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MPC Voting, Forecasting and Inflation

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ABSTRACT

This paper considers the effectiveness of monetary policy committee voting when the inflation forecast signals, upon which decisions are based, may be subject to manipulation. Using a discrete time intertemporal model, we examine the distortions resulting from such manipulation under a three-way voting system, similar to that used by the Bank of Sweden. We find that voting itself creates persistence in inflation. Whilst altering the forecast signal, even if well intentioned, results in a diminished probability of achieving the inflation target. However, if committee members 'learn' in a Bayesian manner, this problem is mitigated.

KEYWORDS: Voting Rules, Monetary Policy, Inflation Targeting

JEL codes: E47, E52, E58

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1. INTRODUCTION

This paper examines how the voting behaviour of members of a monetary policy committee (*MPC)* may influence its ability to targeting inflation. While the subject of the influence of decisions taken by the *MPC* on macroeconomic stability is well researched, relatively little is known about the effects of the intra-committee dynamics of *MPC*'s on future inflation. It is hypothesized here that the manner in which *MPC*'s make decisions, including individual preferences and interactions between *MPC* members, affect the decisions themselves and the subsequent outcomes.

The effect of *MPC*'s decisions on macroeconomic stability has been widely analysed in the literature. Earlier research has looked at the preferences of committees with regards to inflation and output gaps e.g. Rogoff (1985), Waller (1989) and Mihov and Sibert (2006), along with the optimal rules to follow to ensure stability and growth, e.g. Rudebusch (2001) and Clarida *et al.* (2000) and how action are interpreted by the private sector e.g. (Demertzis and Hughes Hallett, 2008). This literature, however, has not usually considered the process by which the monetary decision is made. A smaller body of work has shown that the dynamics of group interactions within *MPC*'s have a significant effect on their ability (e.g. Blinder and Morgan, 2005). These papers, examining heterogeneous voting behaviour under specific voting schemes, have principally been concerned with the real policy effects (Gerlach-Kristen, 2006), informational efficiency (Blinder, 2007), or game-theoretical equilibrium (Berk and Bierut, 2005a,b, 2009). The structure and heterogeneity of signals considered by the *MPC* members in their voting decision, however, has rarely been discussed. The relevant papers looking at this aspect of the problem are that of Gerlach-Kristen (2006) and Weber (2010), who both analyse the effect of different gap signals on voting (see also Blinder, 2007), Brooks *et al.* (2007), where dynamic behaviour of the *MPC* voters is considered, and Gerlach-Kirsten (2004), Sirchenko (2010) and Horváth *et al.* (2010), who use records of *MPC* voting to predict interest rate changes. We focus here on the effect of the *MPC* on inflation; however, historically central banks have also targeted exchange rates with varying degrees of success (Brandner *et al*. 2006). If these interventions are decided by committee they may be subject to the same types of biases we analyse here.

As in Weber (2010) we are assuming heterogeneity of the *MPC* members with respect to the signals they received. However, we concentrate on the heterogeneity of the inflationary rather than output gap signals. We follow Blinder's (2007) suggestion and consider the static and dynamic effects of such heterogeneity on *MPC* monetary decisions and, subsequently, on inflation. More precisely, this paper concentrates on those aspects of *MPC* voting behaviour which are related to the perception and manipulation of the inflation forecasts signals. We investigate the effect of bias resulting from alteration of the forecast signals before they reach the majority of the voters (for a different view on leaders' bias of the voting scheme see Chappell *et. al*, 2007). In many cases the experts who produce the forecasts for the *MPC* work under some institutional influence of the *MPC* members, e.g. they might be employed by the Central Bank and be subordinates of the chair of the *MPC* (who is often a Governor of the Bank). As such it is possible for some members of the *MPC* to pressurise experts in such a way that they would produce forecasts which would suit the preferences of some members of the *MPC* more than the others. This would create a certain bias affecting voting outcome and, consequently, future monetary policy and inflation.

We examine the nature and outcomes of this potential bias using an inter-temporal model of voting. As there are few empirical studies of the subject (the notable exceptions being Chappell *et al*. 2005 and Brooks *et al*., 2007) and analytical solutions in a fully stochastic context are intractable (see Section 3 of this paper) we set up an inter-temporal simulation model. In this model decisions undertaken by the *MPC* directly affect next-period inflation. The crucial aspect of the model is the ability of one member of the committee to alter the inflation forecast signals delivered to the others (see Section 2). We assume that the most influential member of the committee has the power to alter the signals which other members of the committee receive. An alternative description of this behaviour could be that the most dominant member influences more junior members' *perception* of an accurate signal. Regardless of whether this comes through force of argument, seniority, or institutional rules, the dominant member may persuade others to vote in a particular manner even when their individual interpretation of the signal would entail a different action. In this setting Sibert (2003) shows that if more weight is placed on the decisions of senior policy makers the change in expected social welfare is ambiguous. The results presented in this paper may also be interpreted in the light of this setting and demonstrate that bias towards one particular policy maker has a specific effect on the ability to meet inflation targets.

The general model setting differs markedly from those usually applied in the contemporary theory of voting and aggregation rules. The initial assumptions are simple: the *MPC* members are sincere (naïve) voters, refraining from strategic voting. Only under the extreme assumption of independence of voting decisions and identical (for all voters) probabilities of taking the correct decision, together with particular voting scheme designs, can the voting process be regarded as optimal in the Condorcet sense (see e.g. Austen-Smith and Banks, 1996, Ladha, 1992). Our work also relates to that of Dietrich and List (2004) who present a model in which jurors make decision based on a common body of evidence rather than the state of the world. It was shown in this paper that in the limit the probability of a correct decision converges to the probability of the evidence not being misleading. The model presented in this paper sits between these two views. Whilst our committee members receive information on a body of evidence rather than the state of the world, that body of evidence is not common. In fact the information reaching particular *MPC* members are partially stochastic, hence different and, in the general case, correlated. Nitzan and Paroush (1984) consider interdependent voting and find that it is inferior to independent voting. In contrast Estlund (1994) finds that in some circumstances voters may follow opinion leaders and increase overall competence.

