"INFORMATION AND UNCERTAINTY IN THE THEORY OF MONETARY POLICY"

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Helmut Wagner

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INFORMATION AND UNCERTAINTY IN THE THEORY OF MONETARY POLICY[1]

Helmut Wagner
Visiting Fellow, Princeton University, Department of Economics

and

Professor and Chair of Economics, University of Hagen, Germany;
Co-Director of the Hagen Institute for Management Studies
(Macromanagement)

Contact Details:
Department of Economics
University of Hagen
Universitätsstrasse 41
D-58084 Hagen
GERMANY
Tel: +49 2331 987 2640
Fax: +49 2331 987 391
e-mail: helmut.wagner@fernuni-hagen.de
and: hwagner@princeton.edu
www: www.fernuni-hagen.de/HWagner

Abstract

Theory and practice of monetary policy have changed significantly over the past three decades. A very important part of today's monetary policy is management of the expectations of private market participants. Publishing and justifying the central bank's best forecast of inflation, output, and the instrument rate is argued to be the most effective way to manage those expectations.

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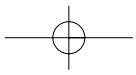
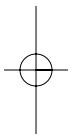
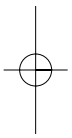
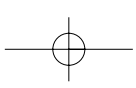


The author works out the foundations of this new consensus view, compares the communication policies of the Federal Reserve, the ECB and the Bank of England, and discusses possible "limits to transparency". He argues that "model uncertainty" has led several central banks to apply simultaneously prognoses based on several alternative models. Special attention is drawn to the optimal degree of openness concerning central bank ignorance and the possible implications for the institution's image of competence.







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1 Introduction

Theory and practice of monetary policy have changed significantly over the past three decades. Not only have hypotheses (consensus views) on monetary policy and its effectiveness changed but also monetary policy institutions have considerably been modified over this period of time.

On the theoretical side, one of the main driving forces has been the change in focus on information and information asymmetries. This is reflected in what is called the 'revolution' through the theory of 'rational expectations' that was introduced in the 1970s and brought with it a fundamental shock to the previously accepted opinion on the effects of monetary policy. It postulated the ineffectiveness (neutrality) of monetary policy. However, from the beginning, this 'ineffectiveness theory' was regarded as extremely doubtful by many observers. To substantiate it, questionable assumptions on the status of information of economic subjects had to be taken as a basis. The main criticism, outlined already in the 70s and 80s, of this ineffectiveness theory can be summarized in the following two points: it is based (i) on a lack of a (or an inadequate) micro basis of the theory, and (ii) on an unsatisfactory consideration of uncertainty. In the next two chapters of this Study, I want to concern myself with whether/how far the theory of monetary policy has since eliminated/taken these alleged weak/critical points into account. I will first show that since then in monetary theory both a more comprehensive micro basis has been supplied and more account has been taken of uncertainty (and learning processes), but the fundamental information assumptions are still very strict.

On the practical side, monetary policy institutions have been modified, too, over the past decades. In particular, central banks have become more independent, more transparent, and are more governed by committees today. In chapter 4, I shall mainly concern myself with information or communication policy, in particular the challenges of central bank communication, under uncertainty. Although the ineffectiveness hypothesis has lost much of its appeal over the last decades, the conventional view nowadays regarding optimal monetary policy has changed paradigmatically from the conviction that monetary policy decisions should take the market by surprise towards the view that central banks should announce their monetary policy decisions in a timely manner and with transparency. Consequently, many central banks have modified their communication policies recently.

This field has been researched on intensively over the last two decades and led not only to changes in theoretical thinking on monetary policy but also to various changes in institutional design (and communication) as well as strategy of central banks, and, moreover, to specific challenges to central bank communication. I shall survey these institutional changes and the challenges for central bank communication, and discuss their theoretical foundations in this chapter 4. Chapter 5 concludes.

2 Micro basis of the theory of monetary policy

The micro basis of macroeconomics, which has advanced successively in the last two decades, has also found acceptance in the theory of monetary policy. The 1990s in particular saw a development that culminated in what is described today as the "new neoclassical synthesis" (NNS) (Goodfriend and King, (1997), Rotemberg and Woodford, (1997)).[2] This unites important elements of "new classical macroeconomics" (NCM), in particular from the "real business cycle" (RBC) theory, with other elements of "new Keynesian macroeconomics" (NKM) models of the 1980s (for the latter see, e.g., Mankiw and Romer (Eds.), (1991)). Like the first, or "old", neoclassical synthesis from Hicks, Samuelson and Patinkin, the new approach attempts to bridge the methodological division into microeconomics and macroeconomics by using the tools of the general equilibrium theory to model Keynesian insights. The NNS stringently realises the demand of the NCM from Lucas and Sargent, who required the use of intertemporal general equilibrium analysis (intertemporal optimizing and rational expectation analysis) to model the complete dynamics of the economy. In so far, their methodology conforms largely to that of the RBC literature. The difference is solely that wage and price rigidities are now permitted as well, but determinants of the (individually) optimal wage and price setting decisions are modelled explicitly. In this way, central elements of the NKM, namely imperfect competition and dynamic wage and price rigidities, are taken over.

In the NNS, delays in wage and price adjustment explain temporary deviations from the potential output, whose development is determined largely by factors that are stressed in the RBC theory. In contrast to monetarist and neoclassical models, which allocated cyclical swings above all to erratic monetary policy actions, in the NNS models real disturbances play a central part as the actual source of short-term output changes.

What differentiates the NNS from the NCM (and from the RBC theory as well) is that cyclical swings are no longer to be regarded as desirable (in the sense of a necessary adjustment of supply and demand on the individual markets), and (!) monetary policy is no longer irrelevant or ineffective either. The ineffectiveness theory that has been criticized in the 80s and 90s is no longer supported by the NNS (at least not in the short to medium term).

[2] For an overview about the NNS see Goodfriend (2004).

Instead, active monetary policy is possible and desired as well, to cushion distortions that would otherwise occur with real shocks because of imperfect wage and price adjustments.[3] In so far, the NNS shares important aspects with Keynesian theory: the emphasis on market failure in the short term after economic shocks, and the role of wage and price inflexibilities as a source of such market failures. The NNS also contains the return to the application of the methods of optimal control (in a modified form), to calculate optimal stabilizing policies. These common features are also a reason why other authors prefer the term "new Keynesian models" for this type of model instead of "NNS" (Gali, (2002)).[4] However, the assertion is somewhat hasty that the NNS has laid the foundation stone for overcoming the separation between microeconomics and macroeconomics. For example, Michael Woodford, one of the architects of the NNS, writes: "In principle, the grounds for reunification (...) seem to be largely in place. Macroeconomics no longer claims that the study of aggregate phenomena requires a distinct methodology; instead, modern macroeconomic models are intertemporal general equilibrium models, derived from the same foundations of optimizing behaviour on the part of households and firms as are employed in other branches of economics. Furthermore, the aims of stabilization policy can now be discussed in terms – namely, the attempt to mitigate quantifiable efficiency losses resulting from identifiable distortions of the market mechanism – that correspond to those used for policy evaluation by microeconomists" (Woodford, (1999), p. 31). It should be noted that the type of micro basis that has asserted itself in the NNS represents only a specific type of micro basis that is exposed to the same criticism as the traditional general equilibrium theory. This concerns in particular the inherent information assumptions and the inadequate consideration of uncertainty.

In so far, the NNS is also subjected to the earlier fundamental objection to the NCM (see above in the Introduction) that it starts from the basis of questionable assumptions on the state of information of economic subjects.

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[3] For example, former NCM (RBC) economists such as Goodfriend and King now confess that "aggregate demand must be managed by monetary policy in order to deliver efficient macroeconomics outcomes" (Goodfriend and King, (1997), pp. 255–6). In the NNS approach, active monetary policy takes effect essentially through the mark-up mechanism. Because of the assumption of rigid prices, not all companies can adjust their prices, and therefore their mark-up, after a shock. In the event of a shock, monetary policy should react so that companies do not have any incentives to alter prices later. Demand shocks must therefore be accommodated in full and productivity shocks accommodated perfectly (Clarida, Gali and Gertler, (1999)). Standard calibrations lead here to surprisingly large values for output fluctuations, which can be initiated through money supply shocks (cf. e.g. Gali, (2002)).

[4] Another frequently used term is "new consensus model" (Goodfriend, (2005)).

In addition, through the strict methodical dependence on the NCM (RBC) the NNS excludes "involuntary unemployment" in the sense of the non-employment (exclusion) of part of the population. In the NNS model all employees are equally employed, even though the hours worked can be less than the social optimum. In this way, essential welfare costs of empirical (full-time) unemployment are not taken into account. This itself is sufficient reason for many "genuine" Keynesians to question the label "neo-Keynesian".

Post-Keynesians also criticise the fundamental new IS curve (see equation (2.2) below), and also reject the concept of a vertical Phillips curve. They point here, among others, to empirical studies that show that the interest elasticity of the investment is non-linear and asymmetrical (Taylor, (1999)), and the impact lags of monetary policy are long and variable (on the post-Keynesian criticism of the NNS see, e.g. Lavoie and Seccareccia (Eds.), (2004), and Kriesler and Lavoie, (2005)).

