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ABSTRACT

Monetary Policy and Lexicographic Preference Ordering

In this Paper we argue that the objectives given to the European Central Bank in the Maastricht Treaty are not well represented by the widely used weighted sum of squared deviations of inflation and output from target (plus possibly terms in squared changes in interest rates to pick up interest rate smoothing). Instead the stated lexicographic ordering should be taken at face value and its implications explored fully. We set out a number of models that do this, and comment on their implications.

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1 Introduction

There have been a lot of analyses of the effects of monetary policy on prices and output fluctuations under EMU, assuming that the independent European Central Bank (ECB) operates monetary policy as specified in the Maastricht Treaty. The Treaty famously requires the ECB to pursue the single goal of price stability, with no trade-off permitted between that and the stabilization of real economic activity. The ECB is allowed to pursue real economic stability only insofar as it is consistent with the goal of price stability, where price stability is usually understood as zero or close to zero inflation. Analyses of this policy have nevertheless typically represented these instructions by an objective function which puts heavy (or infinite) weight on price stability, but includes a small (or zero) weight on output stability. While this is analytically convenient, it arguably does not accurately represent the intention of the Treaty, which clearly implies a lexicographic preference ordering.

The main rationale for this explicit restriction, as with the adoption of monetary targeting, has been the attempt to ensure continuity with respect to the past, in order to help the ECB to inherit the anti-inflationary credibility earned by the Bundesbank. Indeed, the hierarchical formulation of goals is consistent with the well-known formulation of the Bundesbank's goals, where "safeguarding the currency" was interpreted as the primary goal and "support the general economic policy of the Federal Government, but only in so far as this is consistent with the aim of safeguarding the currency" was interpreted as the secondary goal.[1]

Moreover, the introduction of a hierarchical formulation of goals, with medium- or long-run price stability as primary goal increases the accountability of European central bankers in pursuing low inflation and eliminates the uncertainty about the relative weights attached by the policy maker to the achievement of the different goals.

However in order to evaluate the price stability mandate we need a fuller understanding of the implications of a lexicographic preference ordering for the conduct of monetary policy, the control of the money market and the interest rate. In particular, if the ECB's monetary instrument has to be used to achieve price stability, then a first important question is whether there are any degrees of freedom left for moderating real fluctuations. One possible answer to this question might be related to the definition of price stability and the issue of how price stability can be maintained. As explained by Svensson (2001):

[1] See Svensson (1995) and von Hagen (1995).

> “*defining price stability involves deciding between price-level stability and low (including zero) inflation, choosing the appropriate price index, and selecting the appropriate level for a quantitative target. It also involves deciding on the role of real variables, like output, in the objectives for monetary policy. Thus defining price stability boils down to defining the monetary-policy loss function*”.

In this paper we explore a number of models in an attempt to formalize policy with lexicographic objectives. Section 2 discusses at greater length the motivation for this exploration and the weaknesses that we find in the bulk of the extant literature. Section 3 sets out a simple formalization of lexicographic preferences, under a monetary targeting regime, that embodies the idea that forecast future inflation is the primary objective but that policy can respond to short-term shocks to output. In section 4 we extend the analysis to an inflation targeting regime. Here we consider both cases when the target is defined as a point or as a zone for inflation. This latter case is of some interest as inflation zone targeting is another important institutional feature of the ECB. In particular, the possibility of having multiple equilibria in this last setting is examined. Section 5 offers some concluding thoughts.

2 Modeling Monetary Policy

In this section of the paper we review a number of issues raised by the current literature on the modeling of monetary policy, in the context of the “new paradigm”, that is to say the use of short-term interest rates by independent central banks to achieve an inflation target. Despite the primacy given to the stabilization of inflation, most academic analyses assume that the central bank’s objectives include, in addition to deviations of inflation from target, deviations of output from a target value, and also very often a term involving changes in interest rates. This is justified in the face of the stated objectives of central banks by noting that central banks typically do not attempt to achieve inflation targets continuously or immediately, regardless of the cost in terms of fluctuations of output, exchange rates, and interest rates. Central banks instead typically aim to get inflation on target within a period of a year or two from the date of the policy action. They may also specify the target as a range of acceptable rates of inflation rather than a point. They seem reluctant to move interest rates up and down too much, being particularly reluctant to have short term reversals in the direction of interest rate changes. Thus they appear to smooth interest rates. The one-year horizon within which inflation is brought into line also reflects the lags in the effects of interest rates on inflation and maybe also uncertainty about what the effects on interest rate changes are. Attempting to bring inflation into line too rapidly might, it is believed, lead to instrument instability. Central banks themselves declare, as the Bank of England has done, that they are not “inflation nutters”.