The problem of setting the optimal voting rules is not considered here (as it is not considered in the realities of central banks), rather we focus on the efficiency of voting under the aggregation rules frequently used by central bankers. In this perspective the paper extends the currently used framework of voting analysis by adding an intertemporal dimension and allowing for a stochastic rather than deterministic 'state of the world'.

The paper is structured as follows. Section 2 presents the details of the model. Section 3 contains the main distributional results and Section 4 the inter-temporal simulation results. In Section 5 the assumption of sincere voting is relaxed by introducing strategic behaviour based on a Bayesian learning rule. Conclusions call for the independence of the inflation forecasting units from the Central Bank and more heterogeneity, both in terms of greater diversification of the *MPC* members and a larger variety of forecast information.

2. GENERAL SETTINGS

We consider the voting behaviour of a monetary policy committee with n members over time $t = 1,2,\ldots,T$. In each period the *MPC* votes on monetary policy which affects inflation in time $t+1$. We model simple majority voting, with three possible outcomes: an active anti-inflationary decision, an active pro-inflationary decision and no change. In each round all members of the *MPC* simultaneously vote for their preferred outcome. In the case of a tie, one member of the *MPC* (the Governor) has the casting vote.

Adopting the Geraats (2009) model for the case of heterogeneous voters (for heterogeneity of the *MPC* voters' preferences, see Faust, 1996), each *MPC* member, indexed by i, $i = 1,\ldots,n$, maximises, at time t, the expected value of his/her objective function:

$$W_{i,t} = -\frac{1}{2}\omega_i(\pi_t - \pi^T)^2 - \frac{1}{2}(1-\omega_i)(y_t - y^T)^2 \quad , \tag{1}$$

where ω_i is the weight given to the inflationary target by individual *MPC* members (assumed to be constant over time), π_t is inflation in time t, y_t is the output gap and π^T , y^T are respectively the inflation and output gap point targets. Normality of inflation has been assumed. This is not empirically exact, however, it simplifies the design of the experiments and reduces signal-outcome identification problems.

The economy is described by a simple *IS-LM* type model:

'*IS* curve': $$y_t = -r_t + d_t \quad , \tag{2}$$

'*LM* curve': $$\pi_t = \pi^e_{i,t+1} + y_t + \varsigma_{i,t} \quad , \tag{3}$$

where information on the *IS* curve is identical for all *MPC* members, r_t is the riskless one-period nominal interest rate controlled by the monetary authorities, $\pi^e_{i,t+1}$ is the i^{th} members expected inflation in period t for $t + 1$, d_t is the demand shock (identical for all *MPC* members) and $\varsigma_{i,t}$ is the supply shock, different for the *MPC* members, as they all have different perception of the forthcoming inflation. If it is assumed that (1) there is a lack of economic transparency, (2) that participants have the ability to predict or deduce supply or demand shocks and (3), $E(d_t) = E(\varsigma_{i,t}) = 0$ for all i and all t, it may be shown that the first-order condition for the i^{th} *MPC* member, after substituting (2) and (3) into (1) and taking expectations, gives:

$$r_{i,t} = \omega_i \pi^e_{i,t+1} + C_i \text{ , where } C_i = (1-\omega_i)(-y^T) \quad , \tag{4}$$

where $r_{i,t}$ is the interest rate fulfilling the first-order condition, that is, maximizing the utility function subject to inflation signals received by each *MPC* member. Similar results may be obtained using a variety of models and assuming heterogeneity of *MPC* members (see e.g. Woodford, 2003, pp. 246; Besley *et al*., 2008, Eijffinger and Tesfaselassie, 2006).

2.1 Voting

Each *MPC* member decides on his/her vote according to the following rule:

$$v_{i,t} = \begin{cases} 1 & \text{if} \quad s^+ < r_{i,t} \\ 0 & \text{if} \quad s^- < r_{i,t} < s^+ \\ -1 & \text{if} \quad s^- > r \end{cases} \tag{5}$$

where $v_{i,t}$ denotes the decision of the i^{th} *MPC* member to vote respectively for 1, an anti-inflationary measure, -1, a pro-inflationary measure or, 0, for no change in monetary policy (passive voting). Accordingly, s^- and s^+ stand respectively for the lower and upper voting function thresholds.

The inflation signal given to member i at time t, $\pi^f_{i,t+1}$, is a random variable. Although the official forecasts delivered to all *MPC* members are identical, we treat the future inflation signals as heterogeneous but correlated. If the *MPC* members were to rely solely on the official forecast, these forecasts would be perfectly correlated among themselves. We are assuming, however, that each individual forecast is in fact a combination of the official forecast and some other information available (unofficial forecast or personal research) leading to correlated signals. We consider here the simplest case of the linear correlation across voters as being constant. Whilst the conditions for this are stringent we focus on this as the most intuitive case.[1]

As voters are *sincere*, in the sense that their decisions are based on the outcome of (5) alone, the applied voting scheme would be optimal in the Condorcet sense (see e.g. Young, 1995) if (*i*) the weights are identical for each voter,(*ii*) the distributions of $\pi^f_{1,t+1}, \pi^f_{2,t+1}, ..., \pi^f_{n,t+1}$ are independent and (iii) the choice were between two options. In fact none of these assumptions is in general fulfilled here. The sincerity assumption is relaxed further in Section 5.

2.2 Implementation

The *MPC* decision alters the inflation distribution at time *t*+1 by affecting its mean. No other factors alter the distribution of inflation. In other words, if the *MPC* takes no action, the inflation distribution remains unchanged. More generally, the relation between the distribution of inflation at time *t* and the initial distribution of inflation, π_0, is:

$$\pi_{t+1} \triangleq \pi_0 - \kappa \sum_{j=1}^{t} \Psi_j \quad , \tag{6}$$

where $\triangleq$ denotes equality in distribution. This means the current inflationary distribution is equal to the initial distribution minus the effect of the *MPC*'s interest rate changes. The strength of the interest rate effect on inflation, κ, is assumed to be constant in time. More general specifications have been examined, including relating κ to the amount of voting unanimity.[2] Such generalisations, however, do not affect the general message of the paper and make the model less transparent, so are not presented here.

