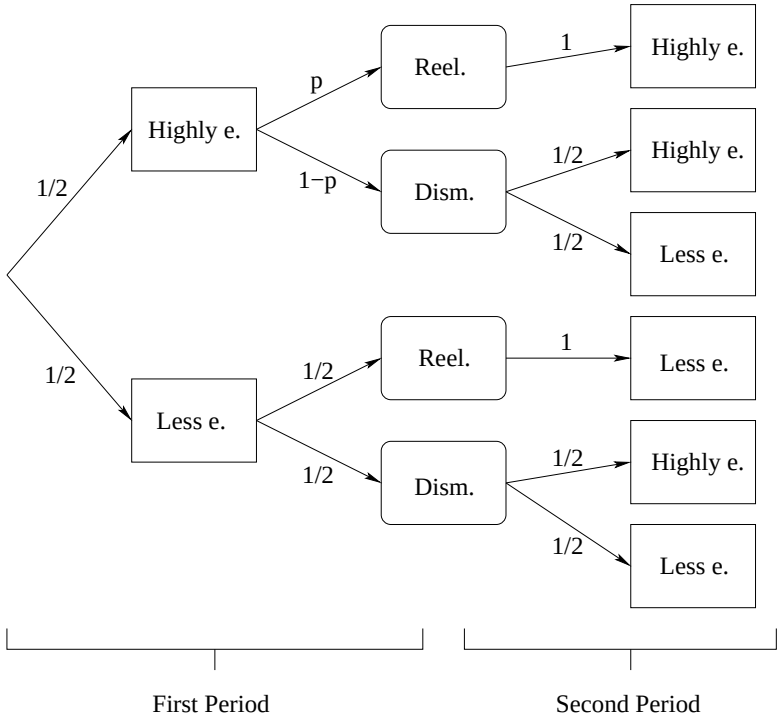


Figure 6.1: The calculation of $\rho_1(0)$ and $\rho_1(1)$.

For $p = 1/2$ we obtain $\rho_1(0) = \rho_1(1) = 1/2$, which is plausible since, for $p = 1/2$, both types are indistinguishable and thus occur with equal probability. Having determined $\rho_1(0)$ and $\rho_1(1)$, we can construct $\rho_N(n)$ by observing that the probability of a single central banker being highly efficient in the second period depends neither on the total number of central bankers N nor on the number of highly efficient central bankers n. We thus obtain the binomial expression:

$$\rho_N(n) = \binom{N}{n} \big(\rho_1(1)\big)^n \big(\rho_1(0)\big)^{N-n} \tag{6.32}$$

6.6.3 Comparison

We compare social losses in the second period using the following proposition:

Proposition 6.6
Losses in the second period are always smaller under transparency.

This is more or less obvious. The average number of highly efficient central bankers in the second period will be larger under transparency since the government can dismiss or re-elect single members of the central-bank council. Since less efficient members will always abstain in the second period, losses are smaller under transparency due to the

larger number of highly efficient central bankers; this, in turn, increases the likelihood of the central bank being correct.

6.7 Overall Comparison

So far, we have established that under opacity losses are lower in the first period but larger in the second. The benefits of voting transparency arise from the way it enables the government to distinguish the highly efficient from the somewhat less efficient central bankers more easily. The government can thus improve the overall competence of the central-bank council over time by re-electing only manifestly highly efficient central bankers. But there is a serious disadvantage to transparency. To avoid being dismissed, less efficient central bankers will try to give the impression of expertise whenever their individual behavior can be observed. They propose the interest policies which a highly efficient central banker would vote for. But since they do not know whether interest rates should be raised or lowered, the probability of them erring is fifty percent. The likelihood that the central bank will adopt the appropriate interest-rate policy decreases and social losses are higher than they would be in the absence of transparency, as this enables less efficient central bankers to abstain. We now show that these costs exceed the benefits of transparency gained by assembling a highly efficient central-bank council.

Thus, the final step is to compare overall losses. While it is hard to compare losses analytically due to the complexity of the respective expressions, the terms can be calculated numerically for any probability p and any number of central-bank council members N. E.g. figure 6.2 shows social losses for both periods and under both scenarios as a function of N for the parameter $p = 0.8$.

Losses always decrease when N increases since the likelihood that the central bank takes directionally correct decisions increases. We also see that under each scenario losses are smaller in the second period compared to the first period. This is due to the following effects: First, especially for small N, losses will differ because in the first period there is socially wasteful randomization in the case of a draw. Second, under both scenarios the average number of highly efficient central bankers is larger in the second period. A larger average number of highly efficient central bankers also lowers second period losses under transparency compared to second period losses under opacity. However, first period losses under transparency are rather large, since less efficient members do not abstain but randomize between the two highly efficient central bankers' positions. For $N = 1$, it does not matter whether we consider transparency or opacity. Therefore,

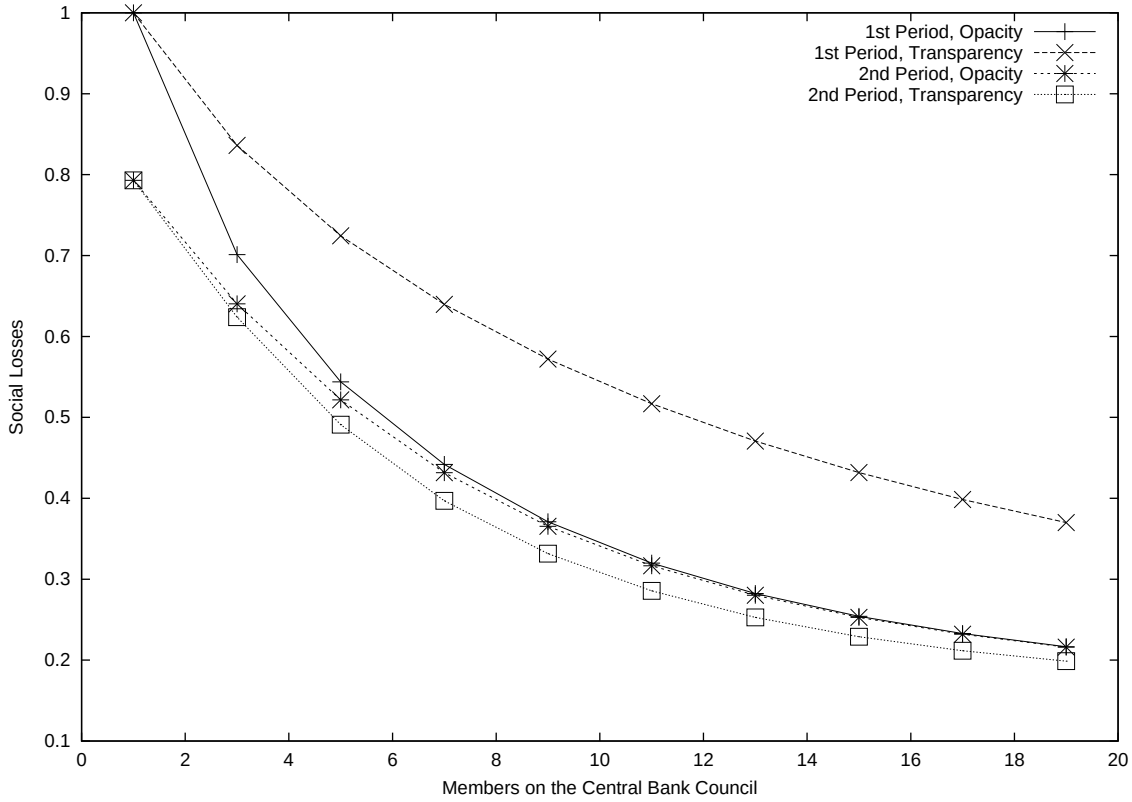


Figure 6.2: Social losses depending on the number of central bankers

social losses under both scenarios are always identical for $N = 1$.

Since the above pattern holds for different values of p, we summarize our main comparison with the following simulation result:

Simulation Result 6.1
If $N > 1$, overall expected losses are always larger under transparency no matter how large the discount rate δ, $0 < \delta < 1$.

The simulation result is supported by our numerical simulations but no formal proof is available as yet. While transparency always reduces second period losses, it always increases first period losses. It is not a priori clear which effect dominates. However, our numerical computations indicate that for any $p > 1/2$ and $N > 1$, the absolute value of the difference of first period losses always exceeds the absolute value of the difference of losses in the second period. Therefore, we can conclude that overall expected losses are always larger under transparency, independently of the parameter δ.

6.8 Equilibrium Selection

In this section we discuss the multiplicity of equilibria and its consequences for the relative advantages of transparency and opacity. We have only considered equilibria in which every highly efficient central banker chooses exactly the interest rate he would choose if he could determine monetary policy alone. These equilibria are not very efficient, i.e. equilibria with lower expected losses do exist. For instance, even when the central-bank council is extremely large, losses for $p < 1$ do not approach zero although the median voter is certainly correct. But losses would approach zero if the interest rates $I' = \pm 1$ were chosen instead of $I^H = \pm(2p - 1)$.

We might consider equilibria with interest rates minimizing losses from an ex ante viewpoint. For example, under opacity, the government would like to choose a re-election scheme where the central-bank council is only re-elected when the absolute value of the interest rate exceeds or equals $2\overline{P} - 1$ and the sign of the interest rate is correct.[15] In the second period, every highly efficient central banker could choose interest rates that would be optimal if every other highly efficient central banker chose these interest rates as well. Second-period interest rates would then depend on the total expected number of highly efficient central bankers. If a highly efficient central banker expected there to be a large number of highly efficient colleagues, he would prefer a large absolute value of the interest rate; by contrast, he would choose a more cautious policy if he expected the number of highly efficient colleagues to be small.

The respective equilibrium implies another advantage of opacity. Assume the central-bank council has been re-elected under opacity. Then central bankers know precisely the number of highly efficient colleagues since they can observe how many central bankers abstained in the first period. Knowing the exact number of highly efficient colleagues, they could choose interest rates which would imply relatively low second period social losses. Under transparency, however, central bankers never know exactly how many highly efficient central bankers are on the council because they cannot distinguish re-elected highly efficient central bankers from less efficient central bankers who estimated the correct direction of the shock by mere luck. Therefore, uncertain about the number of highly efficient colleagues, they could not choose interest rates as appropriate as they would be under opacity. To sum up, opacity would enable central bankers to vote open-mindedly, which, in turn, would improve the central bankers' knowledge about their colleagues' competence. This might enable central bankers to pursue a more favorable monetary policy.

[15] Ex ante the interest rate $2\overline{P} - 1$ is optimal since it solves $\min_I \{\overline{P}(1 - I)^2 + (1 - \overline{P})(1 + I)^2\}$.

6.9 More than Two Periods

In our basic model, opacity is beneficial in the first period, but transparency performs better in the second period. One might legitimately ask whether our conclusion that transparency is better than opacity might be overturned if we considered more than two periods.

Accordingly, we now examine a version of our model with more than two periods. First, we assume that central bankers behave in a similar way as in the two-period case, which we will later verify to be an equilibrium strategy. If the model comprises n periods, highly efficient central bankers will always vote by following their own private signal. In order not to be detected under transparency, less efficient central bankers will randomize in all but the nth period. In the last period, less efficient central bankers will abstain. Under opacity, less efficient central bankers will abstain in every period.

Given this voting behavior by central bankers, we must determine the optimal re-election scheme applied by the government. Let us first discuss transparency. For the decision as to whether a central banker should be re-elected, the government must take into account how the central banker has voted in all periods so far. Given this voting pattern, it has to decide whether the likelihood of this central banker being highly efficient is larger than one-half. If it is, the government should re-elect the central banker, otherwise it would be best to dismiss him. Given his voting behavior in all previous periods, the probability of a central banker being highly efficient amounts to:

$$\Pi_{rw}^{T} = \frac{(1-p)^w p^r}{(1-p)^w p^r + \left(\frac{1}{2}\right)^{w+r}} \tag{6.33}$$

w is the number of wrong votes, r is the number of correct votes; any vote that differs from I^H or has the wrong sign is considered a wrong vote. The exact sequence of correct votes and wrong votes does not matter, since no vote by any central banker depends on past votes.

Note that $\left(\frac{1}{2}\right)^{w+r}$ is the likelihood of a less efficient central banker showing the (w, r) voting pattern and that $(1-p)^w p^r$ is the respective likelihood for a highly efficient central banker.

Given this re-election scheme, it is optimal for highly efficient central bankers and for less efficient central bankers to vote in the manner assumed. Hence, we obtain:

Proposition 6.7
Under transparency, the following perfect Bayesian Nash equilibrium exists: Highly efficient central bankers always vote according to their signals ($I = \pm(2p-1)$). Less

efficient central bankers randomize between the two interest rates that highly efficient central bankers might choose. In the last term, less efficient central bankers abstain. At the beginning of every period, a central banker is re-elected if Π_{rw}^{T} *as defined by* (6.33) *is equal to or larger than* $1/2$*. Otherwise, the central banker is dismissed.*

We now discuss the equilibrium under opacity. Given the council's voting behavior in all periods since its appointment, the government calculates how likely the council is to reach a correct decision, which we define as Π_{rw}^{O}. For this purpose, we define the probability of the council comprising exactly n efficient members to be:

$$\kappa(n) = \frac{\binom{N}{n} (P(n))^r (1 - P(n))^w}{\sum_{i=0}^{N} \binom{N}{i} (P(i))^r (1 - P(i))^w} \tag{6.34}$$

Recall that $P(n)$ is the probability that a council comprising n highly efficient central bankers will arrive at a correct decision. Then Π_{rw}^{O} is given by:

$$\begin{aligned} \Pi_{rw}^{O} &= \sum_{n=0}^{N} \kappa(n) P(n) \\ &= \frac{\sum_{n=0}^{N} \binom{N}{n} (P(n))^{r+1} (1 - P(n))^w}{\sum_{n=0}^{N} \binom{N}{n} (P(n))^r (1 - P(n))^w} \end{aligned} \tag{6.35}$$

Recall that $\overline{P}$ is the probability that a newly elected council reaches a correct decision. If $\Pi_{rw}^{O} \geq \overline{P}$, then it is optimal for the government to re-elect the whole council, otherwise it should form a new council. Given this re-election scheme, the central banker's voting behavior is optimal since it minimizes expected social losses and in addition guarantees the maximum likelihood of getting re-elected. We summarize our observations in the following proposition:

Proposition 6.8
Under opacity, the following perfect Bayesian Nash equilibrium exists: Highly efficient central bankers always vote according to their signals ($I = \pm(2p - 1)$)*, while less efficient central bankers always abstain. At the beginning of every period, the central-bank council is re-elected if* Π_{rw}^{O} *as defined by* (6.35) *is equal to or larger than* $\overline{P}$*. Otherwise, the council is dismissed.*

In order to draw conclusions on the relative performance of voting transparency versus voting opacity, we need to compare expected losses. Due to the high complexity of the respective expressions, we have done this using Monte-Carlo simulations. Two typical examples are demonstrated by figures 6.3 and 6.4. As was to be expected, expected one-period losses are lower under opacity for some periods. Afterwards, expected one-period

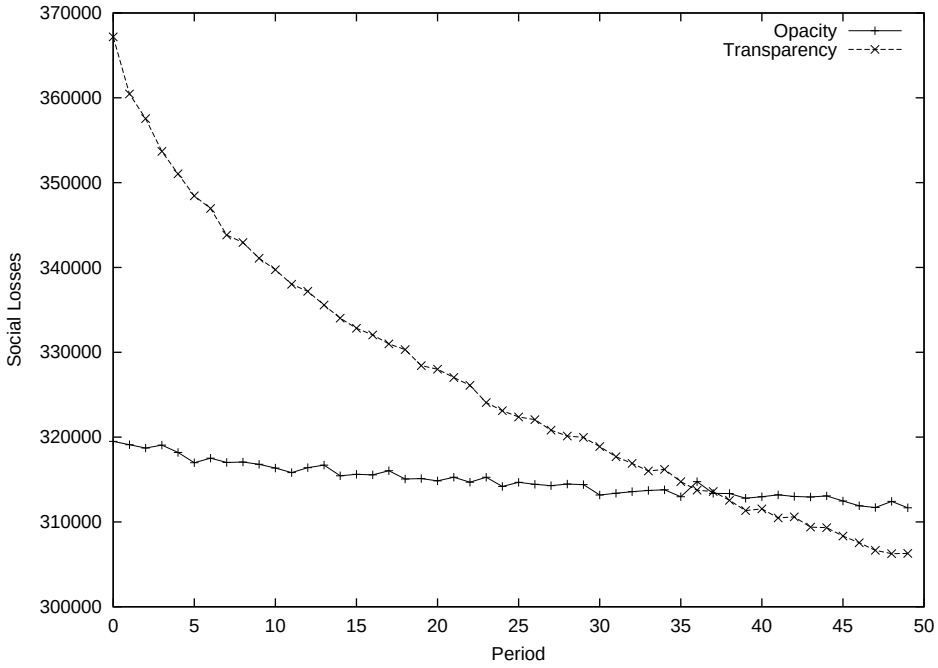


Figure 6.3: Non-discounted one-period social losses for different periods ($N = 11$, $p = 0.6$)

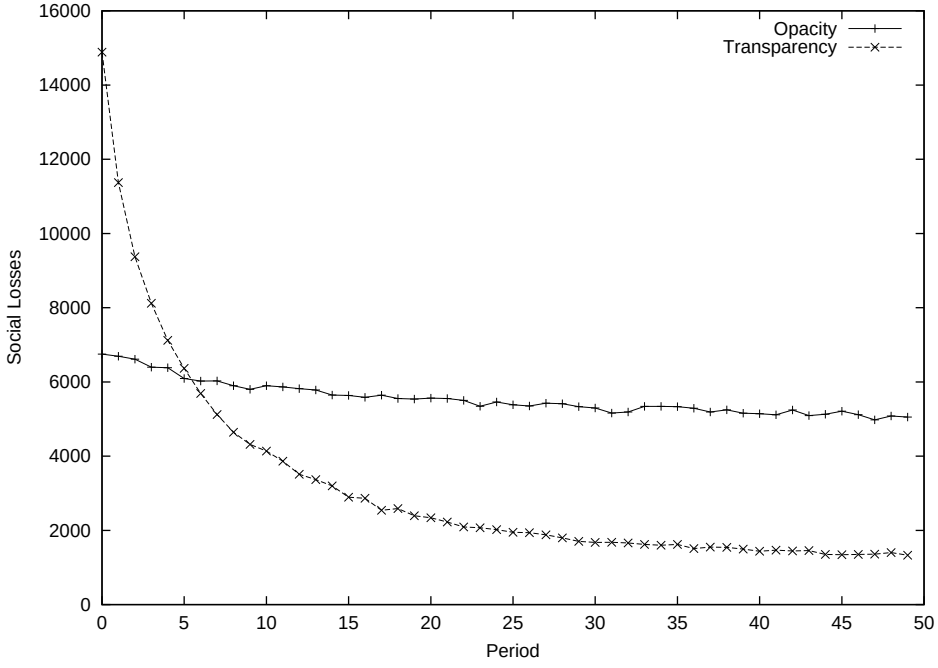


Figure 6.4: Non-discounted one-period social losses for different periods ($N = 11$, $p = 0.8$)

losses are lower under transparency. Thus the tradeoff between the initial benefits from opacity and the benefits from transparency accruing after some time is robust if we introduce several periods.

