Taking two steps at a time: On the optimal pattern of policy rates

Petra Gerlach-Kristen*
University of Hong Kong

May 20, 2004

Abstract

Most central banks change interest rates in steps of 25, 50 or 75 basis points at scheduled dates. This paper presents a model that determines optimally the step size and the frequency of policy decisions. In contrast to the existing literature we argue that the size of interest rate changes is chosen to help focus policy decisions, which we assume are taken by a Monetary Policy Committee. Moreover, we assume that the preparations of policy meetings are costly and that decisions therefore are scheduled such that an interest rate change is "likely". The analysis indicates that the step pattern depends on the variability of the unobserved optimal level of interest rates, policymakers' difficulties observing it and their preferences. The model expands the literature by predicting occasional policy rate adjustments by two steps at a time.

Keywords: interest rate steps, monetary policy committees
JEL Classification: E43, E58

*Hong Kong Institute of Economics and Business Strategy, University of Hong Kong, 919 K.K. Leung Building, Pokfulam Road, Hong Kong, email: gerlach@hku.hk. This research was fully supported by a grant from the University Grants Committee of the Hong Kong Special Administrative Region, China (Project No. AoE/H-05/99). I thank Stefan Gerlach, Charles Goodhart, Anders Vredin, James Yetman and Julian Wright for useful discussions and seminar participants at the Bank of England, the London School of Economics, the Hong Kong Institute for Monetary Research and the University of Hong Kong for helpful comments.

1 Introduction

Central banks in advanced economies conduct monetary policy in much the same way. Following a publicly announced schedule, policymakers meet to consider whether to change some short-term interest rate, the “policy rate”. If they decide to do so, the magnitude of the change is typically of a fixed “step” size. Occasionally, policymakers deem it necessary to adjust the policy rate by more, and then do so by changing it by two or more times the standard step size. For instance, the Federal Open Market Committee (FOMC) meets normally eleven times a year, uses a step size of 25 basis points and quite frequently changes the policy rate by 50 basis points, thus ”taking two steps at a time”. The Monetary Policy Committee (MPC) at the Bank of England convenes twelve, and the Governing Council of the European Central Bank eleven, times a year to discuss the stance of policy. These committees also use a step size of 25 basis points and normally take single steps.

This commonality of the interest rate setting behaviour of central banks has stimulated the development of a growing literature on “interest rate stepping” (see e.g. Goodfriend [12], Eijffinger, Schaling and Verhagen [8] and Guthrie and Wright [14]). In this literature, it is assumed that there is an “optimal” interest rate that evolves over time in response to macroeconomic developments. For instance, a rise of actual output relative to potential, i.e. an increase in the output gap, or a rise in headline inflation is typically seen as warranting a tightening of monetary policy and can thus be thought of as an increase in the optimal interest rate. For analytical clarity, the determination of the optimal rate is often not modelled explicitly, and the rate is instead assumed to evolve over time according to a simple stochastic process. Next it is assumed that in changing the policy rate central banks have to “pay” a fixed cost (see Eijffinger, Schaling and Verhagen [8]). In some models, the adjustment costs may also have a component that is proportional to the size of the policy change, which reflects that excessive interest rate adjustments can increase the market volatility (see Guthrie and Wright [14]). Under these assumptions, it is optimal to change the policy interest rate in several equally sized steps in response to a large shock e.g. to inflation.[1]

[1] The literature on interest rate smoothing also predicts a gradual reaction of monetary policy to

While these models capture important aspects of the interest rate setting behaviour of central banks, in particular the fact that interest rates are changed "rarely", they are unable to explain why policy decisions are taken on regularly scheduled dates and why occasionally double steps are taken. As an illustration of these shortcomings, assume that the current level of interest rates equals the optimal level and that inflation unexpectedly increases, implying that the optimal level of interest rates is rising as well. If the benefit of raising the policy rate exceeds the adjustment costs, policy should be tightened immediately. Thus, the existing models predict that interest rates are changed at random, rather than scheduled, points in time. Since policy is assumed to react immediately when an interest rate adjustment by one step has become necessary, the practice of taking two steps at a time is not accounted for.

This paper presents a model that is not subject to these two weaknesses. As in the existing literature, we assume that there is an optimal interest rate that follows a stochastic process. We extend the present literature in two important directions. First, we assume that policy decisions are taken by a Monetary Policy Committee (MPC) whose members meet to discuss the state of the economy and to vote on interest rates.[2] One important issue in designing the MPC is to determine how frequently it should meet. We assume that it is costly to prepare and hold MPC meetings. Consequently, the choice of meeting frequency involves a trade-off between minimising the difference between the actual and the optimal level of the policy rate and minimising the meeting costs.

Second, we assume that the optimal interest rate is not observed. MPC members therefore have to form a view of the state of the economy from the available data. We assume, quite realistically, that they interpret the data differently, which gives rise to a distribution of views of what level of the policy rate to set. The purpose of the MPC meeting is for the members to attempt to determine the level of the optimal interest rate as precisely as possible. We argue that policymakers consider only a limited number of

shocks, however with larger adjustments of the policy rate at first and smaller changes thereafter. See also Section 3.

[2]While we discuss the step pattern in terms of an MPC, the analysis could easily be adopted to a single policymaker. Papers on MPCs include Aksoy, De Grauwe and Dewachter [1], Gerlach-Kristen [10] and Mihov and Sibert [20].

possible levels of the policy rate that are one step size apart because this simplifies the discussion in the committee in the sense that a majority view can be formed. The step size hence is determined by a trade-off between the desire of reaching a broad majority in the MPC and the need to minimise the difference between the policy and the optimal rate.

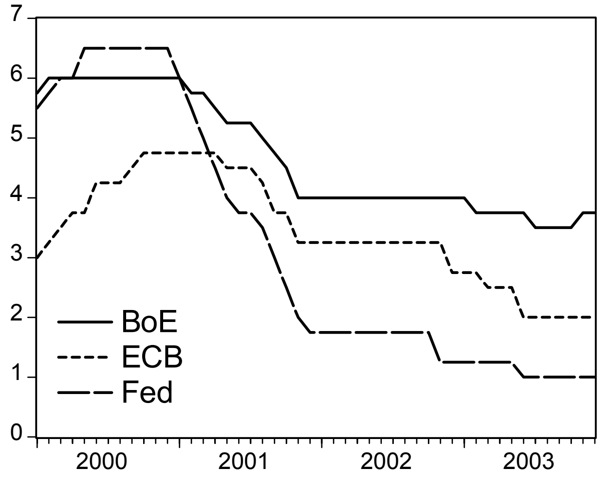
The rest of the paper is structured as follows. Section 2 discusses stylised facts on the step pattern of policy rates in different economies. Section 3 briefly reviews the existing literature. Section 4 presents the model. We first determine the optimal step size and frequency of policy meetings and then perform simulations to examine how the optimal step pattern depends on the parameters in the model. Section 5 concludes.