In the base model the forecasts are made by informed forecasters (experts), who have full knowledge of the inflation distribution at time *t.* However, they do not know the *MPC* decision prior to it being taken. As in reality at most central banks we consider the *MPC* to request forecasts which are made under the assumption that the next monetary decision will be passive. This is similar in spirit to the Sender-Receiver model by Crawford and Sobel (1982). This implies that the initial forecast signals provided by the experts (which, as it is assumed later, are not necessarily the signals delivered to all *MPC* members,), denoted by $\tilde{\pi}^f_{i,t+1}$, are drawn from :

$$\tilde{\pi}^f_{i,t+1} \triangleq \pi_{t+1} \quad .$$

This forecasting scheme is dubbed 'perfect', in the distributional sense, as the forecasters perfectly recognize the distribution of inflation.

2.3 First Receiver

One particular *MPC* member, is the first to receive the inflation forecast signal provided by the experts and generated as a realisation of the random variable. Throughout this paper we

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[1] The main conditions for constant correlation are: (1) the unofficial forecasts are uncorrelated with each other and (2) the weights of the official forecast in combinations with the unofficial are identical for all voters (that is, the members beliefs in the validity of the official forecast are identical).

[2] Making the effect of the interest rate change dependent on the number of members voting in favour of the action increases the degree of MPC transparency. As van der Cruijsen *et al.* (2010) note, however, this does not necessarily increase performance.

call him/her the *First Receiver* (*FR*). Let us, additionally, assume that the *MPC* members are ordered according to their degree of belief in the forecast, so that $\omega_n > \omega_{n-1} >, \cdots > \omega_1$ and the most active *MPC* member, numbered *n*, is the *FR* (although changing this assumption does not affect the results significantly). Suppose, first, that he/she allows the signal to pass unaltered to all other *MPC* members. If the *FR* actively votes (that is, his/her voting indicator is outside of the boundaries), other members may not necessarily do the same as they have lower weights. This means that there is a possibility that the other committee members votes would go against the *FR*. Additionally, if the *FR* votes passively, other *MPC* members vote passively with probability one only in the case where all forecast signals are perfectly correlated. Here, due to the randomness of the forecast signals, some *MPC* members other than the *FR* may receive information which causes them to vote actively, while the *FR* votes passively. Under these circumstances it is natural to suppose that, as the *FR* genuinely believes in the necessity and efficiency of active voting, his/her objective is to win the vote by affecting the other members' decision. This type of behaviour has been observed in *MPC*'s, for instance Alan Greenspan would, on occasion, use his power over other members to change their voting behaviour (Binder, 2007). If neither the thresholds nor weights can be affected, as both of these are characteristics of the individual committee members, the only remaining action for the *FR* is to alter the value of the inflation signal. In practice this is possible when the signal comes from a research division of a central bank which is subordinated, either formally or informally, to the *FR*. Alternatively, as was discussed in the introduction, the *FR* could affect the interpretation of the signal by more junior members of the committee, either through seniority or persuasive argument. The *FR* alters the forecast signal as:

$$f(\pi^f_{j,t+1}) = \begin{cases} f(\tilde{\pi}^f_{i,t+1}) & if \quad v_{n,t} = 0 \\ g(\tilde{\pi}^f_{i,t+1}, v_{n,t}) & if \quad v_{n,t} \neq 0 \end{cases} \quad \text{for } j<n \quad ,$$

Evidently, for the *FR*, $f(\pi^f_{n,t+1}) = f(\tilde{\pi}^f_{n,t+1})$, as he/she is not going to alter their own signal. Ways of constructing $g(\pi^e_{j,t+1}, v_{n,t})$ are discussed in the next section of the paper.

3. VOTING SIGNALS, DECISIONS AND OUTCOMES

Denote the binary random variables explaining voting decisions for the i^{th} *MPC* member, *i*=1,...,*n*, as:

$$I^{(k)}_{i,t} = \begin{cases} 1 & \text{if } v_{i,t} = k \\ 0 & \text{otherwise} \end{cases} \quad ,$$

where *k* = -1, 0, 1, as given by (5). Further denote the sums of identical votes as:

$$I^{(k)}_t = \sum_{i=1}^{n} I^{(k)}_{i,t} \quad .$$

In order to identify the voting outcome, let us denote by $I^{(k)}_{h,t}$ the vote of the h^{th} *MPC* member who has the casting vote. Usually this would be the First Receiver (*h* = *n*), but this does not have be the case. The result decided by majority vote is: $\Psi_t = \{k : \max(I^{(k)}_t)\}$ if:

1. $I^{(k)}_t > I^{(\ell)}_t$, $\ell \neq k$ (absolute majority in favour of k),

2. $I^{(k)}_t = I^{(\ell)}_t$ (split majority) then:

   a) $I^{(k)}_{n,t} = 1$ (casting vote decides when the casting vote holder is in a split majority), or:

b) $I_{h,t}^{(k)} = I_{h,t}^{(\ell)} = 0$, k = 0 (if the casting vote holder is in a minority, in case of an allied split vote, {1,0} or {0,-1}, he/she supports the closest outcome),

c) $I_{h,t}^{(k)} = I_{h,t}^{(\ell)} = 0$, $|k| = 1$ and $\operatorname{sgn}\left(\frac{(s^+ - s^-)}{2} - r_{h,t}\right) = k$ (if the casting vote holder is in a minority in case of an extreme split vote, {1,-1}, he/she supports the side on which he/she would have voted if the vote for 0 was not allowed),

In practice the voting schemes used in banks vary greatly. It is not easy to obtain clear information on the voting algorithms used by particular monetary policy councils. However, the algorithm applied here appears to be close to that used by the Bank of Sweden. *MPC*'s of other major central banks vote either for the motion proposed by the Chairman (the US Federal Reserve Board), do not apply the casting vote (e.g. central banks of Australia and Canada), decide on the basis of the median voter (Bank of England; see also the central bank voting experiment by Lombardelli *et al*. 2005) or apply the absolute majority rule (e.g. Central Bank of Poland). Hoverer, the preliminary results by Charemza and Makarova (2012) indicate that the algorithm applied here is the most efficient, in terms of stabilizing inflation around the target.