Whether overall expected losses are lower for transparency or for opacity depends very much on the size of the discount factor δ and the time horizon. To illustrate the relationship between transparency and opacity we compare non-discounted one-period losses. In the examples illustrated by figures 6.3 and 6.4, non-discounted one-period losses are equal after approximately five ($p = 0.8$) to thirty-five periods ($p = 0.6$) for a central-bank council comprising $N = 11$ members. A value of $p = 0.6$ might be more plausible since differences between highly efficient and less efficient central bankers are likely not to be extremely large and a smaller value of p better reflects the great amount of uncertainty monetary-policy makers are facing. For values of p lower than 0.6, it takes even longer for one-period losses to equal out.

The consequences for expected losses are as follows. Assuming the best case for transparency, i.e. the infinite-horizon scenario and a plausible discount factor of $\delta = 0.9$, expected losses for $N = 11$ and $p = 0.8$ are 0.665 under transparency and 0.608 under opacity.[16] Thus, expected losses are smaller under opacity. The difference is more clear-cut if lower values of the discount factor or lower values of p are considered.

With the exception of very small council sizes, the pattern is robust for variations in the size of the council. Summing up, we can say that for plausible parameter values the advantage of opacity over transparency is preserved as long as the differences in efficiency across central bankers are not very large and the discount factor is not very close to one.

6.10 Discussion and Robustness of the Argument

In this chapter we have argued reasons why voting transparency might not be socially desirable. The disadvantage of transparency in our model stems from the signaling incentives of less efficient central bankers, which has broad parallels in other areas of economics, notably in signaling games (see e.g. Kreps and Sobel (1994)).[17] Transparency, though, has the advantage of revealing inefficiencies more successfully than

[16] Since a central banker's term is longer than one year, a discount factor of $\delta = 0.9$ appears to be rather high, which favors transparency.

[17] The concern about pressure to appear highly efficient in every decision has also been raised in private communications with central-bank council members and individuals involved in central-bank design. Cukierman (2000a) has expressed the concern that, when votes are published, decisions depend more on political and personal considerations and less on professional considerations.

opacity. But even under opacity large inefficiencies cannot be protected, otherwise the central-bank council would be dismissed. And under transparency there is also a chance that inefficiencies will not be detected instantaneously since less efficient members will be re-elected if they vote for the optimal interest rate.[18] On balance, the advantage of transparency is not sufficient to outweigh the costs created by the signaling incentives for less efficient central bankers.

Now we address the robustness of the argument. We consider five aspects: time horizon, non-renewable terms, the behavior of less efficient central bankers, the preferences of central bankers, and generalizations of the monetary model.

First, in the previous section we indicated that a longer time horizon may still preserve the advantage of transparency over opacity as long as the number of terms is not too large. However, it may not seem very realistic for central bankers to be re-elected for more than, say, four times; ECB council members, for example, cannot be re-elected at all.[19]

Second, in our model, every central banker can be re-elected for a second term. The members of the Executive Board of the ECB, who constitute the Governing Council together with the Presidents of the Euro area's National Central Banks (NCBs), are appointed for a single term of eight years. This term is not renewable. But even without the possibility of re-election, our model is applicable if less efficient central bankers wish to be perceived as highly efficient for other reasons. For example, they might aspire to other responsible positions after their term on the central-bank council; or they might simply dislike the idea of appearing less efficient to the public than their colleagues.

Third, one might ask why under opacity less efficient central bankers do not wait for the opinions of highly efficient central bankers. Then less efficient central bankers could mimic the behavior of their more efficient colleagues. In our present model, with all central bankers required to vote simultaneously, waiting is not possible. However, abstention under opacity can be interpreted as equivalent to waiting and following the opinion of the majority. Like abstention, following the majority among the efficient

[18] Both under transparency and under opacity the average member of highly efficient central bankers increases over time. But under transparency it increases faster.

[19] Another interesting extension would be the case where central bankers can only be re-elected once in an infinite-horizon model. Under transparency it would not always be wise for the government to dismiss central bankers who chose the wrong interest rate. Re-electing these central bankers eliminates the risk of new and less efficient central bankers randomizing, which may exacerbate monetary policy. Thus, depending on the structure of the central-bank council, it may sometimes be advantageous to re-elect central bankers who are probably not highly efficient. This would further reduce the performance of transparency compared to opacity, thus strengthening our results.

central bankers has no effect on the voting outcome.[20] This would not be possible under transparency, since if voting records and minutes of the meetings were published, members who simply wait for the statements or votes of others could be detected by the government as less efficient.[21]

Fourth, if, contrary to our assumption, private benefits from holding office are very low, opacity and transparency are equivalent with respect to policy outcomes. In both cases, less efficient central bankers would immediately resign because they would not want to exacerbate the central bank's judgment about the appropriate monetary-policy stance.

Another potential concern is that less efficient central bankers under opacity implicitly reveal their relative incompetence by abstaining from voting. If central bankers cared very much about what their colleagues think about their competence, then less efficient central bankers would not be willing to abstain under opacity, which would imply identical behavior on the part of central bankers for transparency and opacity. Then, transparency would be superior to opacity, since the advantage of transparency that central bankers can be individually dismissed or re-elected remains. However, our assumption that central bankers care less about appearing less efficient under opacity than under transparency seems reasonable, since under opacity the lack of efficiency becomes apparent only to their colleagues and can be disputed in any subsequent public discussion, whereas under transparency it is revealed both to their colleagues and to the general public.

Fifth, the results of our model would not change if we considered different demand and supply equations, as long as these were linear and did not depend on lagged or future variables, and as long as losses are quadratic.

Finally, the negative value of transparency in our set-up has to be contrasted with the positive effects when central bankers have equal competence but differ in the emphasis they put on employment relative to inflation. Whether transparency is socially desirable from an overall perspective depends on the kind of heterogeneity within the central-bank council and on the magnitude of the private benefits emanating from holding office.

[20] Waiting and following the opinion of the majority has the additional advantage of being less embarrassing for less efficient central bankers. Also, literal abstention may not be acceptable behavior in a monetary-policy committee, unless decisions are reached by consensus as in the ECB (cf. section 6.1).

[21] A formal treatment of the case with sequential voting has been examined by Hahn (2001). He shows that the results do not differ substantially from those of the present model.

6.11 Conclusion

In this chapter we have identified costs and benefits of voting transparency, concluding that the costs may be large enough to justify opacity. This conclusion is not restricted to central-bank councils; it could also be applied to other committees consisting of members with different degrees of competence, identical utility functions, and the desire to be re-elected due to the large private benefits this implies.

It is an interesting question whether central bankers would prefer transparency over opacity from an ex ante point of view. Our model suggests the following: Under transparency less efficient central bankers have a probability of one half of getting re-elected. Under opacity the probability of getting re-elected is higher. Therefore incompetent central bankers prefer opacity to transparency. A similar argument holds for highly efficient central bankers. Thus both less efficient central bankers and highly efficient central bankers prefer opacity to transparency from an ex ante point of view. This implication of our model may explain why central bankers are sometimes reluctant to impose transparency on monetary policy.

It may also seem interesting to explore why the government does not constrain the term in office for central bankers to one period. Then, there would be no need for less efficient central bankers to randomize, which would yield lower losses. This re-election behavior, however, would not be time-consistent as it is ex-post optimal in the beginning of the second period to re-elect central bankers who have voted for the correct interest rate. If it is possible to limit the term in office, which e.g. has been done in the Maastricht treaty, it is beneficial to do so. Limiting the term in office destroys the possibility to re-elect central bankers who have shown a desirable voting behavior but, more importantly, induces less efficient central bankers to behave socially optimal and to refrain from socially inefficient attempts to get re-elected. That ECB council members can only be in office for one period could also be interpreted as the doubt of the designers of this institution that voting records can be kept secret.

Under opacity, it is optimal if the council can always be re-elected for as many times as possible. This guarantees that successful councils can be left in office for many periods. Perhaps the FOMC could be an example for this.

Chapter 7

Voting Transparency, Competence, and Sequential Voting

7.1 Introduction

A key assumption of the modeling in the previous chapter has been simultaneous voting. In reality, however, votes and statements of central bankers often occur sequentially. Thus in this chapter we examine sequential voting procedures. This gives rise to new strategic issues since each central banker knows the decisions of the colleagues who have already voted. Sequential voting could also be interpreted as a debate by central bankers in which they sequentially make statements and dislike changing their minds when voting actually takes place.[1] Transparency then would correspond with the publication of the minutes of the council meetings.

We show that transparency is inferior to opacity under sequential voting. Additionally, we show that the introduction of voting transparency is likely to substantially change the pattern of votes. Transparency will lead to more controversial elections within the central-bank council as less efficient central bankers contradict their preceding colleagues more often. Our results therefore suggest that there may be a good case for renouncing transparency requirements for voting in central banks.

This chapter is organized as follows. In the next section, we present a two-period model. The equilibrium in the first period is analyzed in section 7.3, the respective analysis for the second period can be found in section 7.4. In section 7.5 we compare the equilibria under transparency and under opacity. We present our conclusions in section 7.6.

[1] Especially when the minutes of council meetings and voting records are published, central bankers may dislike changing their minds as this prevents them from appearing less competent.

7.2 Model

We consider a two-period model with periods denoted by $t = 1, 2$. A central-bank council comprising three members decides upon a nominal interest rate by majority rule.[2] Per-period social losses are:[3]

$$l_t = \frac{1}{2}(i_t - i_t^*)^2 \tag{7.1}$$

We use i_t to denote the interest rate chosen by the central-bank council in period t. i_t^* is the optimal interest rate in period t. i_t^* is not known with certainty at the time the council's decision takes place. For simplicity's sake, we assume that only two realizations of i_t^* are possible, i.e. $i_t^* = +I$ or $i_t^* = -I$. I is a positive parameter, which without loss of generality we normalize to $I = 1$. Overall social losses are:

$$L = l_1 + \delta l_2 = \frac{1}{2}(i_1 - i_1^*)^2 + \delta\frac{1}{2}(i_2 - i_2^*)^2 \tag{7.2}$$

δ is the discount factor, which satisfies the usual assumption $0 < \delta < 1$. We assume the social loss function is also the government's loss function.

We distinguish between two types of central bankers, highly efficient central bankers, who have incomplete knowledge about the optimal interest rate i_t^*, and somewhat less efficient central bankers, who do not have any information about i_t^*. There is equal probability of any central banker being highly efficient or less so. The efficiency of each central-bank council member is private information. With probability p, $1/2 < p < 1$, a highly efficient central banker's signal about i_t^* is correct; with probability $1 - p$ his signal is wrong. Central bankers draw utility from holding office. For simplicity, central bankers do not care for the outcome of monetary policy.[4] Each central banker has the following loss function:

$$l_t^{CB} = -b_t \tag{7.3}$$

b_t are the potential benefits from holding office. We assume:

$$b_t = \begin{cases} 0 & \text{when not holding office,} \\ b > 0 & \text{when holding office.} \end{cases} \tag{7.4}$$

[2]We only consider a central-bank council with three central bankers since the analysis gets extremely complicated for more central bankers. Our analysis for a central banker's decision following identical votes applies for an arbitrary number of central bankers.

[3]This kind of loss function has been derived in chapter 6 in a simple aggregate demand/aggregate supply framework with supply shocks.

[4]The analysis would be extremely tedious if less efficient central bankers were interested in monetary policy since in the first period each less efficient central banker would have to take into account how the possibility of him being re-elected would worsen the expected performance of second-period monetary policy. There would be a trade-off between the private benefits of re-election and the expected exacerbation of monetary policy due to re-election. Our results would not change if highly efficient central bankers cared for inflation and output.

Overall losses for central bankers are given by:

$$L^{CB} = l_1^{CB} + \delta^{CB} l_2^{CB} = -b_1 - \delta^{CB} b_2 \tag{7.5}$$

δ^{CB} $(0 < \delta^{CB} \leq 1)$ is the central bankers' discount factor, which may differ from the public's discount factor. The benefits from holding office in the first period do not influence the central bankers' behavior in the first period. Thus, it is sufficient to consider the expected value of second-period benefits $\delta^{CB} b_2$. Expected second-period benefits in turn are proportional to the central bankers' probability of being re-elected. Thus, central bankers maximize their re-election probability.

After the first period, the government can re-elect central bankers or dismiss them after observing either the adopted interest rate (opacity) or the voting behavior of each single central banker (transparency). Each newly elected central banker is drawn from a pool of candidates where each candidate has the same probability of being highly efficient or less so.

The sequence of events is as follows:

- **1st Period**
  - At the beginning of the first period, the council is formed, comprising three central bankers. There is an equal probability of any member being highly efficient or less so. The efficiency of each member is private information.
  - Each highly efficient central banker observes a private signal which indicates the size of the optimal interest rate i_1^*. The probability of a highly efficient central banker's signal being correct is p.
  - In random sequence, central bankers vote for their preferred interest rates i from the set of possible optimal interest rates $\{-1, +1\}$. Each central banker knows the votes of the colleagues who have already voted.[5]
  - The interest rate preferred by the majority is set by the central bank.
  - The realization of the optimal interest rate determines social losses.
  - Voting records are either published (transparency) or remain secret for all outsiders (opacity).

[5]Note that in this chapter we assume that abstention is not possible. If abstention were allowed, this would further strengthen our finding that opacity is superior to transparency.

- **2nd Period**
  - At the beginning of the second period, the re-election or dismissal of the members of the central-bank council takes place. Minimizing social losses, the government can dismiss any central banker and replace him by another central banker from a pool of candidates. The probability of newly elected central bankers being highly efficient is 1/2.
  - Highly efficient central bankers observe a signal which indicates the magnitude of the optimal interest rate i_2^*. The probability of their signal being correct is p.
  - In random sequence, members vote for their preferred interest rates.
  - The interest rate that receives the majority of votes is set by the central bank.
  - Social losses are determined by the realization of the optimal interest rate.

A perfect Bayesian Nash equilibrium consists of the central bankers' votes in the first and second period and of the government's re-election scheme. Since first-period equilibrium monetary-policy votes are independent of second-period votes, we can examine the first period before analyzing the second.

The equilibria for opacity and transparency, respectively, are not unique. For each scenario, we therefore construct the equilibrium that yields the lowest social losses. Under opacity, since all central bankers maximize the probability of a correct decision and thereby the probability of their re-election, it will be rather clear that the equilibrium we construct is the one with the lowest social losses.[6] Under transparency, this will probably not be obvious. But the equilibrium we construct implies that all highly efficient central bankers follow their private signals. It is plausible that this guarantees the maximum possible chance of a beneficial monetary-policy outcome, although we will not give a formal proof.

[6]However, another equilibrium exists with the same expected social losses. This equilibrium implies that less efficient central bankers who have to cast the second vote always contradict the first vote. This enables the third central banker, who may be highly efficient, to influence the result of the election. If we considered this equilibrium, our findings about the distribution of votes under transparency and opacity would be reversed.

7.3 First Period

7.3.1 Opacity

In this subsection, we examine how central bankers vote under opacity. Our analysis is divided into three steps. In the first step, we assume a certain re-election scheme of the government. We then derive the optimal behavior of highly efficient central bankers given this assumption. In the second step, we derive the optimal behavior of less efficient central bankers given the assumed re-election scheme of the government. In the third step, it remains to be shown that the assumed re-election scheme is indeed optimal for the government, i.e. minimizes expected social losses, given the central banker's voting behavior.

Step 1: We derive the optimal behavior of highly efficient central bankers given an assumption about the government's re-election scheme.

We assume the following behavior of the government for re-elections. The government re-elects the central-bank council if the first-period interest rate is correct. It dismisses the council if the wrong interest rate was chosen. We will justify this behavior later, arguing it is the best response to the voting behavior of central bankers. Given the proposed re-election scheme of the government, central bankers maximize the likelihood that the adopted interest rates are correct, which in turn maximizes their chances of being re-elected. Highly efficient central bankers choose the interest rate that is optimal given their own signal, i.e. an efficient central banker who obtained the signal that the interest rate $+1$ is optimal always votes for $+1$ and an efficient central banker whose signal suggests -1 to be optimal chooses -1. If a highly efficient central banker made his vote dependent on the voting behavior of the central bankers who have already voted, the probability of the adopted interest rate being correct would decrease since valuable information would get lost.[7]

Step 2: We derive the optimal behavior of less efficient central bankers given an assumption about the government's re-election scheme.

