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

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Abstract

Most central banks change interest rates in steps of 25, 50 or 75 basis points at scheduled dates. This paper models the optimal step size and frequency of policy decisions. In contrast to the existing literature we argue that a fixed step size facilitates policy decisions, which we assume are taken by a monetary policy committee. The step pattern depends on the variability of the optimal interest rate, policymakers' uncertainty and institutional aspects of the committee. The model extends the literature by predicting that interest rates are occasionally adjusted by two or more steps.

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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 ”interest rate” hereafter). If they decide to do so, the magnitude of the change is typically of a fixed step size. Occasionally, policymakers change interest rates by two or more steps. For instance, the Federal Open Market Committee (FOMC) meets normally eight times a year, uses a step size of 25 basis points and quite frequently changes the interest 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 decide on the stance of policy.[1] 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 literature on interest rate stepping (see e.g. Goodfriend, 1991, Eijffinger, Schaling and Verhagen, 1999, and Guthrie and Wright, 2004). This literature assumes 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 are typically seen as warranting a tightening of monetary policy and can thus be thought of as an increase in the optimal interest rate. In the interest of simplicity, most studies do not model the determination of the optimal rate explicitly, but describe it instead as evolving over time according to

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[1] The Governing Council gathers on a bi-weekly basis, but monetary policy decisions are taken only at every other meeting (there is no interest rate decision in August).

a simple stochastic process. Furthermore, the literature assumes that when changing the interest rate the central bank has to pay a fixed cost (see e.g. Eijffinger, Schaling and Verhagen, 1999). In some models, these adjustment costs also include a component that is proportional to the size of the policy change, which captures the notion that excessive interest rate adjustments can trigger volatility in financial markets (see Guthrie and Wright, 2004). Under these assumptions, it is optimal to change the policy-controlled interest rate ("policy rate" hereafter) infrequently and always by the same amount.

While these models capture important aspects of the interest rate setting behaviour of central banks, in particular the fact that interest rates are changed in steps, they are unable to explain why policy decisions are made 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 rises as well. The existing models predict that if the benefit of raising the interest rate exceeds the adjustment costs, policy should be tightened immediately. Thus, 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 also not explained.

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 three important directions that explain why the policy rate may deviate from the optimal rate. First, we assume that policy decisions are costly, whether or not they lead to an interest rate adjustment. Interest rates are set by an MPC, whose members meet to discuss the state of the economy and to vote on interest rates.[2] One consideration in choosing the meeting intervals is how often relevant data become available. Economic data are published at different frequencies, ranging from by the second for financial markets data to annually for GDP figures in certain economies. High-frequency data typically do not signal on a daily basis developments that are relevant for monetary policy; such trends are usually identified at a lower frequency. Given policymakers' time constraints and the staff time involved in preparing MPC meetings, it is therefore not optimal to decide daily on the stance of policy.[3] This, however, implies that the policy rate often deviates from the optimal rate. Another reason against daily interest rate decisions is that trading activity in the currency and bond markets tends to decrease immediately before the announcement of a policy decision (Bank of Canada, 2000). The more often decisions are taken, the more frequently trading is slowed down, which is inefficient. Moreover, policymakers may able to signal their intentions more clearly if they set policy rarely (Demiralp and Jordá, 2002). Below, we refer to the different reasons why daily policy decisions are undesirable as "meeting costs".

Second, we assume that the optimal interest rate is not observed perfectly. This uncertainty also causes the policy rate to deviate from the optimal rate. MPC members form a view of the state of the economy from the available data. We assume, quite

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[2] While we discuss the step pattern in terms of an MPC, the analysis could be easily adapted to a single policymaker. For analyses of MPCs, see e.g. Aksoy, De Grauwe and Dewachter (2002), Gerlach-Kristen (2006a), Gerling, Grüner, Kiel and Schulte (2005), and Mihov and Sibert (2006).

[3] Charles Goodhart, former MPC member at the Bank of England, has argued that "[o]ne obvious advantage of a monthly meeting is that it can be fitted into the monthly cycle of the flow of economic data" (p. 6, Goodhart, 1999a).

realistically, that individual members interpret the data differently and are unable to agree on one common interpretation. This gives rise to a distribution of views of what interest rate to set. In principle the median voter will determine the level of the interest rate.

Third, we assume that, as in practice, policymakers favour consensus decisions. Former FOMC member and current President of the San Francisco Fed Janet Yellen states that

> "FOMC participants are highly motivated to cooperate in seeking, finding, and articulating a Committee consensus and their ability to do so enhances the credibility, legitimacy, and likely effectiveness of monetary policy" (pp. 2-3, Yellen, 2005).

Similarly, former FOMC Vice Chairman Alan Blinder and Charles Wyplosz (2004) suggest that committees strive for a large majority in the interest rate vote "lest the authority of the group may be undermined" (p. 16). Henry Chappell, Rob McGregor and Todd Vermilyea argue that

> "internal consensus gives the FOMC power and credibility in dealing with external clients, including the President, the Congress, and the public" (p. 408, Chappell, McGregor and Vermilyea, 2004).[4]

Thus, policy changes are thought to meet with broader public acceptance if they

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[4] Meade (2005) documents that FOMC members tend to take consensus decisions even if the preceding policy discussion has revealed differences in view. Sager and Gastil (2006) discuss the advantages of consensus over majority decisions from a psychological perspective.

are supported by a large majority of committee members.[5] We demonstrate that by considering only a finite number of interest rate levels (one step size apart) in the policy discussion, the formation of a large majority in the committee is facilitated. The larger the step size between these alternative levels of the policy interest rate, the larger the expected majority, but the larger also the average deviation of the policy rate from the optimal rate.

Policymakers thus face a trade-off between the need to minimise the difference between the actual and the optimal interest rate – which calls for a zero step size and meeting interval – and the desire to minimise the meeting costs and to reach a decision that is supported by a large majority of committee members – which entails a positive step size and meeting interval.