However, even mainstream macroeconomists such as Larry Ball criticise the new consensus model as "flawed" (Ball, (2005), p. 263) and "wildly counterfactual"[5] (p. 265). "In any case, the model's absurd predictions make it a poor tool for policy analysis. (...) In most cases, the output-inflation trade-off still has the wrong sign. The only thing that works is adding lagged inflation to the Phillips curve. But the New Synthesis model does not justify this term. Adding it is equivalent to ignoring the model and going back to the accelerationist Phillips curve" (op. cit.). While some neo-Keynesians such as Mankiw and Blanchard regard the transition from the IS-LM model to the RBC models as a smooth evolutionary process, and for this reason regard the term "new synthesis" as an exaggeration[6] other economists have fundamental doubts. For example, DeVroey ((2004), p. 86) writes: "...the perfectly competitive and imperfectly competitive models must be viewed as rooted in incompatible trade technologies, the Walrasian and the Marshallian. Therefore a merger between them is hard to envisage. The picture that then emerges is rather one of two rival macroeconomic paradigms, a Marshallian (i.e., imperfect competition) and a Walrasian (i.e., perfect competition), existing side by side."

The supply side of the NNS model is based on the foundations of the NKM, in that mainly monopolistic competition on the goods market and price

[5] See Mankiw (2001) as well on this.

[6] Blanchard claims that practically all macroeconomists have always recognized the relevance of the three components of the NNS (intertemporal optimization, nominal rigidities and imperfect competition), but with different weightings (Blanchard, (1997), p. 290).

inflexibilities are imputed[7]. One, widely-used, way to introduce sticky nominal prices is a Calvo-style Phillips curve.[8] Here, only a certain percentage of the randomly selected companies acting in the market can reset prices in each period (Calvo pricing); the empirically observed price movements are to be mapped in this way. Each company sets its price in such a way that the discounted sum of the deviations between optimal and existing prices in future periods is minimized. This results in a dependency of present prices on future prices and, through the companies' mark-up, a dependency of production on price changes. These considerations then lead to the new Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + \gamma(y_t - \bar{y}_t) + \varepsilon_t, \tag{2.1}$$

where π_t and y_t denote inflation and output, $\bar{y}_t$ describes the natural production level (at time t), and E_t stands for the expectations parameter. This Phillips curve, along with the described dependencies, also contains a demand shock ε_t, which is generally defined in detail as a stationary random variable with expected value zero. β and γ are exogenous and positive constants here.

The demand side of the NNS model contains above all considerations of the RBC theory; the consumption, money and leisure demand can be derived from households' optimization calculation. An IS curve with the shape

$$y_t = E_t y_{t+1} - a_1(r_t - \bar{r}) \tag{2.2}$$

is usually derived here, whereby consumption depends on the real interest. $\bar{r}$ is the interest at which production lies at the natural level, a_1 is a positive constant.

In the New Keynesian approach to monetary policy, this is supplemented by a model of the transmission mechanism that should describe the relations between the central-bank's variables of interest (including inflation and output gap, for instance) and its instrument (be it a short-term interest rate or (a component of) the monetary base). How the instrument is determined then depends on the nature of the monetary-policy regime, which could be

[7] In rare cases alternative wage inflexibilities on the labour market are assumed.

[8] Another way that gives rise to effectively sticky prices and/or wages, is based on the sticky expectations approach of Mankiw and Reis (2002), where otherwise rational and forward-looking agents receive information with some delay.

anything. In applied studies, however, often a Taylor-rule is used as a supplement.[9] The LM curve

$$m_t - p_t = b_1 y_t - b_2 \underbrace{(r_t + E_t \pi_{t+1})}_{=R_t},$$

with R_t as the nominal interest in period t, is here to be characterized as positive in the context of the NNS, because, in this approach, monetary policy is supposed to almost never be carried out through money supply control but through an interest rate regulation (such as, e.g., the Taylor rules)

$$r_t = \bar{r} + c_1 \pi_t + c_2 (y_t - \bar{y}_t). \tag{2.3}$$

b_1, b_2, c_1, c_2 are exogenous and positive constants here. The money supply is set by the central bank so that the real interest rate is set according to its rule through households' demand for money. The solutions of the endogenous variables y, p, r, π, R can be calculated with the four equations, because the equation that determines the nominal interest rate is integrated in the LM curve.

In this approach, stability effects of the monetary policy are measured by a loss function that can be understood in certain circumstances as the approximation of a welfare function.

The NNS confirms that the former critics of the ineffectiveness theory were right. However, ad hoc approaches of the NCM theory had already shown at the beginning of the 1980s that slight changes in the assumptions regarding the information level in the NCM approaches led to monetary policy rules not being ineffective, in spite of rational expectations and price flexibility (Canzoneri, Henderson and Rogoff, (1983)). According to this, it is not all the same which rules monetary politicians follow. Modern approaches confirm that different rules lead to different welfare effects. The problem here is not the ineffectiveness of monetary policy rules but the enforceability of optimal policy rules. In addition, game theory approaches show that monetary policy is not dependent on whether it is rule-based (committed) or discretionary. Discretionary policies produce an inflation bias and/or stabilization bias.

[9] It should be made clear that an instrument rule such as the Taylor rule is not inherent in the New Keynesian approach to monetary policy. Using such an instrument rule can even be regarded as a theoretical weakness, as thereby an arbitrary restriction on the set of policy rules is made. For a critique on the use of Taylor rules, see Svensson (2003).

However, it must also be stressed that the NNS model class is still being developed. The (previous) micro basis itself is only partial or incomplete. The standard approaches of the NNS, for example, do not contain a logical substantiation of money holding. That is, the benefit of money is not established adequately. In addition, the standard approaches, as described above, take into account so-called Calvo pricings. However, a convincing micro basis for the delayed price adjustments is missing (cf. e.g. Hall in the discussion on Goodfriend and King, (1997), p. 294). For example, we can ask ourselves why it should be more expensive to change prices than employment. And the empirical evidence for the statements of the NNS have been mixed up to now and do not support the new theory in general (see above). The core of the criticism is: the pricing function in the NNS is empirically very controversial. Apart from this, some also criticise the lack of substantiation for the claim of a long-term vertical Phillips curve. Both lead to uncertainties regarding the adequate supply equation.

More knowledge of the *specific* rigidities that exist empirically is required, because individual NNS model results are sensitive towards the exact character of the rigidities. If the rigidities are sector-specific, this rules out (as Canzoneri et al., (2002) emphasise) perfect stabilization of the aggregated output through re-active monetary policy, because a single monetary policy measure cannot fit all sectors.

This leads in the end as well to an increase in the influence of international policy coordination of the monetary policy, if the producers set prices in their local currency. In older Keynesian models the influence of international coordination is very restricted, in the more modern ones examples can at least be found that make this coordination obvious (see, e.g., Berger and Wagner, (2006)).

The problems that are only hinted at here indicate that the micro basis of the NNS (still) leaves something to be desired and its results entail great uncertainties.

3 Inclusion of uncertainty

A second critical point that was referred to from the beginning was the insufficient consideration of uncertainty and learning in the theory of monetary policy. As a whole, it holds true for the modern theory of monetary policy that a broad consensus appears to exist today with regard to the normative target of a central bank (minimizing inflation volatility and the volatility of the gap between output and the equilibrium output level with flexible prices). There is less consensus with regard to the best strategies for achieving this target. It holds true for the greater part of this modern research that it still largely ignores information imperfections and uncertainty. "The central bank is assumed to know the true model of the economy and to observe all relevant variables accurately. The sources and properties of economic shocks are also taken to be known. Uncertainty arises only due to the unknown future realizations of these shocks.

In practice, [however], policy choices are made in the face of tremendous uncertainty about the true structure of economy, the impact policy actions have on the economy, and even about the current state of the economy." (Walsh, (2004), p. 2)[10]

However, there has recently been a whole series of research work on the role of uncertainty in monetary policy, and we will be discussing this briefly below. A difference can be made here between research work on uncertainty in the central bank policy and on uncertainty in the formation of private expectations.

3.1 Uncertainty in the central bank policy

In the modern theory of central bank policy three types of uncertainty above all are perceived and analysed. These are (a) uncertainty regarding the economic situation (e.g., most economic and financial data are only available after a time lag and are subject to revision after their initial publication); (b)

[10] Walsh himself is one of the leading representatives of the modern theory of monetary policy and author of what is currently perhaps the most famous text book on "Monetary Theory and Policy" (2nd ed., (2003a)), which is found in advanced study and PhD programmes all over the world.

uncertainty regarding the structure and method of functioning of a national economy (because of model uncertainty and of parameter uncertainty, which describes the uncertainty regarding the strength of the structural relationships in the framework of a specific model); (c) strategic uncertainty (that concerns the interplay between central banks and private individuals and in particular the role of expectations that can have a decisive effect on monetary policy transmission). The uncertainty factors, with which central banks are confronted, are not only varied but are also interdependent.[11]

The question now arises regarding the consequences that monetary policy decision makers should draw from the different forms of uncertainty. Research on this is relatively young, although it has exploded recently, triggered above all by cross-border crises and increased (perceived) uncertainty in the course of the consequences of globalization and European integration since the mid-1990s/the end of the 1990s.[12] However, it can be seen here that the political implications of this research are very sensitive as against the different assumptions regarding uncertainty.