Less efficient central bankers do not get an informative signal about the optimal interest rate. Thus they randomize between the two possible interest rates if they have to cast the first vote. If they have to cast the second vote, they take into account that the first

[7]Herding, i.e. following a majority and ignoring the own signal, is never advantageous even for large central-bank councils. Although a central banker might think that the position of the majority is more likely to be correct than his own vote, following the majority will reduce the overall probability of the council being correct. This can be verified formally. Intuitively, the vote of a highly efficient central banker will only matter when there is a draw among the votes of the other members. Then, it seems quite reasonable that it is optimal to follow the private signal.

vote is correct with a likelihood larger than one half since the first voter may have been highly efficient. Therefore, following the first vote is optimal for less efficient central bankers. Now let us consider the behavior of a less efficient central banker who has to cast the third vote. If the first and second vote are identical, a less efficient central banker is indifferent between both interest rates since he cannot influence the result of the election. We assume that the central banker follows the majority, i.e. he votes for the interest rate which he thinks is most likely to be optimal. If, however, the first two votes are different, it is optimal to follow the second vote. If both votes differ, the third central banker knows with certainty that the second voter is highly efficient whereas he is unsure about the efficiency of the first voter. Therefore, it is optimal to support the position of the second central banker, which is more likely to be correct.

Step 3: We show that the assumed re-election scheme of the government is optimal given the voting behavior of central bankers.

Given the voting behavior of central bankers, the government's re-election scheme is optimal due to the following reasons: A council that has voted for an optimal interest rate is more likely to be competent and to choose optimal monetary policy in the future than a newly formed council.[8] A council that has made a wrong decision should be replaced by a completely new council since the new council will be more likely to choose optimal monetary policy in the future.

Summarizing our arguments, we present the following proposition:

Proposition 7.1
In the first period, the perfect Bayesian Nash equilibrium we are constructing for the overall game under opacity can be characterized as follows:

- *Highly efficient central bankers vote by following their signals.*
- *Somewhat less efficient central bankers randomize between the two possible optimal interest rates with equal probability if they have to cast the first vote; they follow the latest vote otherwise.*
- *The government re-elects the central-bank council if the optimal interest rate is chosen. Otherwise it dismisses the whole council and a new council is formed.*

[8]This could of course also be shown formally, but the analysis is omitted here since it is rather tedious.

7.3.2 Transparency

Under transparency, each central banker takes into account the pattern of votes of the central bankers that have already voted. Therefore we separately examine the decisions of central bankers for different voting patterns of the other central bankers.

7.3.2.1 First Vote

The first vote is easy to analyze since the central banker under consideration bases his decision if he is efficient only on his own signal and if he is less efficient he has no information about the optimal interest rate. We will now argue that:

Proposition 7.2
For the first vote, the perfect Bayesian Nash equilibrium we are constructing for the overall game under transparency can be characterized as follows:

- *Highly efficient central bankers choose interest rates by following their signals about the optimal interest rate.*
- *Somewhat less efficient central bankers randomize between the two possible optimal interest rates with equal probability.*
- *The government dismisses the central banker if he has not voted in favor of the optimal interest rate. Otherwise the government re-elects the central banker.*

Proposition 7.2 follows from the following observations. The government's behavior is optimal given the above stated behavior of central bankers since the probability of a central banker who has voted correctly being efficient is higher than the probability of a newly appointed central banker being efficient. A similar argument holds for central bankers who have not voted correctly. Given the government's voting behavior, the central bankers' behavior is also optimal since it maximizes the chances of being re-elected both for highly efficient and for less efficient central bankers.

7.3.2.2 Voting if all Colleagues Have Voted for the Same Interest Rate

The decision of a central banker following one or more identical votes, which contains as a special case the analysis of the second vote, is rather difficult to analyze. We will derive the optimal voting behavior of central bankers and the optimal re-election scheme of the government simultaneously. Our analysis is divided into several steps.

In the first step, we make assumptions about the behavior of less efficient and highly efficient central bankers. We argue that we have to consider a mixed strategy for less efficient central bankers. In the second step, as a preparation for the derivation of the government's optimal re-election scheme, we compute the probabilities of the central banker under consideration being highly efficient depending on the pattern of votes. In step three, using these probabilities, we derive a formal expression of the government's optimal re-election scheme. In steps 4 and 5, given the formal expression of the government's re-election scheme, we derive a condition for the assumed behavior of less efficient central bankers and highly efficient central bankers, respectively, to be optimal. In step 6, we combine these conditions. In step 7, we identify the only possible value of the probability determining the mixed strategy of less efficient central bankers. For this value, the central bankers' behavior is optimal given the behavior of the government. In turn, the government's re-election scheme is optimal given the central bankers' voting behavior.

Step 1: We make assumptions about the behavior of highly efficient and less efficient central bankers.

Since we are interested in an equilibrium with minimum social losses, we assume that highly efficient central bankers always follow their signals. We now argue why a pure strategy of less efficient central bankers cannot be part of such an equilibrium. Suppose it would be optimal for less efficient central bankers to play a pure strategy, e.g. always follow the other votes. Then every central banker who would not choose this behavior would be detected as highly efficient and would thus be re-elected by the government since the government minimizes social losses and re-elects central bankers who are more likely to be highly efficient than a newly appointed central banker. But then we get a contradiction since the assumed pure strategy of less efficient central bankers would not be optimal. It would be optimal to vote for the opposite interest rate.

Thus, we conclude that less efficient central bankers follow a mixed strategy. We use q_n to denote the probability that a somewhat less efficient central banker who has to cast the nth vote follows the other votes.

Step 2: We derive the likelihood of a central banker's efficiency from the government's viewpoint, given the assumptions about the behavior of less efficient and highly efficient central bankers.

To analyze the optimal re-election scheme of the government, a few preparations are necessary. We have to compute the probability that the nth voter is highly efficient depending on the voting behavior of himself, the previous voters and the information about the correct interest rate. $p_{i_1 \ldots i_n}$ denotes the probability that the nth

central banker is highly efficient if the pattern of votes is $(i_1..i_n) \in \{w,r\}^n$ where $i_j \in \{w,r\} \quad (j = 1...n)$ denotes the jth vote, which can be either right (r) or wrong (w). Using the following abbreviation for voting patterns:

$$(i^{n-1}j) := (\underbrace{ii...ii}_{\text{n-1 times}}\ j) \qquad\qquad i,j \in \{w,r\} \tag{7.6}$$

we obtain:

$$\begin{aligned} p_{r^{n-1}r} &= \frac{p}{p+q_n} \\ p_{r^{n-1}w} &= \frac{1-p}{(1-p)+(1-q_n)} \\ p_{w^{n-1}r} &= \frac{p}{p+(1-q_n)} \\ p_{w^{n-1}w} &= \frac{1-p}{(1-p)+q_n} \end{aligned} \tag{7.7}$$

As an example, we will explain how the expression for $p_{w^{n-1}r}$ can be derived. The probability of the nth central banker voting correctly amounts to p if he is efficient. $\frac{1}{2}p$ is the probability that the nth central banker is efficient and chooses the correct interest rate, given that the previous votes are wrong. If the previous votes are wrong, a somewhat less efficient central banker votes for the correct interest rate with probability $1-q_n$ since he follows the previous votes with probability q_n. Hence, $\frac{1}{2}(p+(1-q_n))$ is the probability that the nth vote is correct, given the previous votes are wrong. By Bayes' law the quotient of $\frac{1}{2}p$ and $\frac{1}{2}(p+(1-q_n))$ equals $p_{w^{n-1}r}$.

Step 3: We derive a formal expression of the government's optimal re-election scheme depending on the government's estimate of the efficiency of the central banker under consideration.

Additional notation is required to describe the government's re-election scheme. We use $Q_{i_1...i_n}$ to denote the probability that the nth central banker is re-elected if the pattern of votes is $(i_1..i_n) \in \{w,r\}^n$ where $i_j \in \{w,r\} \quad (j = 1...n)$ denotes the jth vote, which can be either right (r) or wrong (w). For the government's re-election scheme to be optimal, we must have $\forall i, i_n \in \{r,w\}$:

$$Q_{i^{n-1}i_n} = \begin{cases} 1 & \text{if } p_{i^{n-1}i_n} > \frac{1}{2} \\ 0 & \text{if } p_{i^{n-1}i_n} < \frac{1}{2} \\ \text{arbitrary} & \text{if } p_{i^{n-1}i_n} = \frac{1}{2} \end{cases} \tag{7.8}$$

If $p_{i^{n-1}i_n} > \frac{1}{2}$, i.e. if the government estimates the central banker to be highly efficient with a likelihood of more than one half, which is the probability of a newly elected central banker being highly efficient, it always re-elects him. If the government estimates the central banker to be efficient with a likelihood of less than one half, it always

dismisses him. If from the government's viewpoint the probability of the central banker under consideration being highly efficient equals the respective probability for a newly appointed central banker, i.e. if $p_{i^{n-1}i_n} = \frac{1}{2}$, then the government is indifferent between dismissal and re-election.

Step 4: We derive the condition for the assumed behavior of less efficient central bankers, i.e. randomizing between the possible interest rates, to be optimal given the government's re-election scheme Q.

We define z_n to be the probability that the first n votes are correct given the information set of a less efficient central banker who has to cast the $(n+1)$th vote. Then $z_1 = \frac{1}{2}\left(p + \frac{1}{2}\right)$ holds which is the mean of the likelihood of an efficient central banker voting correctly and the respective probability for a less efficient central banker. By defining $q_1 := \frac{1}{2}$, we can write $z_1 = \frac{1}{2}(p + q_1)$. If less efficient central bankers who have to cast the jth vote $(j > 1)$ agree with the preceding votes with probability q_j, the likelihood of n identical votes being correct amounts to:

$$z_n = \frac{\prod_{j=1}^{n}\left(\frac{1}{2}(p+q_j)\right)}{\prod_{j=1}^{n}\left(\frac{1}{2}(p+q_j)\right) + \prod_{j=1}^{n}\left(\frac{1}{2}(1-p+q_j)\right)} \tag{7.9}$$

Note that $\prod_{j=1}^{n}\left(\frac{1}{2}(p+q_j)\right)$ is the likelihood of all votes being identical and correct. $\prod_{j=1}^{n}\left(\frac{1}{2}(1-p+q_j)\right)$ is the likelihood of all votes being identical and wrong. Applying Bayes' law yields the above expression for z_n.

Using the above notation, we are now able to formally describe the condition that it is optimal for a less efficient central banker who has to cast the nth vote to follow a mixed strategy if $n-1$ voters have cast identical votes before. A less efficient central banker is indifferent between agreeing or disagreeing with the other votes if:

$$z_{n-1}Q_{r^{n-1}r} + (1 - z_{n-1})Q_{w^{n-1}w} = z_{n-1}Q_{r^{n-1}w} + (1 - z_{n-1})Q_{w^{n-1}r} \tag{7.10}$$

This can be rearranged to:

$$\Delta Q_{r^{n-1}} \prod_{i=1}^{n-1} \frac{p + q_i}{1 - p + q_i} = \Delta Q_{w^{n-1}} \tag{7.11}$$

where we have introduced the definition:

$$\Delta Q_{i_1 \ldots i_n} := Q_{i_1 \ldots i_n r} - Q_{i_1 \ldots i_n w} \qquad \text{for } (i_1 \ldots i_n) \in \{w, r\}^n \text{ and } n \geq 1 \tag{7.12}$$

ΔQ can be interpreted as the gain in the likelihood of being re-elected for a given pattern of votes of the preceding voters if the central banker chooses the right instead of the wrong interest rate.

Step 5: We derive the conditions for the assumed behavior of highly efficient bankers, i.e. following their private signals, to be optimal given the government's re-election scheme Q.

We have assumed that a highly efficient central banker always prefers to follow his signal no matter what the first votes are. This assumed behavior is optimal if the following conditions hold:

$$\frac{z_{n-1}p}{z_{n-1}p+(1-z_{n-1})(1-p)}Q_{r^{n-1}r}+\frac{(1-z_{n-1})(1-p)}{z_{n-1}p+(1-z_{n-1})(1-p)}Q_{w^{n-1}w}\geq \frac{z_{n-1}p}{z_{n-1}p+(1-z_{n-1})(1-p)}Q_{r^{n-1}w}+\frac{(1-z_{n-1})(1-p)}{z_{n-1}p+(1-z_{n-1})(1-p)}Q_{w^{n-1}r}$$

$$\frac{(1-z_{n-1})p}{(1-z_{n-1})p+z_{n-1}(1-p)}Q_{w^{n-1}r}+\frac{z_{n-1}(1-p)}{(1-z_{n-1})p+z(1-p)}Q_{r^{n-1}w}\geq \frac{(1-z_{n-1})p}{(1-z_{n-1})p+z_{n-1}(1-p)}Q_{w^{n-1}w}+\frac{z_{n-1}(1-p)}{(1-z_{n-1})p+z_{n-1}(1-p)}Q_{r^{n-1}r}$$

The first condition guarantees that the central banker chooses the interest rate that is optimal according to his signal when the first votes coincide with his opinion. The second condition describes the case where the highly efficient central banker's signal suggests the opposite interest rate as the one the other central bankers have proposed. Using (7.9), these inequalities can be simplified to:

$$\begin{aligned}\Delta Q_{r^{n-1}}\frac{p}{1-p}\prod_{j=1}^{n-1}\frac{p+q_j}{1-p+q_j}&\geq \Delta Q_{w^{n-1}}\\ \Delta Q_{w^{n-1}}\frac{p}{1-p}\prod_{j=1}^{n-1}\frac{1-p+q_j}{p+q_j}&\geq \Delta Q_{r^{n-1}}\end{aligned}\tag{7.13}$$

Step 6: We combine the conditions obtained in the two previous steps.

Since $\frac{p}{1-p}>1$, inequalities (7.13) combined with condition (7.11), which guarantees that less efficient central bankers randomize between the two possible interest rates, can be simplified to:

$$\begin{aligned}\Delta Q_{r^{n-1}}&\geq 0\\ \Delta Q_{w^{n-1}}&\geq 0\end{aligned}\tag{7.14}$$

These inequalities are intuitive. It must be more likely, given a certain pattern of previous votes, to be re-elected if one chooses the correct interest rate than when one chooses the wrong interest rate. Otherwise, highly efficient central bankers would prefer to vote for the interest rate opposite to the one suggested by their signals.

Step 7: We identify the mixed strategy of less efficient central bankers for the equilibrium under consideration, i.e. eliminate all values for q_n which cannot represent an equilibrium.

We now analyze what possible values q_n may have for $n > 1$, where q_n is defined as the probability that a less efficient central banker who has to cast the nth vote will take the previous central bankers' position. Using equations (7.7) and (7.8), we are able to compute the values for the re-election probability Q for different values of q_n and different patterns of votes. We summarize these values in table 7.1. A question tag indicates that any value between zero and one is possible, meaning that the government is indifferent between dismissing or re-electing the respective central banker.

	$q_n < 1-p$	$q_n = 1-p$	$1-p < q_n < p$	$q_n = p$	$q_n > p$
$r^{n-1}r$	1	1	1	?	0
$r^{n-1}w$	0	0	0	?	1
$w^{n-1}r$	0	?	1	1	1
$w^{n-1}w$	1	?	0	0	0

Table 7.1: The re-election probabilities of a central banker depending on the pattern of votes

Intuitively, $q_n > p$ is not feasible in equilibrium since, according to table 7.1, the nth central banker would always be re-elected if he contradicted the other central bankers; his probability of being re-elected would be completely independent of the correctness of his vote. Formally, from table 7.1 we obtain $\Delta Q_{r^{n-1}} = -1$, which contradicts (7.14). Similarly, $q_n < 1-p$ is also not possible. According to table 7.1, the nth central banker would always be re-elected if only he had the same opinion as the first voters. Mathematically, $q_n < 1-p$ implies $\Delta Q_{w^{n-1}} = -1$, which violates (7.14).

The intermediate case with $1-p < q_n < p$ can also be ruled out by observing that the nth central banker would always be re-elected if he chose the correct interest rate independent of the previous votes. But since the previous votes are more likely to be correct from the point of view of a less efficient central banker than the opposite opinion, this would induce him to always follow the first central bankers. This, of course, cannot be an equilibrium since it implies that $q_n = 1$, contradicting the assumption that $q_n < p$. By analyzing condition (7.11) it can also be verified formally that this case can be ruled out. For $q_n = 1-p$, condition (7.11) implies that $\Delta Q_{w^{n-1}} > 1$, which is not feasible since $\Delta Q_{w^{n-1}}$ is the difference of two probabilities. Thus the case $q_n = 1-p$ can also be eliminated. The only case left is $q_n = p$.

Step 8: We show that $q_n = p$ represents a possible equilibrium strategy for less efficient central bankers and derive the optimal re-election scheme for $q_n = p$.

$q_n = p$ indeed corresponds to the only possible value of q_n in equilibrium. This is demonstrated now. From table 7.1 we obtain that $Q_{w^{n-1}r} = 1$, i.e. a central banker who has chosen the correct interest rate despite his precedent colleagues choosing the wrong interest rate will always be re-elected. $Q_{w^{n-1}w} = 0$ implies that a central banker who has followed the first voters although the first voters were wrong will be dismissed with certainty. Since $q_j = p$, $\forall j > 1$ and $q_1 = \frac{1}{2}$, (7.11) can be simplified to:

$$\Delta Q_{r^{n-1}} = \frac{3-2p}{2p+1}\left(\frac{1}{2p}\right)^{n-2} \tag{7.15}$$

Equation (7.15) implies that $Q_{r^{n-1}r} > Q_{r^{n-1}w}$. As we have already noted this is necessary for condition (7.13) to hold. Condition (7.13) guarantees that efficient central bankers vote by following their signals. If (7.13) did not hold, following their signals would not be optimal for efficient central bankers since voting for the wrong interest rate would raise their chances of being re-elected.

Since the expression for $\Delta Q_{r^{n-1}}$ in (7.15) is smaller than one, there are always solutions for $Q_{r^{n-1}r}$ and $Q_{r^{n-1}w}$ but these solution cannot be uniquely determined. Any combination of $Q_{r^{n-1}r}$ and $Q_{r^{n-1}w}$ which satisfies condition (7.15), $Q_{r^{n-1}r} \leq 1$ and $Q_{r^{n-1}w} \geq 0$ represents a possible equilibrium. These equilibria, however, differ neither in the voting behavior of central bankers, nor in social losses. The only difference arises from the feature that more or less central bankers whom the government estimates to be highly efficient with a probability of one half, which is also the likelihood of a newly appointed candidate being highly efficient, are dismissed or re-elected.