It should be emphasised that the model assumes that policymakers choose the meeting frequency and the step size once and for all. Thus, if the step size is 25 basis points, policymakers do not adjust interest rates by 10 basis points even if they all think that exactly this adjustment is necessary. This assumption implies a time-inconsistency but keeps the analysis simple and is realistic given that in practice policymakers do infrequently change the step size or the meeting frequency.

The rest of the paper is structured as follows. Section 2 presents some stylised facts concerning the step pattern of interest rates in different economies. We document that rates are normally changed by 25, and more rarely by 50, basis points and that policy decisions are typically taken every four to six weeks. Section 3 briefly reviews the existing

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[5] For a single policymaker, setting interest rates such that a broad majority of the public agrees with his policies arguably also raises his legitimacy.

literature. We argue that it is difficult to rationalise the common assumption that adjusting the interest rate is subject to a fixed cost. Since this cost is a crucial building block in existing models, alternative explanations for the observed step pattern are desirable. Section 4 presents the model, which introduces meeting costs, uncertainty about the optimal interest rate and policymakers' preference for large majorities. Section 5 simulates the model and shows how the optimal step pattern depends on institutional factors such as the size of the MPC, on macroeconomic factors such as the variability of the optimal interest rate and on policymakers' uncertainty. Section 6 concludes.

2 Stylised facts

To illustrate the similarities and differences in the step pattern of interest rates, we plot in Figure 1 the interest rates set by the Bank of England, the European Central Bank and the Federal Reserve between January 2000 and March 2006.[6] The figure shows that interest rates are set in steps and that adjustments were by either 25 or 50 basis points. Importantly, interest rates were frequently held constant for several months in a row. When interest rates were adjusted, this change was gradual in the sense that policy was changed in several consecutive meetings by one or two steps at a time.

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 by changing rates by 50 basis points. A second difference is that the federal funds

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[6] We present the repo rates for the Bank of England and the European Central Bank and the federal funds rate for the Federal Reserve.

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, these findings are compatible with the notion that the level of interest rates 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 or to differences in the structure of the economy or in policymakers' preferences regarding inflation and the output gap. If for instance policymakers attach a great weight to the objective of keeping inflation stable, the implied optimal interest rate follows a different course than if the main objective is the stabilisation of the output gap. Figure 1 suggests that a large step size is desirable in economies in which the optimal interest rate is volatile. The model presented below confirms this view. Since the variance of the shocks affecting different economies is unlikely to be the same, it is therefore surprising that most central banks use a common step size of 25 basis points.[7]

– Figure 1 about here –

The model presented below explains three dimensions of the interest rate setting behaviour of central banks: the step size, the frequency of policy decisions and the occurrence of interest rate changes by several steps. Table 1 shows summary statistics on these characteristics for Australia, Canada, the euro area, Sweden, the UK and the US over

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[7] 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 the committee shortly after its formation in 1997, but that the issue was dismissed as "too academic."

the period January 2000 to March 2006. While the frequencies of policy decisions and multiple steps differ between economies, these central banks all use a step size of 25 basis points.

– Table 1 about here –

Table 1 indicates that the number of scheduled policy meetings a year ranges from eight in Canada and the US to twelve in the UK. The frequency at which the level of interest rates was adjusted was highest in US (at 61.2% of all meetings) and lowest in the euro area (22.5%). Decisions in favour of a multiple step were least frequent in the UK (1.3% of all meetings) and most common in the US (20.4%).[8] One prediction made by the model below is that the rarer meetings are, the more likely are decisions for a policy change. This is compatible with the pattern reported in Table 1, where the correlation between the number of meetings a year and the fraction of decisions in favour of an interest rate change is -0.87. Moreover, the model implies that policymakers are the likelier to take two steps at a time, the fewer meetings there are per year. Also this seems to be borne out by the data; we find a correlation of -0.77 between the number of policy meetings per year and the fraction of decisions in favour of a multiple interest rate change.

An important feature of our model is that monetary policy decisions are taken by a majority vote. We therefore also report summary statistics on the decision procedure in the different central banks, which either take decisions by consensus (the Bank of Canada, the European Central Bank and the Reserve Bank of Australia) and or by a vote

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

(the Bank of England, the Federal Reserve and the Riksbank).[9, 10] In practice, even the average majority by which a voting MPC takes decisions is rather large, lying between 81.7% in the UK and 99.1% in the US. This arguably reflects policymakers' preference for a broad consensus in the committee, which, as discussed in the Introduction, might raise policymakers' legitimacy and authority.

In sum, the stylised facts suggest that policymakers at the central banks considered adjust interest rates at roughly every third meeting by typically 25, and occasionally by 50, basis points. The meetings are scheduled every one to three months, and interest rate adjustments are the likelier, the longer the meeting interval.

3 Brief review of the literature

The theoretical literature on the step pattern of interest rates was sparked by Goodfriend (1991) and still is rather limited. Goodfriend argues that policymakers change interest rates in fixed steps since this allows financial market participants to concentrate on a small number of possible interest rates when forming expectations about future monetary policy. Eijffinger, Schaling and Verhagen (1999), Huizinga and Eijffinger (1999) and Verhagen (2002), by contrast, assume that policymakers are concerned that frequent interest rate adjustments might destabilise the banking system, reduce the signal effect of policy changes or be interpreted as a sign of policymakers' incompetence. Adjusting

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[9] While policymakers at the European Central Bank set interest rates by consensus, its statutes allow them to take decisions by majority.

[10] See Andersson, Dillén and Sellin (2001) for a discussion of the voting record in Sweden, Gerlach-Kristen (2003) for the UK and Meade (2002) for the US.

policy thus comes at a cost, and the interest rate is changed only once the deviation of the interest rate from the optimal level has become excessively large. The more policymakers worry about destabilising the banking system, the effectiveness of monetary policy and their reputation, the higher these adjustment costs. As a consequence interest rate changes are less frequent and the step size is larger.