2 Stylised facts

To illustrate the step pattern of interest rates, we plot in Figure 1 the policy rates set by the Bank of England, the European Central Bank and the Federal Reserve for the period January 2000 to December 2003. One striking difference is that the Bank of England and the European Central Bank tended to change interest rates by 25 basis points, while the FOMC often took two steps at a time, i.e. changed rates by 50 basis points. A second difference is that the federal funds rate moved over a larger range than the repo rates in the UK and the euro area. While it is difficult to generalise on the basis of a short sample, this might indicate that the interest rate that was warranted on the basis of economic conditions (which we refer to as the "optimal" interest rate below) was more volatile in the US over the sample period. That in turn might either be due to larger economic shocks, a different structure of the economy or differences in policymakers' preferences. Intuitively, Figure 1 suggests that a large step size is desirable in economies in which the optimal interest rate is particularly volatile. It therefore is surprising that most central banks use a common step size of 25 basis points.[3]

[3]Indeed, this practice has been questioned by some policymakers. Willem Buiter, who was a member of the MPC at the Bank of England from June 1997 to May 2000, for instance voted for a policy rate change of 40 basis points in March 1999. Charles Goodhart, who also was an MPC member at that time, has in private communication with the author noted that alternative step sizes were discussed briefly by

Figure 1: Policy interest rates



Note: Policy rates of the Bank of England (repo rate), the European Central Bank (repo rate) and the Federal Reserve (federal funds rate), January 2000 to December 2003.

The model we present in this paper explains three dimensions of the step pattern of policy rates: the step size, the frequency of policy decisions and the occurrence of interest rate changes by several steps.[4] Table 1 shows summary statistics on these characteristics for Australia, Canada, the euro area, Sweden, the UK and the US over the sample period January 2000 to December 2003. While the frequencies of policy decisions and multiple steps differ between economies, the step size is 25 basis points for all central banks considered.[5] The number of scheduled policy meetings a year ranges from eight in Canada and the US to twelve in the UK.

Table 1 indicates that policy changes were most frequent in Canada (59.4% of all decisions) and rarest in the UK (24.5%). The probability that at a given MPC meeting the level of interest rates is changed is an important parameter in the model we present

---

the committee shortly after its formation in 1997, but that the idea was dismissed as "too academic".

[4] The model, though not designed to address the issue of interest rate smoothing, also predicts that policy rates should be adjusted sluggishly.

[5] Table 1 does not list the Bank of Japan. Since interest rates in Japan were close to zero over the sample considered, the central bank used a number of instruments to impact on the economy. As a consequence, providing summary statistics proves difficult. Nevertheless, it should be noted that the Bank of Japan reduced its policy rate in 2001 from 50 basis points, to subsequently 35, 25 and finally to 10 basis points, thus not adhering to the standard step size of 25 basis points.

in Section 4. Decisions in favour of a multiple step were least frequent in the UK (2.0% of all occasions) and most common in the US (31.2%).[6]

Table 1: Empirical evidence on interest rate changes

	BoC	ECB	RBA	BoE	Fed	RB
Step size (basis points)	25	25	25	25	25	25
Scheduled policy decisions a year	8	11	11	12	8	8 to 9
Fraction of decisions in favour of an interest rate change (%)	59.4	30.4	32.6	24.5	50.0	34.4
Fraction of decisions in favour of a multiple interest rate change (%)	12.5	10.9	7.0	2.0	31.2	9.4
Frequency of unanimous decisions (%)	no MPC	consensus	consensus	30.9	80.0	55.9
Average size of majority (%)	no MPC	consensus	consensus	85.1	98.7	90.7

Note: Scheduled policy meetings January 2000 to December 2003. Data from the central bank websites. BoC denotes the Bank of Canada, ECB the European Central Bank, RBA the Reserve Bank of Australia, BoE the Bank of England, Fed the Federal Reserve and RB the Swedish Riksbank.

A second important parameter in the model below is related to the desired size of majority in policy decisions. We therefore also report, where available, summary statistics for the voting record. To this end, we distinguish between central banks with a single policymaker in charge of interest rate decisions (the Bank of Canada), those where a policy committee takes decisions by consensus (the European Central Bank and the Reserve Bank of Australia) and those where a committee votes on the level of interest rates (the Bank of England, the Federal Reserve and the Riksbank). Table 1 shows that for the last group, unanimous decisions were rarest in the UK (30.1% of all occasions) and most

[6]In the period under consideration, the Bank of Canada changed the policy rate on one occasion by 75 basis points. All other changes were by 25 or 50 basis points.

frequent in the US (80.0 %).[7] Nevertheless, the average size of the majority tends to be rather large, ranging between 85.1% in the UK and 98.7% in the US. Intuitively, this supports the conjecture that the step size is set to be sufficiently large for there to be few plausible alternative levels of the policy rate that have to be discussed at the meeting.

As a last empirical observation, it should be noted that the low frequency of policy decisions and the adoption of a step size of 25 basis points are relatively new phenomena at least in the US. Rudebusch [21] documents that the step size of the federal funds rate was 6.25 basis points in the 1970s and 80s and that policy tended to be adjusted more frequently than thereafter. In 1975, for instance, the policy rate was changed 24 times, and the shortest interval between two policy rate adjustments was two days. The last time the federal funds rate was changed by 6.25 basis points was in 1989, the third year of Alan Greenspan's tenure as FOMC chairman. Since then, the smallest step taken was 25 basis points. Meade [19] reports that the frequency of dissents has been lower under Greenspan's chairmanship than it was under both Miller's and Volcker's. While many factors may explain this, one interpretation is that using a larger step size makes it easier for policymakers to agree on the level of interest rates, as we argue below.

In sum, the stylised facts suggest that policymakers decide for an adjustment of the level of interest rates at roughly every other occasion. Decisions in favour of a policy rate change by 50 basis points do occur but are rather rare. Finally, the majority in MPCs that vote on the level of the policy rate tends to be large.

3 Review of the literature

The theoretical literature on the step pattern of policy rates seems to have been sparked by Goodfriend [12]. He argues that policymakers use a fixed step size since this allows financial market participants to concentrate on a small number of possible policy rates when forming expectations about future monetary policy. In particular, policymakers are thought to worry about adjusting the level of interest rates excessively because unexpected

[7] See Andersson, Dillén and Sellin [2] for a detailed discussion of the voting record in Sweden, Gerlach-Kristen [9] for the UK and Meade [19] for the US.

large changes could increase the volatility in financial markets. Thus, there is an upper limit to the size of interest rate adjustments. If a large shock occurs, policymakers may therefore change interest rates in several small steps rather than one large step.

These gradual policy reactions link the literature on interest rate stepping to that on interest rate smoothing. Smoothing captures the notion that monetary policy does not react fully to a shock in the period it occurs. Rather, the policy rate is adjusted gradually, with earlier changes being larger than later changes. Explanations for smoothing range from policymakers' concern about their reputation (see e.g. Goodhart [13]), about the stability of financial markets (Goodfriend[11]) and about the effectiveness of monetary policy (Woodford [27]) to unobserved variables (Rudebusch [22]) and uncertainty. Martin and Salmon [18] discuss that uncertainty about the structure of the economy can lead policymakers to smooth interest rates, whereas uncertainty about the state of the economy should not cause smoothing since certainty equivalence holds.[8]

However, Swanson [25] demonstrates that certainty equivalence breaks down if policymakers use Bayesian updating to assess the state of the economy. In our model, MPC members are confronted with a signal-extraction problem (see e.g. Sargent [23]), and as a consequence, their current assessment of the state of the economy and thus of the optimal interest rate depends on their past views thereof. Since the latter influenced the interest rate decision last period, the lagged policy rate is correlated with the current stance of monetary policy. To see this more clearly, denote policymakers' assessment of the optimal interest rate by z_t and the policy rate by p_t, so that

$$p_t = z_t. \tag{1}$$

Assume furthermore that the assessment z_t evolves over time according to

$$z_t = \gamma z_{t-1} + \varepsilon_t. \tag{2}$$

Replacing z_t in equation (1) by (2) and z_{t-1} by p_{t-1}, we obtain

$$p_t = \gamma p_{t-1} + \varepsilon_t.$$

[8] On monetary policy under uncertainty, see also Blinder [6] and Rudebusch [21].