For all these reasons it is argued that a period loss function such as

$$L = \left[(\pi - \overline{\pi})^2 + \lambda \left(y - \overline{y} \right)^2 + \zeta \left(i - \overline{i} \right)^2 \right], \tag{1}$$

is appropriate to represent central banks’ objectives, where it is assumed that $\lambda, \zeta > 0$ and time subscript is eliminated for simplicity. However, when combined with a supply function that has expectational elements, such as the Lucas price-surprise supply function

$$y = \pi - \pi^e - \varepsilon, \tag{2}$$

it inevitably introduces the phenomenon of time-inconsistency, and much of the academic literature continues to be preoccupied with it. Taking this model as its starting point, much analysis goes on to assume that policy-making is discretionary, i.e., based on period-by-period optimization of the objective function, rather than adherence to a rule that has good long-run properties. It is argued that the predictions of this model accord well with observed behavior of central banks.

However, this kind of analysis does not take the stated objectives of, say, the European Central Bank at face value, and in a number of ways seems inappropriate for modelling central banks. The assumed objectives are arguably inappropriate. Many central banks seem to have accepted with alacrity that they should have a responsibility for stabilizing inflation, and appear very happy to have, only as subsidiary objective, a responsibility for output and employment. As part of a wider-ranging comment on modeling monetary policy, Eric Rasmussen (1998) has argued that central banks might strongly prefer to have responsibility only for matters that are under their control. Hence they accept willingly the inflation objective and reject responsibility for output. The advantage for central banks is that their performance is more easily measured if they have the sole objective: that is, it enhances transparency of policy. Rasmussen argues that central banks want to establish a reputation for carrying out their duties competently. For this reason they prefer to have targets that they can achieve. The output target does not meet this criterion. The natural level of output, around which they might stabilize actual output is measured with wide margins of error, and errors in setting the output target would lead to persistent inflation or deflation. For example, the natural rates of unemployment in the United States and in the United Kingdom in the 1990s appear to have fallen to levels much lower than anyone would have predicted in advance. Monetary policy that had targeted output at the estimated natural level for this period would have been unnecessarily restrictive. Blinder (1998), in discussing central banks, has argued that time-inconsistency is not an issue. They do not want to spring surprises on the public in order to stimulate short-term increases in output. Mervyn King of the Bank of England has famously remarked that they (the Bank of England) want to make monetary policy boring. Even though one might not wish to take central bankers' statements about themselves entirely at face value, all these observations are consistent with the view that central bank objectives are not such as to lead to the dilemmas for policy engendered by the one given above.

The assumption of discretionary policy that is carried through in much of the literature may also be inappropriate. Independent central banks have frequently been granted freedom to conduct monetary policy as they see fit to meet governmentally determined objectives, and generally have institutional features designed to reinforce their independence of political pressure. Their senior officials – the governor and so on – often have long tenures of office and in some cases may be allowed only one term so that the desire to be re-appointed cannot lay them open to pressure. The institutional culture of a central bank is likely to produce continuity across the terms of individual governors. In these circumstances, central banks are likely to behave so as to establish reputations for doing their job well, and this suggests that their behavior is likely to be better represented by a precommitted policy rule rather than short-term optimization.

The above model also effectively assumes that central banks can influence inflation immediately by setting interest rates appropriately, since current inflation is taken as the control variable. If in fact central banks can only influence inflation rates with a lag of six months or longer, then the time-inconsistency problem is less important. If the policy lag is in fact longer than the life of currently existing contracts, then there may be no time-inconsistency issue at all, as Goodhart and Huang (1998) have argued.

3 A simple framework with monetary targeting

In order to build a useful framework for examining monetary policy under the case of lexicographic preferences we consider a discretionary regime, i.e. a regime where monetary policy is time consistent and the policy maker is unable to precommit ex ante to a rule for setting the instrument.