Guthrie and Wright (2004) argue that the adjustment costs have one fixed component and one proportional to the size of the interest rate change. This latter assumption captures the hypothesis that policymakers abstain from large interest rate adjustments so as not to trigger unwarranted volatility in financial markets and implies that 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 interest rate changes well (see e.g. BIS, 1998 and Goodhart, 1999b).

Overall, the literature suggests that policymakers set interest rates in steps because they face a trade-off between the costs of having the interest rate deviate from the optimal level and the costs of policy adjustments. However, this assumption is unattractive for two reasons. First, if policy is changed as soon as the benefits of an adjustment exceed the costs, the interest rate is always changed by the same amount. The fact that central banks often take multiple steps thus is not explained. Second, if policy is changed whenever the benefits of an adjustment are larger than the costs, decisions are necessarily taken at random points in time. This does not match the fact that policy is typically changed on dates scheduled several months in advance.[11], [12] The model we present does not suffer from these shortcomings.

One crucial new assumption in our model is that policymakers are uncertain about the optimal level of interest rates. Such uncertainty can arise if the data available to policymakers are published with lags and subject to revisions, if policymakers need to rely on unobservable variables such as the output gap and if the exact impact of a change in interest rates on the economy is unclear. We concentrate below on data uncertainty. Orphanides (2001) documents that inflation and especially output gap data are subject to considerable revisions over time and shows that policy recommendations differ depending on the use of real-time or ex-post data.[13] Orphanides and van Norden (2005) show that output gap revisions are roughly as large as movements in the output gap itself. Consequently, monetary policymakers face a high degree of uncertainty when assessing the optimal level of interest rates.

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[11] Even if we assumed that policy meetings are scheduled at fixed intervals, we would not observe multiple steps in models with fixed adjustment costs. Interest rate changes would be equal to or larger than a minimum amount, which is determined by the adjustment costs, but not be restricted to integer multiples of this minimum step size.

[12] Guthrie and Wright (2004) discuss an extension of their model in which policymakers schedule dates for policy changes in advance. If the interest rate is changed on such a date, the effect on financial market volatility is assumed to be smaller than on other days. While this assumption explains why a fixed time schedule for interest rate changes may be desirable, it also implies that when policy is adjusted between scheduled dates, the amount by which it is changed is larger than otherwise and the larger, the closer the next announced decision date. Thus, the step size ceases to be fixed.

[13] The Federal Reserve Bank of Philadelphia provides a large real-time data set for the US going back to 1947.

4 The model

As in the literature we assume that the central bank sets a short-term interest rate, the "optimal" level of which minimises a loss function consisting of the squared deviation of inflation from target and the squared output gap (see e.g. Svensson, 1997). For simplicity, we do not model the economy explicitly but instead consider a law of motion for the optimal interest rate i_t^*. In particular, we let i_t^* evolve over time as a continuous-time Ornstein-Uhlenbeck process

$$di_t^* = -\alpha i_t^* dt + d\omega_t, \tag{1}$$

where $d\omega_t$ is the increment of a standard Wiener process (see e.g. Arnold, 1974) and captures the shocks affecting the optimal rate.[14] This innovation is uncorrelated over time and has a mean of zero and the variance $\sigma_*^2 dt > 0$, where the variance is larger in economies that face more volatile macroeconomic conditions. The coefficient α reflects how mean reverting the optimal rate is ($\alpha = 0$ implies that i_t^* is non-stationary, $\alpha = \infty$ that it follows a white noise process). We let $\alpha > 0$, so that the optimal rate is stationary.[15]

Harvey (1989) shows that equation (1) can be expressed in discrete time as

$$i_t^* = e^{-\alpha\tau} i_{t-\tau}^* + w_t, \tag{2}$$

with $w_t = \int_0^\tau e^{-\alpha(\tau-v)} d\omega_v dv \sim N(0, \widetilde{\sigma}_*^2)$ with $\widetilde{\sigma}_*^2 = (1-e^{-2\alpha\tau})\sigma_*^2/(2\alpha)$ and where τ denotes the interval between two policy decisions. It is the task of monetary policy to ensure that the policy rate i_t follows i_t^* as closely as possible. Formally, policymakers attempt to

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[14] We do not allow for a jump process (see e.g. Ball and Torous, 1985) in equation (1). Such a process could account for multiple interest rate steps even if there were no fixed meeting frequency.

[15] In Section 5 we consider the case of $\alpha = 0$ as alternative model specification.

minimise $E(i_t - i_t^*)^2$, which, assuming no other constraints, would be achieved if i_t was adjusted continuously. We next discuss three features of the model that lead to deviations of i_t from i_t^*.

4.1 Meeting costs

The first of these is that policy is set by a committee that meets only at certain intervals τ because interest rate decisions are costly. Such meeting costs c arise because policymakers' schedules are busy, whereas relevant economic data become available relatively rarely, which makes daily MPC meetings undesirable; because imminent policy decisions slow down trading in financial markets, which is inefficient; and because frequent decisions reduce the signal value of policy announcements and thus the power of monetary policy.

Policymakers' loss function therefore includes meeting costs as well as the expected deviation of the policy rate from i_t^*. At each meeting, the MPC faces the loss function

$$l = \tau E(i_t - i_t^*)^2 + c, \tag{3}$$

where we multiply the first term by τ to capture that the policy rate remains fixed until the next policy meeting. To compare whether a longer or shorter meeting interval is preferable, this loss function needs to be converted into a loss function over a fixed time period (e.g. a year). Normalising 1τ to equal one month, we obtain the annual loss function L by multiplying equation (3) by $12/\tau$,

$$L = 12E(i_t - i_t^*)^2 + \frac{12c}{\tau}. \tag{4}$$

Policymakers face a trade-off in minimising equation (4) in that choosing a large τ means low meeting costs but also implies that any deviation of the policy rate from i_t^* is protracted.