In particular, the debate on model uncertainty, and there on the robustness of monetary policy, has been in the focus of research recently. For this reason, this point is to be considered in some more detail below.

3.1.1 Bayesian approaches of model uncertainty

Model uncertainty means that a decision maker does not have *complete* confidence in his model. The existence of model uncertainty is not actually a new discovery. Even Milton Friedman pointed out repeatedly in the 1960s that there are impact lags of monetary policy (and of fiscal policy) that are long and variable (uncertain). This implies, as he argued, that the prognosis capability of politicians is restricted, with the consequence that an active (activist) policy can destabilize the economy, instead of stabilizing it as planned.

In the mid-1990s, Bennet McCallum and others went on from Friedman's point of view when they initiated a research programme that was to evaluate the robustness of monetary policy rules over a set of alternative models. McCallum stressed ((1997), p. 355): "I have favored a research strategy centering around a rule's robustness, in the following sense: Because

[11] ECB (2001).

[12] cf. on this, e.g. Wagner (2001).

there is a great deal of professional disagreements as to the proper specification of a structural macroeconomic model, it seems likely to be more fruitful to strive to design a policy rule that works reasonably well in a variety of plausible quantitative models, rather than to derive a rule that is optimal in any one particular model." Most central banks now agree with the view that they should not rely on prognoses that are based on a single model only. On the contrary, each forecast calculation should be compared with prognoses that are based on alternative models, and with information that was acquired through different processes. The monetary policy is to be enabled in this way to supply similar results with a large number of alternative models.

However, one problem here is the, in the end, unavoidable arbitrariness in the selection of the observed/compared/integrated models and the methods (processes) used, and the retroactive effect of the model selection on the target function. A discussion is taking place in the current literature that the target function is endogenous with regard to the model selection. This means that the target function that is suitable for one model cannot be used directly to appraise and compare the results in another model. Put another way, uncertainty on structural parameters also implies uncertainty on the correct loss function (Walsh, (2005)).[13] This was not taken sufficiently into account in the many robustness studies in the recent past.[14]
In addition, the question arises whether specific probabilities of events can be assigned to the individual alternative models. If not, we now have the second variant of research on model uncertainty and robustness of central bank policy, namely the theory of robust control.

3.1.2 Approaches of robust control

The theory of robust control differs from the classical control theory in that it assumes that decision makers are uncertain about their model. Users of the techniques of robust control in monetary theory are concerned to draw up an optimal monetary policy that is robust in the sense that it protects the economy from the worst conceivable consequences if the monetary policy decision maker's model is based on a faulty specification. They assume that the monetary policy decision maker's problem is so complex that probabilities of an event occurring can no longer be assigned to the conceivable scenarios (models). Model uncertainty is then linked with the existence of a series of non-specified alternatives for a specific reference

[13] See Woodford (2003) as well here.

[14] For recent attempts see e.g. Levin et al. (2005) or Smets and Wouters (2005).

model, which is regarded as an approximation of the true but unknown model of the economy. Lars Hansen and Thomas Sargent, as the currently most prominent proponents of the theory of robust control in macroeconomics, refer here to Milton Friedman, who, as they write, "expressed an enduring concern when he recommended that designers of macroeconomic policy rules acknowledge model uncertainty. His style of analysis revealed that he meant a kind of model uncertainty that could not be formalized in terms of objective or subjective probability distributions over models" (Hansen and Sargent, (2003), p. 582).

This approach usually shows that in these cases of extreme uncertainty waiting to see cannot be expedient and that the monetary policy should be selected that avoids the worst conceivable development path (the so-called "worst case").[15] A policy of this nature can be understood as insurance against this case.

While McCallum and his comrades-in-arms take a small number of special models, of which some at least are rational expectation models, and evaluate the performance of one (!) given rule throughout these models, Thomas Sargent and his comrades-in-arms proceed as follows. They assume that political decision makers and private individuals share a model, but regard this as an approximation model of the true, but unknown, model. However, it is possible that each group has different preferences regarding the faulty specification so that to a certain degree heterogeneity is mapped. As with rational expectations, an equilibrium concept is assumed here "in which the private sector and the government share the same approximating model of the stochastic variables shaking the economy. But both types of agent have doubts about that model in the form of possibly different penumbras of alternative models that surround the approximating models" (Hansen and Sargent, (2003), p. 584).[16] They regard this approach as a further development

[15] "Robust control theory instructs decision makers to investigate the fragility of decision rules by conducting worst-case analyses. When both types of agent prefer robustness, the approximating model for each agent must include a description of the robust decision rules of the other type of agent, and of how they respond to his own actions. Though they share a common approximating model, because their preferences may differ, the different types of agent may *not* share the same worst-case model". (Hansen and Sargent, (2003), p. 582)

[16] It is increasingly recognized here that rational expectation models, which have dominated macroeconomics for the last three decades, "impute much more knowledge to the agents within the model ... than is possessed by an econometrician, who faces estimation and inference problems that the agents in the model have somehow solved" (Sargent, (1993), p. 3, emphasis in the original). This does not imply that economic subjects are irrational. Instead of this it can be assumed that "rational expectation formation" implies a "superfluity" of rationality. For example, →

of or alternative to the dominating literature of the "new neoclassical synthesis", which does not take account of robustness.[17]

Robustness is understood here technically as a Markov perfect[18] equilibrium of a two-player zero-sum game. The game has only a single value function and can be transformed with the methods of robust control into a Bellmann equation in a linear quadratic context and then reformulated into a simpler Riccati equation in matrix form. On the demarcation between traditional and robust control theory Hansen and Sargent state (Hansen and Sargent, (2006), p. 21): "Standard control theory tells a decision maker how to make optimal decisions when his model is correct. Robust control theory tells him how to make good decisions when his model only approximates the correct one."

Here the central bank has a model that, as we have said, in its opinion represents a reasonable approximation of the true model, but which can be incorrectly specified. In an environment of this kind an optimal policy aims at minimizing the worst-case result that can occur.

To illustrate this: let the central bank's reference model be assumed to be

$$y_{t+1} = Ay_t + BU_t + \varepsilon_{t+1}, \tag{3.1}$$

whereas the real (but unknown) model is

$$y_{t+1} = Ay_t + BU_t + C(\varepsilon_{t+1} + w_{t+1}). \tag{3.2}$$

y_t consists of the natural state variables and the endogenous variables. The vector U_t groups the control variables. ε_t is a normally distributed random process with expectation value 0 and the identity as variance-covariance

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Sims (2003) stresses that optimum information processing on the basis of a restricted cognitive capacity is reflected in processes of expectation formation that are fundamentally different from those that are imputed in rational expectation models. To take this into account, Simon (1978) proposed designating Muth's (1961) concept of expectation formation not as "rational" but as "model-consistent". In this context various model studies have found that monetary policies that are efficient under "rational" expectations come off very badly when knowledge is imperfect (see e.g. Orphanides and Williams, (2006)).

[17] "The equilibrium concept ... will allow us to compute robust Ramsey plans for macroeconomic models with forward-looking agents, like the 'new synthesis' models of Clarida, Gali, Gertler (1999), King and Wolman (1999), Rotemberg and Woodford (1997) and others." (Hansen and Sargent, (2003), pp. 601–2)

[18] A Markov perfect equilibrium leads in every subgame with Markov strategies to a Nash equilibrium. Markov strategies do not depend on memoryless variables, with the exception of variables influencing amounts paid out.

matrix. w_{t+1} expresses the non-linear and time-dependent reactions to past states of y^t and can therefore cover a large set of possible faulty specifications. A, B and C are well-defined and suitable dimensioned matrices. The politician regards (3.1) as a good approximation of the true model. In the robust control approach by Hansen and Sargent the central bank bases its monetary policy on a distorted model that contains the worst-case process for w_{t+1}, but then acts as if model uncertainty no longer exists. A further overview of modelling robust control can be found below in the Annex C.

In a neo-Keynesian model with parameter uncertainty this can mean that the central bank is pursuing a more aggressive policy,[19] i.e., for example, it increases the interest rate more severely as a response to inflation than with a standard optimal commitment policy of an expected utility maximiser[20] (for more details of this, see e.g. Walsh, (2004)).

However, there is still another interpretation of robust control, which is supported by Hansen and Sargent. They argue that a central bank pursues the same aggressive policy when it takes its approximation (3.1) as the true model, but maximizes a target function that reflects an additional risk sensitivity (see Hansen and Sargent, (2006)). Through this more aggressive policy it attempts to avoid possible future costs that result from the fact that shocks in the worst-case scenario prove to be more persistent than in the approximation model. Greater risk sensitivity therefore serves to ensure, as did the incorrect specification of the model, that the monetary politician takes measures against persistent shocks.