Thus, the policy rate appears to be smoothed, while in truth the sluggish movement of p_t is due to the way in which policymakers' views change over time.

Goodfriend moreover argues that there is a lower limit to the size of policy rate changes in the sense that interest rates are adjusted only once sufficient evidence in favour of such a move has been accumulated. Eijffinger, Schaling and Verhagen [8], Huizinga and Eijffinger [17] and Verhagen [26] interpret this to imply that the central bank is faced with "menu costs" of adjusting policy. In particular, they suggest that policy rate changes are costly in the sense that frequent adjustments might be interpreted as a sign of policymakers' incompetence and could reduce the signaling power of policy rate changes. In these models, the central bank trades off the adjustment costs with the costs arising when the policy rate does not equal its optimal level. The higher the adjustment costs, the rarer and larger the policy rate changes.

Guthrie and Wright [14] assume that the adjustment costs have one constant component and one proportional to the size of the considered policy rate change. The constant cost implies the existence of a lower, and the variable cost that of an upper, limit to the size of the policy rate change. In this setup, policy is smoothed in the sense that interest rate changes are autocorrelated. Moreover, the time between two policy adjustments in the same direction is shorter than if the direction is reversed. These results match the empirical evidence on policy rates well (see e.g. BIS [5] and Goodhart [13]).

The existing literature has three major shortcomings. First, it is difficult to provide convincing examples of constant adjustment costs. It seems unrealistic to assume that policymakers routinely and knowingly allow the policy rate to deviate from its optimal level because they are concerned about their reputation or the signaling power of interest rate adjustments. Second, the models assume that policy is adjusted as soon as the policy rate deviates by a certain margin from the optimal rate. As a consequence, interest rates are always changed by the same amount. The fact that central banks often take multiple steps thus is not explained. Third, the existing models do not take into account that monetary policy is changed on scheduled dates. Assuming a fixed decision frequency is desirable since it can explain the occurrence of multiple interest rate steps. If the MPC meeting schedule determines when policy may be adjusted, the difference between the policy and the optimal rate can occasionally be large enough to warrant an adjustment by two steps.

Overall, the literature suggests that policymakers set interest rates in steps because they face a trade-off between the costs of letting the policy rate deviate from its optimal level and the costs of a policy adjustment. Since it is difficult to provide a plausible rationale for adjustment costs that prevent policymakers from changing the level of interest rates by a small amount, we assume below that the reason for setting interest rates in steps is that it simplifies the policy discussion and increases the public's acceptance of interest rate decisions. We furthermore assume that the preparation of MPC meetings is costly. With these two assumptions, we can explain the observed step pattern of policy rates.

4 The model

As noted in the introduction, the literature on monetary policy assumes that central banks set a short-term interest rate, the optimal level of which depends on the state of the economy, in particular on inflation and the output gap (see e.g. Svensson [24]). For simplicity, we do not model the economy explicitly but instead assume a law of motion for the optimal interest rate i_t^*. In particular, we assume that i_t^* evolves smoothly over time according to an Ornstein-Uhlenbeck process

$$di_t^* = -\alpha i_t^* dt + d\omega_t, \tag{3}$$

where ω_t is a Wiener process (see e.g. Arnold [3]).[9] The innovation $d\omega_t$ is assumed to have a mean of zero, the variance $\sigma_*^2 dt$ and to be uncorrelated over time. We let $\alpha > 0$, so that the optimal interest rate is stationary, and normalise i_t^* such that it has a mean of zero. Harvey [15] shows that an alternative way of expressing equation (3) is

$$i_t^* = e^{-\alpha\tau} i_{t-\tau}^* + w_t, \tag{4}$$

[9] We do not allow for a jump process (see e.g. Ball and Torous [4]) in equation (3). Note that such a process could account for multiple interest rate steps even if there were no fixed meeting frequency.

where $w_t = \int_0^\tau e^{-\alpha(\tau-v)} d\omega_v dv \sim N[0, (1-e^{-2\alpha\tau})\sigma_*^2/(2\alpha)]$ and where τ denotes the interval between two policy decisions.[10] Thus, the optimal interest rate follows an AR(1) process in discrete time.

We assume that monetary policy is conducted by an MPC with n members. Table 1 showed that MPC members often disagree about the optimal stance of policy. If the committee members share the same objective for monetary policy and do not behave strategically, which we assume from here on, the degree to which their views diverge reflects their uncertainty about the optimal level of interest rates. We assume that this uncertainty concerns the state, rather than the structure, of the economy. Formally, we assume that each policymaker j "observes" i_t^* with an error, such that

$$i_{j,t} = i_t^* + u_{j,t}, \tag{5}$$

with $u_{j,t} \sim N(0, \sigma_u^2)$, where we assume that $E(u_{j,t}u_{k,t}) = 0$ for all $j \neq k$. We also assume that policymakers are equally "skilled" in the sense that their "observation" errors have the same variance σ_u^2.[11] Technically, equations (4) and (5) constitute an signal-extraction problem.[12] We refer to $i_{j,t}$ as policymaker j's "observation" of i_t^* since this notion is common in the literature on signal extraction. However, it is more appropriate to think of $i_{j,t}$ as that view of the optimal interest rate policymaker j would hold if his information set was exclusively given by data on the state of the economy that have become available in the current period. Since the optimal interest rate is autocorrelated, MPC member j does not only use $i_{j,t}$ to form his assessment of i_t^*, but also takes into consideration what he thought the state of the economy was last period. Using Kalman filtering, policymaker j's optimal assessment of the current optimal interest rate, $i_{j,t|t}$, can be shown to equal

$$i_{j,t|t} = \kappa i_{j,t} + (1-\kappa)e^{-\alpha\tau} i_{j,t-\tau|t-\tau} \tag{6}$$

with

$$\kappa = \frac{e^{-\alpha\tau}\Sigma}{\Sigma + \sigma_u^2} \quad \text{and} \quad \Sigma = \frac{\sigma_*^2 - \sigma_u^2(1-e^{-2\alpha\tau})}{2} + \sqrt{\left(\frac{\sigma_*^2 - \sigma_u^2(1-e^{-2\alpha\tau})}{2}\right)^2 + \sigma_u^2\sigma_*^2}.$$

[10] This assumption implies that the model focuses on policy decisions taken at scheduled dates. Unscheduled policy adjustments can, however, easily be implemented (see Appendix A).

[11] Allowing for correlation would not alter the conclusions below substantially.

[12] See Harvey [15] for a discussion of signal-extraction problems in continuous time.