4.2 Uncertainty

The second feature that makes i_t deviate from i_t^* is the assumption that policymakers are uncertain about the current level of i_t^*. We model this by denoting policymaker j's "observation" of the optimal interest rate by

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

with $u_{j,t} \sim N(0, \sigma_u^2)$, where $\sigma_u^2 > 0$, $E(u_{j,t}u_{k,t}) = 0$ for all $j \neq k$ and $E(u_{j,t}u_{j,t-q}) = 0$ for all $q \neq 0$. The observation error $u_{j,t}$ captures the data uncertainty the committee members are exposed to.[16] This uncertainty arises because policymakers interpret the same economic data slightly differently and contributes to the deviation of i_t from i_t^* in the loss function.

An alternative way to model data uncertainty, which we consider in Section 5.2, is to let

$$i_{j,t} = i_t^* + u_{j,t} + z_t, \tag{6}$$

where $z_t \sim N(0, \sigma_z^2)$, where $u_{j,t}$ and z_t are uncorrelated and where z_t captures uncertainty about the data that is due to difficulties in measuring the state of the economy in real time.[17] This measurement error is common to all policymakers and disappears once the

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[16] It should be noted that policymaker j observes i_t^* continuously. Since the committee members exchange information on the optimal rate only during MPC meetings, it is however appropriate to model $i_{j,t}$ in discrete time.

[17] Orphanides and van Norden (2005) discuss how new data vintages reduce the initial measurement

data are revised. As Coenen, Levin and Wieland (2005), we assume that there is only one such revision and that it takes place after one period. Policymaker j's observation of the optimal rate last period then is given by

$$i_{j,t-1|t} = i_{t-1}^{*} + u_{j,t-1}. \tag{7}$$

Thus, in this specification of the model policymakers learn about the past mistakes they have made in forming views of the optimal interest rate and can thereby improve their assessment of the current i_t^*.

Monetary policy is conducted by an MPC with n members who share the same policy objective and do not behave strategically. The degree to which their views diverge reflects their uncertainty about the optimal level of interest rates (without uncertainty, all decisions should be taken by consensus). We assume that policymakers are equally "skilled" in the sense that their observation errors have the same variance σ_u^2.[18]

At the MPC meeting, policymakers discuss their views to obtain as good an estimate of i_t^* as possible. However, they are unable to reveal completely their views to one another (if the information exchange was complete, all policy decisions should be taken unanimously, which is not the case in practice). Assuming no data revisions, we let policymaker j's understanding of his colleague k's information on i_t^* be given by

$$i_{jk,t} = i_t^* + u_{k,t} + v_{jk,t}, \tag{8}$$

with the shock $v_{jk,t} \sim N(0, \beta\sigma_u^2)$, $v_{jj,t} = 0$ and $\beta > 0$ reflecting the communication

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error in GDP data.

[18] Gerlach-Kristen (2006a) discusses how differences in skill impact on the optimal decision procedure in an MPC.

difficulties.[19] We denote below the $n \times 1$ vector containing as jth element $u_{j,t}$ and zeros elsewhere by $U_{j,t}$ and the $n \times 1$ vector containing $v_{j1,t}$ to $v_{jn,t}$ by $V_{j,t}$.

Since i_t^* follows an autoregressive process, policymaker j combines his current observation of i_t^* and his understanding of his colleagues' views with his past assessment of the optimal rate to judge the level of i_t^*.[20] Using Kalman filtering (see e.g. Hamilton, 1994), we can show that policymaker 1's optimal "assessment" of i_t^*, $i_{1,t|t}^*$, equals

$$i_{1,t|t}^* = (1 - K_1 H') e^{-\alpha\tau} i_{1,t-1|t-1}^* + K_1 \begin{bmatrix} i_{1,t} \\ i_{12,t} \\ ... \\ i_{1n,t} \end{bmatrix}, \tag{9}$$

where H denotes a $1 \times n$ vector of ones, K_1 the gain vector, which equals $p_1 H (H' p_1 H + \Sigma_1)^{-1}$,

$$\Sigma_1 = (U_{1,t} + V_{1,t})(U_{1,t} + V_{1,t})' = \begin{bmatrix} \sigma_u^2 & 0 & ... & 0 \\ 0 & (1+\beta)\sigma_u^2 & ... & 0 \\ ... & ... & ... & ... \\ 0 & 0 & ... & (1+\beta)\sigma_u^2 \end{bmatrix}. \tag{10}$$

and p_1 the forecast error variance, which is given by $\widetilde{\sigma}_*^2 / [1 - e^{-2\alpha\tau}(1 - K_1 H')]$. Each policymaker arrives at a different $i_{j,t|t}^*$, and his assessment relies more on his current observation, the larger the gain vector. K_j in turn is larger, the larger the variance σ_*^2 of the shocks affecting the optimal interest rate (since this makes new information more valuable) and the larger the committee (since there is more new information available).

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[19] For a detailed discussion of this model, see Gerlach-Kristen (2006b).

[20] We assume that policymakers never know the level of the optimal interest rate with certainty.

The impact of the remaining parameters on K_j is ambiguous.

4.3 Voting scheme

The third feature that causes i_t and i_t^* to differ is that policymakers appear to prefer taking interest rate decisions by large majorities in practice. Large majorities can be achieved if the policy rate is set in steps. To see this, consider first the situation in which each policymaker simply advocates his $i_{j,t|t}^*$. In this case, the median voter's view would prevail, with a majority of $(n+1)/2$ voting for his $i_{j,t|t}^*$ and $(n-1)/2$ committee members voting against it. This would imply majorities of close to fifty percent, much smaller than what is observed in the data.[21]

For decisions to be taken by large majorities, policymakers' assessments have to be "grouped" in some way. If only certain levels of the policy rate i_t, each a step size s apart, are considered and if s is large enough, it is possible for all $i_{j,t|t}^*$ to lie close to the same step of i_t, which then gives rise to a unanimous decision. Below we consider a "majority vote", where interest rates are changed if a majority larger than 50% favours such an adjustment, and a "consensus procedure", in which all committee members have to agree on an interest rate change.