Let's assume that the supply function takes the form of a standard expectations augmented Phillips curve as expressed by (2). In (2) ε is a random shock with mean zero and variance σ_ε^2. Private sector's inflation expectations are rational, i.e. $\pi^e = E\pi$. The instrument is money growth m and is related to inflation by the a simple equation of the form

$$\pi = m. \tag{3}$$

Given the present aim of describing the conduct of monetary policy under lexicographic preferences, adding a velocity shock or a control error to equation (3) complicates the algebra without yielding important additional insights.

Society and government have the following loss function

$$L^{s,g} = \left[(\pi - \bar{\pi})^2 + \lambda(y - \bar{y})^2\right]. \tag{4}$$

Expression (4) is a particular case of (1) with the weight ζ on the interest-rate smoothing motive set equal to zero. Following the time-inconsistency literature, the socially optimal level of output is higher than the natural level of output, here equal to zero.

In the present framework the central banker may have two alternative types of preferences: those expressed by a standard linear quadratic loss function or a lexicographic ordering. If the central banker has a standard linear quadratic loss function we assume that there is uncertainty about the weights attached by the central banker to the objectives. In this case for the central banker we have the following loss function

$$L = \left[(1+\alpha)(\pi - \bar{\pi})^2 + (\lambda - \alpha)(y - \bar{y})^2\right]. \tag{5}$$

In the expression (5) we follow the formalization of Beetsma and Jensen (1998). The parameter α is a stochastic variable unobserved by the government and the private sector, defined in the interval $-1 < \alpha < \lambda$. In particular, it is assumed that $E[\alpha] = 0$; $E[\alpha^2] = \sigma_\alpha^2$ and $E[\alpha\varepsilon] = 0$.

If the central banker has lexicographic preferences we have the following expressions. As primary goal the central banker has price stability, expressed as

$$L^1 = (E\pi - \bar{\pi})^2. \tag{6}$$

As secondary goal the central banker has output stability, expressed as

$$L^2 = (y - \bar{y})^2. \tag{7}$$

In the case of a lexicographic ordering the optimization process is divided into two steps: first the primary objective is minimized; second as long as the first order condition for minimizing the primary objective remains satisfied it is possible to use the residual degrees of freedom for minimizing the secondary objective. In other words the optimization of the secondary objective is conditioned on the optimization of the primary objective. Moreover, solutions which imply a lower value for L^1 are strictly preferred by the central banker and similarly solutions which imply the same value of L^1 but a lower value of L^2 are strictly preferred as well.

The expression (6) is one possible definition of price stability. An alternative definition of price stability, used in the literature, is the following[2]

$$E\pi = \bar{\pi}. \tag{8}$$

The problem with this last condition is that it is too general and, as price stability is not expressed in terms of a loss function, it does not allow to order the multiple solutions that satisfy the above condition. Price stability can also be defined in terms of price level stabilization, but even if this is an interesting theoretical case it is not adopted in practice.

3.1 Delegation with standard linear quadratic preferences

Let's suppose first that monetary policy is delegated to a the central banker with a standard linear quadratic loss function, as expressed by (5). In this case Jensen and Beetsma (1998) have shown that there does not exist an optimal institutional arrangement that ensures the same welfare outcome achievable for the society under a precommitment regime. Under preferences uncertainty even the optimal combination of an optimal linear (and quadratic) inflation contract, along the lines of Walsh (1995) and Persson and Tabellini (1993), with an optimal linear inflation target, along the lines of Svensson (1997), does not attain the welfare outcome of the precommitment solution. Moreover, they show that societies with relatively high macroeconomic variability (a high σ_ε^2) may find it undesirable to delegate monetary policy to a central banker. This conclusion follows from the finding of the their analysis that in presence of preferences uncertainty not necessarily delegation improves upon discretion without delegation.

[2]See for example Smets (2000).

3.2 Delegation with lexicographic preferences

Now we examine lexicographic preferences in the context of a monetary targeting regime with an announced long-run money growth target. In all the cases considered announcements made by the central bank will play a key role in the optimization process. The reason is the following. If the period loss function L^1 is minimized by choosing ex post - after expectations are formed and shocks are realized - the actual value of money growth there will be no degrees of freedom left for achieving other objectives. Indeed in this case the optimal value of m is $\bar{\pi}$, which implies a strictly preferred value for L^1. However this last case is not interesting as lexicographic preferences coincide with the case of a single objective. Thus only if the optimization of L^1 is made ex ante it is possible to have some degrees of freedom left for optimizing other objectives. This explains why the primary objective is minimized by choosing an optimal announcement on the level of the instrument ex ante.