To sum up, a possible equilibrium for the nth vote in the first period under transparency if the votes $1, ..., n-1$ are identical can be characterized as follows:

Proposition 7.3
Suppose all $n-1$ votes in the previous stages of the game are identical under transparency. Then, for the nth vote, the perfect Bayesian Nash equilibrium we are constructing for the overall game can be characterized as follows:

- *Then highly efficient central bankers choose interest rates by following their signals.*
- *Somewhat less efficient central bankers randomize between the two possible optimal interest rates. They join the previous votes with probability p; they choose the opposite option with probability $1-p$.*

- *The nth voter is*
  - *dismissed if he chooses the wrong interest rate following the first votes ("$w^{n-1}w$").*
  - *re-elected with certainty if he chooses the correct interest rate although the first votes are wrong ("$w^{n-1}r$").*
  - *re-elected with probability $Q_{r^{n-1}w}$ if he chooses the wrong interest rate and the first votes are correct where $0 \leq Q_{r^{n-1}w} \leq 1 - \frac{3-2p}{2p+1}\left(\frac{1}{2p}\right)^{n-2}$.*
  - *re-elected with probability $Q_{r^{n-1}r} = Q_{r^{n-1}w} + \frac{3-2p}{2p+1}\left(\frac{1}{2p}\right)^{n-2}$ if all votes are correct.*

Note that $\Delta Q_{r^{n-1}} < \Delta Q_{w^{n-1}}$, i.e. a central banker can gain a lot ($\Delta Q_{w^{n-1}}$) by voting correctly if all other votes are wrong, his losses improve only by a comparably small amount ($\Delta Q_{r^{n-1}}$) if he is correct and his colleagues' votes are correct as well. This makes contradicting earlier statements rather attractive for less efficient central bankers, guaranteeing that they are indifferent between voting for an interest rate that is more likely to be correct, i.e. the opinion of the other voters, and an interest rate that is more likely to be wrong, i.e. the opposite opinion.

7.3.2.3 Third Vote Following Two Different Votes

The case where the first two votes differ is examined now. The analysis is similar to the analysis with the first two votes being equal. Again, our analysis is divided into several steps.

In the first step, preparing the analysis of optimal behavior of less efficient central bankers, we compute which interest rate is more likely to be correct from the viewpoint of a less efficient central banker given the first two votes. In the second step, we assume that less efficient central bankers play a mixed strategy and derive a condition for this mixed strategy to be optimal, i.e. for less efficient central bankers to be indifferent between the two possible interest rates. In the third step, we derive the condition when it is optimal for highly efficient central bankers to behave in the assumed way, i.e. follow their private signals. In step 4, preparing the derivation of the government's optimal re-election scheme, we compute the probability from the government's view that the central banker under consideration is efficient given the assumption that highly efficient central bankers follow their signals and less efficient central bankers randomize between the two possible interest rate. In step 5, using this probability we derive a formal expression of the government's optimal re-election scheme. In step 6, we identify

the only possible value of the probability in the mixed strategy of less efficient central bankers. For this value, the central bankers' behavior is optimal given the behavior of the government. And the government's re-election scheme is optimal given the central bankers' voting behavior.

Step 1: We derive a less efficient central banker's estimate of the optimal interest rate, given the first two votes.

Given that the first two votes differ, a less efficient third central banker estimates the chances of the second vote being correct to be:

$$\begin{aligned} z' &:= \frac{(1-z_1)\,(p+(1-q_2))}{z_1\,((1-p)+(1-q_2))+(1-z_1)\,(p+(1-q_2))} \\ &= \frac{1-z_1}{2z_1(1-p)+(1-z_1)} \end{aligned} \tag{7.16}$$

where we have used that the probability of a less efficient central banker in the second period following the first vote, q_2, is p. One can easily show that $z' > \frac{1}{2}$, i.e., from the perspective of a less efficient third central banker, the second vote is more likely to be correct than the first vote if the first two votes differ.

Step 2: We assume a mixed strategy for less efficient central bankers, i.e. randomizing between the two possible interest rates, and derive the condition when a mixed strategy is optimal.

Due to reasons similar to those explained in the last subsection, we assume a mixed strategy for less efficient central bankers, i.e. less efficient central bankers randomize between the two possible interest rates. We use q_3' to denote the probability of a less efficient central banker following the second vote instead of the first vote. Less efficient central bankers randomize between the two options available to them if they are indifferent between them. This implies that expected pay-offs from agreeing with the first vote and agreeing with the second vote must be equal.

$$\begin{aligned} z'Q_{wrr} + (1-z')Q_{rww} &= z'Q_{wrw} + (1-z')Q_{rwr} \\ z'\Delta Q_{wr} &= (1-z')\Delta Q_{rw} \end{aligned} \tag{7.17}$$

Solving for ΔQ_{wr}, we obtain:

$$\begin{aligned} \Delta Q_{wr} &= \frac{1-z'}{z'}\Delta Q_{rw} \\ &= \frac{2z_1(1-p)}{1-z_1}\Delta Q_{rw} \\ &= \frac{2(2p+1)(1-p)}{3-2p}\Delta Q_{rw} \end{aligned} \tag{7.18}$$

Step 3: We establish the conditions for the assumed behavior of highly efficient central bankers, i.e. following their private signals, to be optimal.

We assume that highly efficient central bankers who have to cast the third vote when the first vote and second vote differ follow their signals. This is an optimal behavior only if the following conditions hold:

$$\begin{aligned} z'p\Delta Q_{wr} &\geq (1-z')(1-p)\Delta Q_{rw} \\ (1-z')p\Delta Q_{rw} &\geq z'(1-p)\Delta Q_{wr} \end{aligned} \tag{7.19}$$

By inserting (7.18) into (7.19) we obtain:

$$\begin{aligned} \Delta Q_{wr} &\geq 0 \\ \Delta Q_{rw} &\geq 0 \end{aligned} \tag{7.20}$$

Step 4: We derive the probability from the government's viewpoint of the central banker under consideration being highly efficient.

We have to identify the formal expression for the probability of the central banker under consideration being highly efficient given the government's information set. This likelihood will enter into the government's optimal re-election scheme, which also depends on the assumed behavior that highly efficient central bankers follow their signals and less efficient central bankers follow the second vote with probability q_3' if the first and second vote are contradictory. From the government's perspective, the probability of the third central banker being highly efficient is:

$$\begin{aligned} p_{rwr} &= \frac{p}{p+(1-q_3')} \\ p_{rww} &= \frac{1-p}{(1-p)+q_3'} \\ p_{wrr} &= \frac{p}{p+q_3'} \\ p_{wrw} &= \frac{1-p}{(1-p)+(1-q_3')} \end{aligned} \tag{7.21}$$

Recall that q_3' is the probability of a less efficient central banker following the second vote.

Step 5: We derive a formal expression for the optimal re-election scheme of the government, given the assumptions about the behavior of central bankers.

The probability of re-election Q that is optimal for the government depends on the pattern of votes. It is 1 if the probability of the central banker being highly efficient is larger than fifty percent and 0 if the probability of the central banker being highly

	$q_3' < 1-p$	$q_3' = 1-p$	$1-p < q_3' < p$	$q_3' = p$	$q_3' > p$
rwr	0	?	1	1	1
rww	1	?	0	0	0
wrr	1	1	1	?	0
wrw	0	0	0	?	1

Table 7.2: The re-election probabilities of a central banker depending on the pattern of votes

efficient is smaller than fifty percent. The possible values of the re-election probabilities that result from this are summarized by table 7.2. A question tag indicates that any value between zero and one is possible, meaning that the government is indifferent between dismissing or re-electing the respective central banker.

Step 6: We identify the mixed strategy of less efficient central bankers, i.e. determine q_3'.

By condition (7.20), we can eliminate the cases $q_3' < 1-p$ and $q_3' > p$. The case $1-p < q_3' < p$ implies $\Delta Q_{rw} = \Delta Q_{wr} = 1$ which violates (7.18). Equation (7.18) implies that $\Delta Q_{wr} < \Delta Q_{rw}$, which eliminates the possibility $q_3' = 1-p$ and leaves $q_3' = p$ as the only possible equilibrium. Hence, less efficient central bankers follow the second vote with probability p and follow the first vote with probability $1-p$.

Why is it better for less efficient central bankers to follow the second vote more often than the first vote? The reason is that $z' > \frac{1}{2}$, i.e. the second vote is more likely to be correct than the first vote when the first two votes differ.

Overall, we obtain the following proposition for the third-vote equilibrium if the first two votes differ:

Proposition 7.4
For the third vote following two different votes, the perfect Bayesian Nash equilibrium we are constructing for the overall game under transparency can be characterized as follows:

- *Highly efficient central bankers choose interest rates by following their signals about the optimal interest rate.*
- *Somewhat less efficient central bankers randomize between the two possible optimal interest rates. They join the second vote with probability* p*; they choose the opposite option with probability* $1-p$.

- *The third voter is*
  - *re-elected if he chooses the correct interest rate and the first vote is also correct but the second vote is not ("rwr").*
  - *dismissed if he chooses the wrong interest rate and the first vote is also correct but the second vote is not ("rww").*
  - *re-elected with probability Q_{wrr} with $\frac{2(2p+1)(1-p)}{3-2p} \leq Q_{wrr} \leq 1$ if he chooses the correct interest rate, the first vote is wrong and the second vote is correct.*
  - *re-elected with probability $Q_{wrw} = Q_{wrr} - \frac{2(2p+1)(1-p)}{3-2p}$ if he chooses the wrong interest rate, the first vote is also wrong and the second vote is correct.*

7.3.3 Overall Equilibrium in the First Period

As we have argued in step 8, subsection 7.3.2.2, we can normalize $Q_{wrw} = 0$, $Q_{rrw} = 0$ and $Q_{rw} = 0$ without loss of generality. We then obtain the re-election probabilities Q for the first central banker:

r	w
1	0

and for the second central banker:

ww	wr	rw	rr
0	1	0	$\frac{3-2p}{2p+1}$

and for the third central banker:

www	wwr	wrw	wrr	rww	rwr	rrw	rrr
0	1	0	$\frac{2(2p+1)(1-p)}{3-2p}$	0	1	0	$\frac{3-2p}{2p(2p+1)}$

Not surprisingly, social losses in the first period are lower under opacity. Since, under opacity, both types of central bankers, in their attempt to maximize the probability of being re-elected, do their very best to avoid socially undesirable outcomes, this solution represents the social optimum. Social losses under transparency are therefore higher. This stems from the behavior of the less efficient central bankers, who follow the interest rate that is most likely to be correct only with a probability of p. This randomization makes transparency suboptimal in the first period. We obtain:

Proposition 7.5
In the first period, transparency is inferior to opacity since social losses are higher.

The exploration of the distribution of votes under both scenarios yields further insights. One would expect the degree of disagreement to be higher under transparency than under opacity. Current ECB President Duisenberg has often stressed that decisions in the ECB Council, where several observers think that transparency is low, are reached by consensus (cf. e.g. the ECB press conference by Duisenberg and Noyer (2000)). On the other hand, Buiter (1999) has emphasized that the publication of voting records and minutes would foster open-minded discussions and would enable members with dissenting views to engage the public into the debate. This seems to indicate that more controversy among the central bankers is to be expected under voting transparency. Turning to the the Bank of England's Monetary Policy Committee (MPC), which publicizes voting records and the minutes of the meetings, there is a lot of disagreement. Between June 1997 and March 2001, in only seventeen of forty-six meetings unanimous decisions on the interest rate were reached.[9] In fact, our model predicts an increased likelihood of controversial elections under transparency. More controversy within the framework of our model implies that results with one central banker being in opposition to two colleagues are more likely. The distribution of votes in our model shows this pattern as can be verified by figure 7.1, which is based on results obtained from Monte-Carlo simulations. The shape of the distribution is not surprising if we recall the different behavior of less efficient central bankers under both scenarios. Under opacity, less efficient central bankers follow the vote that is most likely to be correct; under transparency, in contrast, less efficient central bankers randomize in those cases. This makes a consensus decision where three central bankers opt for the same interest rate more likely under opacity. We must admit, however, that this result hinges on our assumption that, under opacity, central bankers who have to cast the third vote, choose the interest rate that is most likely to be correct even if the result of the election cannot be changed anymore, i.e. even if the other central bankers have agreed upon the same interest rate.

The distribution of correct votes minus wrong votes is not symmetric, but slanted to the right since correct overall outcomes are more likely than wrong outcomes.

7.4 Second Period

The analysis of the voting behavior in the second period is rather simple. There is no need for a distinction between the opacity and the transparency case as re-election has already taken place. We assume that central bankers respect the Pareto criterion

[9] The data are available under "www.bankofengland.co.uk/mpc/minutes.htm". Also compare Kristen (2001).

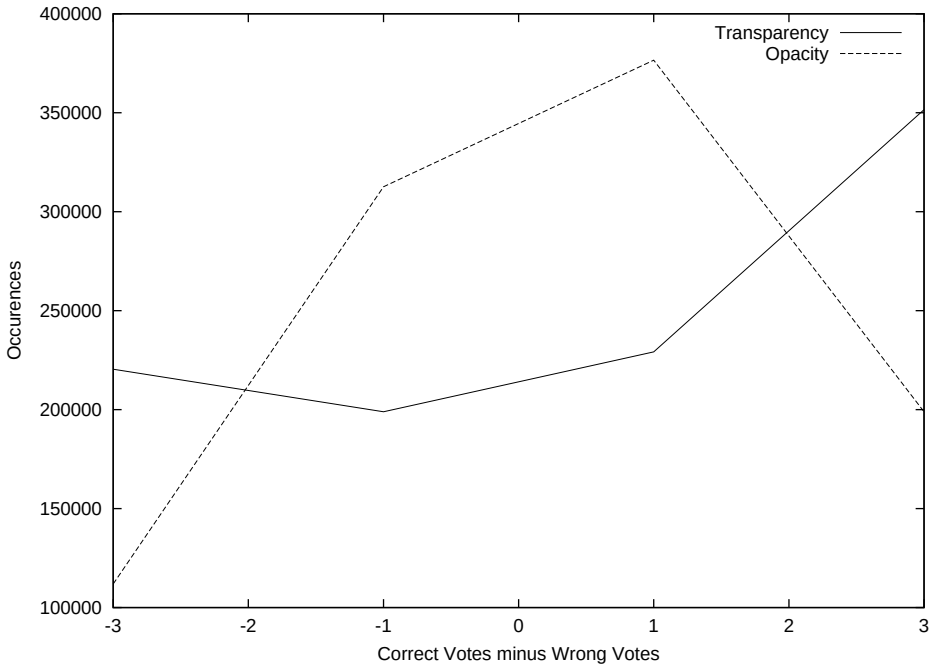


Figure 7.1: Distribution of Votes for $p = 0.6$.

and try to conduct socially beneficial monetary policy. Hence, highly efficient central bankers vote for the interest rate that is suggested by their private signals and less efficient central bankers behave as under opacity in the first period. This behavior minimizes social losses. Losses in the second period merely depend on the distribution of highly efficient and somewhat less efficient central bankers, which in turn depends on the central banker's voting behavior in the first period and the government's re-election scheme. We summarize our observations by the following proposition:

Proposition 7.6
Under both scenarios in the second period, highly efficient central bankers vote for interest rates by following their signals about the optimal interest rate. Somewhat less efficient central bankers randomize between the two possible optimal interest rates with equal probability if they have to cast the first vote; they follow the latest vote otherwise.

We now compare second-period social losses for both scenarios. Since central bankers behave identically under both scenarios, the difference in losses must stem from the different distributions of highly efficient and less efficient central bankers in the second period. Intuitively, on average, there should be more highly efficient central bankers under transparency since the central bank can re-elect or dismiss single central bankers. While a formal proof is not available yet, Monte-Carlo simulations yield the following:

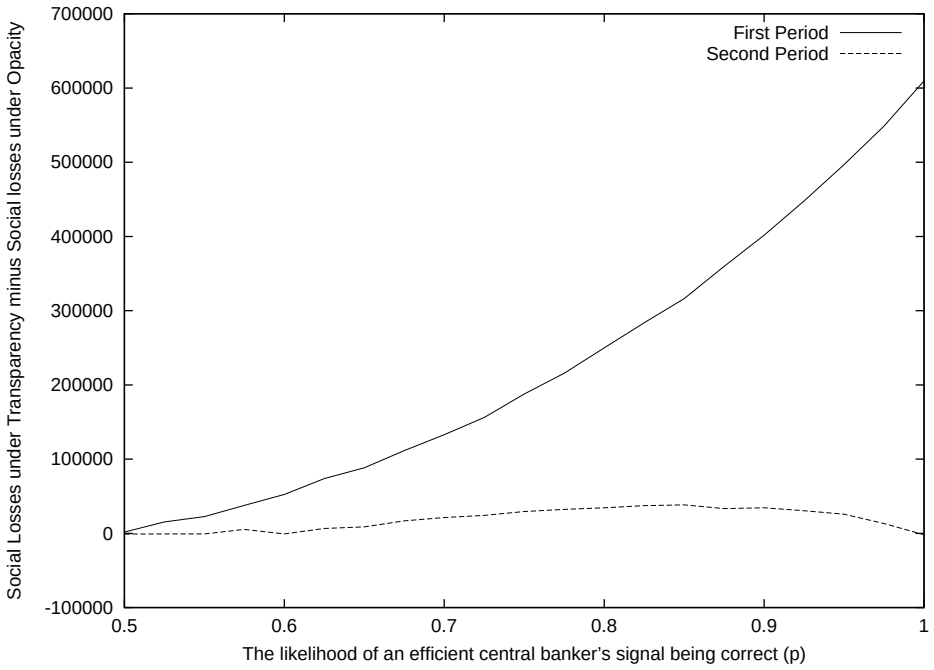


Figure 7.2: Difference in social losses

Simulation Result 7.1
In the second period, expected social losses appear to be lower under transparency.