While using a positive step size thus facilitates the formation of large majorities, it has the disadvantage that the discrete variable i_t only rarely coincides with the continuous variable i_t^*. The larger s, the larger the expected deviation. Policymakers thus face a

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[21] It would also rule out situations in which three different levels of the interest rate find support. While such outcomes are rare, they have occurred at the Bank of England (in May and August 1998 and in January 1999).

second trade-off in minimising the loss function (4).

4.4 Summary

The MPC attempts to set the policy rate i_t as close as possible to the optimal rate i_t^*, subject to the constraints that policy meetings are costly, that policymakers' observations of i_t^* are imperfect and that they have a preference for decisions to be taken by large majorities. Committee members minimise the annual loss function

$$L = 12\left[E(i_t - i_t^*)^2 + \frac{c}{\tau}\right] \tag{11}$$

by choosing the meeting interval τ and the step size s, but face two trade-offs doing so. First, a large τ leads to protracted deviations of i_t from i_t^* but at the same time keeps meeting costs down. Second, a large s implies that the average majority is large, but it also means that the absolute deviation of the policy rate from i_t^* is large. We next study how the optimal size of τ and s depends on the model parameters.

5 Simulations

In this section we simulate the model in order to evaluate how the optimal step pattern depends on the assumptions regarding (1) the time-series characteristics of the optimal interest rate, (2) policymakers' uncertainty and (3) institutional factors such as the size of the committee. We first discuss a base-line specification and then turn to alternative specifications, which are summarised in Table 2.

5.1 Base-line specification

We first calibrate the model such that the time-series characteristics of the policy interest rate, in particular the step size and the frequency of policy changes, match what is observed in the data. Thus we normalise τ such that 1τ corresponds to one month. To capture the dynamics of the optimal rate, we set $\alpha = 0.05$ and $\sigma_*^2 = 0.05$, which implies that the autoregressive coefficient $e^{-\alpha\tau}$ of i_t^* in equation (2) equals 0.95 for $\tau = 1$, while the standard deviation $\widetilde{\sigma}_* = \sqrt{(1 - e^{-2\alpha\tau})\sigma_*^2/(2\alpha)}$ of the shocks is 0.30. This means that the monthly innovation of i_t^* is with a probability of 95% no larger than ± 0.60 percentage points.

We capture policymakers' uncertainty by setting $\sigma_u^2 = 0.2$. This implies that policymakers' observations of i_t^* lie within ± 0.89 percentage points of the optimal rate with a probability of 95%. While this variance may at first thought appear large, it has to be borne in mind that it reflects a single policymaker's uncertainty whose entire information set is given by this month's economic data. Since policymaker j's judgement of the optimal rate also makes use of past information and of his colleagues' current views, the variance of $i_{j,t|t}^*$ is considerably smaller. For the parameters assumed in the base-line specification, the variance of $i_{j,t|t}^*$ equals 0.01 and thus lies much below σ_u^2. The parameter β, which captures the communication difficulties, is set equal to 0.5, which implies that policymaker j's understanding of his colleague k's observation of the optimal interest rate has a variance of $1.5\sigma_u^2$. We assume that there are no data revisions, so that $\sigma_z^2 = 0$.

The institutional factors impacting on the optimal step pattern are the size of the committee, the meeting costs c and the decision procedure. We set $n = 9$, which lies in the intermediate range of observed MPC sizes, assume meeting costs of $c = 0.05$, which suggests that meeting costs are relatively unimportant compared with the costs arising when the policy rate deviates from the optimal level, and choose as decision procedure the majority vote.

– Table 2 about here –

To obtain the optimal values of s and τ, we draw 1000 random values for w_t, the innovation of the optimal interest rate, n random series of 1000 observations each for policymakers' observation errors $u_{j,t}$ and $n(n-1)$ series for the communication errors $v_{jk,t}$. We then compute

$$L = \frac{12}{1000} \sum_{l=1}^{1000} [(i_{t+l} - i^*_{t+l})^2 + c/\tau] \tag{12}$$

for all combinations of $s = [0.05; 1.00]$ and $\tau = [0.25; 6]$, i.e. we consider step size 5 basis points, 10 basis points etc up to one percentage point and meetings that take place once a week, every other week etc up to twice a year. The combination of s and τ that minimises the loss function represents the optimal step pattern.

Table 3 shows that for the base-line specification the optimal step size is 30 basis points and the optimal meeting frequency is eight times a year, a pattern that is realistic. We find that interest rates are changed on 39.4% of all occasions at which the committee meets. In practice, Table 1 shows that policy meetings between January 2000 and May 2006 ended with an interest rate change in 22.5% (ECB) to 61.2% (Federal Reserve) of all occasions. A fraction of 0.8% of all decisions in the base-line simulation are for a multiple interest rate change, whereas the central banks we surveyed above take multiple steps in

1.3% to 20.4% of all cases.[22] The average size of majority is simulated as 81.4%, which is close to the reported majorities (81.7% to 99.1%).

– Table 3 about here –

Table 3 also presents the step pattern that results if either the step size is set equal to twice its optimal value or if instead the length between two meetings is doubled. For $s = 60$ basis points and $\tau = 1.5$ months, the average majority increases to 86.8%. Interest rate changes are much rarer than in the optimal case since a majority in favour of an adjustment is more difficult to be formed: only 28.7% of all meetings end with an interest rate change, and a double step is taken in one of the thousand simulated interest rate decisions.

If we consider instead $s = 30$ basis points and $\tau = 3$ months, policymakers' views are less uniform and the average majority is smaller than in the base-line specification since the optimal rate may have moved considerably over the last three months. The fact that i_t^* may have changed much also explains why meetings end more often with a policy adjustment (57.1% of all cases) and why double steps are frequently taken (on 12.1% of all occasions). The pattern that rare policy decisions make it likely that MPC meetings end with an interest rate adjustment (by one or several steps) matches the empirical evidence in Table 1.