Equation (6) shows formally that policymaker j's current assessment of the optimal interest rate depends on his past assessment at date $t-\tau$ and the new observation $i_{j,t}$.[13] The larger his difficulties in observing the optimal interest rate, i.e. the larger σ_u^2, the smaller κ and the more backward-looking his assessment of i_t^*. Note that κ corresponds to parameter γ in equation (2). If policymaker j were responsible for monetary policy on his own, he would set the policy rate p_t equal to $i_{j,t|t}$, and monetary policy would seem to be smoothed.

Instead of a single policymaker, we assume an MPC that votes on the level of the policy rate. The MPC meets to discuss the state of the economy and seeks to set p_t as closely as possible to i_t^*. We assume that the MPC is subject to two constraints in doing so. The first constraint is that policymaker prefer taking decisions by a large majority. Policymakers' "ownership" and the public's acceptance of a policy decision are arguably the greater, the larger the majority supporting it. The second constraint is that MPC meetings are costly since they involve the preparation of background notes, the briefing of committee members and so on. It therefore is desirable for the MPC to meet only if the probability of an interest rate change is "large".

4.1 Step size

We capture the constraint that policymakers wish to take clear decisions by the desired size of majority μ. We next demonstrate that a large majority can be brought about by setting the policy rate in large steps.

As a starting point, it should be noted that since the committee members' views of the optimal interest rate depend on their individual observation errors, it is unlikely that two policymakers share the same $i_{j,t|t}$. Consider five policymakers whose $i_{j,t|t}$:s are given by 2.89, 2.96, 3.16, 3.24 and 3.33 percent, respectively. Moreover, assume that the optimal interest rate i_t^* equals 3.15%. If the policy rate may be set equal to any value, each policymaker votes for his $i_{j,t|t}$. The first column in Table 2 shows that no majority is formed and that the policy rate, which is set equal to the median voter's view, deviates

[13] Note that we use for simplicity the steady state, rather than the real-time, Kalman gain κ and variance Σ of the forecast error.

by one basis point from i_t^*.

Now assume that the policy rate may only be set equal to values that are ten basis points apart from each other.[14] We denote this step size by s. In this situation, each policymaker favours a level of the policy rate that deviates slightly from his $i_{j,t|t}$. Policymaker 1 votes for a policy rate of 2.90 percent, policymaker 2 for 3.00 percent and so on. Policymakers 3 and 4 happen to vote for the same level of p_t and thus form a majority. The policy rate is set equal to 3.20 percent and now deviates from i_t^* by five basis points.

Next, we increase s to 25 basis points. In this situation, only two policy options need to be considered, and a majority of 60 percent favours $p_t = 3.25\%$. While the policy decision has now the support of more committee members, $|p_t - i_t^*|$ has increased to ten basis points. Finally, if we set $s = 0.50\%$, the committee unanimously votes for $p_t = 3.00\%$, and the deviation of the policy rate from its optimal level increases to 15 basis points.

Table 2: Example 1

policymaker $j =$	no steps	$s = 0.10\%$	$s = 0.25\%$	$s = 0.50\%$
1	2.89%	2.90%	3.00%	3.00%
2	2.96%	3.00%	3.00%	3.00%
3	3.16%	3.20%	3.25%	3.00%
4	3.24%	3.20%	3.25%	3.00%
5	3.33%	3.30%	3.25%	3.00%
p_t	3.16%	3.20%	3.25%	3.00%
number of policy options	5	4	2	1
size of majority	no majority	40%	60%	100%
i_t^*	3.15%	3.15%	3.15%	3.15%
$\|p_t - i_t^*\|$	0.01%	0.05%	0.10%	0.15%

It thus appears that the larger a majority policymakers favour, the larger a step size should be used. However, a large majority also seems to imply a large difference between the policy rate and its optimal level. To verify these conjectures, we need to consider the

[14] We make the normalising assumption that zero is one step of the policy rate.

formal link between μ, s and $|p_t - i_t^*|$. Appendix B shows that the step size for which we expect the majority μ to agree on one level of the policy rate is given by

$$s = 2\sqrt{V}\Phi^{-1}\left(\frac{1+\mu}{2}\right), \tag{7}$$

where Φ^{-1} is the inverse of the cumulative standard normal distribution and where V reflects how dispersed policymakers' views of the optimal interest rate are. Since V is increasing in $e^{-\alpha\tau}$, the step size should ceteris paribus be the larger, the more autocorrelated the optimal interest rate is. The intuition for this result is that if i_t^* evolves sluggishly over time and is hit by a large shock, it returns slowly to equilibrium, making large adjustments of the policy rate desirable. Appendix B moreover demonstrates that V depends in a non-linear fashion on σ_*^2 and σ_u^2, so that their effect on the optimal step size depends on the assumed size of the other parameters in the model. We return to this issue in Section 4.3.

Equation (7) shows that, as in Table 2, the greater a majority policymakers wish to achieve, the larger a step size they should use. Furthermore, large majorities indeed imply that the policy rate often deviates from its optimal level. Figure 2 illustrates this trade-off policymakers face. We assume as benchmark case $\mu = 0.9$ and show by how many percentage points the policy rate deviates more (less) from i_t^* for larger (smaller) μ.

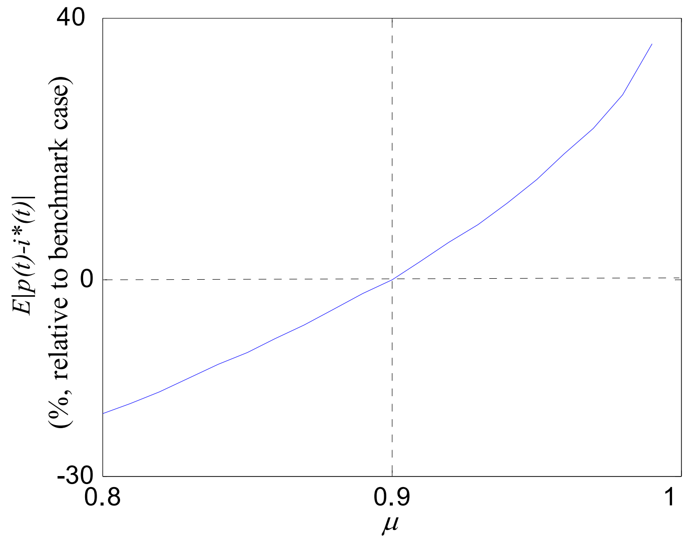
This section showed that the constraint that policy discussions should consider only few alternatives impacts on the optimal step size of the policy rate. We next demonstrate that the second constraint, which says that policymakers attempt to minimise the costs associated with MPC meetings, determines the frequency of policy decisions.

4.2 Frequency of policy decisions

We assume that the preparation of MPC meetings, which involves the writing of background notes by central bank staff and the briefing of committee members, is costly.[15] Policymakers hence face a second trade-off, namely between the meeting costs and the

[15] Another reason for scheduling MPC meetings at fixed points in time is to co-ordinate them with the release of economic data. Demiralp and Jordá [7] moreover suggest that policymakers can signal their intentions more clearly if they adhere to scheduled decision dates.