7.5 Overall Comparison

So far, we have derived that social losses under transparency are higher in the first period but lower in the second period. Our simulations indicate that the absolute amount of difference in losses is always higher in the first period compared to the second. This can also be seen from figure 7.2. Therefore, since the discount rate δ is less than one, we obtain:

Simulation Result 7.2
For all values of p and δ, overall expected losses under transparency appear to be higher than under opacity.

7.6 Conclusion

In this chapter we have shown that the results of chapter 6 remain valid if we consider sequential voting procedures instead of simultaneous voting. If central bankers differ in

competence, less efficient central bankers have an incentive to vote socially inefficiently in their bid to be re-elected. This makes first-period social losses rather large. These losses from transparency cannot be compensated by the welfare gains in the second period which stem from the increased average efficiency of the central-bank council. Additionally, we have shown that transparency makes dissenting voting behavior more likely while consensus decisions occur more often under opacity.

Transparency would lead to even worse results for councils comprising more than three members if individual voting behavior were published without the sequence of votes. Then problems of herding and informational cascades, which are often considered in the context of financial markets, would occur, leading to highly inefficient information aggregation.[10] Suppose the public makes its re-election decision dependent only on individual voting behavior. Then, intuitively, if p is not too large, even efficient central bankers would not follow their own information when a number of preceding voters have voted for the opposite interest rate, because the preceding colleagues' votes are more likely to be correct.[11] This effect leads to inefficient aggregation of information. One may conclude that intermediate transparency, i.e. the publication of votes without the sequence of votes, is not advisable. If full opacity, understood to be the secrecy of votes and the sequence of votes, cannot be guaranteed,[12] then full transparency, i.e. the publication of voting records including the exact sequence of votes, could be a second-best solution.

In the model examined in this chapter, herd behavior of efficient central bankers does not occur even for large central bank councils. We have shown that, no matter how many central bankers have voted for the same interest rate, a highly efficient central banker will always follow his own private information if he has to make his decision following identical votes of his colleagues. The reason for this is that the public takes into account the complete pattern of votes when making its re-election decision instead of considering only the correctness of the individual vote.

If the sequence of votes were endogenous, opacity might perform even better. Under opacity, less efficient central bankers will rather wait for the opinions of their colleagues and then follow their colleagues' decisions. This would increase the overall likelihood of a correct decision. Under transparency, waiting would reveal relative incompetence. Thus the beneficial effect of waiting would not occur.

[10] Cf. Scharfstein and Stein (1990) for an analysis of herd behavior and investment. See also Bikhchandani, Hirshleifer, and Welch (1992) for an examination of conformity of behavior, fragility of mass behavior, and informational cascades.

[11] A thorough analysis reveals that this effect can occur if more than two central bankers have voted for the same interest rate.

[12] Buiter (1999) seems to have a similar viewpoint.

Chapter 8

Voting Transparency and Different Preferences

8.1 Introduction

In this chapter we explore how the transparency of voting records affects monetary policy and social losses when central bankers differ with respect to preferences. For instance, central bankers may value the relative importance of inflation stabilization and output stabilization differently. We analyze this question by considering a simple aggregate-demand/aggregate-supply framework in which central bankers set nominal interest rates.

We show that the transparency of voting records is socially desirable.[1] Central bankers with preferences differing from those of the public have an incentive to vote strategically in order to get re-elected and to influence future monetary policy. However, we show that this incentive is too low to compensate for the utility loss they incur today when they misrepresent their preferences. Consequently, under transparency, the government can dismiss central bankers who have preferences differing from those of the public since those central bankers vote differently from the central bankers who share the public's preferences. Over time, the preferences of the central-bank council are aligned with those of the public. Social losses are therefore lower than under opacity.

Our model also implies that central bankers with the same preferences as the public prefer transparency over opacity. In contrast, central bankers with preferences differing from those of the public prefer opacity over transparency. An intriguing but more speculative implication would be that central bankers opposing transparency might simply have different preferences than the public.

[1] As we argue in section 8.7, when private incentives for holding office are sufficiently strong, transparency and opacity yield identical results and there is no strict social preference for transparency.

This chapter is organized as follows: In the next section, we describe the model. The reappointment scheme is derived in section 8.3. The results under transparency and opacity are derived in the following two sections. We attempt an overall comparison between transparency and opacity in section 8.6. Our conclusions are presented in section 8.7.

8.2 Model

We examine a two-period model in which the government can re-elect or dismiss members of the central-bank council after the first period.

Social losses per period are denoted by $l_A(i)$. The interest rate i is chosen by the central-bank council. Overall losses are:

$$L_A = l_A(i^1) + \delta l_A(i^2)$$

i^1 is the interest rate chosen in the first period and i^2 is the interest rate chosen in the second period. We use δ to denote the discount factor, $0 < \delta < 1$. We deliberately refrain from assuming any particular functional form for social losses and the losses of central bankers. The only assumptions are that there exists a unique interest rate that minimizes losses and that there are no lags that cause the minimum of second-period losses to depend on first-period monetary policy.[2]

It is obvious that the publication of voting records can only have a differential impact if there is some heterogeneity among central bankers.[3] There are two ways in which differences among central bankers can emerge:

- Central bankers may have different preferences, e.g. put different weights on output stabilization.
- Central bankers may have different knowledge about the economy.

In this chapter we follow the first approach. Since there are dissenting views in the central-bank council with respect to what a good monetary policy is, central bankers may be inclined to choose different interest rates.

[2]Particular functional forms can be derived with any monetary model where interest rates have an impact on inflation and/or output and thus on central-bank losses. For concreteness, losses could be given by $(i - i_A)^2$ where i_A, the optimal interest rate, depends on shocks to the economy. In chapter 6 we show that one can obtain such a functional form of losses when considering standard demand and supply equations without time lags, social losses that are quadratic in inflation and output, and supply shocks that are normally distributed.

[3]The heterogeneity could also be caused by identical central bankers belonging to different generations. A model of overlapping generations of central bankers is examined in Sibert (1999).

To focus on the simplest case, we consider two types of central bankers. The first type of central banker, type A, is characterized by the same loss function as the public, whereas the second type, type B, has a different loss function:

$$l_B = l_B(i^1) + \delta l_B(i^2)$$

The optimal interest rate for central bankers of type A is denoted by i_A and the optimal interest rate for type B by i_B.[4] We assume that $i_A \neq i_B$.

By definition of i_A and i_B, and if the optimal interest rates are unique, the following two equations hold:

$$\begin{aligned} l_A(i_A) &< l_A(i_B) \\ l_B(i_B) &< l_B(i_A) \end{aligned}$$

Monetary policy will be conducted by the council of the central bank, which decides on the magnitude of the short-term interest rate by majority rule.

The sequence of events is given as follows:

- **1st Period:**
  - In the beginning of the first period, the original council with N central bankers is formed ($N \geq 1$, N odd). Each member is either of type A with probability p or of type B with probability $1-p$. Each member's preferences are private information.
  - Members simultaneously vote for their preferred interest rate i.
  - The interest rate preferred by the median central banker is set by the central bank.
  - Voting records are published under the transparency requirement or remain secret for all outsiders under intransparency or opacity.
- **2nd Period:**
  - At the beginning of the second period, the re-election of the members of the central-bank council takes place. The government can dismiss any central banker and replace him by another central banker from a pool of candidates. Newly elected central bankers will be of type A with probability p and of type B with probability $1-p$.

[4] Note that, in general, the optimal interest rates i_A and i_B are not constant over time. For instance, they may depend on shocks affecting the supply side of the economy.

– Members simultaneously vote for their preferred interest rate i.

– The interest rate of the median voter is set by the central bank.

8.3 Re-election Schemes

In this section, we discuss the government's re-election procedure. The optimal re-election procedure and the monetary policy proposed by the two types of central bankers interact and must be formulated as equilibrium strategies in the overall game. However, we simplify the analysis at this stage by assuming a certain pattern of monetary policy for different types of central bankers. Later we will justify these assumptions as equilibrium strategies. We assume that one out of only two different possible interest rates will be chosen in the first period of the game. Central bankers will either vote for i_A or for i_B.

Under transparency, it is optimal for the government to re-elect any central banker who has chosen i_A, which is the interest rate preferred by type A central bankers and the public. This strategy will minimize expected social losses in the second period. The re-election scheme is:

$$\begin{aligned} i_{chosen\,by\,j} = i_A \quad &\Rightarrow \quad \text{member } j \text{ is re-elected} \\ i_{chosen\,by\,j} \neq i_A \quad &\Rightarrow \quad \text{member } j \text{ is dismissed} \end{aligned}$$

Without transparency, the government will either fire the whole council or leave them in office because the government does not know how each central banker has voted. If the central bank sets an interest rate i_A, then the public will expect a majority of central bankers to be of type A and will re-elect the whole council. For any other interest rate including i_B, the council will be dismissed.

$$\begin{aligned} i_{chosen\,by\,median\,CBer} = i_A \quad &\Rightarrow \quad \text{the whole council is re-elected} \\ i_{chosen\,by\,median\,CBer} \neq i_A \quad &\Rightarrow \quad \text{the whole council is dismissed} \end{aligned}$$

A subgame-perfect Bayesian equilibrium consists of monetary policy votes in the first and second period, and the re-election scheme.

8.4 Transparency

In the second period, every central banker will choose his preferred interest rate. A central banker of type A will always choose i_A and a central banker of type B will

always vote for i_B. A type A central banker also chooses i_A in the first period. Type B central bankers, however, have an incentive to imitate type A central bankers in the first period in order to get re-elected. Potential influence on future monetary policy is the motive for getting re-elected by imitating a central banker of type A.

In the appendix we show, however, that misrepresenting their preferences is not beneficial for type B central bankers:

Proposition 8.1
Given the proposed re-election scheme, a central banker of type B will always choose i_B in the first period.

By virtue of proposition 8.1, the following equilibrium exists:

Proposition 8.2
Under transparency, a subgame-perfect equilibrium exists in which central bankers of type A choose i_A and type B central bankers vote for i_B in both periods. According to the proposed re-election scheme, every type A central banker is re-elected after period 1 *whereas every type B central banker is dismissed.*

We now justify the proposed re-election scheme (cf. section 8.3). The re-election scheme is optimal since it minimizes expected social losses in the second period. The government knows that each central banker will choose the interest rate that he would set if he were alone. Therefore it is optimal to re-elect only central bankers who have voted for i_A. A larger number of type A central bankers will always improve the outcome of monetary policy in the second period. Therefore, the re-election scheme and the central bankers' interest-rate votes constitute a subgame-perfect equilibrium of the overall game.

8.5 Opacity

We now discuss opacity, implying that voting records are not published. In the second period, each central banker will again vote for his preferred interest rate i_A or i_B respectively. We show that under opacity each central banker behaves in the same manner in the first period. While it seems trivial that no type A central banker has an incentive to deviate from i_A, we show that the respective behavior is also optimal for type B.

In the appendix we prove:

Proposition 8.3
Given the proposed re-election scheme, a central banker of type B will always choose i_B in the first period.

Accordingly, the following equilibrium exists:

Proposition 8.4
Under opacity, a subgame-perfect equilibrium exists in which central bankers of type A choose i_A and type B central bankers vote for i_B in both periods. According to the proposed re-election scheme, the central-bank council will be dismissed if it adopts i_B in the first period. Otherwise, it gets re-elected.

For reasons similar to those detailed in section 8.4 this re-election scheme is optimal.

8.6 Comparison

As we have demonstrated in the last two sections, the central bankers' voting behavior does not depend on the transparency regime under consideration. Each central banker always votes for the interest rate he would choose if he alone could determine monetary policy.[5] The reasoning runs as follows. Central bankers with preferences differing from those of the public have an incentive to vote strategically by pretending to share the public's preferences. This behavior would enable them to get re-elected and hence influence future monetary policy. But these incentives are not sufficiently strong. The benefits from sincere voting stemming from the expected improvement of today's monetary policy are always larger than the benefits gained from voting strategically.

The only difference between transparency and opacity arises in our model due to the government's improved ability to re-elect single favorable central bankers under transparency. Under opacity, only the whole council can be dismissed, whereas under transparency the government can pick individual central bankers with the same preferences as the public and can re-elect them. This makes a monetary policy reflecting the preferences of the public more likely in the second period. Therefore, second-period social losses are lower under transparency. First-period social losses are identical under both

[5]Note, however, that for this result to hold it is crucial that no large private benefits arise from being a central banker, as is assumed in Gersbach and Hahn (2001c). If private benefits accrue to central bankers from their jobs, central bankers preferring a monetary policy different from the one preferred by the public are less willing to reveal their preferences in the first period. A strong desire to get re-elected would yield equivalent results both under transparency and opacity.

regimes since the central bankers' behavior does not depend on the degree of transparency. Hence, from a social perspective the transparency of voting records is more desirable than opacity. This result is summarized by the following proposition:

Proposition 8.5
Expected social losses are lower under transparency.

8.7 Discussion and Conclusion

In this paper we have highlighted that there are considerable benefits resulting from voting transparency since the government can distinguish between single central-bank council members and can make central bankers individually accountable. This conclusion is not restricted to central-bank councils but could be applied to other committees consisting of members with different preferences. However, our analysis is still only a first step towards a firm conclusion about the social desirability of voting transparency.

When sufficiently strong private incentives exist for holding office, transparency and opacity yield identical results with respect to both voting behavior and social welfare. This is the case since strong private incentives for getting re-elected will induce central bankers whose preferences do not square with those of the public to imitate central bankers whose preferences are identical to those of the public. Hence, the public is not able to identify the central bankers' preferences in the first period. It follows that first-period losses are identical under both scenarios. Second-period losses do not differ either since the average distributions of central bankers' preferences are identical and, under neither scenario would any central banker want to misrepresent his preferences in the second period.

It is an interesting question whether central bankers would prefer transparency over opacity. Our model provides a simple answer. Central bankers with the same preferences as the public prefer transparency over opacity, which immediately follows from our main result to the effect that social losses are lower under transparency. In contrast, central bankers with preferences differing from those of the public have a higher probability of getting re-elected under opacity and therefore have a higher chance of achieving an outcome favorable to them in the second period. Therefore those central bankers prefer opacity over transparency. An intriguing but speculative implication would be that real-life central bankers opposing transparency might simply have different preferences than the public.

The positive value of transparency in our set-up needs to be contrasted with the negative net effect of transparency derived in Gersbach and Hahn (2001c), where we consider

different degrees of technical proficiency among central bankers and central bankers with a strong desire to stay in office. Whether transparency is socially desirable from an overall perspective depends on the kind of heterogeneity in central-bank councils.

While differences with respect to preferences are prevalent in central-bank councils, as e.g. the minutes of the Monetary Policy Committee in the UK document, much less information is available on other types of heterogeneity. From such a perspective one might arrive at the tentative conclusion that voting transparency is socially beneficial.

Chapter 9

Goal Transparency

9.1 Introduction

In this chapter we present a simple one-period model in the spirit of Kydland and Prescott (1977) and Barro and Gordon (1983) to evaluate whether goal transparency, i.e. transparency about the objectives of monetary policy, is desirable. In recent years, many central banks, especially inflation-targeting central banks, have specified numerical values for their inflation targets or the respective target ranges. The ECB has also specified its objective as an inflation rate of more than 0% and less than 2%. However, it is beyond doubt that central banks often also care about other goals such as employment or output stabilization in the short run. But no central bank has specified yet the exact relative significance of the sometimes conflicting objectives for output and inflation.[1] This raises the question of whether more transparency in this respect would be beneficial. This question will be addressed in the following model.

9.2 Model

Let us assume that employment l is described by the expectations-augmented Phillips curve:

$$l = l_0 + \pi - \pi^e \tag{9.1}$$

l_0 is the natural rate of employment. We use π to denote inflation and π^e to denote the inflation expectations of the public. Central-bank losses are assumed to be:

$$L^{CB} = \pi^2 + a(l^* - l)^2$$

[1] Also cf. Cukierman (2000b).

a is the significance the central bank attaches to the employment target and is assumed to be uniformly distributed on $[0; A]$, with $A > 0$. The employment target equals $l^* = l_0 + \Delta$ and is above the natural rate of employment l_0 ($\Delta > 0$). Inserting the Phillips-curve equation (9.1), we can rewrite the central-bank loss function as:

$$L^{CB} = \pi^2 + a(\Delta + \pi^e - \pi)^2$$

The realization of a is always known to the central bank, but remains unknown to the public under secrecy. Under transparency, the realization of a is revealed to the public. The different realizations of a could be interpreted as the uncertain impact of lobbying by different interest groups, some of them favoring low inflation, some of them putting high emphasis on low employment. Or a may simply reflect the idiosyncratic preferences of elected central bankers.

We assume social losses to be non-stochastic and given by:

$$L^S = \pi^2 + b(l^* - l)^2$$

The fixed parameter b ($b \geq 0$) is the significance society assigns to the employment target. In general, b is therefore different from a, but we will later examine the case where $b = A/2$, i.e. where a and b are on average identical.

After the public has formed its inflation expectations, the central bank chooses its monetary instrument, namely inflation. The minimization of the central bank's loss function yields the first-order condition for the central bank's optimal choice of π as a function of π^e:

$$\pi = a(\Delta + \pi^e - \pi)$$

Solving for π, we obtain:

$$\pi = \frac{a}{1+a}(\Delta + \pi^e) \tag{9.2}$$

For further evaluation, we need to distinguish between transparency and opacity.

9.3 Transparency

First, we consider the case with goal transparency. Since the public knows the central bank's preferences, inflation expectations depend on the realization of a. Using the above equation (9.2) for π, we obtain that rational inflation expectations are given by:

$$\pi^e = a\Delta$$

Inserting $\pi^e = a\Delta$ into equation (9.2) yields:

$$\pi = a\Delta$$

Summarizing our result, we present the following proposition:

Proposition 9.1
Under transparency, for every realization of a, a unique subgame-perfect Nash equilibrium exists. The public expects inflation to be $\pi^e = a\Delta$ and the central bank chooses an inflation rate of $\pi = a\Delta$. Social losses amount to $L_T^S = a^2\Delta^2 + b\Delta^2$.