However, robustness approaches also mean problems. The main problem when a distorted model is used is that it can be more difficult for a central bank to communicate the logical foundation of its political actions. And the distinction between forecasters and decision makers is blurred. The forecast has to include the decision maker's preferences when forming his forecast, because they are also responsible for determining the worst-case result. In this context Svensson (2000) has objected that the worst-case results are probably low-probability results. Consequently, a robust policy, seen from a Bayesian aspect, is too

[19] However, as more recent studies show, this does not necessarily apply. For example, Leitemo and Söderström (2005) come to the conclusion that an optimal robust policy, at least in an open economy, can be either more aggressive or more cautious, depending on the source of the incorrect specification and the type of shock that affects an economy. See Zakovic, Rustem and Wieland (2005) as well.

[20] The latter usually builds on Brainard's principle (Brainard, (1967)) and favours a cautious policy with parameter uncertainty.

heavily influenced by results of this kind.[21] [22] This also means that a robust policy is sensitive to assumptions on the largest and smallest possible values that a parameter can have. In addition, Onatski and Williams (2003) made the point that any progress on model uncertainty requires structural assumptions about the nature of model uncertainty. However, the robust control literature, even the refinements of Hansen and Sargent, do not provide sufficient structure and can, as shown by Onatski and Williams, give quite misleading results.

In contrast, with the last variant of the robustness approach referred to, which builds on a distorted target function, there is the problem of the selection of the additional risk sensitivity in the target function. Sims (2001) characterises such distorted references, in relation to politicians, as "subrational".[23]

3.1.3 A compromise variant

The objection from Sims (2001) to the maxmin approach of the theory of robust control is basically that the former often implies unreasonable priors (a priori probability distributions). This criticism has led to a more general compromise variant being discussed recently as well, which contains as border cases the Bayesian and the maxmin approach (see Brock, Durlauf and West, (2004), as well as Kuester and Wieland, (2005)). This compromise variant is based on the decision-theory foundation of the so-called Ellsberg paradox by Gilboa and Schmeidler (1989) and Epstein and Wang (1994). See below in Annex A for more details of this. The compromise variant states:
Let the decision maker maximise the following utility function

$$U(x) = \gamma u(x(t)) + (1-\gamma)\left[\min_{s\in[\underline{s},\bar{s}]} u(x(s))\right] \tag{3.3}$$

whereby $(1 - \gamma)$ indexes the degree of the desired insurance as against the

[21] "'Robust control' consists of selecting the policy that results in the best outcome for the worst possible model" whereby "the assumptions about the feasible set of models are crucial for the outcome. Robust control has been proposed as a non-Bayesian alternative that utilizes less prior assumptions about the model. ... Furthermore, if a Bayesian prior probability measure were to be assigned to the feasible set of models, one might find that the probability assigned to the models on the boundary are exceedingly small. Thus, highly unlikely models can come to dominate the outcome of robust control." (Svensson, (2000), pp. 6–7)

[22] However, there are statements from leading central bank practitioners, in particular in the context of the search for adequate strategic behaviour of monetary policy in an asset price boom, which stress the relatively heavy weighting of such low probability events in central bank decisions (see, e.g., Svensson, (2004)).

[23] Sims argues that "the criteria for acceptable shortcuts in decision-making by a central bank should generally be much stricter than those applying to, say, a consumer buying a new washing machine" (Sims, (2001), p. 51).

worst case; see equation (3.4) in Section 3.2.2 as well. These preferences are also described as "ambiguity averse" (Brock et al., (2004)), because the decision maker places particular weight on the uncertain worst case. If $\gamma = 1$, this corresponds to a maximizing of the expected utility from a Bayesian perspective. In contrast, with $\gamma = 0$ we have the maximum case (analogue to the minimax on loss minimizing). The preferences can also be understood as parameters of confidence in their own assessment.

Somewhat more detailed notes on the theoretical background of this compromise approach can be found in Annex A (see Section 3.2.2 as well). This compromise variant can also be understood as a "link" between the two decision theory concepts of "risk" and "uncertainty".

3.1.4 Risk vs. uncertainty (Knightian uncertainty)

The differentiation between "risk" and "uncertainty" was made by Frank H. Knight (Knight, (1921)). According to Knight, "risk" is characterized by it being possible to assign objective probabilities, which are known to the decision maker, to the different possible states of nature. In contrast, "uncertainty" for Knight describes a situation in which no probabilities at all are known. This is also referred to as an "incalculable" risk or **ambiguity**. Risk can be incalculable here for two reasons. On the one hand, it can be impossible to assign different future scenarios to an unambiguous (subjective) probability distribution. On the other hand, it can be difficult to assign an unambiguous result to each scenario. Ambiguity is found in both cases.

Whereas, therefore, the traditional Bayesian approach to the uncertainty analysis assumes that the central bank estimates the joint probability distribution over all scenarios/results and then maximizes the expected utility of its target function, the probability distribution is not even known here.

The starting point here is the theory that the uncertainty case (the case of Knightian uncertainty) cannot be said to be caused by the risk case through permitting subjective probabilities. The attempt to transfer uncertainty fully to risk by means of subjective probabilities (cf. e.g. Savage, (1954)), was shown by Daniel Ellsberg (1961) to be questionable in an impressive experiment. Ellsberg shows that persons who are confronted by two uncertainty situations of basically the same type, which only differ in the fact that one of them has objective probabilities and the other does not, usually display a clear preference for the risk situation and shy away from the uncertainty situation. This behaviour, which is referred to as the "Ellsberg paradox", leads many

decision theoreticians to look for uncertainty dimensions that cannot be led back to probabilities (so-called ambiguity). But Schmeidler (1982/1989) was the first to succeed in placing the difference between risk and ambiguity on a solid axiomatic foundation that was on a par with the subjective expected utility theory. It was only through the axiomatizing of preferences, which he invented and which leads to the behaviour dealt with by Ellsberg, that the theoretical solution proposed by Ellsberg was considered (again), e.g. in the form of the E(llsberg) capacities introduced by Eichberger and Kelsey (1998) (as an overview, see Spanjers, (1999), Chap. 8 as well).

Adherents of robust control (Hansen, Sargent, Turmuhambetov and Williams (HSTW), (2006)) also take heed of the "maxmin expected utility approach", in which the minimum of the expected utility is taken over the set on the non-excluded probability distributions[24] (Gilboa and Schmeidler, (1989), Arrow and Hurwicz, (1972)), and that is based on a special case of the solution proposed (ad hoc) by Ellsberg. HSTW have shown namely that the set of alternative models that surrounds the approximation model in the robust control approach, can be seen as the a priori probability distributions ('priors') that turn up in Gilboa and Schmeidler's maxmin expected utility theory (1989).[25] However, the essential difference between Hansen and Sargent's robust control theory and Gilboa and Schmeidler's maxmin expected utility theory is rather that the latter, in a greater deviation from the theory of rational expectations, deliberately waive the heroic assumption of a joint approximation model and assume "real" ambiguity.[26]

3.1.5 Summary

We have presented three variations of the discussion on model uncertainty in the theory of central bank policy. The first (Bayesian) variation emphasises above all the difference between model-specific optimal and average optimal policies. The robustness of the monetary policy is understood here essentially as a property of the monetary policy that ensures that in the "average" of

[24] This implies some uncertainty aversion of consumers, through which the maxmim expected utility approach differs from the Choquet expected utility theory. However, it permits considerably more different classes of the existing uncertainty.

[25] HSTW interpret robust control here in the form of a recursive version of the maxmin expected utility theory.

[26] Using so-called "Gilboa-Schmeidler preferences" represents only one possibility for modelling the decision rules with Knight's uncertainty. Another possibility is based on so-called "Bewley preferences" (Bewley, (1986)), which do not concentrate on the worst case only. See, e.g. Cagliarini and Heath (2000), on possible different monetary policy (interest) decision simplifications.

alternative scenarios (models) it provides good results. Some economists (cf. Taylor or McCallum) interpret the results of this research direction in the sense of an argument for pursuing simple instrument rules in the monetary policy, while others (cf. Svensson or Woodford) recommend optimal target rules, in which the monetary policy instrument does not necessarily follow simple rules. If we take the phenomenon of parameter or model uncertainty into account, reasons can be found for extending the safety equivalence principle by a cautionary aspect in accordance with Brainard: with parameter uncertainty the monetary policy instrument should regulate more cautiously. A special feature of the second variation (maxmin or robust control) is that for reasons of monetary policy caution completely different conclusions regarding the regulating of the use of the instruments can be arrived at. The robustness of the monetary policy here is a characteristic of the monetary policy that ensures the ability to defend against the conceivably worst case scenario as well. Monetary policy caution is therefore just about expressed through the inclusion of events that are probably completely unlikely but have a catastrophic effect. However, this does not lead to the conclusion that the regulating of the monetary policy instrument should take place comparatively cautiously. On the contrary, taking the most unfavourable developments into consideration can imply a relatively aggressive monetary policy. The third variant is a compromise variant of both. Here, it is not yet possible to foresee the monetary policy implications that will possibly be derived in the future. However, as our arguments in Section 3.2.2 will show, the effects for the monetary policy could be drastic.