The likelihood of different vote distributions (splits between outcomes) depends on assumptions about the nature of the inflationary signals passed to the voters. The forecast signals delivered to all *MPC* members (with the exception of the *FR*) are:

$$\pi_{i,t+1}^{f} = \tilde{\pi}_{i,t+1}^{f} + \beta v_{n,t} \quad , \tag{7}$$

where β is the strength of the mean alteration by the *FR*, assumed here to be identical for all i. Hence, if $|v_{n,t}| = 1$, the *FR* alters the mean of the signal delivered to the other *MPC* members in such a way that it inflates the inflation signal by β when he/she wants to vote for an anti-inflationary measure and deflates the inflation signal by β in the opposite case. Otherwise the signal is passed on unaltered. The distribution of voting outcomes becomes the Bernoulli only in case where the probabilities of all three outcomes for all voters are identical. Otherwise it becomes a special case of the Poisson binomial distribution (see e.g. Johnson, 2005) and must be calculated numerically.

3.1 Static Analysis

In order to avoid blurring the results by changes to less relevant parameters the remaining parameters are kept constant. These are:

(i) Variance of the initial distribution of inflation is equal to unity that is $\pi_0 \sim N(\bar{\pi}, 1)$;

(ii) $\omega_i = i/n$ (as voters are ordered from the most sceptical to the most believing, the *FR*). Hence, random variables $I_t^{(k)}$ take values from 0 (no vote for outcome k) to n (unanimous voting for outcome k);

(iii) $y^T = 0$, that is the output gap target is zero. This simplifies the interest rate equation (4), so that it becomes a linear function of the expected inflation;

(iv) $\kappa = 0.5$ (which corresponds to the magnitude of shifting the mean of inflation distribution by 0.5 in case of an active vote);

(v) β = 1.

Figures 1 and 2 examine the effect of the First Receivers actions. They show the simulated distributions of 250,000 replications of the altered forecast signals delivered to the median voter at time t = 1 for time t = 2. Here n = 9 so the median is the 5th voter, denoted $\pi^f_{5,2}$.

Throughout the paper the inflation target is defined as $\pi^T = 0$ with upper and lower bounds at ± 0.4307. As the initial distribution of inflation is standard normal, this gives, for $\bar{\pi} = 0$, the probability of hitting the inflation target being equal to 0.333, if the true distribution of inflation is known.

Figure 1: Distributions of $\pi^f_{5,2}$, $\rho = 0.5$

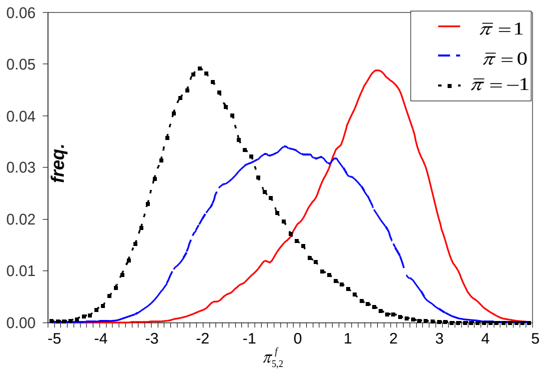

Figure 2: Distributions of $\pi^f_{5,2}$ with different correlation between forecast signals, $\bar{\pi} = \pi^T = 0$

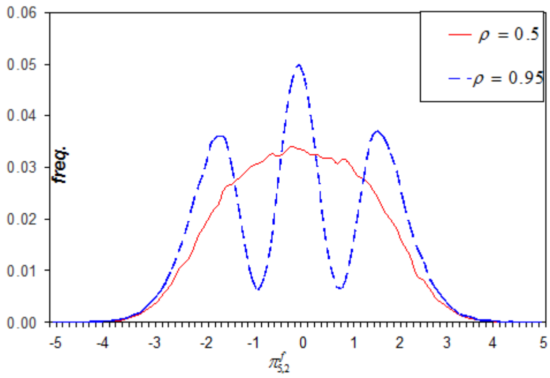

Figure 1 examines the effect on the altered signal given to the median voter for different means of the inflation distribution (correlation coefficient ρ between $\tilde{\pi}^f_{1,2}, \tilde{\pi}^f_{2,2}, \ldots, \tilde{\pi}^f_{n,2}$ is equal to 0.50). In particular it considers the distribution when the mean is within the target zone ($\bar{\pi}$ = 0) and when it is outside ($\bar{\pi}$ = 1,-1). In the first case the distribution of signals is symmetric. The First Receiver imparts no bias on the signal received. Whilst when the mean lies outside of the target zone, with a moderate degree of correlation, the distributions are unimodal and asymmetric (skewed towards zero). As such the effect of the first receiver may be observed. The means of these distributions lie further from the target zone than the means of the underlying inflationary distribution making active policy more likely.

Figure 2 examines the effect of the correlation of signals in more detail for the case $\bar{\pi} = 0$ and for two levels of correlation: ρ = 0.50 and ρ = 0.95. It reveals the bimodal nature of the marginal distributions of forecast signals for cases of high correlation between the signals. The 'saddles' reflect that three normal distributions with different means are combined. That of the unaltered signal and the two distribution when the First Receiver believes action is necessary (either pro or anti inflationary). The distance between the true mean and either unaltered mean is equal to β, the size of the first receivers 'push'. The probability of other signals being within this distance increases with the increase in correlation of signals. In the extreme case, where the correlation is unitary (all *MPC* members believe only in the official forecast), the conditional probability of $\Pr(\tilde{\pi}^e_{n,t+1} - \pi^e_{i,t+1} < \beta \mid I^{(1)}_{n,t} = 1) = 0$ for all $i<n$.[3] As such

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[3] This result shed a new light on the problem of correlated votes in the heterogeneous case (see Kaniovski, 2010). It shows that in the case of strong correlation between voters and signal alteration, extreme behaviour is likely to appear, as the signals delivered to the median voter are unlikely to be of a moderate magnitude. This finding might have further, interesting implication of a more general nature (sociological or psychological), however, this is beyond the scope of this paper.

correlation makes the effect of the first receivers signal alteration broader across more of the members.