Figure 2 shows over fifty months the simulated path of the optimal interest rate i_t^* together with the rate i_t set by the committee for $s = 30$ basis points and $\tau = 1$ month.

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[22] Arguably, the shocks affecting i_t^* might be leptokurtic, which would account for the high observed frequency of multiple steps in practice. We assume normal innovations for simplicity.

The optimal rate ranges between -2.10% and 0.31% (note that i_t^* is assumed to have a zero mean). We see that i_t moves only over a range from -1.80% to 0% and lags behind i_t^*. This "too little, too late" tendency results from policymakers' uncertainty and the autoregressive pattern of i_t^*.[23] The step pattern is overall similar to that shown in Figure 1: policy often remains unchanged for several months and then tends to be adjusted in several consecutive steps in the same direction.[24] In sum, our simple model matches the time-series behaviour of actual policy rates quite well.

– Figure 2 about here –

5.2 Alternative specifications

To check the robustness of the optimal s and τ obtained in the base-line specification, we next simulate the model changing the underlying model assumptions one at a time. The discussion is grouped by the parameters describing the pattern of the optimal rate, by those capturing policymakers' uncertainty and by institutional factors.

5.2.1 Alternative pattern of i_t^*

To evaluate the impact of a changed pattern of the optimal interest rate, we first assume that the optimal rate ceases to follow an AR(1) process and instead is described by a random walk (i.e. we change α from 0.05 to 0). Next, we assume again that $\alpha = 0.05$ and increase the variance σ_*^2 of the shocks affecting the optimal rate from 0.05 to 0.5.

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[23] See also Gerlach-Kristen (2005).

[24] However, we also observe some immediate policy reversals in Figure 2, which are highly uncommon in practice. One reason for this may be that we do not model policymakers' dislike of such reversals (see Goodhart, 1999b).

In Case A, where $\alpha = 0$, the optimal step size falls to 20 basis points, and meetings should be held monthly. It is desirable to assess the stance of policy more frequently than in the base-line specification since i_t^* displays no mean reversion if $\alpha = 0$. A smaller step size is optimal because i_t^* on average moves less over one month rather than over 1.5 months. Consequently, policymakers' views are less dispersed than in the base-line case. The change in s and τ affects the pattern of the policy rate. Table 4 reports that the committee changes rates slightly more frequently than in the base-line scenario (51.8% of all cases) and takes double steps more frequently (5.5% of all decisions). The average majority is with 69.7% smaller than before.

– Table 4 about here –

The simulations for Case B, which assumes a variance of the shocks affecting the optimal rate of 0.5 instead of 0.05, indicate that the optimal meeting frequency increases to roughly 24 meetings a year, while the optimal step size drops to 25 basis points. This change occurs because i_t^* moves over a larger range, which makes frequent policy evaluations desirable. A small step size is attractive since policymakers rely heavily on their current observation of i_t^* if this rate is exposed to large shocks, which in turn renders their views more similar given the other parameter assumptions.[25] The new optimal values for s and τ make interest rate changes more likely (66.0% of all MPC meetings end with a policy adjustment, and 2.8% of all decisions are in favour of a multiple-step change), but decrease the average size of majority to 74.7%.

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[25] This result can be reversed by assuming a very large variance σ_u^2 of policymakers' observation errors. However, our assumption of $\sigma_u^2 = 0.2$ is, if anything, already on the large side.

5.2.2 Alternative assumptions about policymakers' uncertainty

We next consider alternative assumptions regarding policymakers' ability to observe the optimal interest rate. Case C assumes that the variance σ_u^2 of the observation error is 2 instead of 0.2. This increase in uncertainty renders policymakers more cautious in changing interest rates, and the optimal step pattern now is given by $s = 40$ basis points and $\tau = 1$. Thus, a larger step size than in the base-line specification is optimal, the reason being that more uncertainty causes a wider dispersion of policymakers' views and thus renders the formation of an absolute majority more difficult. The optimal frequency of policy decisions increases to ensure that when there is a majority for an interest rate change, the MPC indeed meets and thus is able to adjust rates. The large step size causes interest rate changes to be rare (27.7% of all occasions; 0.1% of all decisions are for a change by two or more steps). The average majority is with 69.8% smaller than in the base-line scenario, which suggests that the larger step size does not fully compensate for the fact that higher uncertainty causes a wider distribution of policymakers' views.

Case D assumes that policymakers have greater difficulties in communicating their views to one another, which we model by a rise of β from 0.5 to 5. This increase in uncertainty does not affect the optimal step pattern identified for the base-line specification, presumably because the comparatively large committee size of nine ensures a wealth of data on i_t^*. Nevertheless, policymakers' views are more dispersed and the MPC finds it more difficult to agree, which is reflected in the lower probability of an interest rate change (35.5% of all occasions; 0.3% for a multiple change) and in the lower average majority of 72.4%.

Case E considers the impact of data revisions. Whereas we assumed $\sigma_u^2 = 0.2$ and $\sigma_z^2 = 0$ in the base-line specification, we here set $\sigma_u^2 = \sigma_z^2 = 0.1$. Thus, uncertainty about the optimal rate is as large as in the base-line model in the period the data are first observed. Subsequently, however, the data are revised and uncertainty is reduced by half. These new data vintages allow policymakers to improve their assessment of the current i_t^*. Table 4 shows that this makes it possible to use a smaller step size of only 20 basis points. The optimal meeting interval remains unchanged. The smaller step size leads to more frequent policy adjustments (60.1% of all meetings end with an adjustment, 14.9% with a multiple interest rate step) but also to a slightly smaller average majority of 79.5%.