Figure 2: Deviation of the policy rate from its optimal level (in percentage points relative to benchmark case) and size of majority



Note: The dotted lines show the benchmark case. $\pi = 0.5$ and $\alpha = 0.3$, $\sigma_*^2 = \sigma_u^2 = 0.1$, s and τ are computed with equations (7) and (10). We assume an MPC with nine members and let μ range from 0.80 to 0.95. The simulations are based on 10000 draws.

costs associated with the deviation of the policy rate from i_t^*. We assume that the MPC meets at fixed intervals and that meetings are scheduled such that an interest rate change is "likely". The probability π of a policy rate change is hence, as μ, given by policymakers' preferences.[16]

To determine the optimal frequency of policy decisions, we first analyse by how much the optimal interest rate has to move to make an interest rate change desirable. It is useful to start out again with an example. Consider Cases A1 and A2 in Table 3. We assume that the policy rate is changed in steps of 25 basis points, that the optimal interest rate equaled 4.00 percent at the last MPC meeting and that the policy rate was set equal to that value. If the optimal interest rate has since the last meeting increased by 12.5 basis points, the

[16]More precisely, π is the probability that a policy rate change is desirable when the MPC meets, i.e. that the optimal interest rate is closer to a new level of the policy rate than to the rate set at the last meeting. Since policymakers' views evolve more sluggishly than i_t^* itself, the probability that the policy rate indeed is adjusted to the new level is smaller than π. We concentrate on the movement of i_t^* rather than $i_{j,t|t}$ for simplicity.

policy rate should be raised by one step to 4.25%. Likewise, if $i_t^* - i_{t-\tau}^* = -0.125\%$, the policy rate should be cut to $p_t = 3.75\%$. Thus, on average a movement of the optimal interest rate by $s/2$ ought to cause a policy adjustment by one step.

Table 3: Example 2

Case	s	$i_{t-\tau}^*$	$p_{t-\tau}$	$i_t^* - i_{t-\tau}^*$	i_t^*	p_t	$\mid i_t^* - i_{t-\tau}^* \mid$
A1	0.25%	4.00%	4.00%	0.125%	4.125%	4.25%	0.125%
A2				-0.125%	3.875%	3.75%	
B1	0.25%	4.10%	4.00%	0.025%	4.125%	4.25%	0.125%
B2				-0.225%	3.875%	3.75%	
C1	0.25%	4.00%	4.00%	0.375%	4.375%	4.50%	0.375%
C2				-0.375%	3.625%	3.50%	

Cases B1 and B2 assume that the optimal interest rate at the time of the last MPC meeting equalled 4.10 percent. In this situation, an increase of i_t^* by 2.5 basis points should cause a tightening of monetary policy to $p_t = 4.25\%$, and a fall by 22.5 basis point ought to trigger a loosening to $p_t = 3.75\%$. The movement of the optimal interest rate thus has to equal $s/2$ on average. Thus, if the MPC meets such that a policy adjustment is desirable with probability π,we have that

$$\pi = prob(\mid i_t^* - i_{t-\tau}^* \mid > s/2). \tag{8}$$

To determine the optimal length of time between MPC meetings, we would like to solve equation (8) for τ. Since $i_t^* - i_{t-\tau}^*$ follows a normal distribution with an unconditional mean of zero, expression (8) can be written as

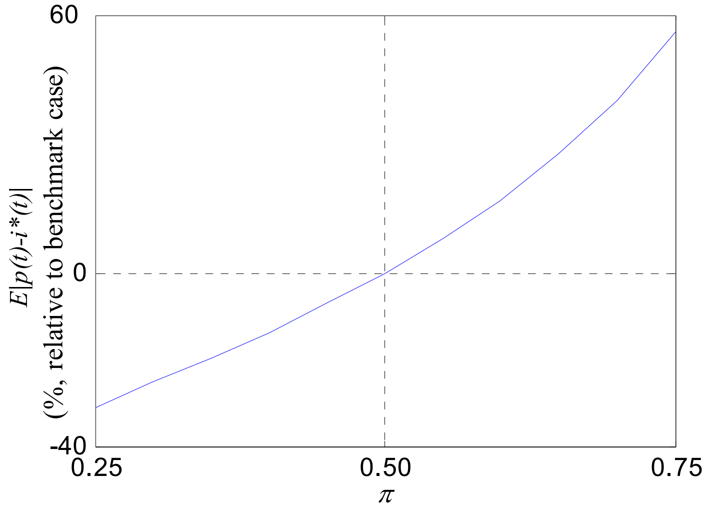
$$2\left[1 - \Phi\left(\frac{s/2}{\sqrt{Var(i_t^* - i_{t-\tau}^*)}}\right)\right] = \pi. \tag{9}$$

Noting that $Var(i_t^* - i_{t-\tau}^*) = (1 - e^{-\alpha\tau})\sigma_*^2/\alpha$ and replacing s with equation (7) yields

$$2\left\{1 - \Phi\left[\Phi^{-1}\left(\frac{1+\mu}{2}\right)\sqrt{\frac{\alpha V}{(1 - e^{-\alpha\tau})\sigma_*^2}}\right]\right\} = \pi. \tag{10}$$

The optimal frequency of policy decisions is thus given by that τ which solves equation (10).

Figure 3: Deviation of the policy rate from its optimal level (in percentage points relative to benchmark case) and size of probability of interest rate change



Note: The dotted lines show the benchmark case. $\mu = 0.9$ and $\alpha = 0.3$, $\sigma_*^2 = \sigma_u^2 = 0.1$, s and τ are computed with equations (7) and (10). We assume an MPC with nine members and let π range from 0.25 to 0.75. The simulations are based on 10000 draws.

Three points are worth noting. First, policymakers again face a trade-off. The costlier the MPC meetings, i.e. the larger π, the larger the average deviation between the policy rate and its optimal level i_t^*. Figure 3 illustrates this. Second, equation (10) cannot be solved analytically. We therefore resort in Section 4.3 to simulations to study how the different parameters in the model impact on the optimal meeting frequency. Since the optimal step size in equation (7) depends on V, which is a function of τ, we also need to simulate s. Third, once we have determined τ and s, we can infer how frequently the policy rate should be adjusted by several steps at a time. Cases C1 and C2 in Table 3 illustrate that a policy rate change by two steps is desirable if $\mid i_t^* - i_{t-\tau}^* \mid > 1.5s$. We denote the probability of a multiple policy rate change by m and calculate it as

$$m = prob(\mid i_t^* - i_{t-\tau}^* \mid > 1.5s). \tag{11}$$

In contrast to the existing literature, our model hence predicts that occasionally policymakers should take two steps at a time.

4.3 Simulations

Since equation (10) cannot be solved for τ, we simulate the model to determine how the step pattern depends on the time series properties of the optimal interest rate (given by α and σ_*^2), policymakers' difficulties observing i_t^* (σ_u^2) and their preference parameters (μ and π).

We choose benchmark values for each parameter and report them in Table 4. We assume that $\pi = 0.5$, which implies that MPC meetings are scheduled such that the policy rate is desirable at every other meeting. This is compatible with the frequency of policy rate changes for the central banks we discussed in Section 2. We set the benchmark value for μ equal to 0.90, which seems reasonable given the large majorities reported in central bank voting records. The benchmark value for α is set as 0.3. In choosing this benchmark, we assume implicitly that time is measured in months. If $\tau = 1$, the AR coefficient of the optimal interest rate equals $e^{-\alpha\tau} = 0.741$. Policymakers' uncertainty implies that the policy rate evolves more sluggishly than i_t^*. Finally, we set a benchmark value of 0.1 for the variances of the optimal interest rate and policymakers' observation errors.