3.3 Disciplined discretion

Let's start with the case when deviations from the announcement made are not costly. Suppose that in each period before expectations are taken by the private sector the central banker announces a reference target for money growth, $\bar{m}^a$, consistent with the achievement of the primary objective of price stability. We can express deviations from the announcement made in the following way

$$\pi = m = \bar{m}^a + \Delta, \tag{9}$$

where $\bar{m}^a$ is the announcement made ex ante and Δ is the adjustment made ex post for stabilizing the secondary target, given of course that it is consistent with the achievement of the primary objective. Minimization of L^1 with respect to $\bar{m}^a$, subject to the constraint that $\pi = \bar{m}^a + \Delta$, yields the following first order condition

$$E\pi = \bar{\pi}. \tag{10}$$

This condition implies that

$$\bar{m}^a = \bar{\pi} - E\Delta. \tag{11}$$

Substituting this last expression back in the expression for inflation we get

$$\pi = \bar{\pi} + \Delta - E\Delta. \tag{12}$$

The term $(\Delta - E\Delta)$ in (12) represents the notion of disciplined discretion within the present framework. In other words it expresses the margin available for stabilizing output fluctuations, given that the first order condition required for price stability is satisfied.

Laubach and Posen (1997) discuss at length the idea of disciplined discretion for the case of the Bundesbank and the Swiss central bank without, however, providing an analytical framework. In particular they question the highly stylized framework used in the 'rules versus discretion' debate. What emerges from their study is:

> "a*n interpretation of German and Swiss monetary practice that we call 'disciplined discretion'. The practice followed by the central banks of the two countries should not be constructed simply as a more complicated rule; it should be seen, instead, as a system of commitments meant to clarify publicly and continuously the intent and stance of monetary policy. [...] It is not necessary to bind a central bank's hands extremely tightly in order to sustain low inflation. It is, however, crucial that a central bank achieves transparency and provides structured accountability over the medium term."*

In order to find the value of $(\Delta - E\Delta)$ we minimize the secondary objective with respect to Δ, by taken the announcement and private sector's expectations as given. This yields the following first order condition

$$\Delta = -\bar{m}^a + \pi^e + \bar{y} + \varepsilon. \tag{13}$$

Taking the expectation of the above expression we get

$$E\Delta = -\bar{m}^a + \pi^e + \bar{y}. \tag{14}$$

Now by subtracting this last expression from the first order condition (13) we obtain

$$\Delta - E\Delta = \varepsilon. \tag{15}$$

In the present case we can completely eliminate the variability of output without violating the first order condition for the minimization of L^1. The fact that Δ can be chosen only for stabilizing the shock ε implies that

$$\Delta = \varepsilon. \tag{16}$$

Given the condition (11), in equilibrium the announcement made by the central bank will be

$$\bar{m}^a = \bar{\pi}. \tag{17}$$

So in this case we have the following equilibrium values:

$$\begin{aligned} \pi^e &= \bar{\pi}, \\ \pi &= \bar{\pi} + \varepsilon, \\ y &= 0. \end{aligned} \tag{18}$$

This equilibrium implies excessively high inflation volatility. Hence the question that we will try to answer in the subsequent sections is whether there exist better equilibria.[3]

4 Inflation targeting

4.1 Inflation point targeting

Let's examine an inflation targeting regime. Here we focus on the announcements on the inflation target, rather than on the money growth target, and for simplicity we assume that the monetary instrument is the actual inflation rate. Suppose that, along the line of Rogoff's (1985), the government introduces an incentive scheme for achieving the inflation target announced by the central bank. In this case L^2 is given by

$$L^2 = (y - \bar{y})^2 + \omega \left(\pi - \bar{\pi}^a\right)^2, \tag{19}$$

where the parameter $\omega > 0$ is chosen ex ante by the government.

Considering the loss function (19) and using the same algorithm used in section 3.3 we get the following equilibrium values

$$\begin{aligned} \bar{\pi}^a &= \bar{\pi}, \\ \pi^e &= \bar{\pi}, \\ \pi &= \bar{\pi} + \frac{1}{1+\omega}\varepsilon, \\ y &= -\frac{\omega}{1+\omega}\varepsilon. \end{aligned} \tag{20}$$

[3] See also Driffill and Rotondi (2002) for some extensions of the analysis of this part of the paper, under a regime of monetary targeting. In particular, these extensions include the possibility of having mixed strategies and costly announcements of money growth tartgets.