5.2.3 Alternative institutional assumptions

We now turn to the impact of institutional factors on the optimal step pattern. Case F considers an MPC with 18 instead of nine members. Since an increase in the number of policymakers implies more information on i_t^* and thus means that an absolute majority is more easily formed, a smaller step size of 15 basis points can be used. The optimal meeting frequency is unaffected. As a consequence of the smaller step size, policy is adjusted more frequently (in 59.0% of all cases, double or larger changes occurring on 14.3% of all meetings). The reduced step size leads to an average majority of only 69.2%.

Case G shows that if the meeting costs in policymakers' loss function rise from 0.05 to 0.5, rare meetings become attractive. The optimal meeting interval increases to almost five months, which implies protracted deviations of i_t from i_t^*. The optimal step size falls to 20 basis points, which helps reduce this deviation and which renders decisions to change the interest rate more likely (62.2% of all cases; 15.7% of all decisions are for two or more steps) than in the base-line case. The average majority, however, is smaller (75.0%).

In Case H we assume that the decision to change interest rates must be taken by consensus rather than an absolute majority. The optimal meeting frequency is the same as in the base-line specification. The optimal step size of now 55 basis points facilitates the achievement of unanimous decisions, but also implies that the considered interest rate adjustment is almost twice as large as in the base-line specification. Consequently, a consensus to change interest rates is rarely reached, with only 12.1% of all meetings ending with an interest rate adjustment and 0.1% with a double step.

5.3 Summary

Table 5 summarises how different assumptions about the model parameters impact on the optimal step pattern. The optimal step size is smaller and the optimal time between meetings shorter if the optimal rate follows a random walk rather than an autoregressive process and if it is affected by larger shocks. A smaller step size than in the base-line specification is also desirable if there are data revisions and if the MPC size is increased. A smaller s but a larger τ are optimal if meeting costs are higher and if policymakers are better able to observe the optimal rate. Assuming that policymakers convey their views more clearly to one another does not affect the optimal step pattern in our simulation. Finally, taking decisions by consensus instead of a majority vote makes a larger step size desirable without affecting the optimal τ.

– Table 5 about here –

6 Conclusions

This paper studies interest rate stepping. We assume that the interest rate is set by an MPC that values consensus decisions, that faces meeting costs and whose members do not observe the optimal level of the interest rate perfectly.

The optimal step size and meeting frequency in our model are determined by three sets of factors. The first set represents the dynamics of the optimal rate. We show that high autocorrelation, large shocks and transitory data uncertainty make frequent MPC meetings and a small step size desirable. The second set of factors relates to policymakers' uncertainty. Larger difficulties in observing the optimal rate lead to a larger optimal step size and shorter meeting intervals. Assuming better communication within the MPC does not seem to affect the optimal step pattern, while data revisions make a small step size attractive. The third set comprises institutional factors. A larger MPC reduces the uncertainty policymakers face and makes a smaller step size desirable, while larger meeting costs decrease the optimal step size and increase the optimal time span between two meetings. If, finally, interest rate changes must be decided by consensus, it is ideal to use a large step size.

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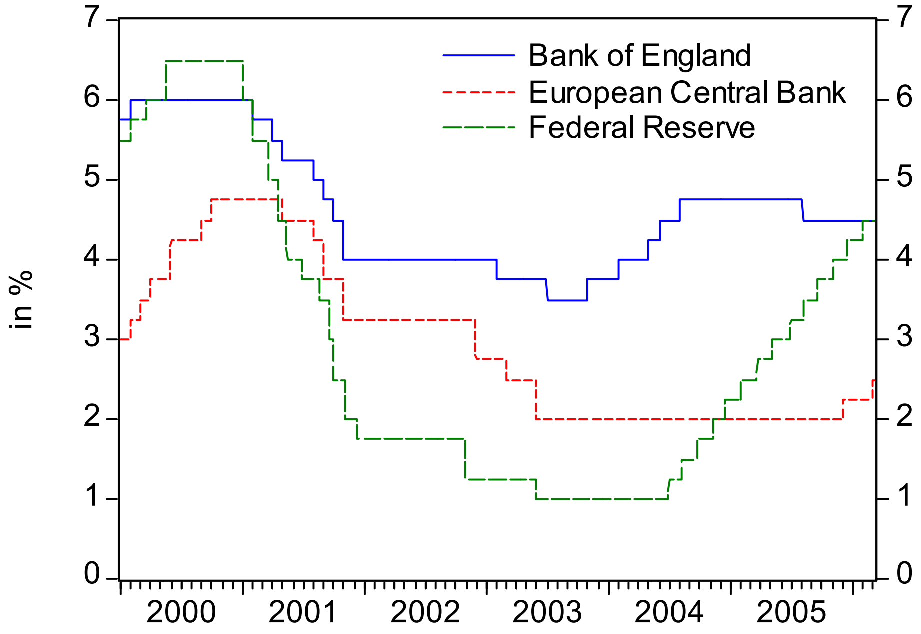
Figures and Tables

Figure 1:

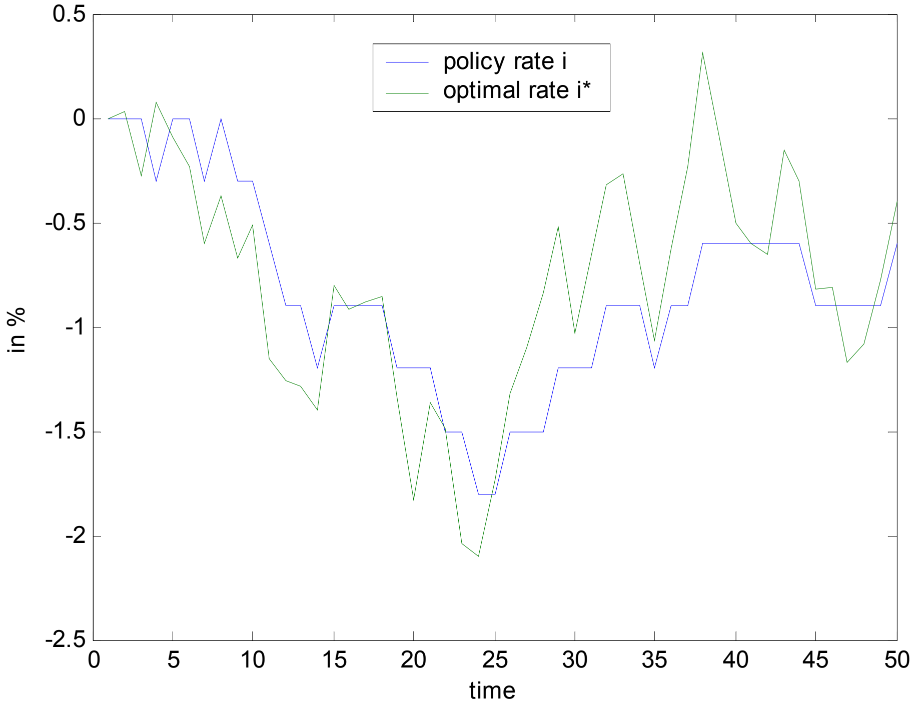
Policy interest rates



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 March 2006.

Figure 2:

Path of the optimal interest rate i_t^* and the policy rate i_t obtained from the base-line specification



Note: Simulation of the base-line specification. The optimal rate is assumed to have a mean of zero.

Table 1: Empirical evidence on interest rate changes

January 2000 to March 2006

	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	7 to 8
Fraction of decisions in favour of an interest rate change (%)	56.0	22.5	22.7	22.7	61.2	33.3
Fraction of decisions in favour of a multiple interest rate change (%)	8.0	7.7	4.5	1.3	20.4	10.4
Size of MPC	6	18	9	9	12	6
Average size of majority (%)	consensus	consensus	consensus	81.7	99.1	91.7

Note: The table uses data on scheduled policy meetings taken from the respective 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.

Table 2: Parameters in simulation

Base-line specification	Alternative specifications	Interpretation
Assumptions regarding the optimal rate		
$\alpha = 0.05$	Case A: $\alpha = 0$	$e^{-\alpha\tau}$ is the AR coefficient of i^*_t, $(1 - e^{-2\alpha\tau})\sigma^2_*/(2\alpha)$ its variance
$\sigma^2_* = 0.05$	Case B: $\sigma^2_* = 0.5$	$(1 - e^{-2\alpha\tau})\sigma^2_*/(2\alpha)$ is the variance of i^*_t
Assumptions regarding policymakers' uncertainty		
$\sigma^2_u = 0.2$	Case C: $\sigma^2_u = 2$	Variance of policymakers' observation error
$\beta = 0.5$	Case D: $\beta = 5$	Policymakers' communication difficulties
$\sigma^2_u = 0.2$, $\sigma^2_z = 0$	Case E: $\sigma^2_u = 0.1$, $\sigma^2_z = 0.1$	σ^2_u is variance of policymakers' observation error, σ^2_z that of the data measurement error
Assumptions regarding institutional factors		
$n = 9$	Case F: $n = 18$	Number of MPC members
$c = 0.05$	Case G: $c = 0.5$	Meeting costs
Majority vote	Case H: Consensus	Decision procedure

Note: Assumptions underlying the results presented in Tables 3 and 4.

Table 3: Base-line step pattern

	Base-line $s = 30$, $\tau = 1.5$	$s = 60$, $\tau = 1.5$	$s = 30$, $\tau = 3$
L	1.008	1.080	1.188
Fraction of decisions in favour of an interest rate change (%)	39.4	28.7	57.1
Fraction of decisions in favour of a multiple interest rate change (%)	0.8	0.1	12.1
Average size of majority (%)	81.4	86.8	72.5

Note: Obtained from simulations with 1000 draws.

Table 4: Optimal step pattern

	Base-line	Case A: $\alpha = 0$	Case B: $\sigma_*^2 = 0.5$
s (basis points)	30	20	25
τ (in months)	1.5	1	0.5
Policy decisions a year	8	12	24
Fraction of decisions in favour of an interest rate change (%)	39.4	51.8	66.0
Fraction of decisions in favour of a multiple interest rate change (%)	0.8	5.5	20.8
Average size of majority (%)	81.4	69.7	74.7

	Case C: $\sigma_u^2 = 2$	Case D: $\beta = 5$	Case E: $\sigma_u^2 = 0.1$, $\sigma_z^2 = 0.1$
s (basis points)	40	30	20
τ (in months)	1	1.5	1.5
Policy decisions a year	12	8	8
Fraction of decisions in favour of an interest rate change (%)	27.7	35.5	60.1
Fraction of decisions in favour of a multiple interest rate change (%)	0.1	0.3	14.9
Average size of majority (%)	69.8	72.4	79.5

	Case F: $n = 18$	Case G: $c = 0.5$	Case H: consensus
s (basis points)	15	20	55
τ (in months)	1.5	4.75	1.5
Policy decisions a year	8	2.5	8
Fraction of decisions in favour of an interest rate change (%)	59.0	62.2	12.1
Fraction of decisions in favour of a multiple interest rate change (%)	14.3	15.7	0.1
Average size of majority (%)	69.2	75.0	consensus

Note: Obtained from simulations with 1000 draws.

Table 5: Summary of alternative scenarios

Effect relative to base-line specification	s	τ
Case A ($\alpha = 0$): No mean reversion of i_t^*	-	-
Case B ($\sigma_*^2 = 0.5$): Larger shocks affecting i_t^*	-	-
Case C ($\sigma_u^2 = 2$): Larger uncertainty regarding i_t^*	+	-
Case D ($\beta = 5$): More communication difficulties within MPC	0	0
Case E ($\sigma_u^2 = 0.1$, $\sigma_z^2 = 0.1$): Data revisions after one period	-	0
Case F ($n = 18$): Larger MPC	-	0
Case G ($c = 0.5$): Larger meeting costs	-	+
Case H: Decisions taken by consensus	+	0

Note: + indicates a larger step size / longer meeting interval than in the base-line specification.