Table 4: Simulation benchmarks and ranges

	benchmark	simulation range
π	0.500	[0.100 - 0.990]
μ	0.900	[0.800 - 0.990]
α	0.300	[0.010 - 0.500]
σ_*^2	0.100	[0.001 - 0.500]
σ_u^2	0.100	[0.001 - 0.500]

In the simulations, we hold all parameters but one constant, solve equation (10) numerically for τ and calculate s using equation (7) and m using equation (11). The first row in Figure 4 shows the reaction of the optimal step pattern to an increase in π. We consider π:s in the range of 0.10 to 0.99 and think of large probability parameters as reflecting situations in which MPC meetings are particularly costly. We find that the larger

π, the larger τ, the smaller s and the larger m. Indeed, as π approaches unity, m rises to unity as well. The reason for this is that if policymakers wish to be absolutely certain that an interest rate change is necessary when they meet, they should use a step size that approaches zero, which in turn implies that the policy rate virtually always is changed by more than one step.

To see why an increase in π is associated with longer meeting intervals and a smaller step size, note that the probability of a policy rate change can be raised in two ways, namely by decreasing the step size and by raising the expected value of $\mid i_t^* - i_{t-\tau}^* \mid$ in equation (10). The expected movement of the optimal interest rate is the larger, the larger τ.[17] Thus, if policymakers meet rarely, they are likely to favour a policy change. This effect is reinforced by the fact that an increase in τ causes a fall in the dispersion of policymakers' perceptions of i_t^* as measured by V and thus in the step size.

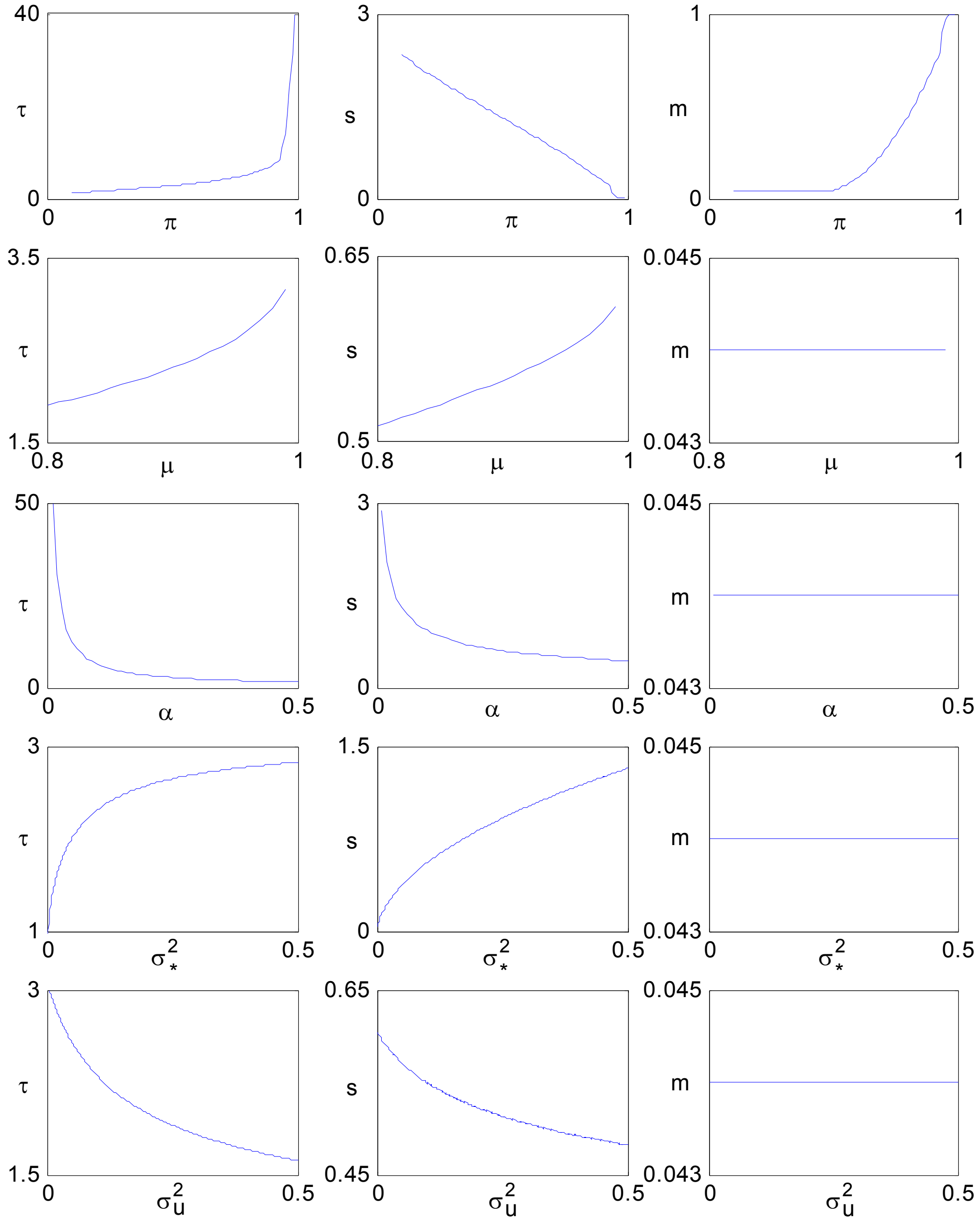
The second row of Figure 4 studies how the step pattern changes if the committee members wish to focus the policy discussion more. We increase μ from 0.80 to 0.99 and find that the majority in the MPC is the larger, the longer the periods between policy meetings and the larger the step size. This result is due to the fact that a large majority can be achieved by using a large step size. Since we hold π constant, a large s implies that $E \mid i_t^* - i_{t-\tau}^* \mid$ and thus τ must be large.[18] The probability of a multiple policy rate change is unaffected by variations in μ. Indeed, m reacts only to changes in π. The reason for this is that if the probability of a policy rate change is held constant, so is the likelihood of a multiple adjustment.

The third row shows the impact of changes in α on the optimal step pattern. We vary α between 0.01 and 0.5 and find that an increase in α (i.e. ceteris paribus an decrease in the AR coefficient of the optimal interest rate) is associated with a reduction in τ and s. The explanation for this is that a rise in α reduces the variance of i_t^*, which is given by $\sigma_*^2/2\alpha$. Given our assumptions regarding the other parameters in the model,

[17] The reason for this is that $\mid i_t^* - i_{t-\tau}^* \mid$ follows a half-normal distribution, so that $E \mid i_t^* - i_{t-\tau}^* \mid = \sqrt{Var(i_t^* - i_{t-\tau}^*)}$ (see e.g. Hogg and Tanis [16]). Since $Var(i_t^* - i_{t-\tau}^*) = (1 - e^{-\alpha\tau})\sigma_*^2/\alpha$, an increase in τ raises $E \mid i_t^* - i_{t-\tau}^* \mid$.

[18] Note that an increase in τ lowers the variance V of policymakers' views, thus making in principle a smaller s desirable. However, this effect is too weak to matter in the simulations.

Figure 4: Simulations



Note: Benchmark parameters and simulation ranges as given in Table 4.

policymakers' views become more similar as α increases, which makes a smaller step size desirable. For π to remain unchanged, τ has to fall as well.