In the remainder of this section we discuss selected distributions of voting results and decision for the model defined above. Figures 3-6 present the simulated distributions of $I_t^{(k)}$ k ={-1,0,1}, when $\bar{\pi}=0$, both with ($\beta=1$) and without signal alteration ($\beta=0$) and for two different signal correlations: ρ = 0.5 and ρ = 0.95. As expected, the results in Figures 3-6 show the symmetry of the active voting results, as the probabilities of voting -1 or 1 are practically identical. In the case of a moderate correlation between forecast signals and no First Receiver intervention, the distribution of passive votes $I_t^{(0)}$ is close to being symmetric and unimodal. This reflects the centre distribution in Figure 1, the majority of signals in this case lie within the inflation target and so entail passive voting. The *FR*'s intervention flattens the distributions; fewer individuals vote for passive policies and three way split outcomes become less frequent as members are 'persuaded' to change their decisions by receiving altered signals.

Increased correlation between signals causes the distribution to become *U*-shaped. Probabilities of split votes are again visibly smaller. More weight is given to zero or high numbers of votes for particular actions. The decisions are determined more by the weights (preferences) of the particular *MPC* members rather than by the forecast signals. The combination of high correlation and signal alteration makes most decisions near unanimous.

Figure 3: Distributions of voting results, $\rho=0.5$, $\beta=0$

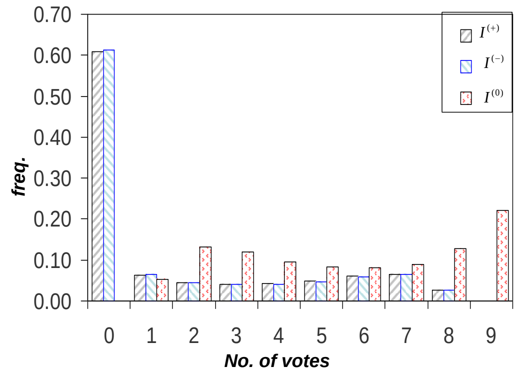


Figure 4: Distributions of voting results, $\rho=0.5$, $\beta=1$

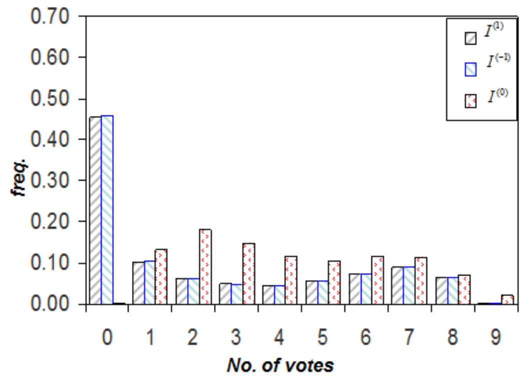


Figure 5: Distributions of voting results, $\rho=0.95$, $\beta=0$

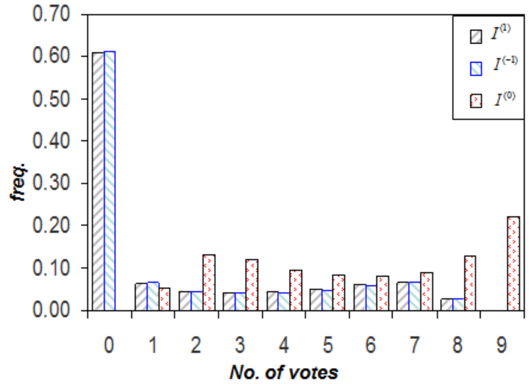
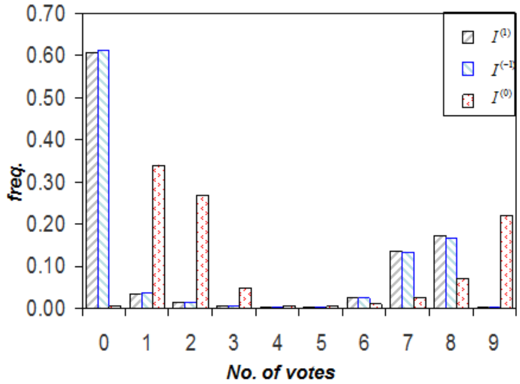


Figure 6: Distributions of voting results, $\rho=0.95$, $\beta=1$



The model presented above has a relatively simple specification, however, similar results may be obtained with more general variations. In particular, we have examined models where:

- The decision barriers in (5) are not constant (values dependent on time and on previous voters' behaviour).
- In (6) the strength of monetary decisions varies according to the degree of unanimity of the Board.
- The distribution of inflation is skewed normal rather than normal.
- Different voting schemes other than the three-way voting.
- The deviation of the output gap from the target is not zero.
- A nonstationary (random walk) inflation process.
- The *FR* not being the member which is most active (with the highest weight).

In all cases these generalisations do not change the results in a significant way.

4. DYNAMIC ANALYSIS

This section explains the intertemporal aspect of the model and focuses on the static and dynamic characteristics of the inflation distribution and the efficiency of monetary policy over a longer time period. Recall the only factors affecting the distribution of inflation at time *t*+1 is the decision of the *MPC* and its strength, see (6). If there were no voting the inflation distribution π_t is (for $\bar{\pi}=0$) a standard normal. However, any active *MPC* decision affects the distribution, as is evident from (6) and from the distributional results shown above.

Figures 7 and 8 show the standard deviation of inflation and a measure of the effectiveness of monetary policy at hitting the inflationary target, over 25 consecutive periods. The settings of the experiments are as described in Section 2 points (*i*)-(*v*), whilst the initial inflation is on target $\bar{\pi}=0$ and the correlation is $\rho = 0.5$. There are 25,000 replications of each run. Policy efficiency is measured by the ratio of the *ideal undisturbed inflation distribution* π^{IU} (that is, the hypothetical inflation distribution not subject to *MPC* decisions and with a mean in the middle of the inflation target) being within the target relative to that of the inflation distribution subject to *MPC* actions being within the target at time *t*. This ratio, called the *ratio of deviations from target* and denoted by *RDT*, is computed as:

$$RDT_t = 1 - \frac{\Pr(\pi^- < \pi_t < \pi^+)}{\Pr(\pi^- < \pi^{IU} < \pi^+)}$$

where π^- and π^+ are respectively the lower and upper limit of the inflation target. $\Pr(\pi^- < \pi_t < \pi^+)$ is approximated by running 10,000 replications of voting for *t* = 1, 2,...,25. Other settings are as given in Section 3 above, with the correlation coefficients between forecast signals, ρ, being equal to 0.5. Under these settings, for $\pi_0 \sim N(0,1)$ and $\pi^+ = -\pi^- = 0.4307$:

$$\Pr(\pi^- < \pi^{IU} < \pi^+) = \Pr(\pi^- < \pi_0 < \pi^+) = 0.333$$

If *RDT*=0, it indicates that the efficiency (in terms of probabilities of hitting the inflation target) is equal to that of π^{IU}, i.e. *MPC* actions do not on average improve the probability of hitting the inflation target. If *RDT*<0, the target hitting efficiency is better than that of the π^{IU}, and if *RDT*>0 , it is worse. It is convenient to give the *RDT* measure in percentages, which show to what extent the current inflation distribution is worse (or better) than the ideal unaffected case.