The discussions surrounding central banks show that the argument regarding the adequate consideration of uncertainty or robustness in the monetary policy is not merely an academic dispute. For example, the ECB regards the following as signs of an adequate monetary policy in an uncertain environment: that the central bank (a) pursues in most cases a moderate and reserved monetary policy aligned towards the medium term in the event of transmission or structural uncertainty, but (b) with data and model uncertainty pursues a robust monetary policy (which implies that the central bank should not rely on specific individual indicators or models considered in isolation). In addition, (c) to reduce the strategic uncertainty in an economy, credibility with regard to a properly understood target is regarded as a necessary orientation aid for market expectations. The ECB also understands these signs as an adequate foundation for the selection of its monetary policy strategy (see ECB, (2001), Kißmer and Wagner, (2002, 2004a)).

As is known, the ECB pursues a so-called two-pillar strategy, in which short-term indicators (pillar 1 = economic analysis) for future price outlooks are combined with longer-term indicators (pillar 2 = monetary analysis). The ECB in fact also explains its unwillingness to integrate the pillars or to commit itself to one indicator pillar with the phenomenon of model uncertainty. From its point of view, in view of the uncertainties regarding the adequate theory, the optimal political time window, the structure of the economy, etc., it is not advisable to be bound to one model, one fixed indicator system or even to one simple rule.

If the explanations of the ECB are considered from a "Bayesian point of view", it would have to be argued that, for example, the weighting of the pillars in the ECB strategy could be carried out in accordance with the models that are deemed to be relevant that are included for analysis within the pillars. In fact, the designation "pillar 1 and 2" and the change in this sequence that was carried out in 2003 indicate that the ECB has an idea of which pillar or which associated theoretical approaches it regards as relevant under "normal" circumstances.

At the same time, Otmar Issing, the then-ECB's Chief Economist, speaks in this context explicitly of the existence of "**Knightian uncertainty**", and this, interestingly, not only in relation to the new foundation of the ECB but also very generally in relation to (strategic) central bank decisions: "(W)hile the academic profession has made tremendous progress in analysing risk in well-defined stochastic economies, the "Knightian" uncertainty that confronts central bankers is altogether of another dimension." (Issing, (2002)). The latest explanations of the ECB to justify the monetary pillar within the monetary policy strategy emphasise not only, as previously, the long-term correlation between money and price stability, but also point frequently to the role of the money supply and credit supply aggregates for a prognosis of asset price crises. This could result in dangers for price stability in periods still further in the future that cannot be covered in models for the standard two-year prognosis. Now, the empirical data show that not all asset price crises lead to the monetary policy targets being missed by a wide margin. Asset price crises of this kind that affect the monetary policy targets on a sustained basis are classical examples of events that are classified in the run-up as improbable and very difficult to forecast. Seen in this way, taking the monetary pillar into consideration in the ECB strategy could be understood as an expression of robust control or as a type of insurance against conceivably unfavourable developments.

3.2 Uncertainty in private expectation formation

There have also been major developments with regard to the modelling of uncertainty in private expectation formation during the past two or three decades. For example, aspects such as confidence building and reputation have been increasingly included in the theory of monetary policy. This was done initially in the framework of so-called reputation models and modified the previous views concerning the superiority of binding to rules over the discretionary behaviour of a central bank or a government. Recently, there have also been attempts to include ambiguity in this monetary policy context.

3.2.1 Bayesian reputation models

In the framework of the time-inconsistency models introduced into monetary policy in 1983 by Barro and Gordon (1983a,b)[27], given rational expectations, reputation approaches modelled multiperiod games in which compliance with notified policies can lead to long-term reputation utility, while the gains from a surprise inflation (discretionary behaviour) are always only of a short to medium-term nature. For this reason it is certainly possible within these models that the government estimates the gain from a surprise inflation too low to compensate for reputation losses that persist for a longer period. Consequently, circumstances permitting it will keep to its announcement without there being a need for rule binding. This is referred to as the "reputation solution" of the time inconsistency problem.

In the following, I will be considering only the case in which private individuals do not know the qualities (preferences, incentive structures) of the politicians, in other words, in which there is uncertainty regarding the qualities of politicians.

Whereas in the approach in which knowledge of the qualities of politicians is assumed, reputation equilibrium is only possible if the time horizon is infinite, this restriction no longer applies if the environment for action is uncertain. Reputation can then be included as a solution approach of the time-inconsistency problem if politicians are in office for longer than one period and the public is uncertain regarding the qualities of the politicians. The preferences of politicians with regard to output (or unemployment) and inflation, or politicians' views on the Phillips curve trade-off, can be regarded

[27] See Kydland and Prescott (1977) even before this.

as qualities of this kind, or the credibility of politicians, i.e. whether their announcements regarding future policies are binding. In situations of this kind politicians' behaviour provides information on their qualities. This information then influences the public's inflation expectations, and also the result of the game between the government and private individuals. The basic idea is simple. The public is uncertain which policy the government will pursue in future periods. Under plausible assumptions it can be shown that, the lower the rate of inflation that they observe today, the lower are their expectations of inflation in future periods. This generates an incentive in politicians to keep inflation low. This also applies for governments that would prefer a higher rate of inflation given knowledge/certainty of the public regarding the qualities of politicians.

This was shown in more detail in various reputation models of a different kind, e.g. from Backus and Drifill (1985) and Barro (1986). (In Annex B I have sketched a simple reputation model with uncertainty regarding the qualities of politicians as an illustration.) It is important here that the private economic subjects draw conclusions on the behaviour of the central bank from the observed rate of inflation. In other words, they **learn** during the game. This increases the incentive for the central bank to behave time-consistently initially, i.e. in accordance with its announcements.

Evaluation

These reputation solutions have been discussed in great detail in the literature. They appear tempting in that they suggest that, circumstances permitting, the inflation problem can be solved endogenously even without state institutional innovations through the immanent costs of loss of reputation on inflationary policies. And that considerations of reputation play a part in decisions by politicians appears to go practically without saying. However, the above reputation models do in fact have some snags. Reputation models with knowledge of politicians' qualities show firstly that a reputation solution of the time-inconsistency problem is only possible in a game with infinite periods. Even more important, these models produce multiple equilibria and argue with long-term sanction strategies, although, in view of the great number of private individuals taking part, it is probably not even possible to arrive at a consensus for fixing such sanction strategies. This would probably break down as early as the transaction costs problem and the problem of asymmetric information is introduced.

Doubts are also advisable with regard to the second variant of reputation models described here (and in the Annex B), i.e. those that assume uncertainty regarding politicians' qualities and also enable a reputation solution on an infinite periods game. In particular the assumption that private individuals carry out learning processes in accordance with the Bayes rule appears somewhat questionable. The attempt to transmit signals on the preferences of politicians through exceedingly restrictive monetary and financial policies can even aggravate the credibility problem in certain circumstances, instead of alleviating it. The expected loss of output with a programme of this kind can increase the expectation that the policy will soon be changed and thus impairs credibility. This makes it questionable that weak politicians really sense an incentive to mislead for long enough to achieve a reputation as strong politicians, if it can be assumed that the unemployment that is accepted in this way is increased endogenously through persistence effects/hysteresis and the strategy becomes too expensive. Put another way, the credibility that politicians will keep to an announced strategy depends not only on their preferences but also on the expected costs of the strategy. The latter namely influence the enforceability of the strategy or the (political) muscle of the politicians, and this influences the development of credibility more than the restrictive degree of policy measures at the start of a programme of stabilization. Macroeconomic measures that are regarded as not being enforceable either politically or economically (within the limits of a democratic system), cannot be credible and lead to self-fulfilling failure (on this point see, e.g., Drazen and Masson, (1994)).

The reputation solution requires that the monetary policy decision makers have a long time horizon, in principle, (at least with the same preferences found among the public) an infinitely long one, and do not discount the results of future years too heavily. In addition, a reputation solution presupposes that the monetary policy decision makers must expect a sufficiently high "penalty" from private market agents on deviations from announced policies, which itself presupposes a not too high degree of forgetfulness on the part of private individuals.[28] Finally, given a finite time horizon and uncertainty regarding politicians' inflation preferences, the number of alternative policies (politicians) for private individuals, and how great their ignorance of politicians' preferences is, also play a part. It seems obvious here that an attempt should be made to create favourable conditions for fulfilling the above-mentioned criteria for reputation formation. For example, politicians

[28] On this topic, see, e.g., Drazen (2000).

whose periods of office overlap can be elected to a permanent decision making committee, which decides with a simple majority. In this way, the "median voter" in the decision making committee, in contrast to individual politicians, does not have a final period of office.

The strict assumption of rational expectation formation, which in recent years, as noted above, has been questioned ("softened up"), can be regarded as a fundamental problem with this approach.[29] One possible alternative is, instead of assuming decisions under certainty or under risk, to start from decisions under uncertainty (ambiguity), as in the following section and in Section 3.1.2 above.