In order to compare the performance under goal transparency and the performance under the secrecy of objectives, we have to compute social losses under transparency, which are given by:

$$E[L_T^S] = E\left[a^2\right]\Delta^2 + b\Delta^2$$

Using that a is uniformly distributed, this equation can be simplified to:

$$E[L_T^S] = \frac{1}{3}A^2\Delta^2 + b\Delta^2$$

Note that $E[L_T^S]$, i.e. expected social losses, are increasing in A. This means that the more conservative on average the central bank is, the lower the social losses are. This is another variant of the famous result by Rogoff (1985) that the appointment of a conservative central banker, i.e. a central banker who cares less about employment than society, can be beneficial.

9.4 Opacity

Under opacity, inflation expectations do not depend on the realization of a, because the realization of a is unknown to the public at the point in time when they form expectations. Using equation (9.2), $\pi = \frac{a}{1+a}(\Delta + \pi^e)$, we obtain that:[2]

$$\begin{aligned}\pi^e &= E\left[\frac{a}{1+a}\right](\Delta + \pi^e)\\ &= \frac{1}{A}\left[a - \ln(1+a)\right]_{a=0}^{A}(\Delta + \pi^e)\\ &= \frac{1}{A}\left(A - \ln(1+A)\right)(\Delta + \pi^e)\end{aligned}$$

Solving for π^e yields:

$$\pi^e = \frac{A - \ln(1+A)}{\ln(1+A)}\Delta$$

Using again equation (9.2), $\pi = \frac{a}{1+a}(\Delta + \pi^e)$, inflation can be computed as:

$$\pi = \frac{a}{(1+a)}\frac{A}{\ln(1+A)}\Delta$$

[2]Note that we use the definition $[F(a)]_{a=0}^{A} := F(A) - F(0)$.

Summarizing our results, we obtain the following proposition:

Proposition 9.2
Under opacity, the following perfect Bayesian Nash equilibrium exists. Society expects inflation to be $\pi^e = \frac{A-\ln(1+A)}{\ln(1+A)}\Delta$. *Depending on the realization of* a, *the central bank chooses an inflation rate of* $\pi = \frac{a}{(1+a)}\frac{A}{\ln(1+A)}\Delta$.

In order to be able to compare the performance of goal transparency and the secrecy of objectives, we again have to compute expected social losses, denoted by $E[L_O^S]$:

$$\begin{aligned} E[L_O^S] &= E\left[\left(\frac{a}{1+a}\right)^2\right]\left(\frac{A}{\ln(1+A)}\right)^2\Delta^2 \\ &\qquad + bE\left[\left(\Delta + \frac{A-\ln(1+A)}{\ln(1+A)}\Delta - \frac{a}{1+a}\cdot\frac{A}{\ln(1+A)}\Delta\right)^2\right] \\ &= \frac{1}{A}\left[a - \frac{1}{1+a} - 2\ln(1+a)\right]_{a=0}^{A}\left(\frac{A}{\ln(1+A)}\right)^2\Delta^2 \\ &\qquad + bE\left[\left(\frac{1}{1+a}\cdot\frac{A}{\ln(1+A)}\right)^2\right]\Delta^2 \end{aligned}$$

Simplifying further, we obtain:

$$\begin{aligned} E[L_O^S] &= \frac{1}{A}\left(A - \frac{1}{1+A} - 2\ln(1+A) + 1\right)\left(\frac{A}{\ln(1+A)}\right)^2\Delta^2 \\ &\qquad + \frac{1}{A}\left[-\frac{1}{1+a}\right]_{a=0}^{A}\left(\frac{A}{\ln(1+A)}\right)^2 b\Delta^2 \\ &= \left(\frac{2+A}{1+A} - \frac{2\ln(1+A)}{A}\right)\left(\frac{A}{\ln(1+A)}\right)^2\Delta^2 + \frac{1}{1+A}\left(\frac{A}{\ln(1+A)}\right)^2 b\Delta^2 \end{aligned}$$

Again, one can show that expected social losses $E[L_O^S]$ increase when A increases. Hence, the more conservative the central bank is on average, i.e. the less it cares about employment, the lower social losses are. For $A \to \infty$ social losses become $\lim_{A\to\infty} = b\Delta^2$.

9.5 Comparison

In this section we examine whether transparency or opacity yield lower social losses. Let us first compare the second term of expected losses under transparency with the second term of expected losses under opacity. In the appendix we show that:

$$1 < \frac{1}{1+A}\left(\frac{A}{\ln(1+A)}\right)^2$$

Thus for sufficiently large values of b, which imply that the second terms of the expressions for social losses, i.e. $bE\left[(l-l^*)^2\right]$, dominate, social losses are lower under transparency.

The first terms of the expressions for social losses, i.e. $E\left[\pi^2\right]$, dominate for very low values of b, i.e. if society does not care very much about the employment target. Numerical computations show that:[3]

$$\frac{1}{3}A^2 > \left(\frac{2+A}{1+A} - \frac{2\ln(1+A)}{A}\right)\left(\frac{A}{\ln(1+A)}\right)^2$$

Thus, for sufficiently small values of b, our findings about the relative performance of goal transparency and opacity is reversed; losses are lower under opacity.

Hence, transparency may lead to lower losses in terms of employment $E\left[(l^*-l)^2\right]$, but to larger losses in terms of inflation $E\left[\pi^2\right]$.

Applying the mean-value theorem, we obtain the following proposition:

Proposition 9.3
For each value of the parameter A, a unique value of b exists, which we denote by b^*, such that for $b = b^*$, social losses are identical under goal transparency and opacity. If and only if $b > b^*$, i.e. if society cares sufficiently about employment, then goal transparency yields lower social losses than opacity. If and only if $b < b^*$, i.e. if society cares sufficiently little about employment, then goal transparency yields higher social losses than opacity.

An interesting case is $b = A/2$ which implies that on average the preferences of the public are identical to the central banks' preferences. Numerical computations for show that:[4]

$$\left(\frac{2+\frac{3}{2}A}{1+A} - \frac{2\ln(1+A)}{A}\right)\left(\frac{A}{\ln(1+A)}\right)^2 > \frac{1}{3}A^2 + \frac{A}{2}$$

This implies the following corollary:

Corollary 9.1
For $b = A/2$, i.e. if on average the central bank has the same preferences as the public, then social losses are larger under opacity.

If, however, $b > A/2$, which seems realistic since the central bank is usually thought to generally care more about inflation relative to employment than the public, then it is unclear whether transparency or opacity yield lower social losses.

[3] This has been confirmed numerically for $A = 0.01, 0.02, ..., 99.99, 100$.
[4] This has also been confirmed numerically for $A = 0.01, 0.02, ..., 99.99, 100$.

Another interesting question is whether goal transparency or opacity yield lower social losses if we consider a fixed value of b and let A be close to zero. This represents the realistic case where the central bank is very conservative whilst a small amount of uncertainty about its preferences may remain. Then we obtain the following result:

Corollary 9.2
If b is fixed and A is sufficiently small, then goal transparency is socially detrimental.

Proof. First note that for $A = 0$ social losses under transparency and opacity are identical and equal to $b\Delta^2$. It can be easily verified that $\lim_{A\to 0} \frac{\partial E[L_O^S]}{\partial A} = 0$. On the other hand, $\lim_{A\to 0} \frac{\partial E[L_T^S]}{\partial A} = 0$.[5] Hence, the first derivatives equal for $A \to 0$ and we have to examine the second derivatives. Again, it is readily verified that $\lim_{A\to 0} \frac{\partial^2 E[L_O^S]}{\partial A^2} = \frac{2}{3}$. On the other, $\lim_{A\to 0} \frac{\partial^2 E[L_T^S]}{\partial A^2} = \frac{2}{3} + \frac{1}{6}b$.[6] Hence, the second derivative of social losses under transparency is larger than the second derivative of social losses under opacity for $b > 0$.

□

Nevertheless, for small A, the difference in losses under transparency and opacity is very small, thus opacity and transparency are almost equivalent.

9.6 Conclusions

We have shown that goal transparency has two effects on social losses. Firstly, it raises social losses in terms of inflation, i.e. $E[\pi^2]$. And secondly, it lowers social losses in terms of employment, i.e. $E\left[(l^* - l)^2\right]$. Whether goal transparency is socially desirable thus depends on the relative significance a society assigns to the inflation target and the employment target, i.e. on the size of the parameter b.

Why are losses in terms of employment larger under opacity? The reason is that under transparency there is symmetric information and thus inflation expectations always equal actual inflation. Employment does not depend on the realization of the shock to the central bank's preferences. This is different under opacity. On average, inflation expectations also equal actual inflation. But due to the asymmetric information, for some realizations of the shock to central-bank preferences inflation is above expectations and for some realizations inflation is lower than expectations. This causes variations in employment, which in turn create social losses as they depend quadratically on the

[5] This result has been obtained analytically using "Maple V Release 4".
[6] This result has also been obtained by "Maple".

deviation of employment from its target. Hence, goal transparency eliminates socially detrimental variations in employment since under transparency inflation expectations are more accurate.

The intuition for the second effect of goal transparency, which leads to larger losses in terms of inflation, is more subtle. Suppose first that the realization of a is rather large. Then under transparency, inflation expectations are also comparably large. But under opacity, since a is not known to the public, inflation expectations are smaller. Since inflation expectations are higher under transparency for large a, marginal benefits of surprise inflation $MB = -\frac{\partial a(\Delta+\pi^e-\pi)^2}{\partial \pi} = 2a(\Delta+\pi^e-\pi)$ are larger compared to opacity for a given value of π. Marginal costs of inflation $MC = \frac{\partial \pi^2}{\partial \pi} = 2\pi$ do not depend on inflation expectations. The optimal choice of inflation by the central bank equalizes marginal costs and benefits of inflation. Since for every given value of π marginal benefits of inflation are larger under transparency whilst marginal costs are identical, the central bank chooses larger inflation rates under transparency than under opacity if a is large. If the realization of a is small, then the opposite holds and inflation rates are higher under opacity. Note that inflation rates under both scenarios are the larger, the larger are the realizations of a. Therefore, since social losses are a convex function of inflation, the increase in inflation rates caused by goal transparency for large values of a has a stronger impact on ex-ante social losses than the respective reduction in inflation rates for low values of a. Hence, expected social losses in terms of inflation are larger under transparency from an ex-ante viewpoint.

Since it is necessary to examine the robustness of our findings more thoroughly, the findings of this model should be taken with caution. Other kinds of uncertainty about central bank's preferences should be considered, e.g. shocks to the central bank's inflation target. The robustness in respect to shocks and variations of the model should be considered carefully.

Another concern stems from the fact that announcements about objectives, in particular announcements about the relative significance of objectives, may be non-verifiable. If the time-inconsistency problem cannot be neglected, then there are incentives for central bankers to misrepresent their preferences. It is not clear how transparency as defined in the model, i.e. the mere release of a parameter of the central-bank loss function, can be achieved. Another important aspect is that goal transparency is often introduced in cooperation with the government. E.g. in New Zealand, goal transparency was improved substantially by a formal contract - the Policy Targets Agreement - where the government and the central banks define the goals of monetary

policy.[7] This contract contributes to goal transparency, but also affects the objectives of the central bank. If goal transparency has the side-effect that the preferences of the central bank are closer to those that are socially optimal, then goal transparency may be beneficial.

[7] Cf. Briault, Haldane, and King (1996).

Appendix A

Proofs for Chapter 2

Proof of Proposition 2.1 Using equation (2.2), the expected losses of union j are given by:

$$L_j = -2(w_j - E[p|x]) + AE[u_j^2|x] + BE[p^2|x]$$

Minimizing the expected losses for union j and using $\frac{\partial \overline{w}}{\partial w_j} = \frac{1}{n}$ yields the first-order condition:

$$\begin{aligned} 0 &= \frac{1}{2}\frac{\partial}{\partial w_j}E[L_j|x] \\ &= \frac{a\alpha^2}{n(1+a\alpha^2)} - 1 + A\alpha\frac{n+(n-1)a\alpha^2}{n(1+a\alpha^2)}E[u_j|x] + B\frac{a\alpha^2}{n(1+a\alpha^2)}E[p|x] \end{aligned}$$

This equation describes the optimal choice of w_j depending on the wages set by the other unions. Due to the symmetry of the problem, all wages must equal in equilibrium. Therefore, $w_j = \overline{w}$ holds. It follows from (2.5) and (2.10) that

$$E[u_j|x] = \alpha\big(w_j - E[p|x] - E[\epsilon|x] - w_r^c\big)$$

and

$$E[p|x] = \frac{a\alpha^2}{1+a\alpha^2}\big(w_j - w_r^c - E[\epsilon|x]\big).$$

Inserting these equations into the first-order condition for the best response and rearranging the terms we obtain:

$$n(1+a\alpha^2) = a\alpha^2 + (\overline{w} - w_r^c - E[\epsilon|x])\left(\frac{A\alpha^2\big(n+(n-1)a\alpha^2\big)}{1+a\alpha^2} + B\frac{a^2\alpha^4}{1+a\alpha^2}\right).$$

Solving for $\overline{w}$ yields the equilibrium wage, denoted by $\overline{w}^{NR}$. Inserting $\overline{w}$ into equation (2.11) leads to the equilibrium inflation rate.

□

Proof of Proposition 2.2 The minimization of union j's loss function yields the first-order condition:

$$\begin{aligned} 0 &= \frac{1}{2}\frac{\partial}{\partial w_j}E[L_j|x] \\ &= \frac{\partial}{\partial w_j}E[p|x] - 1 + A\alpha E[u_j|x]\left(1 - \frac{\partial}{\partial w_j}E[p|x]\right) + BE[p|x]\frac{\partial}{\partial w_j}E[p|x] \end{aligned}$$

In a symmetric equilibrium, we must have $w_i = w_j$, $\forall i \neq j$ and therefore $\overline{w} = w_j$, $\forall i \neq j$. In a fully separating equilibrium, the central bank can completely infer the unions' information from the observed wage, i.e. $E_{CB}[\epsilon|\overline{w}] = E[\epsilon|x]$. We define $f(w_j) := E_{CB}[\epsilon|w_j]$ and use (2.5) and (2.10) to obtain:

$$\begin{aligned} E[p|x] &= \frac{a\alpha^2}{1+a\alpha^2}\Big(\overline{w} - w_r^c - f(\overline{w})\Big), \\ E[u_j|x] &= \alpha\big(w_j - E[p|x] - E[\epsilon|x] - w_r^c\big) \\ &= \alpha\left(w_j - \frac{a\alpha^2}{1+a\alpha^2}\Big(\overline{w} - w_r^c - f(\overline{w})\Big) - E[\epsilon|x] - w_r^c\right), \\ \frac{\partial}{\partial w_j}E[p|x] &= \frac{a\alpha^2}{1+a\alpha^2}\left(1 - f'(\overline{w})\right)\frac{\partial}{\partial w_j}\overline{w} \\ &= \frac{a\alpha^2}{n(1+a\alpha^2)}\left(1 - f'(\overline{w})\right), \\ \frac{\partial}{\partial w_j}E[u_j|x] &= \alpha\left(1 - \frac{a\alpha^2}{1+a\alpha^2}\left(1 - f'(w_j)\right)\frac{\partial}{\partial w_j}\overline{w}\right) \\ &= \alpha\left(1 - \frac{a\alpha^2}{n(1+a\alpha^2)}\left(1 - f'(\overline{w})\right)\right). \end{aligned}$$

In a symmetric fully separating equilibrium $\overline{w} = w_j$ and $E[\epsilon|x] = f(w_j)$ must hold. Then the third of the above equations simplifies to:

$$E[u_j|x] = \frac{\alpha}{1+a\alpha^2}\Big(w_j - w_r^c - f(w_j)\Big)$$

Inserting these equations into the first-order condition, we obtain the following differential equation:

$$\begin{aligned} 0 = {} & \frac{a\alpha^2}{n(1+a\alpha^2)}\big(1 - f'(w_j)\big) - 1 \\ & + \frac{A\alpha^2}{1+a\alpha^2}\big(w_j - w_r^c - f(w_j)\big)\left(1 - \frac{a\alpha^2}{n(1+a\alpha^2)}\big(1 - f'(w_j)\big)\right) \\ & + B\frac{a^2\alpha^4}{n(1+a\alpha^2)^2}\big(w_j - w_r^c - f(w_j)\big)\big(1 - f'(w_j)\big) \end{aligned}$$

In a fully separating equilibrium, the central bank's beliefs must satisfy $E_{CB}[\epsilon|\overline{w}] = E[\epsilon|x]$. Together with $E_{CB}[\epsilon|w_j] = E[\epsilon|x]$ which must hold for every union j this implies

that $f(w_j)$ is a linear function if $n \geq 2$. Therefore, we can set $f(w_j) = (1-m)w_j - q - w_r^c$, with m and q parameters left to be determined. Inserting this expression into the differential equation, which must hold for any w_j, yields:

$$m = 0, \qquad q = \frac{1}{A}\left(a + \frac{1}{\alpha^2}\right)$$

Thus, we have identified $E_{CB}[\epsilon|\overline{w}]$ and shown that it is unique.[1] Using these results we obtain the proposed equilibrium values for p and w_j.