Active monetary policy decisions undertaken unnecessarily, as in this case where $\bar{\pi} = 0$, will result in a decrease in the inflation targeting efficiency in the sense that the probability of hitting the inflation target is diminished. This is seen in Figure 8, in both cases the *RDT* is markedly above one, indicating a loss in efficiency in relation to the case where no decision is made. However, in the case where there is signal alteration the *RDT* is markedly higher. This inefficiency comes from a higher standard deviation of inflation. Recall that the standard deviation of the inflation distribution under no decisions is 1. Figure 7 shows that in both voting cases, although notably more for the altered signal, the inflation dispersion is greater than the initial unitary dispersion, i.e. voting makes inflation variation greater leading to less efficiency.

Figure 7: Standard deviations of inflation distributions

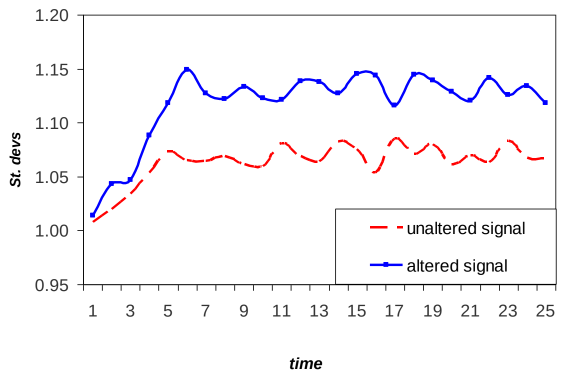
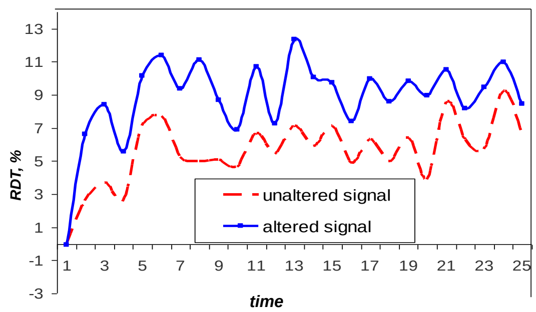


Figure 8: Ratios of deviations from target

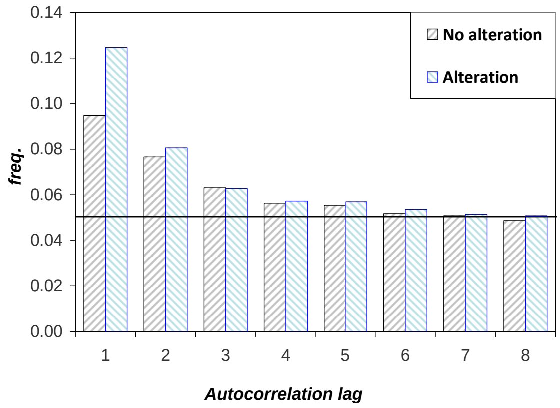


Further analysis suggests there may be some degree of persistence explained by time delays in taking the inflation process back towards the inflation target zone after a disturbance. As the presence and degree of this depends on the initial draw from π_0, a more sophisticated simulation is needed in order to assess whether such persistence is independent from initial values. Using the same settings as above, 5,000 runs of the dynamic experiment are performed, each with a different initial value. In each run t = 1,2,..,50 and, for each t, there are 5,000 replications, giving a total of 25,000,000 replications. For the resulting series of means of inflation distributions, $\pi_1, \pi_2, ..., \pi_{50}$, autocorrelation coefficients of orders up to 8 are computed and tested for one-sided (positive) significance at the 5% level. If there is no autocorrelation, the empirical frequency of rejections in a sample of 5,000 autocorrelation coefficients should be around 5%. Figure 9 presents the frequencies of such rejections for cases where there is no signal alteration ($\beta = 0$) and with signal alteration ($\beta = 1$).

It is evident that *MPC* voting substantially contributes to inflationary persistence by creating positive autocorrelation up to an order of at least 3. Moreover, voting alteration visibly increases such persistence at early lags. As a result active monetary policy set through voting can be seen to add persistence to inflation and may partially explain the fat tailed distributions seen empirically. This finding is robust across different values of ρ, the within period correlation of signals received by committee members.

The above experiments have been performed under the assumption that voting was unnecessary, as inflation, in terms of its distribution, was already on target $\bar{\pi} = \pi^T = 0$. It is, however, important to know to what extent signal alteration by the *FR* might be effective if

Figure 9: Frequencies of rejecting the null of positive autocorrelation of means at 5% level



inflation is initially off target. Clearly, if it differs from the target in the sense that $\bar{\pi} \neq 0$ and $\Pr(\pi^- < \pi_0 < \pi^+) < 0.333$, then active policy may be beneficial and intervention of the *FR* may lead to an increase in the probability of hitting the target. This potential benefit, however, may be offset by an increase in volatility and persistence as seen above. Figures 10-12 present the simulated offset effect, measured by a comparison of *RDT* with and without signal alteration over, respectively, 1, 2 and 3 periods, for initial inflation $-1 \leq \bar{\pi} \leq 1$. Recall that, for a given $\bar{\pi}$, the lower the *RDT* is, the more efficient is the monetary policy. The distance

between the upper and lower points for which the *RDT*'s of policy with and without signal alteration coincide define the *non-advantage band*. Within this band it is counterproductive to alter forecast signals, as the distance between the mean of actual inflation and the target is not sufficiently large. If the *FR* alters the signal the action is likely to overshoot the target and the alteration is not beneficial. In all cases, however, there exist initial inflation disturbances which are sufficiently large to make the signal alteration of the First Receiver beneficial to the economy. As the policy horizon increases, *FR* intervention becomes less likely to help. Both *RDT* curves flatten as the committee has multiple chances to act to return inflation to the target and as a result the non-advantage band increases in width. For longer horizons it is only under very large deviations that the first receiver's actions reduce the *RDT*. With relatively small deviations, it does not pay to intervene in the forecast signals.