3.2.2 Decisions under ambiguity

The attention that has been paid recently to Knightian uncertainty (= ambiguity) in the theory of central bank policy (see 3.1 above) has not been repeated in other monetary policy areas. However, initial approaches can certainly be found here as well.

A more recent approach will be referred to below, one that is equivalent to the compromise approach in Section 3.1.3 above (Spanjers, (2007)). This ambiguity approach will be examined with regard to its transferability to the theory of monetary policy. The approach is a generalization of the expected utility theory and again contains both the above-mentioned Bayesian approach and the maxmin approach as special cases. And apart from a random variable x with an (estimated) probability distribution P and a von Neumann-Morgenstern utility index u, other variables are also taken into account that determine the utility function U. These additional variables contain the degree of optimism of the decision maker, $\beta \in [0,1]$,[30] his degree

[29] For some time there has been detailed literature on economics that links rational expectations with learning and the adaptive formation of expectations (Bray, (1982), Bray and Savin, (1986), Marcet and Sargent, (1989), Woodford, (1990), Bullard and Mitra, (2002)). A central finding of this literature is that in certain circumstances an economy converges under learning to rational expectation equilibrium (Townsend, (1978), Bray, (1982, 1983), Blume and Easley, (1982)). However, until the economic subjects have acquired sufficient knowledge of the economy economic results depend during the transition on adaptive learning processes (Lucas, (1986)). In addition, economic subjects learn constantly in a changing environment and, if they converge, their opinions will not converge to a fixed rational expectation equilibrium but to an "ergodic" distribution around this (Sargent, (1999), Evans and Honkapohja, (2001)). However, there is a series of additional approaches that are occupied with learning processes in the economy (overviews are provided by, e.g., Clemens and Haslinger, (2001) or Barnett et al. (Ed.), (2004)). However, up to now these have been included in the theory of monetary policy to a limited extent only.

[30] Decisions under uncertainty depend, as Keynes and Knight hinted, on the behaviour of decision makers with regard to the uncertainty. Optimists hope for the best, pessimists fear the worst.

of confidence in his estimate of probability, $\gamma \in [0,1]$, the smallest value of the natural state $\underline{s}$ and the largest value $\bar{s}$ that the decision maker regards as plausible.[31] The utility function, which maps the preferences of the decision maker, then looks like the following:

$$U(x) := \gamma \cdot E_P\{u(x(s))\} + (1-\gamma)\cdot\beta\cdot\left[\max_{s\in[\underline{s},\bar{s}]} u(x(s))\right] + (1-\gamma)\cdot(1-\beta)\cdot\left[\min_{s\in[\underline{s},\bar{s}]} u(x(s))\right]. \tag{3.4}$$

The utility function is the sum of three components. *The first component* shows the expected utility for this variable. Its weight corresponds to the degree of confidence in the probability estimate γ. $(1-\gamma)$ corresponds to the degree of uncertainty (ambiguity).

The second component contains the von Neumann-Morgenstern utility for the best plausible result. The weight of this term is $(1-\gamma)\cdot\beta$, whereby β shows the degree to which the decision maker tends to think/assume that uncertainty implies an advantageous result ("degree of optimism").

The third component contains the von Neumann-Morgenstern utility for the worst plausible result. The weight of this term is $(1-\gamma)\cdot(1-\beta)$. $1-\beta$ is the degree to which the decision maker tends to think/assume that uncertainty implies a disadvantageous result ("degree of pessimism").

If we place our emphasis on decision makers who tend towards pessimistic thinking ($\beta = 0$), and, in addition (to simplify matters) focus our considerations on probability distributions that concentrate all probability dimensions in a single natural state t, we arrive at the following utility function:

$$U(x) := \gamma u(x(t)) + (1-\gamma)\left[\min_{s\in[\underline{s},\bar{s}]} u(x(s))\right]. \tag{3.5}$$

For $\gamma = 0$ we arrive at the above maxmin approach, for $\gamma = 1$ at the traditional (Bayesian) expected utility-approach.[32]

[31] We can understand $\underline{s}$ and $\bar{s}$ here as the downside and upside risks of the natural state.

[32] As was already said, (3.1) and (3.2) are not introduced here ad hoc but are based on the decision-theoretical micro-basis of Gilboa and Schmeidler (1989) and its further development in Epstein and Wang (1994) (see Brock, Durlauf and West, (2004) as well).

Application to monetary policy

This approach provides a possibility of examining the influence of Knightian uncertainty on monetary policy in more detail. For example, the effect of the public's strategic uncertainty with regard to the monetary policy of the central bank and of state uncertainty on the part of the central bank regarding the position of the short-term supply curve can be examined under a rule-bound and (alternatively) a discretionary monetary policy. In the following we will be concentrating on discretionary monetary policy on strategic uncertainty.[33]

In his model Spanjers (2007) assumes a game between the central bank and the public that follows the approach of Barro and Gordon (1983a, b) in its material parts. However, and this is the decisive further development, he takes the uncertainty of private expectation into account. It is assumed in concrete terms that the public is exposed to uncertainty with regard to the decisions of the central bank, so-called strategic uncertainty. This means that it expects that the central bank will select a specific inflation rate, but is not quite certain whether the central bank will in fact deviate from this in a way that is unforeseeable.

In the face of the uncertainty regarding the central bank's strategy selection the problem of multiple equilibrium convictions and equilibrium strategies tends to arise, whereby the model does not put forward any reason for the selection of a specific equilibrium. However, it could be assumed that the corresponding uncertainty convictions ("I believe ..., but I'm not sure ...") can be understood as the result of a cognitive process in the shape of plausible upper and lower limits (upside and downside risks) for inflation ($\bar{\pi}$, $\underline{\pi}$). The convictions that describe strategic uncertainty are considered here as an exogenously given individual characteristic of each player. However, this reveals a potential weakness of this approach, because convictions of this nature (and a certain degree of optimism and pessimism) arise in reality through social processes, just as learning itself is in the end social learning.[34] But this (without a doubt strong) assumption ensures that even with (strategic) uncertainty or uncertainty in the Knightian sense the usual concepts of Nash equilibrium and of backwards induction can continue to be applied.

[33] Spanjers (2007) analyses in addition policies that are rule-bound as well as the case of "state uncertainty".

[34] In the above model, learning would be in contrast (through an uncertain variable) only an "undefined" improvement of the information on the upside and downside risks, i.e. "plausible" upper and lower limits ($\bar{\pi}$, $\underline{\pi}$) and a reduction of uncertainty.

Let us assume that private individuals are pessimistic in the sense explained above (i.e. $\beta = 0$, cf. equation (3.4)). In this case their lack of confidence in their own estimate implies that in forming their expectations they take account of the most unfavourable inflation development, weighted with the extent of the uncertainty $(1-\gamma)$. This can be expressed formally as follows:

$$\max_{\pi^e \in (\underline{\pi}, \bar{\pi})} \gamma \left[-(\pi - \pi^e)^2 \right] + (1-\gamma) \left[\min_{\pi^e \in (\underline{\pi}, \bar{\pi})} -(\pi - \pi^e)^2 \right]. \tag{3.6}$$

The following results from this for private inflation expectation:

$$\pi^e = \gamma\pi + (1 - \gamma)\,\bar{\pi}. \tag{3.7}$$

In the absence of Knightian uncertainty ($\gamma = 1$), $\pi^e = \pi$, while with uncertainty inflation expectations go beyond this, because they explicitly include the upper limit of the inflation that is held to be possible, $\bar{\pi}$. Spanjers now integrates this expectation formation hypothesis in a conventional game theory approach to optimal monetary policy. It is assumed here that the central bank maximises the following target function:

$$\max_{\pi} b(y - y^n) - (\pi - \pi^T)^2. \tag{3.8}$$

b describes the weighting of the production target, y^n the natural output, and π^T the target inflation rate.
The central bank is aiming there for the highest possible output and in addition would like to avoid deviations of inflation from a target value. Let

$$y = y^n + a(\pi - \pi^e) \tag{3.9}$$

apply for the short-term aggregated supply curve, with a as the measure of the effectiveness of surprise inflation.

This approach allows the discretionary solution of the model to be calculated as usual as a Nash equilibrium, whereby the expectation hypothesis (3.6) has to be considered now. The consequence of this is that private inflation expectations on discretionary monetary policy contain not only the usual inflation bias $(\frac{1}{2}ba)$ but also a "bonus" for the worst case:

$$\pi^e = \pi^T + \frac{1}{2}ba + (1-\gamma)\left(\bar{\pi} - \pi^T - \frac{1}{2}ba \right). \tag{3.10}$$

In contrast, the inflation rate selected by the central bank corresponds to the standard discretionary result, i.e. in the distance to the target value plus the inflation bias. The consequence of this is that the output lies "systematically" below the natural rate level:

$$y = y^n - a(1-\gamma)\left(\bar{\pi} - \pi^T - \frac{1}{2}ba\right) < y^n. \tag{3.11}$$

In this approach a greater uncertainty (falling γ) and a worsened assessment of the "worst case" (rising $\bar{\pi}$) bring about a reduction in production, because both impulses induce rising inflation expectations in spite of unchanged inflation.