□

Proof of Proposition 2.3 We first derive unions' losses if the central bank observes the information of unions directly. Recall from proposition 2.1 that the equilibrium values of inflation and real wage are given by

$$\begin{aligned} p^{NR} &= c\,a \\ \overline{w}^{NR,r} &= w_r^c + E[\epsilon|x] + c\,\frac{1}{\alpha^2} \end{aligned}$$

where we have set

$$c := \frac{1}{A + \frac{a^2\alpha^2}{n+(n-1)a\alpha^2}B}.$$

Inserting these equations into union j's loss function we obtain:

$$L_j^{NR} = -2\left(w_r^c + E[\epsilon|x] + \frac{c}{\alpha^2}\right) + A\Big(c + \alpha\left(E[\epsilon|x] - \epsilon\right)\Big)^2 + Bc^2a^2$$

In order to compute union j's losses if the central bank knows the mean wage only, which corresponds to proposition 2.2, we can simply set $c := 1/A$. We obtain

$$L_j^N = -2\Big(w_r^c + E[\epsilon|x] + \frac{1}{A\alpha^2}\Big) + A\Big(\frac{1}{A} + \alpha\left(E[\epsilon|x] - \epsilon\right)\Big)^2 + \frac{B}{A^2}a^2$$

We compute the difference of losses:

$$\begin{aligned} \Delta L_j &= L_j^{NR} - L_j^N \\ &= -\frac{2}{\alpha^2}\Big(c - \frac{1}{A}\Big) + A\left(\Big(c^2 - \frac{1}{A^2}\Big) + 2\alpha\Big(c - \frac{1}{A}\Big)\left(E[\epsilon|x] - \epsilon\right)\right) + Ba^2\Big(c^2 - \frac{1}{A^2}\Big) \\ &= 2\Big(\frac{1}{A} - c\Big)\left[\frac{1}{\alpha^2} - \frac{A + Ba^2}{2}\Big(\frac{1}{A} + c\Big) - A\alpha\left(E[\epsilon|x] - \epsilon\right)\right] \end{aligned}$$

[1] For $B = 0$ another solution exists for m: $m = na\alpha^2/(1+a\alpha^2)$. The resulting equilibrium, however, is not stable, since all unions would be indifferent between the equilibrium wage and any other wage. In addition, the central bank's expectation about the shock would decrease when wages increase, which does not seem plausible.

The expected difference of losses hence amounts to

$$E\big[\Delta L_j|x\big] = 2\Big(\frac{1}{A} - c\Big)\left[\frac{1}{\alpha^2} - \frac{A + Ba^2}{2}\Big(\frac{1}{A} + c\Big)\right]$$

For the direct observation of real variables by the central bank to be beneficial for unions, this expression must be positive. Rearranging the resulting inequality, inserting the definition of c, and using the fact that $c < 1/A$ yields the proposed condition.

□

Appendix B

Proofs for Chapter 4

Proof of Proposition 4.2 Let us consider only the behavior of CB^+. Assume $\pi^e(\pi_t) = \pi_t$. According to our rational-expectations assumption it follows that CB^+ has no incentive to create surprise inflation, i.e. to choose $\pi = \pi_t + \delta$ given $\pi^e = \pi_t$. Equilibrium losses for CB^+ are:

$$L^+ = \pi_t^2 + a\Delta^2$$

Losses for CB^+ when creating surprise inflation would amount to:

$$L^{+\prime} = (\pi_t + \delta)^2 + a(\delta - \Delta)^2$$

Thus, surprise inflation is not profitable if

$$\begin{aligned} L^+ &\leq L^{+\prime} \\ \pi_t^2 + a\Delta^2 &\leq (\pi_t + \delta)^2 + a(\delta - \Delta)^2 \\ \pi_t &\geq \frac{2a\Delta - (1+a)\delta}{2} = \frac{b-1}{2}\delta =: \pi_c. \end{aligned}$$

Let us briefly summarize our arguments: if $\pi^e(\pi_t) = \pi_t$, then $\pi_t \geq \pi_c$ holds. If $\pi_t < \pi_c$, then $\pi^e(\pi_t) \neq \pi_t$ must hold for a central bank of type CB^+.

□

Proof of Proposition 4.4 Let us now check whether the proposed equilibrium actually exists.

1. First, assume that we can neglect the behavior of CB^- and that it will simply imitate CB^0. Hence, we will only consider two types of bank. This assumption will be justified later.

2. Now we derive some properties of the expectations of the public $\pi^e(\pi_t)$. This function must be a step function with possible values of $\pi^e = \pi_t$, $\pi^e = \pi_t + \frac{1}{2}\lambda\delta$ or $\pi^e = \pi_t + \delta$, representing the different possible beliefs of the public about the type of central bank.[1] Suppose a separating equilibrium in pure strategies exists. The inflation target chosen by CB^+ and CB^0 is denoted by π_t^+ and π_t^0 respectively. Then, in equilibrium, we must have $\pi^e(\pi_t^0) = \pi_t$ and $\pi^e(\pi_t^+) = \pi_t + \delta$. Note that $\pi^e(\pi_t)$ must be constant in an open interval around π_t^+. Otherwise CB^+ could change π_t by an infinitesimal amount and thereby reduce its losses. But this means that π_t^+ must equal $-\delta$ since only at this point CB^+ does have no incentive to change π_t, provided the expectations of the public are $\pi^e = \pi_t + \delta$. From these first results, we can also derive the value π_t^0.

3. CB^+ has no incentive to mimic CB^0, i.e. to choose $\pi_t = \pi_t^0$ (or even higher values of π_t). Equilibrium losses for CB^+ amount to:

$$L^+ = a\Delta^2$$

If CB^+ chooses $\pi_t = \pi_t^0$, losses are:

$$L^{+\prime} = (\pi_t^0 + \delta)^2 + a(\delta - \Delta)^2$$

CB^+ does not want to deviate if

$$\begin{aligned} L^{+\prime} &\geq L^+ \\ (\pi_t^0 + \delta)^2 &\geq \delta(2\Delta - \delta). \end{aligned}$$

Thus, the lowest level of π_t^0 consistent with this condition is given by:

$$\pi_t^0 = \sqrt{a\delta(2\Delta - \delta)} - \delta = (\sqrt{b} - 1)\delta$$

4. It is not reasonable for CB^0 to choose $\pi_t > \pi_t^0$ since losses would increase. Now we show that CB^0 has no incentive to choose $\pi_t < \pi_t^0$ either. If this deviation were profitable, CB^0 would do best to choose $\pi_t = 0$. Equilibrium losses are:

$$L^0 = (\pi_t^0)^2 + a\Delta^2 + (1 + a)\delta^2$$

If CB^0 deviates, losses amount to:

$$L^{0\prime} = a(\delta + \Delta)^2 + (1 + a)\delta^2$$

[1] We only consider equilibria in pure strategies.

The deviation is not profitable if

$$\begin{aligned} L^0 &< L^{0\prime} \\ (\pi_t^0)^2 + a\Delta^2 &< a(\delta + \Delta)^2 \\ (\sqrt{b} - 1)^2 &< b + 2a \\ \sqrt{b} &> \frac{1}{2} - a. \end{aligned}$$

Since by assumption $b \geq 1$ and $a > 0$, this inequality holds.

5. We will now justify our assumption concerning the behavior of CB^-. Obviously no profitable deviation $\pi_t' < \pi_t^0$ for CB^- exists since the best deviation $\pi_t' < \pi_t^0$ for CB^- is the same as the best deviation for CB^0 (i.e. $\pi_t = 0$ and therefore $\pi = 0$). Hence, the only deviation left to be checked is: CB^- chooses $\pi_t = \pi_t^0$ but selects a monetary policy that yields $\pi = \pi_t^0 - \delta$. This deviation is not profitable if

$$\begin{aligned} (\pi_t^0)^2 + a\Delta^2 &< (\pi_t^0 - \delta)^2 + a(\Delta + \delta)^2 \\ 2\sqrt{b} &< b + 2a + 3 \end{aligned}$$

which always holds for $b > 1$ and $a > 0$.

6. Now we need to check whether $\pi_t^0 < \pi_c$. If not, there could be a contradiction between our assumptions on the inflation expectations $\pi^e(\pi_t)$ and proposition 4.2.

$$\begin{aligned} \pi_t^0 &< \pi_c \\ \sqrt{b} - 1 &< \frac{b-1}{2} \end{aligned}$$

This is always true since $b \geq 1$. Thus there is no contradiction to our assumption about $\pi^e(\pi_t)$.

7. Finally, we check whether the intuitive criterion is satisfied. We can be sure that $\pi_t \in]-\delta, \pi_t^0[$ is equilibrium dominated for CB^+ because losses for CB^+ definitely decrease if it chooses $\pi_t \in]-\delta, \pi_t^0[$ and the public believes $\pi^e = \pi_t$. Hence, the intuitive criterion is satisfied in the crucial region $\pi_t \in]-\delta, \pi_t^0[$.

Hence, the proposed equilibrium exists.

□

Proof of Proposition 4.6 While pooling equilibria may exist for special parameter values, we will now show that no pooling equilibrium for $b \geq 1$ satisfies the intuitive criterion.[2]

Assume a pooling equilibrium exists with inflation targets π_t^* for all types of banks. For this equilibrium to exist the public must make every deviation from this equilibrium inflation target unprofitable by expecting high inflation. Thus, for the expectations of the public we obtain:

$$\pi^e(\pi_t) = \pi_t + \begin{cases} 1/2\lambda\delta & \text{for } \pi_t = \pi_t^* \\ \delta & \text{otherwise} \end{cases} \tag{B.1}$$

Pooling equilibria can be eliminated by applying the intuitive criterion if a deviation π_t' exists for every equilibrium inflation target π_t^*, which fulfills the following properties:

1. CB^+ does not want to select π_t' (independent of the beliefs of the public at π_t');
2. at π_t' CB^0 has losses lower than the equilibrium losses if the public expects the type of central bank to be CB^0 at π_t'.

These two conditions yield two different inequalities:

1. Equilibrium losses for CB^+ amount to:

   $$L^+ = (\pi_t^* + \delta)^2 + a\Big((1 - 1/2\lambda)\delta - \Delta\Big)^2$$

   The deviation would be most profitable if the public believed the type to be CB^0 at π_t'. Thus losses would amount to:

   $$L^{+\prime} = (\pi_t' + \delta)^2 + a(\delta - \Delta)^2$$

   The deviation is not desirable if:

   $$\begin{aligned} L^{+\prime} &> L^+ \\ (\pi_t' + \delta)^2 &> (\pi_t^* + \delta)^2 + a\Big(\big((1 - 1/2\lambda)\delta - \Delta\big)^2 - (\delta - \Delta)^2\Big) \end{aligned}$$

[2] We will omit the conditions for the existence of pooling equilibria here. We can however establish that these conditions can be satisfied for sufficiently large values of a. The inflation expectations (equation (B.1)) lead to costs for a central bank's deviations. These costs are increasing in a. Therefore, pooling equilibria exist for large a.

Reorganizing the second term of the right side

$$\begin{aligned} & a\Big(\big((1-1/2\lambda)\delta-\Delta\big)^2-(\delta-\Delta)^2\Big) \\ = \;& a\delta\Big(\big((1-1/2\lambda)^2-1\big)\delta+2\Delta\big(1-(1-1/2\lambda)\big)\Big) \\ = \;& \lambda\delta a\Big(-\delta+1/4\lambda\delta+\Delta\Big) \\ = \;& \lambda\delta^2 a\Big(\frac{b+a}{2a}+a\big(1/4\lambda-1\big)\Big) \\ = \;& \frac{\lambda\delta^2}{2}\Big(b+a\big(1/2\lambda-1\big)\Big) \end{aligned}$$

we obtain the condition:[3]

$$(\pi_t'+\delta)^2 > (\pi_t^*+\delta)^2+\frac{\lambda\delta^2}{2}\Big(b+a\big(1/2\lambda-1\big)\Big) =: e^2 \qquad e>0$$

2. The deviation must be profitable for CB^0 if the public believes the type is CB^0 at π_t'. Equilibrium losses are given by:

$$L^0 = \pi_t^{*2}+a\big(1/2\lambda\delta+\Delta\big)^2$$

Losses for the deviation amount to:

$$L^{0\prime} = \pi_t'^2+a\Delta^2$$

For the deviation to be profitable we must have:

$$\begin{aligned} L^{0\prime} &< L^0 \\ \pi_t'^2 &< \pi_t^{*2}+a\delta\big(\lambda\Delta+1/4\lambda^2\delta\big) \\ \pi_t'^2 &< \pi_t^{*2}+\frac{\delta^2\lambda}{2}\big(b+a(1+1/2\lambda)\big) =: f^2 \qquad f>0 \end{aligned}$$

A sufficient condition for the existence of a π_t' satisfying the two inequalities is:

$$\delta+f>e$$

Inserting the expressions for e and f and simplifying the inequality yields:

$$\sqrt{\pi_t^{*2}+\frac{\delta^2\lambda}{2}(b+a(1+1/2\lambda))} > \pi_t^*-\frac{\lambda\delta a}{2}$$

This inequality holds if either

$$\pi_t^* < \frac{\lambda\delta a}{2}$$

[3]Obviously, e does not necessarily exist, i.e. e^2 may be negative. But this is not essential since the proposition holds trivially if e does not exist. This follows because of the next condition $\pi_t'^2 < f^2$. E.g. $\pi_t{}' = 0$ is always a solution when $e^2 < 0$.

or

$$\begin{aligned} \pi_t^{*2} + \frac{\delta^2\lambda}{2}\Big(b + a(1+1/2\lambda)\Big) &> \Big(\pi_t^* - \frac{\lambda\delta a}{2}\Big)^2 \\ \pi_t^* &> \frac{\delta}{2}\Big(\frac{\lambda}{2}a - \frac{b}{a} - 1 - \frac{1}{2}\lambda\Big). \end{aligned}$$

But since the right side of the last inequality is smaller than $\lambda\delta a/2$, a deviation π_t' exists for every π_t^* that satisfies the two conditions enabling us to exclude the pooling equilibrium. Hence, any pooling equilibrium can be eliminated using the intuitive criterion.

□

Proof of Proposition 4.7 There are two candidate deviations (all other deviations are less attractive).

1. CB^0 chooses $m = \delta$. Losses would be:

   $$L^{0\prime} = \delta^2 + a(\Delta - \delta)^2 + (1+a)\delta^2$$

   Equilibrium losses amount to:

   $$L^0 = a\Delta^2 + (1+a)\delta^2$$

   For the deviation to be unprofitable $L^{0\prime} \geq L^0$ must hold and therefore

   $$\begin{aligned} \delta^2 + a(\Delta - \delta)^2 &\geq a\Delta^2 \\ b &\leq 1 \end{aligned}$$

   which corresponds to our assumption.

2. CB^+ chooses $m = 0$. The computations are similar and yield the same result as in the first candidate deviation. Since CB^+ can control inflation exactly, the respective losses in this case, L^+ and $L^{+\prime}$, only differ from L^0 and $L^{0\prime}$ by the term $(1+a)\delta^2$.

Since there is no profitable deviation, the proposed equilibrium exists.

□

Proof of Proposition 4.8 Due to arguments similar to those established in the proof of proposition 4.4, the money growth rate m^+ must equal $-\delta$ in any separating equilibrium. Having set the equilibrium value for m^+ we are able to derive the value of m^0 which must hold in equilibrium. Last but not least we can construct the equilibrium value for m^-. The following deviations have to be checked:

1. CB^+ has no incentive to mimic CB^0, i.e. to choose $m = m^0$ or higher monetary growth rates. Equilibrium losses are:

$$L^+ = a\Delta^2$$

If m^0 were chosen, losses would be:

$$L^{+\prime} = (m^0 + \delta)^2 + a(\delta - \Delta)^2$$

Thus, $L^{+\prime} \geq L^+$ if and only if:

$$\begin{aligned} (m^0 + \delta)^2 &\geq b\delta^2 \\ m^0 &\geq (\sqrt{b} - 1)\delta \end{aligned}$$

Hence, the lowest sustainable level of monetary growth is $m^0 = (\sqrt{b} - 1)\delta$ which corresponds to the proposed equilibrium. We next derive m^-.

2. There are two properties m^- must fulfill.

   (a) CB^0 has no incentive to choose m^-. Equilibrium losses are:

$$L^0 = (m^0)^2 + a\Delta^2 + (1 + a)\delta^2$$

   Losses for the deviation $m = m^-$ are:

$$L^{0\prime} = (m^-)^2 + a(\delta - \Delta)^2 + (1 + a)\delta^2$$

   For the equilibrium to exist $L^{0\prime} \geq L^0$ must hold, which implies:

$$\begin{aligned} (m^-)^2 + a(\delta - \Delta)^2 &\geq (m^0)^2 + a\Delta^2 \\ m^- &\geq \sqrt{(m^0)^2 + b\delta^2} \\ m^- &\geq \delta\sqrt{2b - 2\sqrt{b} + 1} \end{aligned}$$

   The lowest level of m^- consistent with this condition is:

$$m^- = \delta\sqrt{2b - 2\sqrt{b} + 1}$$

   (b) CB^+ does not want to choose m^- as constructed under (a). Equilibrium losses for CB^+ are given by:

$$L^+ = a\Delta^2$$

Losses when CB^+ chooses m^- instead of $m^+ = -\delta$ amount to (choosing m^- results in huge surprise inflation):

$$L^{+\prime} = (m^- + \delta)^2 + a(2\delta - \Delta)^2$$

Hence, the deviation is not profitable if $L^{+\prime} \geq L^+$ which yields:

$$\begin{aligned} (m^- + \delta)^2 &\geq 4a\delta(\Delta - \delta) \\ (m^- + \delta)^2 &\geq 2(b-a)\delta^2 \\ 1 + a + \sqrt{2b - 2\sqrt{b} + 1} &\geq \sqrt{b} \end{aligned}$$

This inequality always holds for $a \geq 0$ and $b \geq 1$.

3. CB^0 does not want to deviate from m^0. The computations are the same as for inflation targeting (see the proof of proposition 4.4). Therefore they are omitted here.

4. Since CB^- incurs the highest losses in this equilibrium, there might be an incentive for CB^- to deviate. Two cases must be distinguished:

   (a) Assume $m^0 < \delta$, i.e. $b < 4$. The candidate deviation that yields the lowest losses is $m' = \delta$. Equilibrium losses amount to:

   $$L^- = (m^- - \delta)^2 + a\Delta^2$$

   Losses when deviating are given by:

   $$L^{-\prime} = a(\Delta + \delta)^2$$

   We obtain the condition:

   $$\left(\sqrt{2b - 2\sqrt{b} + 1} - 1\right)^2 < b + 2a$$

   This inequality holds for $1 \leq b < 4$.