Figure 10: Offset effect, 1 periods policy, av. *RDT*

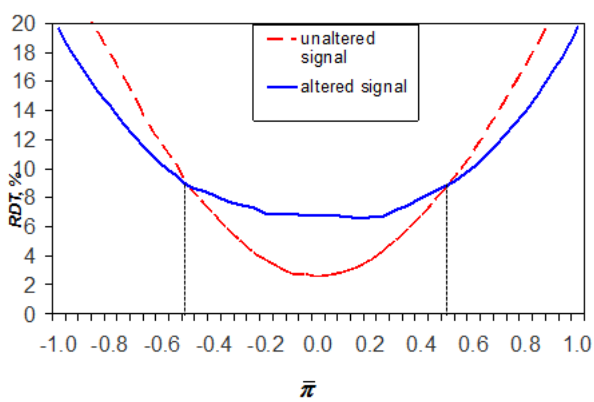


Figure 11: Offset effect, 2 periods policy, av. *RDT*

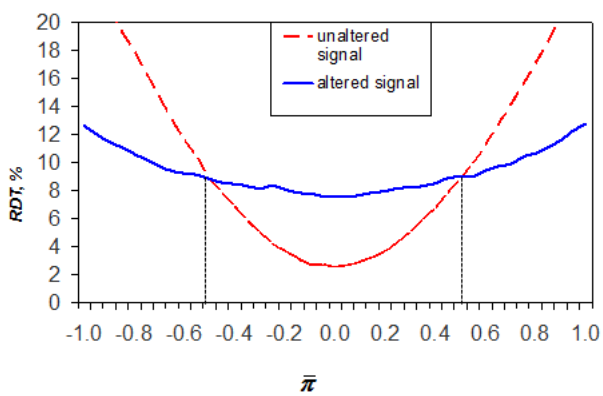
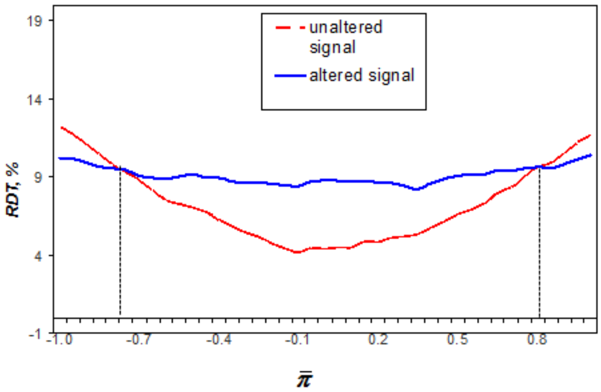


Figure 12: Offset effect, 3 periods policy, av. *RDT*



5. LEARNING

In previous sections we have assumed that all voters behave sincerely, that is they base their votes solely on the information received, as incorporated in their decision functions. We have assumed so far that voters other than the *FR* do not actively oppose or adapt their behaviour to possible *FR*'s manipulation and that they are fully convinced by the forecast signals received. In reality, however, committee members may have incentives to modify their behaviour according to their beliefs regarding the sincerity of the *FR* actions. In this section we consider a mechanism by which they could do this. Individuals may learn from previous 'suspicious' behaviour of the *FR*. They may treat inflation forecasts from the *FR* with a degree of scepticism, changing the degree to which they respond to these signals. In the context of *MPC*'s Lim and McNelis (2004) consider how the *ECB* may learn the laws of motion of inflation under different targets.

We model learning through the naive Bayesian classifier (see e.g. Mitchell, 1997, Domingos and Pazzani, 1997 and, for further development, Chapelle *et al*., 2006). It is assumed that the *MPC* members other than the *FR* might suspect the *FR* of signal alteration and, if this suspicion is strong enough, they may attempt to offset this possible signal alteration by shifting the mean of the forecast distribution in the opposite direction.

Recalling that the *FR* is the n^{th} *MPC* member, $\Pr(v_{n,t} \neq 0)$ is defined as the probability that at time t the *FR* will conduct signal alteration (see Section 2). Similarly $\Pr(v_{i,t} \neq 0 \mid v_{n,t} \neq 0)$, $\Pr(v_{i,t} \neq 0 \mid v_{n,t} = 0)$ denote the probabilities, respectively with and without signal alteration, that the i^{th} *MPC* member ($i<n$) after receiving information should vote actively *i.e.* $v_{i,t} \neq 0$. The committee member can classify the state of the world in which it was conducive for the *FR* to alter the signal ($v_{n,t} \neq 0$) or not ($v_{n,t} = 0$) by selecting from:

$$d_{n,t}^{Bayes} = \underset{\{v_{n,t} \neq 0, v_{n,t}=0\}}{\arg\max} \{\Pr(v_{n,t} \neq 0)\Pr(v_{i,t} \neq 0 \mid v_{n,t} \neq 0), \Pr(v_{n,t} = 0)\Pr(v_{i,t} \neq 0 \mid v_{n,t} = 0)\} \quad , \qquad (8)$$

that is, choosing such arguments from $v_{n,t} = 0$, $v_{n,t} \neq 0$ which maximizes the posterior probability of voting actively. If $d_{n,t}^{Bayes} = \{v_{n,t} = 0\}$ he/she decides that no voting alteration took place and votes according to the signal received. If, however, $d_{n,t}^{Bayes} = \{v_{n,t} \neq 0\}$, the n^{th} *MPC* member decides that the alteration took place they revise the signal accordingly.