We will not be dealing here with the details of the results of this study. Some of Spanjers' results (2007) should certainly be queried. The model-theoretical acquisition of inflation expectations implies in the end that inflation errors in the present approach are also possible permanently. It is questionable whether the processes acquired through Knightian uncertainty can in fact be the occasion for lasting and systematic expectation errors. And his finding (that is not shown in more detail here) that a rule-bound monetary policy is more suited than a discretionary monetary policy for dealing with uncertainty if the private sector and the central bank tend to pessimism[35] must be taken with a pinch of salt. I am only interested here in starting a debate on the method described as a possible alternative, and one capable of development, to the current (more) usual approaches.

[35] Put more exactly, the effects of uncertainty point for both policy frameworks in the same direction, but rules weaken the influence of uncertainty, in comparison with a discretionary policy. Uncertainty of the effectiveness of a surprise inflation only influences the monetary policy with a rule-bound monetary policy if the public does not have full confidence in the central bank. What is decisive (and debatable) with this approach is that the strategic uncertainty of the public with regard to the monetary policy of the central bank (and so "mistrust" of their announcements) is not reduced in time but is systematically present.

4 Information asymmetries, uncertainty and central bank communication

We have seen that, over the past two decades, monetary policy theory has increased its focus on information and information asymmetries between the monetary authorities and markets, as well as (more recently) on uncertainty, as critical elements determining the outcome of monetary policy decisions.

This led in the 1980s to the rise of the New Keynesian economics approach (information asymmetry is to be seen here as the main reason for price rigidities) and of the reputation models (see section 3.2.1 above), and over the last decade has led to further progress in the theory of monetary policy, particularly with respect to the development of new monetary policy strategy concepts[36] (for a summary see, e.g., Walsh, (2003b), Woodford, (2003), and Svensson, (2003, 2005)). Moreover, and perhaps even more importantly, it has significantly changed both the institutional design and the communication and information policy of central banks. The conventional view nowadays calls for simple (targeting) rules, for central banking by committees, and for transparency and efficient communication by central banks. In particular, the recognition of information asymmetries (and of uncertainty) has led central banks to use information and communication policy as a strategic instrument to achieve maximum impact. Here, the conventional conviction among academics and practitioners has shifted from the conviction that monetary policy decisions should surprise markets if necessary, to achieve maximum impact, towards the view that monetary authorities should announce their policy decisions in a timely manner and with ample explanations.

In this chapter, I shall concern myself with this paradigmatic change in view and its theoretical foundations and discuss the modern theory of optimal central bank communication and information policy. This will be done under specific consideration of the uncertainty surrounding central banks' decision-making. One final point to be explored in this context will be whether (how) central banks should communicate their own uncertainty or "ignorance".

[36] The inflation targeting approach in particular comes to mind here.

4.1 Information Asymmetry, Transparency and Central Bank Communication[37]

Transparency and communication with the general public have gradually become prominent and challenging tasks for central banks throughout the world. With the rise of "independent" central banks, transparency and accountability have become necessary institutional requirements of efficient (modern) central banking – aiming at overcoming the problems associated with information asymmetries between central banks and the general public. In particular, if a prominent opinion within the theory of central bank communication is followed that says that an (independent) central bank should, on the one hand, be accountable and, on the other hand, should teach the markets to think like the central bank, then full transparency (or the reduction of information asymmetry) appears to be a "must" for modern central banks.

With this in mind, central bank communication has been increasingly recognized as an important tool in the implementation of monetary policy during the last decade. Two cases for central bank communication can be distinguished here: the political and the economic. Many good reasons for increasing transparency and central bank communication have been put forward with regard to both cases. However there are still some controversial issues to be analyzed in more detail.

4.1.1 The Rationalization of Central Bank Communication (CBC)

4.1.1.1 The Political Case for CBC: Accountability

The past fifteen years have witnessed a spread of laws prescribing central bank independence. In the 1990s, numerous countries provided their central banks with greater legal independence from the government. This trend towards increased central bank independence has been witnessed in both industrialized and developing countries. Central bank accountability is now regarded as a "natural corollary of central bank independence" (Blinder, (2002)); and central bank communication as a natural corollary of accountability. The argument is that accountability requires transparency, and transparency requires external CBC. A central bank, being a public institution, "must be fully accountable for all its actions and procedures. This broad and uncontroversial principle establishes the basic presumption that all

[37] I would like to thank Friedrich Kißmer and Rolf Knütter for research assistance in structuring this sub-chapter.

information ought to be released, unless a good case can be made to the contrary." (Blinder et al., (2001), p. 22)

4.1.1.2 The Economic Case for CBC: Policy Effectiveness

Here it is useful to differentiate between internal CBC and external CBC. It is argued that internal CBC leads to better decisions by pooling knowledge – and thus smoothing information asymmetries *within* the MPC. External CBC is supposed to foster the management of expectations of central banks.

(1) Internal CBC: Pooling Knowledge

Asymmetry of information calls for transparency (and communication) of central banks, and, because of efficiency arguments, for monetary policy by committees.

In recent years, many central banks have followed the example of the Bundesbank and the Fed and transferred decision-making powers from a single individual to a monetary policy committee. It makes sense to assume that the members of monetary policy committees may receive, and/or keep, different information and may have different decision-making skills.[38] Hence, communication between MPC members may improve the quality of monetary policy. The reason is that committee members learn from each other. By sharing information, MPC members may improve their knowledge of future economic developments. Empirical support for this is provided, for example, by Gerlach-Kristen (2003a, b) and Meade and Sheets (2005). Hence it should be beneficial for members to communicate with each other. Without internal communication, the quality of monetary policy of MPCs could only be improved by adding members. However, adding members to an MPC also increases costs: In particular, coordination costs tend to go up progressively. Therefore, to improve the collective outcome, communication and learning is important, and becomes the more important, the larger an MPC already is, and the more diverse information and decision-making skills among the MPC members are.

Against this background, there is a broad consensus that internal CBC is beneficial because pooling knowledge in an uncertain world should lead to

[38] In contrast, much of the recent (theoretical) literature has assumed that members are identical in terms of decision making skills but differ in preferences, thereby bringing in strategic behaviour (see, e.g., Hefeker, (2003), or Sibert, (2003)).

better analysis and forecasts, and hence to better decisions. Furthermore, group decision-making may provide some insurance against possibly extreme preferences of an individual central banker. In addition, as empirical studies have demonstrated (see, e.g., Hong and Page (2004), and Blinder and Morgan (2005)), a diverse group of people who process information and achieve decisions differently can outperform even highly-skilled individuals when complex tasks have to be executed.[39]

Summing up, internal CBC leads to convergence of knowledge among the MPC members and, even more importantly, supposedly to an increase in their average knowledge and hence in their decision-making skills.

(2) External CBC: Management of Expectations

The policy-effectiveness argument of central bank transparency largely amounts to teaching the markets to "think like the central bank" and thereby letting the central bank manage expectations of its future policy better (Blinder, (2006)). The modern view of central banking emphasizes that the impact of central banks on the economy runs at least as much through their influence on expectations as through any direct, mechanical instruments (such as overnight cashing). The reason is that the key decision-makers in an economy are forward-looking, and therefore a central bank is well advised to commit itself to a systematic approach to policy, which includes explaining its decisions to the public. In other words, the public's understanding of the central bank's approach is critical for the effectiveness of monetary policy. However, nowadays it is regarded as "prudent not to rely too heavily on the assumption that the public will understand policy perfectly regardless of the efforts that are made to explain it" (Woodford, (2005), pp. 4–5).

The benefits of CBC, on the one hand, refer to the **transmission mechanism**:

Central banks, by using their monetary policy instruments, only affect a short-term interest-rate directly. More relevant long-term yields (longer-term interest rates, and asset prices and exchange rates) depend on the expected future path of short-term interest rates. However, private sector expectations

[39] Hong and Page (2004) define diversity so that the members of the group use different decision-making heuristics. Different people use different decision-making methods (called *heuristics*) because "... the implicit optimization problem facing a monetary policy committee is far too hard to be solved explicitly. It may not even be well defined." (Blinder, (2006), p. 8). Accordingly, Blinder and Reis (2005) argued that the Fed under Greenspan has followed a "risk-management" process rather than trying to optimize.

about this can be influenced significantly by central bank communications. Thus, central bank communications can ease the conduct of monetary policy, notwithstanding the fact that there is also scope for misinterpretation and overreaction, particularly in financial markets.

In the short run, CBC is expected to increase the predictability of near-term policy decisions (by making the central bank's intentions known), thus reducing financial market volatility, and allowing for smoother adjustments: When the private sector uses central bank forecasts to improve its own forecasts, aggregate uncertainty and volatility can be reduced. In the long run, communicating the central banks' objectives and policy strategies is expected to anchor the public's long-term forecasts or expectations with respect to the interest rate, inflation, and output-gap (Bernanke, (2005), Issing, (2005a)).