This equilibrium implies that $E\pi = Em = \pi^e = \bar{\pi}$, i.e. there is perfect credibility, and average inflation is equal to the announced long-run target $\bar{\pi}^a$. Moreover, if the government sets $\omega = 1/\lambda$, for the society and the government it is possible to achieve the same value of the loss function obtained under a regime with commitment without delegation.

According to Svensson (1997) having a central banker with an inflation target $\bar{\pi}^a$ lower than the socially optimal one, would yield that in equilibrium inflation is equal to the optimal level. However, it may be argued that this result is merely a curiosity because the central banker makes an announcement about the programmed inflation that is never honored. Arguably this scenario does not correspond with the behavior of central banks in practice.

In the present framework with lexicographic preferences it is possible to eliminate this odd feature for an inflation targeting regime by combining the case of disciplined discretion with costly deviations from the announced inflation target.

4.2 Inflation zone targeting

Instead of having a point target we consider now a target range for inflation. The case of inflation zone targeting is discussed by Orphanides and Wieland (2000) and Terlizzese (1999).[4] Here we focus on escape clause regimes and we ask whether there might be the risk of having multiple equilibria, as shown for example by Obstfeld (1991) and Obstfeld and Rogoff (1996) in the case of exchange rate pegging by using a framework closer to the present one.[5]

In order to simplify the analysis, we assume that the shock ε is uniformly distributed with support $[-\bar{\varepsilon}, \bar{\varepsilon}]$ and again that the monetary instrument is the actual inflation rate. The central banker has lexicographic preference with price stability as primary objective. However, opposite to the previous analysis now the requirement that must be fulfilled for satisfying the primary

[4]Terlizzese (1999) does an analysis similar to the present one. However he does not take into account the possibility of deviations from the target range and, hence, he neither considers the implications of the presence of fixed versus flexible costs for deviating in the policy maker's loss function.

[5]As in Obstfeld and Rogoff (1996), also Alexius (1999) extends the Obstfeld (1991) model to the case of a uniform distribution for the supply shocks, instead of a triangular distribution. But contrary to them he does not realize that multiple equilibria may exist also under this extension.

objective is the following

$$0 \leq E\pi \leq \bar{\pi}. \tag{21}$$

We assume that if inflation is within the target range $[0, \bar{\pi}]$, the central banker's secondary objective is given by the following period loss function

$$L = (y - \bar{y})^2. \tag{22}$$

On the contrary, if inflation is greater than $\bar{\pi}$ his secondary objective is given by

$$L = (y - \bar{y})^2 + \chi_0 + \chi_1 (\pi - \bar{\pi})^2. \tag{23}$$

Finally, if inflation is negative his secondary objective is given by

$$L = (y - \bar{y})^2 + \psi_0 + \psi_1 \pi_t^2. \tag{24}$$

In the above expressions it is assumed that any deviation from the target range leads to both a fixed and a variable (quadratic) extra cost to the central banker. The parameters χ_0, χ_1, ψ_0 and ψ_1 are all positive.

4.3 Equilibrium

Let us consider first the case when inflation is within the target range. In this case equilibrium inflation is derived by minimizing (22) with respect to π. From this first order condition we can obtain the threshold values for the shock ε in this case. We have

$$\begin{aligned} \varepsilon &\leq \bar{\varepsilon}_{\mathrm{u}} \equiv \bar{\pi} - \pi^e - \bar{y}, \\ \varepsilon &\geq \bar{\varepsilon}_l \equiv -\pi^e - \bar{y}. \end{aligned} \tag{25}$$

When these conditions are satisfied with the inequality sign, equilibrium output is equal to $\bar{y}$ and equilibrium inflation is

$$\pi = \pi^e + \bar{y} + \varepsilon. \tag{26}$$

While when the supply shock is equal to one of the above threshold values inflation is equal to one of the two extreme values of the target range.

Let's consider the case when the supply shock is greater than $\bar{\varepsilon}_{\mathrm{u}}$ or lower than $\bar{\varepsilon}_l$. In this case the central banker must decide whether to deviate from the target range or stick to one of the extreme values of the target range. He takes this decision by comparing the two losses corresponding to the two possibilities.