In order to make (8) operational, it is assumed here that the *MPC* members have information regarding earlier signal alterations and their magnitude, i.e. they know β in (7). These values are constant over time and so we assume the members may estimate them through observing previous inflation outcomes and signals. Hence $\Pr(v_{n,t} \neq 0)$ is estimated as:

$$\hat{\Pr}(v_{n,t} \neq 0) = \frac{1}{t-1}\sum_{j=i}^{t-1}(v_{n,j} \neq 0) \text{ and } \hat{\Pr}(v_{n,t} = 0) = 1 - \hat{\Pr}(v_{n,t} \neq 0) \quad .$$

With Bayesian learning, (7) is replaced by:

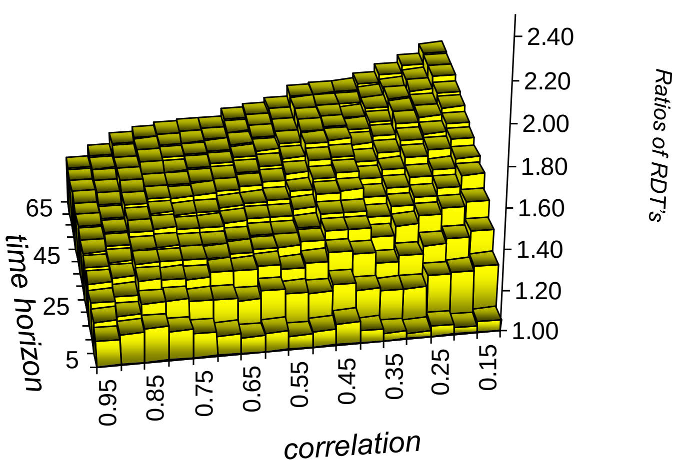
$$\breve{\pi}^{f}_{i,t+1} = \tilde{\pi}^{f}_{i,t+1} + \beta v_{n,t} \quad \text{, and:}$$

$$\pi^{f}_{i,t+1} = \begin{cases} \tilde{\pi}^{f}_{i,t+1} & \text{if} \quad d^{Bayes}_{n,t} = \{v_{n,t} = 0\} \\ \tilde{\pi}^{f}_{i,t+1} - \beta v_{n,t} & \text{if} \quad d^{Bayes}_{n,t} = \{v_{n,t} \neq 0\} \end{cases} \quad . \tag{9}$$

Under (9) it is possible for the i^{th} *MPC* member to make a mistake by wrongly correcting previous unaltered forecast as finding that $d^{Bayes}_{n,t} = \{v_{n,t} \neq 0\}$ does not necessarily mean that signal alteration really took place.

The effect of learning on the probability of reaching the inflation targets is illustrated in Figure 13. The figure shows the ratios of average *RDT's*, where the numerator is the average *RDT* of the model without learning and the denominator is an analogous average *RDT*'s for a model with learning. As the *RDT* shows losses in efficiency due to signal alterations, the ratio can be interpreted as the average gain of implementing a voting defence mechanism relative to the case where such a mechanism is absent. All model settings are as above with $\bar{\pi} = \pi^{T} = 0$ for different ρ (correlation between inflation signals delivered to the particular *MPC* members) changing by 0.05 from 0.15 to 0.95 (17 cases) and time horizons, changing by 5 from 5 to 65 (13 cases). The number of replications for each combination of time horizon and *r* is equal to 25,000 in all cases.[4]

Figure 13: Gains from learning



[4] Costs of these computations are significant and in practice require a high-powered (parallel) computer.

The *RDT* ratios in Figure 13 are always greater than one, which illustrates that learning provides a strong countermeasure to signal alteration despite the fact that individual decisions can sometimes be wrong (that is, voters might think that the *FR* has altered the signal, when in fact such action has not taken place). Dependence on correlation and time is evident here. Bayesian learning is more efficient with longer time horizons (more time to learn) and is also more efficient when inflation signals are more heterogeneous. Clearly the time dependence is nonlinear here, with gains rising more quickly with the increase in time horizons for shorter rather than longer periods of time.

6. CONCLUSIONS

This paper finds that if a particular member of a *MPC* is in position to alter inflation forecast signals delivered to the rest of the committee, it may negatively affect the ability of the committee to meet an inflationary target. This is the case even if alteration is well-motivated, that it, aimed at achieving an inflationary target. Negative effects of signal alteration are evident when the inflation distribution is in fact on (or close to) the target in terms of it mean. In this case any active voting can be damaging so that, if signal alteration increases the possibility of such voting, it worsens the efficiency of the monetary policy. The excessive decision activity increases the volatility of inflation and, perversely, decreases the chances of hitting the target zone. It also creates persistence in inflation, which additionally negatively affects the monetary policy effectiveness and is one of the sources of non-normality of the distribution of inflation. Only if inflation is a long way from the target can alteration of signals improve the efficiency of the *MPC*. If members of the Monetary Policy Board can learn about such alterations, they may counteract the changes effectively even if occasionally they misjudge the alteration.

In practice signal alterations can be made either by the Governor of the Bank, the head of its forecasting (research) division, or a person who has particularly strong institutional or psychological influence on the forecasters. The simplest practical solution here would be to separate the process of forecasting from the Bank and put it in the hands of an independent organisation such as a university or a consulting firm. As heterogeneity of forecasting signals plays an important, positive, role in increasing efficiency, it is relevant to diversify such signals and gain forecast information from as many independent sources as feasible. Presumably a better, albeit more costly, way out of the problem, could be to create a designated separate unit (panel) of professional forecasters, fully independent from the Bank in terms of accountability and influences. As the quality of forecasts positively affects the *MPC's* efficiency, it is important that such a panel consists of the best available professionals or research units.

Under the alternative interpretation of the model, as suggested in Section 1, where the First receiver affects the perception rather than signals themselves, conclusions are similar. Even if only one forecast is delivered to the monetary policy board, its quality or interpretation should not be subject of discussion, as it would result in correlation of perceptions and strengthening the power of the First Receiver in relation to other members of the *MPC*.

It would be superficial to conclude that the paper disputes the findings of Gerlach-Kristen (2005) and earlier papers which claim that monetary policy decisions were not taken actively enough. As in our simulations the inflation distributions which are not subject to signal alteration are independent in time (to allow for identification of the alteration effect), the Gerlach-Kirsten conclusion may still be valid under inflationary persistence.

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