   (b) Assume $m^0 \geq \delta$, i.e. $b \geq 4$. There are two potentially profitable deviations. First, CB^- chooses $m' = \delta$. But in this case inflation expectations are 2δ higher than actual inflation. Equilibrium losses and losses for the deviation are:

   $$\begin{aligned} L^- &= (m^- - \delta)^2 + a\Delta^2 \\ L^{-\prime} &= a(\Delta + 2\delta)^2 \end{aligned}$$

The deviation is not profitable for $L^{-\prime} \geq L^{-}$ which corresponds to

$$\left(\sqrt{2b - 2\sqrt{b} + 1} - 1\right)^2 < 2(b + 3a)$$

which always holds for $b \geq 4$. Second, we have to check whether CB^{-} could benefit from setting $m' = m^0$. Losses for this deviation amount to:

$$L^{-\prime} = (m^0 + \delta)^2 + a(\Delta + \delta)^2$$

The deviation is not profitable for $L^{-\prime} > L^{-}$ and therefore

$$\left(\sqrt{2b - 2\sqrt{b} + 1} - 1\right)^2 < 2(b + a)$$

which holds for $b \geq 4$.

Thus we have proved the existence of the separating equilibrium.[4]

□

Proof of Proposition 4.9 We will show that for every pooling equilibrium monetary growth rate m^* a deviation m' exists

1. that is profitable for CB^{-} if the public believes the deviating bank is CB^{-} and,
2. that is never profitable for either CB^0 or CB^{+}.

First, we derive the condition for CB^{-},

$$\begin{aligned} L^{-} &= (m - \delta)^2 + a(\delta + \Delta)^2 \\ L^{-\prime} &= (m' - \delta) + a\Delta^2 \\ L^{-\prime} &< L^{-} \\ (m' - \delta)^2 &< (m - \delta)^2 + \delta^2(b + 2a) \end{aligned}$$

then the condition for CB^{+},

$$\begin{aligned} L^{+} &= (m + \delta)^2 + a(\Delta - \delta)^2 \\ L^{+\prime} &= (m' + \delta)^2 + a(\Delta - 2\delta)^2 \\ L^{+\prime} &> L^{+} \\ (m' + \delta)^2 &> (m + \delta)^2 + \delta^2(b - 2a) \end{aligned}$$

[4] This separating equilibrium is the only separating equilibrium that satisfies the intuitive criterion. The arguments are essentially the same as in the proof of proposition 4.5.

finally, the condition for CB^0:

$$\begin{aligned} L^0 &= m^2 + a\Delta^2 + (1+a)\delta^2 \\ L^{0\prime} &= m'^2 + a(\Delta-\delta)^2 + (1+a)\delta^2 \\ L^{0\prime} &> L^0 \\ m'^2 &> \delta^2 b + m^2 \end{aligned}$$

Sufficient conditions for the existence of a deviation m' satisfying the preceding three conditions are (where we have set $\delta = 1$, without loss of generality):

$$\begin{aligned} \sqrt{(m+1)^2 + b - 2a} &< \sqrt{(m-1)^2 + b + 2a} + 2 \\ \sqrt{b + m^2} &< \sqrt{(m-1)^2 + b + 2a} + 1 \end{aligned}$$

Tedious calculations yield that these two inequalities hold for any value of m, any $a > 0$ and any $b > 1$.[5] Thus, we have proved that we can eliminate all pooling equilibria for $b > 1$ by applying the intuitive criterion.

□

[5] If the root on the left side of the first inequality does not exist, this condition must be omitted.

Generalization for equally distributed shocks

The distribution of shocks in our model may seem artificial since only two types of shocks are possible, i.e. $\epsilon \in \{-\delta, +\delta\}$. We will now briefly demonstrate that the proposed results do not depend on this assumption. For both monetary and inflation targeting we will derive equilibria which are similar to those in propositions 4.4 and 4.8.

Suppose the shocks are equally distributed on the interval $[-\delta, +\delta]$. The punishment schemes implied by equations (4.5) and (4.6) can still be applied.

Let us consider inflation targeting first. As with our previous assumption on the distribution of shocks, only central banks that have observed a positive shock can profit from imitating other central banks. We will now construct an equilibrium where the public can infer the exact type of any central bank that has observed a positive shock from the announced inflation target while the other types of central banks pool, i.e. choose the same inflation targets.

Losses for a central bank that observes a positive shock and chooses $m = \pi_t$ are given by:

$$L = (\pi_t + \epsilon)^2 + a\big(\pi_t + \epsilon - \pi^e(\pi_t) - \Delta\big)^2$$

Differentiating this equation with respect to π_t yields the following differential equation:

$$\pi_t + \epsilon + a\big(\pi_t + \epsilon - \pi^e(\pi_t) - \Delta\big)\big(1 - \pi^{e\prime}(\pi_t)\big) = 0 \tag{B.2}$$

By assumption, the public can infer the central bank's signal from the inflation target. Thus, $\pi^e = \pi_t + \epsilon$ must hold. Using this equation, equation (B.2), and the border condition $\pi^e|_{\pi_t = -\delta} = 0$, we obtain the expectations of the public $\pi^e(\pi_t)$:

$$\pi^e(\pi_t) = a\Delta\left(1 - \exp\Big(-\frac{\pi_t + \delta}{a\Delta}\Big)\right) \tag{B.3}$$

Note that the central bank that observes a shock of size zero will choose π^0 which is defined as the solution of $\pi^e(\pi_t) = \pi_t$. An incompetent bank and a central bank that has observed a negative shock will do the same (cf. proposition 4.4). The bank that observed a positive shock of size δ chooses an inflation target $-\delta$ and an inflation rate 0. Central banks with shocks $\epsilon \in]-\delta, 0[$ choose inflation targets between $-\delta$ and π^0 which imply positive inflation rates up to π^0. It is reasonable to assume linear out-of-equilibrium expectations, i.e. for $\pi_t < -\delta$ and $\pi_t > \pi^0$, since there is a maximum possible amount of surprise inflation, δ, which cannot be exceeded. The expectations of the public are shown in figure B.1.[6]

[6]For a central bank that has observed a negative shock or that is incompetent, no profitable

Under monetary targeting the results change slightly. The expectations $\pi^e(m)$ take the same form as $\pi^e(\pi_t)$ in equation (B.3). The only difference is that central banks observing a negative shock will signal their types in order to prevent imitation (cf. section 4.5 for the intuition). For instance the central bank observing $-\delta$, which is the smallest possible shock, will choose an inflation rate $\pi^- > \pi^0$ which is the solution of $\pi^e(m) = m - \delta$. The expectations of the public are shown in figure B.2. Thus, we have constructed an equilibrium where the public can always infer the precise size of the shock from the announced target m_t.[7]

We may conclude from this that central banks that are incompetent or have observed a positive shock will choose a policy resulting in the same inflation rates both under monetary and inflation targeting. But central banks observing negative shocks choose policies that produce higher inflation rates under monetary targeting. Hence, our main results remain valid if we consider equally distributed shocks.

□

deviation from the constructed equilibrium can exist. But there is one possible deviation left to be checked. A central bank that has observed a positive shock could choose $\pi = \pi_t$ instead of $m = \pi_t$. It is however not easy to derive the resulting condition for the existence of the equilibrium (which would correspond to the condition $b \geq 1$ derived for only two possible shocks) since the equilibrium choice of π_t cannot be solved analytically as a function of the observed shock.

[7]The public is, however, unable to distinguish an incompetent central bank from a bank that has observed a shock of size zero since both central banks will choose the same monetary targets which amount to π^0.

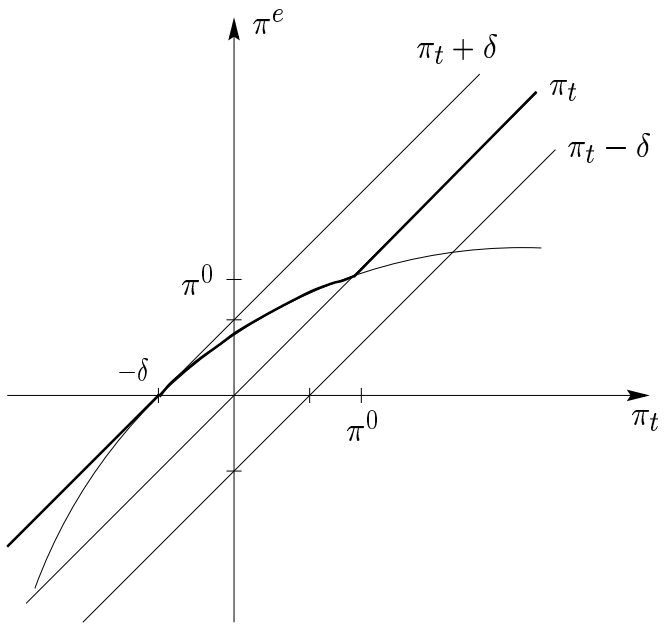


Figure B.1: Expectations of the public depending on the announced target value under inflation targeting

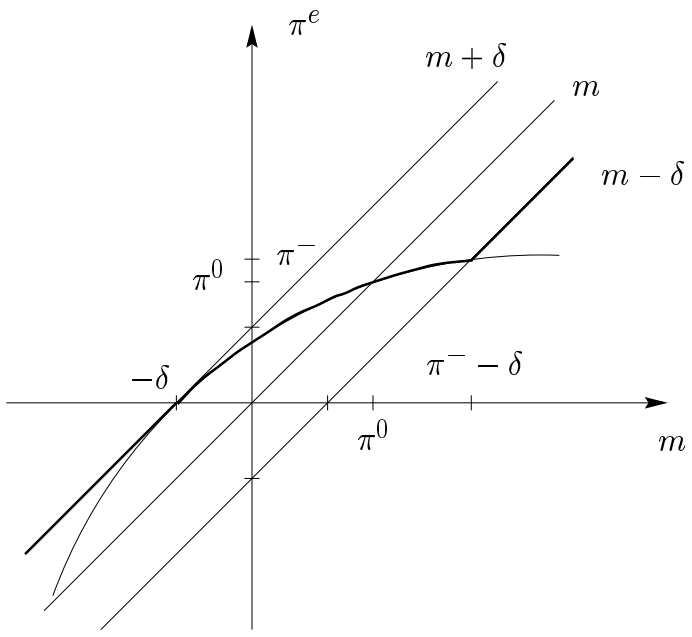


Figure B.2: Expectations of the public depending on the announced target value under monetary targeting

Appendix C

Proofs for Chapter 8

Proof of Proposition 8.1 We show that expected losses for a type B central banker increase if he chooses i_A. We use q to denote the type B central banker's probability assessment of the council choosing interest rate i_A if all central bankers choose the proposed equilibrium strategy. The respective probability for the second period is denoted by r. If the central banker under consideration deviates, i.e. if he votes for i_A, probabilities are denoted by q' and r', accordingly. A type B central banker will not want to choose i_A if:

$$\begin{aligned} q l_B(i_A) + (1-q) l_B(i_B) &< \delta\big(r l_B(i_A) + (1-r) l_B(i_B)\big) \\ 0 &< \big(l_B(i_A) - l_B(i_B)\big)\big(q' - q + \delta(r' - r)\big) \end{aligned}$$

Since $l_B(i_A) > l_B(i_B)$ and $\delta < 1$, the above condition is fulfilled if

$$q' - q \geq r - r'.$$

The interpretation is straightforward. If a type B central banker votes for i_A in the first period, two effects occur. From the central banker's perspective, it is more likely that bad monetary policy will be conducted in the first period since it is possible for him to cast the decisive vote. On the other hand, voting for i_A enables him to get reelected. This makes expected second-period monetary policy more favorable for him. The above inequality guarantees that the negative effect on first-period losses is always stronger than the beneficial effect on second-period losses. If the deviation to i_A will decrease the probability of a preferred result in period 1 by more than the increase in the likelihood of a good result in period 2, then the deviation is not profitable for the central banker.

We will now show that the equilibrium condition $q' - q \geq r - r'$ holds. The probability q for i_A being implemented in equilibrium in the first period amounts to:

$$q = \sum_{n=\frac{N-1}{2}+1}^{N-1} \binom{N-1}{n} p^n (1-p)^{N-1-n}$$

The probability q' for i_A being adopted in the first period if the central banker deviates is given by:

$$q' = \sum_{n=\frac{N-1}{2}}^{N-1} \binom{N-1}{n} p^n (1-p)^{N-1-n}$$

We obtain:

$$q' - q = \binom{N-1}{\frac{N-1}{2}} p^{\frac{N-1}{2}} (1-p)^{\frac{N-1}{2}}$$

This is precisely the likelihood of the central banker under consideration casting the decisive vote in the first period.

We use p^* to denote the probability that a single central banker in period 2 is of type A in equilibrium. Then p^* is:

$$p^* = p + p(1-p) = p(2-p)$$

The explanation for this expression is straightforward. A central banker is of type A in period 1 with probability p. In equilibrium, he will be reelected. If a central banker is not of type A in period 1, which happens with probability $1-p$, he will be dismissed. His successor in the second period will be of type A with probability p. Therefore a central banker is of type A in period 2 with probability $p^* = p + p(1-p)$.

The probability r for i_A being implemented in the equilibrium in the second period amounts to:

$$r = p\binom{N-1}{\frac{N-1}{2}} (p^*)^{\frac{N-1}{2}} (1-p^*)^{\frac{N-1}{2}} + \sum_{n=\frac{N+1}{2}}^{N-1} \binom{N-1}{n} (p^*)^n (1-p^*)^{N-n-1}$$

If the central banker deviates, the probability that the interest rate i_A is adopted in period 2 changes to:

$$r' = \sum_{n=\frac{N+1}{2}}^{N-1} \binom{N-1}{n} (p^*)^n (1-p^*)^{N-1-n}$$

We obtain:

$$r - r' = p\binom{N-1}{\frac{N-1}{2}} (p^*)^{\frac{N-1}{2}} (1-p^*)^{\frac{N-1}{2}}$$

The condition $q' - q \geq r - r'$ is fulfilled if

$$\begin{aligned} p^{\frac{N-1}{2}}(1-p)^{\frac{N-1}{2}} &\geq p \cdot (p^*)^{\frac{N-1}{2}}(1-p^*)^{\frac{N-1}{2}} \\ 1 &\geq p^{\frac{2}{N-1}}(2-p)(1-p) \end{aligned}$$

One can easily verify that the latter inequality holds for any value of p and $N > 1$.

□

Proof of Proposition 8.3 In analogy to the proof of proposition 8.1, no profitable deviation exists for type B central bankers if

$$q' - q \geq \rho - \rho'.$$

Analogously to the proof of proposition 8.1, q is the probability assessment by the type B central banker that outcome i_A will be realized in period 1 in equilibrium while q' is the respective probability if the central banker under consideration deviates. The probabilities ρ and ρ' correspond to r and r'. For instance, ρ is the probability that i_A will be adopted in period 2 when the central banker does not deviate.

The expressions for ρ and ρ' are slightly more complicated than those for r and r' since under opacity a single central banker's reelection cannot be considered independently from the behavior of the other council members.

$$\begin{aligned} \rho &= \sum_{n=\frac{N+1}{2}}^{N-1} \binom{N-1}{n} p^n (1-p)^{N-n-1} \\ &\quad + \left[1 - \sum_{n=\frac{N+1}{2}}^{N-1} \binom{N-1}{n} p^n (1-p)^{N-n-1}\right] \times \left(\sum_{n=\frac{N+1}{2}}^{N} \binom{N}{n} p^n (1-p)^{N-n}\right) \end{aligned}$$

$$\begin{aligned} \rho' &= \sum_{n=\frac{N+1}{2}}^{N-1} \binom{N-1}{n} p^n (1-p)^{N-n-1} \\ &\quad + \left[1 - \sum_{n=\frac{N-1}{2}}^{N-1} \binom{N-1}{n} p^n (1-p)^{N-n-1}\right] \times \left(\sum_{n=\frac{N+1}{2}}^{N} \binom{N}{n} p^n (1-p)^{N-n}\right) \end{aligned}$$

The first terms of the expressions for ρ and ρ' represent the case in which type A central bankers have the initial majority in the first period. Then the whole council will be reelected and i_A will be chosen. The second terms represent the case in which i_B is adopted in the first period, the council is dismissed, and the new council consists of a majority of type A central bankers.

The difference of the likelihoods ρ and ρ' is:

$$\rho - \rho' = \left(\binom{N-1}{\frac{N-1}{2}} p^{\frac{N-1}{2}} (1-p)^{\frac{N-1}{2}} \right) \times \left(\sum_{n=\frac{N+1}{2}}^{N} \binom{N}{n} p^n (1-p)^{N-n} \right)$$

The above expression describes the constellation when there is a one-vote majority for central bankers of type B in the initial council.

Since $\sum_{n=\frac{N+1}{2}}^{N} \binom{N}{n} p^n (1-p)^{N-n} < 1$, we obtain that $q' - q \geq \rho - \rho'$, which implies that no deviation is profitable for a central banker of type B.

□

Appendix D

Proofs for Chapter 9

We show that:

$$1 < \frac{1}{1+A}\left(\frac{A}{\ln(1+A)}\right)^2$$

This inequality holds if:

$$\ln(1+A) < \frac{A}{\sqrt{1+A}}$$

We introduce the following definitions: $f(A) := \ln(1+A)$ and $g(A) := \frac{A}{\sqrt{1+A}}$. Note that $f(0) = g(0) = 0$. Now we show that $f'(A) < g'(A), \forall A > 0$. The derivative of $f(A)$ is given by:

$$f'(A) = \frac{1}{1+A}$$

The derivative of $g(A)$ is given by:

$$g'(A) = \frac{1+\frac{1}{2}A}{\left(\sqrt{1+A}\right)^3}$$

We obtain that $f'(A) < g'(A)$ if:

$$\sqrt{1+A} < 1 + \frac{1}{2}A$$

which holds since:

$$1 + A < 1 + A + \frac{1}{4}A^2$$

Since $f(0) = g(0) = 0$ and $f'(A) < g'(A), \forall A > 0$, we have shown that $f(A) < g(A), \forall A > 0$, which guarantees that $1 < \frac{1}{1+A}\left(\frac{A}{\ln(1+A)}\right)^2$.

□

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