When he deviates from the upper bound of the target range the equilibrium inflation rate is found by minimizing (23) with respect to π. We have in this case

$$\pi = \frac{\pi^e + \varepsilon + \bar{y} + \chi_1 \bar{\pi}}{1 + \chi_1}. \tag{27}$$

Similarly, by minimizing (24) we find that when he deviates from the lower bound of the target range equilibrium inflation is given by

$$\pi = \frac{\pi^e + \varepsilon + \bar{y}}{1 + \psi_1}. \tag{28}$$

Substituting these values for inflation back in their corresponding loss functions and comparing them with the case when inflation is equal to one of the two extreme values of the target range we obtain the following requirements for not deviating and sticking to one of the two extreme values of the target range. We have

$$\begin{aligned} \varepsilon &\leq \varepsilon_{\mathrm{u}} \equiv \bar{\pi} - \bar{y} - \pi^e + \sqrt{\chi_0 (1 + \chi_1)}, \\ \varepsilon &\geq \varepsilon_l \equiv -\bar{y} - \pi_t^e - \sqrt{\psi_0 (1 + \psi_1)}. \end{aligned} \tag{29}$$

Now we can compute private private sector's inflation expectations. Let's consider the case of perfect symmetry, when $\chi_1 = \psi_1 = \theta_1$ and $\chi_0 = \psi_0 = \theta_0$. In this case it is possible to show that we have a unique solution given by[6]

$$\pi^e = \frac{2 (2\bar{\varepsilon} + \theta_1 \bar{\pi}) \bar{y} + \theta_1 (2\bar{\varepsilon} - \bar{\pi}) \bar{\pi}}{2\theta_1 (2\bar{\varepsilon} - \bar{\pi})}. \tag{30}$$

Expression (30) is always positive if $\bar{\varepsilon} > \frac{\bar{\pi}}{2}$. Moreover, the requirement $0 \leq E\pi \leq \bar{\pi}$ implies that the values of the parameter $\theta_1$must satisfy the following requirement:

$$\frac{4\bar{y}\bar{\varepsilon}}{\bar{\pi} [\bar{\pi} - 2 (\bar{\varepsilon} + \bar{y})]} < \theta_1 < \frac{4\bar{y}\bar{\varepsilon}}{\bar{\pi} [2 (\bar{\varepsilon} - \bar{y}) - \bar{\pi}]}, \tag{31}$$

with

$$\begin{aligned} \frac{4\bar{y}\bar{\varepsilon}}{\bar{\pi} [\bar{\pi} - 2 (\bar{\varepsilon} + \bar{y})]} &< 0, \\ \frac{4\bar{y}\bar{\varepsilon}}{\bar{\pi} [2 (\bar{\varepsilon} - \bar{y}) - \bar{\pi}]} &> 0, \end{aligned} \tag{32}$$

[6]See Appendix A for the derivation.

if $\bar{\varepsilon} > \frac{\bar{\pi}}{2} + \bar{y}$.

In Appendix B it is possible to find an analysis of the existence of multiple equilibria for the case when $\chi_1 > \psi_1$, i.e. when deviations from the upper bound of the target range are penalized more heavily than deviations from the lower bound. We show that in this case there exist two solutions, but one can be eliminated by means of a continuity argument. Obstfeld and Rogoff (1996) have shown the existence of multiple equilibria in a framework closer to the present one, but referred to the case of fixed but adjustable exchange rate scheme. In their analysis the fact that private sector's expectations are not bounded, while the distribution of the stochastic supply shock is bounded, with support $[-\bar{\varepsilon}, \bar{\varepsilon}]$, may lead to multiple equilibria. The rationale for this result can be found in the negative relationship between the threshold values for the shock ε, given by expressions (25) and (29), and inflation expectations. As inflation expectations rise the threshold values for the shock fall towards the lower bound of the support of shock ε. When one of the threshold values reaches the lower bound of the support of shock ε we may have multiple equilibria for inflation expectations. However, in our framework this does not happen as inflation expectations are bounded. In fact, the requirement $0 \leq E\pi \leq \bar{\pi}$, due to the presence of lexicographic preferences, combined with rational expectations implies that in equilibrium we must have $0 \leq \pi^e \leq \bar{\pi}$. By substituting 0 and $\bar{\pi}$ for π^e into the expressions of the threshold values for the shock ε, we can always find the supports for the shock ε that are consistent with the restriction $0 \leq \pi^e \leq \bar{\pi}$. Thus, as long as the assumed support for the shock ε includes all possible supports consistent with the restriction $0 \leq \pi^e \leq \bar{\pi}$, it is not possible to have multiple equilibria.