The fourth row illustrates the role of σ_*^2 in the determination of the optimal step pattern. We vary σ_*^2 between 0.001 and 0.5 and find that a rise in σ_*^2 increases τ and s. This effect again is due to $Var(i_t^*)$, which increases in the simulation as σ_*^2 is raised and hence widens the dispersion of the committee members' views. Note that α and σ_*^2 affect $Var(i_t^*)$ and thus the step pattern with opposite signs. Therefore, the more variable the optimal interest rate, the larger the optimal step size and the longer the optimal interval between MPC meetings.

In the last row of the figure, we increase σ_u^2 from 0.001 to 0.5. Within the simulation range, an increase in policymakers' uncertainty makes them use a smaller step size and meet more frequently. The reason for this is that uncertain MPC members are more backward-looking in their assessment of the optimal interest rate than policymakers with a small σ_u^2. For our benchmark parameters, this means that their views are rather similar, so that a small step size should be used. For π to be constant, this implies that frequent committee meetings are desirable.

5 Conclusions

This paper studies the choice of the step pattern of policy rates. We illustrate that interest rates are commonly changed in steps of 25 basis points on publicly scheduled dates. We present a model of the step pattern that makes two main assumptions. First, we assume that policymakers are uncertain about the optimal level of interest rates and that the policy rate is set in steps because this focuses the discussion in the MPC and thus renders the decision clearer. Second, we assume that policy decisions are scheduled such that an interest rate adjustment is "likely" when the MPC meets. We discuss that such a scheduling strategy is desirable if the preparation of committee meetings is costly.

While our model assumes that interest rate decisions are made by a committee, the framework could easily be adopted to a single policymaker. If a single policymaker wishes for a large majority of the public to approve of his interest rate decisions and if he chooses the step size accordingly, the remainder of the model can be applied without further changes.

The main policy conclusion to be drawn from this paper is that an identical step size of 25 basis points is unlikely to be optimal for economies as different as Sweden and the US. The model shows that policy decisions should be rare, the step size small and multiple policy rate changes frequent if the costs of preparing an MPC meeting are high. Moreover, it is optimal for policymakers to meet infrequently but to take large steps if they favour policy discussions that focus on a small set of alternative options. The same step pattern is desirable if the optimal interest rate is highly variable and if it is easily observed. We leave the question which of these factors might explain the observed differences in step pattern between economies for future research.

A Modelling unscheduled policy meetings

We denote the costs associated with an unscheduled policy meeting by c and the benefit of an interest rate adjustment by

$$b|p_t - i^*_{t+x\tau}|, \tag{12}$$

where $b > 0$ and where x lies between zero and unity. The subscript $t + x\tau$ indicates that $x\tau$ units of time have passed since the last policy decision. Thus, if $x = 0.5$ and interest decisions are made every four weeks, two weeks have passed since the MPC met last. The costs c represent e.g. the time central bank staff need to spend on the preparations for an unscheduled MPC meeting.

Expression (12) indicates that the more the policy rate deviates from its optimal level, the larger the benefit of adjusting monetary policy before the next MPC meeting. Since unscheduled policy changes are rather rare, we assume that c is so large that most of the time

$$c > b|p_t - i^*_{t+x\tau}|.$$

However, if the optimal interest rate is exposed to an exceptionally large shock, the difference between p_t and i^*_t can widen so much that the benefit of an unscheduled adjustment exceeds the costs. In this case we expect a policy change between two regular MPC meetings.

B Deriving the step size

B.1 Deriving V

Denote the distribution of policymakers' views regarding the optimal interest rate by $i_{j,t|t} \sim N(E, V)$. The larger difficulties policymakers have observing i_t^*, the more widely dispersed are their views and the larger is V. To derive V, note that

$$Var(i_t^*) = e^{-2\alpha\tau} Var(i_t^*) + E\left[\int_0^\tau e^{-\alpha(\tau-v)} d\omega_v dv\right]^2$$

which can be shown to equal

$$Var(i_t^*) = \frac{\sigma_*^2}{2\alpha}.$$

Correspondingly, the covariance between i_t^* and $i_{t-l\tau}^*$ is given by

$$Cov(i_t^*, i_{t-l\tau}^*) = E\left[e^{-\alpha l\tau} i_{t-l\tau}^* i_{t-l\tau}^*\right] = e^{-\alpha l\tau}\frac{\sigma_*^2}{2\alpha}. \tag{13}$$

Equation (6) can be re-written as

$$\begin{aligned} i_{j,t|t} &= \kappa(i_t^* + u_{j,t}) \ + (1-\kappa)e^{-\alpha\tau}[\kappa(i_{t-\tau}^* + u_{j,t-\tau}) \ + (1-\kappa)e^{-\alpha\tau}\{\kappa(i_{t-2\tau}^* + u_{j,t-2\tau}) + ...\}] \\ &= \kappa\sum_{l=0}^{\infty}(1-\kappa)^l e^{-\alpha l\tau}(i_{t-l\tau}^* + u_{j,t-l\tau}). \end{aligned}$$

Taking expectations of the square of this expression yields

$$\begin{aligned} Var(i_{j,t|t}) \ \equiv \ V = & \frac{\kappa^2}{1-(1-\kappa)^2 e^{-2\alpha\tau}}[\sigma_u^2 + Var(i_t^*)] + \\ & 2\kappa^2[(1-\kappa)e^{-\alpha\tau}Cov(i_t^*, i_{t-\tau}^*) + (1-\kappa)^2 e^{-2\alpha\tau}Cov(i_t^*, i_{t-2\tau}^*) + ... \\ & +(1-\kappa)^3 e^{-3\alpha\tau}Cov(i_{t-\tau}^*, i_{t-2\tau}^*) + (1-\kappa)^4 e^{-4\alpha\tau}Cov(i_{t-\tau}^*, i_{t-3\tau}^*) + ...]. \end{aligned}$$

Noting that $Cov(i_t^*, i_{t-\tau}^*) = Cov(i_{t-\tau}^*, i_{t-2\tau}^*)$ and rearranging gives

$$\begin{aligned} V \ = \ & \frac{\kappa^2}{1-(1-\kappa)^2 e^{-2\alpha\tau}}[\sigma_u^2 + Var(i_t^*)] + \\ & 2\kappa^2\{(1-\kappa)e^{-\alpha\tau}Cov(i_t^*, i_{t-\tau}^*)[1 + (1-\kappa)^2 e^{-2\alpha\tau} + ...] + \\ & (1-\kappa)^2 e^{-2\alpha\tau}Cov(i_t^*, i_{t-2\tau}^*)[1 + (1-\kappa)^2 e^{-2\alpha\tau} + ...] + ...\}. \end{aligned}$$