5 Conclusions

In this paper we have taken issue with the preferences or objectives conventionally held to underlie central banks' behavior, and have instead proposed that the lexicographic ordering set out in the Treaty of Maastricht for the European Central Bank should be taken at face value. We have explored a number of formulations of the policy problem with these objectives. As the models developed in the present analysis show the lexicographic ordering, which puts inflation stabilization first and other objectives second, may be seen as way of enshrining commitment to inflation stabilization. By increasing central bankers accountability on the achievement of price stability, lexicographic ordering disciplines the discretionary setting of the monetary instrument. The lexicographic ordering may nevertheless permit a considerable degree of output smoothing.

Morevover, lexicographic ordering increases also the transparency of monetary policy by eliminating the uncertainty relative to the weights attached to the different objectives in the central banker's loss function. As shown by Jensen and Beetsma (1998), with uncertainty about the weights attached to those objectives there does not exist an optimal combination of a linear (and quadratic) inflation contract with a linear inflation target that ensures the same welfare outcome under the precommitment equilibrium. We argue instead that if the lexicographic ordering is combined with an optimal linear inflation contract it is possible to attain the same welfare outcome of the precommitment solution.

In our analysis announcements on inflation or money growth targets have a key role in ensuring some degrees of freedom left for optimizing secondary objectives. The framework developed can be extended to a dynamic framework with unemployment or inflation persistence. However, in this case the optimal announced target for inflation or money growth will be state contingent.

The implications of inflation targeting with a target range for inflation are also examined. We show that modelling the inflation target as a range, with additional penalties for letting inflation stay outside the range, does not lead to multiple equilibria. In particular, we argue that in the case of an escape clause regime aimed at price stability with lexicographic ordering there is no risk of having multiple equilibria as inflation expectations are bounded within the target range for inflation.

Finally, the main motivation of the present study can be found in the fact that the standard analysis based on central bank's loss functions which trade off between alternative objectives does not accurately represent the intention of the Treaty, which clearly implies a lexicographic preference ordering for the ECB. However it is possible to see our analysis as a more general and alternative framework for making monetary policy, intermediate between a rule-based approach and one that makes reliance on discretion. In fact there are close similarities between what Bernanke defines as "constrained discretion" and the lexicographic ordering of preferences.[7] As Bernanke (2003) argues:

> "*is there then no middle ground for policymakers between the inflexibility of ironclad rules and the instability of unfettered discretion? My thesis today is that there is such middle ground - an approach that I will refer to as 'constrained discretion' - and that it*

[7] See Bernanke and Mishkin (1997) for the first use of the notion of "constrained discretion" in monetary policy.

is fast becoming the standard approach to monetary policy around the world, including in the United States. As I will explain, constrained discretion is an approach that allows monetary policymakers considerable leeway in responding to economic shocks, financial disturbances, and other unforeseen developments. Importantly, however, this discretion of policymakers is constrained by a strong commitment to keeping inflation low and stable. In practice, I will argue, this approach has allowed central banks to achieve better outcomes in terms of both inflation and unemployment, confounding the traditional view that policymakers must necessarily trade off between the important social goals of price stability and high employment."

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Appendices

Appendix A. Derivation of Private sector's expectations under the inflation zone targeting regime

This follows Driffill and Rotondi (2002). Private sector's inflation expectations are given by

$$\begin{aligned} E\pi &= \qquad (A.1) \\ E\left[\pi \mid \bar{\varepsilon}_l < \varepsilon < \bar{\varepsilon}_{\mathrm{u}}\right] \Pr(\bar{\varepsilon}_l &< \varepsilon < \bar{\varepsilon}_{\mathrm{u}}) \\ +E\left[\pi \mid \bar{\varepsilon}_{\mathrm{u}} \leq \varepsilon \leq \varepsilon_{\mathrm{u}}\right] \Pr(\bar{\varepsilon}_{\mathrm{u}} &\leq \varepsilon \leq \varepsilon_{\mathrm{u}}) \\ +E\left[\pi \mid \varepsilon < \varepsilon_l\right] \Pr(\varepsilon &< \varepsilon_l) \\ +E\left[\pi \mid \varepsilon > \varepsilon_{\mathrm{u}}\right] \Pr(\varepsilon &> \varepsilon_{\mathrm{u}}); \end{aligned}$$

where we have used the fact that $E\left[\pi \mid \varepsilon_l \leq \varepsilon \leq \bar{\varepsilon}_l\right] \Pr(\varepsilon_l \leq \varepsilon \leq \bar{\varepsilon}_l)$ is equal to zero.

In equilibrium expectations must be rational and, hence, we must have that

$$\pi^e = E\pi. \tag{A.2}$$

After substituting the expressions from (25) to (29), found in the text, in (A.1) we get

$$\begin{aligned} E\pi &= \frac{\varepsilon_{\mathrm{u}} - \bar{\varepsilon}_{\mathrm{u}}}{2\bar{\varepsilon}}\bar{\pi} + \frac{\bar{\varepsilon}_{\mathrm{u}} - \bar{\varepsilon}_l}{2\bar{\varepsilon}}\left(\pi^e + \bar{y}\right) + \frac{\varepsilon_l + \bar{\varepsilon}}{2\bar{\varepsilon}}\left(\frac{\pi^e + \bar{y}}{1+\psi}\right) \\ &\quad + \frac{\bar{\varepsilon} - \varepsilon_{\mathrm{u}}}{2\bar{\varepsilon}}\left(\frac{\pi^e + \bar{y} + \chi\bar{\pi}}{1+\chi}\right) + \frac{\bar{\varepsilon}_{\mathrm{u}}^2 - \bar{\varepsilon}_l^2}{4\bar{\varepsilon}} \\ &\quad + \frac{\varepsilon_l^2 - \varepsilon^2}{4\bar{\varepsilon}\left(1+\psi\right)} + \frac{\bar{\varepsilon}^2 - \varepsilon_{\mathrm{u}}^2}{4\bar{\varepsilon}\left(1+\chi\right)}. \end{aligned} \tag{A.3}$$

Using (A.2) we can solve the expression (A.3) for π^e and obtain the expression (30) given in the text.

Appendix B. Existence of multiple equilibria under the inflation zone targeting regime

This follows Driffill and rotondi (2002). In order to see whether we might have multiple equilibria we examine also the case when $\chi_1 > \psi_1$, i.e. when deviations from the upper bound of the target range are penalized more heavily than deviations from the lower bound. In order to simplify the algebra we set $\chi_0 = \psi_0 = \theta_0$. In this case we get two solutions:

$$\pi_1^e = \frac{\chi_1 \bar{\pi} - \bar{\varepsilon}\left(\chi_1 + \psi_1\right) + \bar{y}\left(\psi_1 - \chi_1\right) + \psi_1 \chi_1 \left(\bar{\pi} - 2\bar{\varepsilon}\right) - \sqrt{\Phi}}{\chi_1 - \psi_1}, \tag{B.1}$$

and

$$\pi_2^e = \frac{\chi_1 \bar{\pi} - \bar{\varepsilon}\left(\chi_1 + \psi_1\right) + \bar{y}\left(\psi_1 - \chi_1\right) + \psi_1 \chi_1 \left(\bar{\pi} - 2\bar{\varepsilon}\right) + \sqrt{\Phi}}{\chi_1 - \psi_1}, \tag{B.2}$$

with

$$\Phi \equiv \left(1 + \psi_1\right)\left(1 + \chi_1\right)\left[4\bar{\varepsilon}\bar{y}\left(\chi_1 - \psi_1\right) + \psi_1 \chi_1 \left(2\bar{\varepsilon} - \bar{\pi}\right)^2\right]. \tag{B.3}$$

For $\bar{\varepsilon} > \frac{\bar{\pi}}{2}$ the expression (B.3) in the square root is positive. In order to rule out the possibility of having multiple equilibria we can observe that

$$\begin{aligned} \lim_{\chi \to \psi} \pi_1^e &= \text{undefined}, \\ \lim_{\chi \to \psi} \pi_2^e &= \pi^e, \end{aligned} \tag{B.4}$$

with $\chi_0 = \psi_0 = \theta_0$ and $\psi_1 = \theta_1$.

Hence we can rule out the solution (B.1) by using a continuity argument.