Equation (13) implies that

$$
\begin{aligned}
V &= \frac{\kappa^2}{1-(1-\kappa)^2 e^{-2\alpha\tau}}\left[\sigma_u^2 + \frac{\sigma_*^2}{2\alpha}\right] + \\
&\quad \frac{2\kappa^2}{1-(1-\kappa)^2 e^{-2\alpha\tau}}[(1-\kappa)e^{-\alpha\tau}e^{-\alpha\tau}\frac{\sigma_*^2}{2\alpha} + (1-\kappa)^2 e^{-2\alpha\tau}e^{-2\alpha\tau}\frac{\sigma_*^2}{2\alpha} + ...],
\end{aligned}
$$

which corresponds to

$$V = \frac{\kappa^2}{1-(1-\kappa)^2 e^{-2\alpha\tau}}\left[\sigma_u^2 + \frac{\sigma_*^2}{2\alpha} + \frac{\sigma_*^2}{\alpha}\frac{(1-\kappa)e^{-2\alpha\tau}}{1-(1-\kappa)e^{-2\alpha\tau}}\right]$$

or, equivalently,

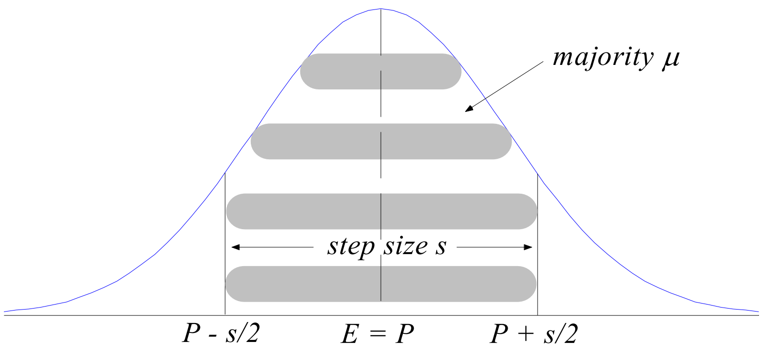
$$V = \frac{\kappa^2}{1-(1-\kappa)^2 e^{-2\alpha\tau}}\left[\sigma_u^2 + \frac{\sigma_*^2}{\alpha}\left\{\frac{1}{2} + \frac{(1-\kappa)e^{-2\alpha\tau}}{1-(1-\kappa)e^{-2\alpha\tau}}\right\}\right].$$

Since $\partial V/\partial\alpha < 0$ and $\partial V/\partial\tau < 0$, policymakers' views of i_t^* are the more widely dispersed, the larger $e^{-\alpha\tau}$. The impact of σ_*^2 and σ_u^2 on V is unclear since these parameters also enter κ.

B.2 Deriving equation (7)

Figure 5 plots the distribution of policymakers' $i_{j,t|t}$:s, $i_{j,t|t} \sim N(E, V)$. We assume that the mean E coincides with a step P of the policy rate.

Figure 5: Distribution of policymakers' assessment of the optimal interest rate



Policymakers who believe that the optimal interest rate lies in the range of $P - s/2$ to $P + s/2$ vote for P, policymakers with a smaller $i_{j,t|t}$ vote for a lower level of the policy rate and committee members with $i_{j,t|t} > P + s/2$ for a higher rate. The majority μ we expect to support P is related to the probability that policymaker j's $i_{j,t|t}$ falls between $P - s/2$ and $P + s/2$. In particular, μ equals

$$\mu = \Phi\left(\frac{P + s/2 - E}{\sqrt{V}}\right) - \Phi\left(\frac{P - s/2 - E}{\sqrt{V}}\right),$$

where Φ denotes the cumulative density function of the standard normal distribution. Since P and E coincide, we can rearrange to yield equation (7),

$$s = 2\sqrt{V}\Phi^{-1}\left(\frac{1+\mu}{2}\right).$$

It should be noted that for a given s, the majority is expected to be smaller than μ if E and P do not coincide. We therefore consider large μ:s in the simulations.

References

[1] Aksoy, Yunus, Paul De Grauwe, and Hans Dewachter (2002), Do asymmetries matter for European monetary policy?, European Economic Review 46(3), 443-469.

[2] Andersson, Malin, Hans Dillén and Peter Sellin (2001), Monetary policy signaling and movements in the Swedish term structure of interest rates, Sveriges Riksbank Working Paper 132.

[3] Arnold, Ludwig (1974), Stochastic differential equations: Theory and applications, Wiley, New York.

[4] Ball, Walter and Clifford A. Torous (1985), On jumps in common stock prices and their impact on call option pricing, Journal of Finance 40, 155-173.

[5] Bank for International Settlements (1998), 68th annual report.

[6] Blinder, Alan S. (1997), What central bankers could learn from academics – and vice versa, Journal of Economic Perspectives 11(3), 2-19.

[7] Demiralp, Selva and Oscar Jordá (2002), The announcement effect: Evidence from open market desk data, Economic Policy Review, Federal Reserve Bank of New York, May, 29-48

[8] Eijffinger, Sylvester, Eric Schaling and Willem H. Verhagen (1999), A theory of interest rate stepping: Inflation-targeting in a dynamic menu cost model, CEPR Discussion Paper 2168.

[9] Gerlach-Kristen, Petra (2003), Insiders and outsiders at the Bank of England, 2003, Central Banking XIV(1), 96-102.

[10] Gerlach-Kristen, Petra (forthcoming), Monetary policy committees and interest rate setting, European Economic Review.

[11] Goodfriend, Marvin (1987), Interest-rate smoothing and price level trend-stationarity, Journal of Monetary Economics 19, 335-348.

[12] Goodfriend, Marvin (1991), Interest rates and the conduct of monetary policy, Carnegie-Rochester Conference Series on Public Policy 34, 7-30.

[13] Goodhart, Charles Goodhart, Charles (1999), Central bankers and uncertainty, Bank of England Quarterly Bulletin, February, 102-121.

[14] Guthrie, Graeme and Julian Wright (forthcoming), The optimal design of interest rate target changes, Journal of Money, Credit, and Banking.

[15] Harvey, Andrew C. (1989), Forecasting, structural time series models and the Kalman filter, Cambridge University Press, Cambridge.

[16] Hogg, Robert V. and Elliot A. Tanis (1997), Probability and statistical inference, Prentice Hall, Upper Saddle River.

[17] Huizinga, Harry and Sylvester Eijffinger (1999), Should monetary policy be adjusted frequently?, CEPR Discussion Paper 2074.

[18] Martin, Ben and Chris Salmon (1999), Should uncertain monetary policy-makers do less?, Bank of England Working Paper 99.

[19] Meade, Ellen E. (2002), Central bank decisions: How does one good head compare with a rule?, AICGS/DAAD Working Paper.

[20] Mihov, Ilian and Anne Sibert (2002), Credibility and flexibility with monetary policy committees, CEPR Discussion Paper 3278.

[21] Rudebusch, Glenn D. (1995), Federal Reserve interest rate targeting, rational expectations, and the term structure, Journal of Monetary Economics 35, 245-274.

[22] Rudebusch, Glenn D. (2001), Is the Fed too timid? Monetary policy in an uncertain world, Review of Economics and Statistics 83, 203-217.

[23] Sargent, Thomas J. (1979), Macroeconomic theory, Academic Press, New York.

[24] Svensson, Lars E.O., 1997, Inflation forecast targeting: Implementing and monitoring inflation targets, European Economic Review 41, 1111-1146.

[25] Swanson, Eric T. (2004), On signal extraction and non-certainty-equivalence in optimal monetary policy rules, Macroeconomic Dynamics 8(1), 27-50.

[26] Verhagen, Willem H. (2002), Interest rate stepping, interest rate smoothing and uncertainty: Some views from the literature, De Nederlandsche Bank Research Memorandum 683.

[27] Woodford, Michael (1999), Optimal monetary policy inertia, The Manchester School of Economics 67(1), 1-35.