On the other hand, external CBC is expected to keep the **time-inconsistency** problem at bay by reducing the dangers of an inflation bias and a stabilization bias. Optimal monetary policy can be characterized as 'constrained discretion' or as a 'state-contingent rule'. External CBC is regarded as necessary here because

– optimal policy is too complex to be explained in a single statement
– it helps monetary policymakers to put the focus on their objectives
– it helps the public to verify whether or not the central bank is pursuing the mandated objectives

(Woodford, (2005), Macklem, (2005)).

Increasing transparency is regarded as welfare-improving since it increases the central bank's ability to build a reputation and reduce the inflation bias.[40] Transparency may act like an implicit commitment mechanism if it gets a central bank to adhere to its announced policy more closely by reducing the scope for surprise inflation. Thus a transparent central bank can build and maintain a reputation for low inflation.

4.1.2 Controversial Issues

The theoretical literature on transparency appears, however, to have abstracted too much from the complications that arise when central banks try to diminish information asymmetries through communication.

[40] This, however, may not apply to increasing transparency about its own ignorance, as argued below in section 4.3.

"Most transparency models simply assume that information somehow gets perfectly conveyed. In fact, some models do not even have explicit announcements. However, in practice it is not trivial to communicate information effectively and there is a lot of scope for misinterpretation." (Geraats, (2006a), p. 144).

In principle, improving the transparency of monetary policy means reducing information asymmetries between monetary policymakers and the private sector. However, there is still a lack of consensus on whether and to what extent increasing transparency is beneficial. Various theoretical and empirical analyses have shown that improving transparency does not necessarily create social benefits, nor does it necessarily increase central bankers' private utility (Blinder, (2006), Cukierman, (2001), Geraats, (2006b, 2006c), Gersbach and Hahn, (2001), Tong, (2005)). In particular, if specific information is not reliable or the information receiver (i.e., here, the central bank) is uncertain about how to value specific incoming information, then it may not make sense for the receiver (the bank) to try to pass this information on to the public without knowing the consequences (reactions of the markets), i.e. whether the public/markets really is/are able to correctly understand the kind of uncertainty that surrounds information. Similar problems arise when a central bank tries to pass on information about its own uncertainty/ignorance in the context of monetary policy decision-making. The question then is how open a central bank should be about its own uncertainty or "ignorance".[41]

4.1.2.1 The Political Case for CBC

The main argument for (full) transparency of central banks here was: central bank accountability is a natural corollary of central bank independence; accountability, however, requires transparency, and transparency demands open CBC.

Two controversial issues against the above arguments have been brought forward in the literature.
(1) One issue refers to the difference between legal and actual central bank independence. In many developing or emerging countries the question arises whether the delegation of independence to the central bank is actual or only legal (see Cukierman, (1998)). If it is only "legal", i.e. only exists on paper, as is still the case in many transitional countries, there is a danger that it will not only be ineffective but even counterproductive (Wagner, (1999)). Political

[41] On the last question, see section 4.3 below.

pressure and influence exerted by the government is then hidden behind the veil of central bank independence.[42] The general question is now: Does the existence of 'behind-the-scenes' political pressure justify some degree of central bank opacity? Various academics argue that "procedural opaqueness" (Issing, (1999, 2005a)), or "monetary mystique" (Geraats, (2006b)) could be efficient ways to prevent political pressures. Geraats presents a model in which transparency is only beneficial with central bank independence. If the government is able to override the central bank's decisions, i.e. the central bank is not completely independent in this regard, uncertainty about economic information then leads to restraint on the part of politicians concerning intervention by the government. Hence, the central bank can use the monetary mystique to obtain greater independence.

Nevertheless, it can be argued that secretive central banks are inherently undemocratic. However, central banks need public support to be effective/efficient (Mishkin, (2004)) and only get this support by demonstrating that they are democratic.[43] A possible counter-argument is that this depends on the political culture, which differs across countries and over time.

Furthermore, it must be taken into account that agents are constrained by limited resources, so that flooding them with data may not help them to extract the relevant information. Therefore, transparency is sometimes said to be better understood in terms of openness, clarity and common understanding (see, e.g., Winkler, (2002)).

(2) Another controversial issue refers to the "quiet revolution" (Blinder, (2004)) of the above-mentioned increase in central banking by committees. The question here is: Should members of a monetary policy committee have individual accountability or just group accountability? A common-sense view seems to be emerging here that argues that this depends on the internal structure of the committee. A distinction has to be made here between individualistic committees and collegial committees. Individualistic committees (the Bank of England is a prime example) are those whose members not only express their own opinions verbally (internal CBC), but probably also act on them by voting. In contrast, collegial committees agree in advance and arrive at a group

[42] However, even in industrialized countries central bank independence is not "perfect"; i.e., 'behind-the-scenes' political pressure exists even here (see, e.g., Kißmer and Wagner, (2004b)).

[43] Moreover, it may be argued that transparency may bolster central bank independence (Buiter, (1999)). While Mishkin (2004) tends to refer to the exertion of influence in a party-political way, Buiter (1999) stresses the regional aspect in a monetary union (the EMU).

decision. Here, sometimes a further difference is drawn (see, e.g., Blinder, (2006)) between "genuinely-collegial committees" (prime example: the ESCB) where the members argue strenuously for their own views behind closed doors, but compromise ultimately on a group decision, and "autocratically-collegial committees" (prime example: the US Fed under Greenspan) where the chairman dictates the group "consensus".

A consensus view appears to be emerging that the appropriate volume and style of central bank communication depends on the type of central bank committee. That is, votes and minutes should be disclosed in individualistic committees whereas disclosure of votes may not be very informative in collegial committees (Blinder, (2006)). In the latter case, publishing dissenting votes may impair the committee's ability to project the desired aura of consensus. Moreover, the formal vote may be a poor indicator of the actual amount of disagreement in a collegial committee (i.e. one that demands consensus). Indeed, procedural transparency may make it more difficult to reach a consensus view within collegial committees (Issing, (2005a)). Moreover, some models argue that voting transparency may be problematic if, on the one hand, external interest groups try to influence committee decisions biased toward special interest policy, and, on the other hand, central bankers focus too much on appearing to be competent individuals and less on overall problems (see, e.g., Gersbach and Hahn, (2001)). If members of a committee know that their arguments will become public they may be affected in their voting behavior in a political and private sense (Cukierman, (2005)).

4.1.2.2 The Economic Case for CBC

The main argument for CBC here is two-fold. A differentiation must be made between internal and external CBC.

(1) Internal CBC

The argument for internal CBC is: Internal CBC should lead to better monetary policy decisions by pooling knowledge.

The main controversial issue here is:
There may be doubts about the general effect. Recently, Berk and Bierut (2005) have shown, in an admittedly very stylized model, that the value of internal CBC may depend on the degree of skill asymmetry. If skill asymmetry is very high, it may be beneficial to exclude presumably less-skilled committee members (this could possibly be the non-hub-members) from information

sharing. From a politico-economic standpoint, however, this hardly appears to be a stable, superior institutional solution. While the hub may have better access to information, the non-hub has normally got the voting majority, so it will be difficult to exclude the non-hub-members from information sharing.

(2) External CBC

The argument for external CBC was that it should foster the management of expectations of central banks by getting the public "to think like the central bank".

There are several controversial issues here:
They refer to the communication of the

(i) objectives
(ii) strategy
(iii) decision-making of central banks.

Open questions here are:[44]

(i) How open should central banks be about their loss function?
(ii) How open should central banks be about their forecasts? And: How should central banks communicate their likely future policies? Furthermore, how should central banks communicate the role of asset prices?
(iii) How open should central banks be about disagreements among decision-makers? In addition, should central bankers communicate in a collegial manner or in an individualistic way?

I shall briefly describe (1) the practice of central banks and (2) theoretical findings with respect to (a) the desirability and (b) the feasibility of transparency in relation to the above three issues and the related open questions.

(i) Communication of Objectives

It has often been claimed that central banks should be clear about their objectives in order to anchor the public's expectations. For example, Svensson (2005) demands that central banks should reveal their intertemporal loss function.

[44] These questions also define important research topics for the future.

(1) In practice, central banks have become more open about their inflation targets. However, there is still a "dirty little secret of central banking" (Mishkin, (2004), p. 20): That is, there is an opaque concern about output fluctuations ('real stability').[45]

(2) The **theoretical findings** on the question of how to communicate central bank objectives have been mixed (and are not easy to summarize). I shall differentiate between results regarding desirability and feasibility of transparency.

(a) The **Desirability** of Transparency and Clear CBC:
Transparency about objectives has been argued to increase the sensitivity of the public's expectations. This may be beneficial for reputation building (Faust and Svensson, (2001)). It may also be a substitute for otherwise time-consuming learning by the private sector (Orphanides and Williams, (2005)) and may therefore foster stabilization policies.
However, there are also reasons why more openness about objectives may hamper stabilization policies: Jensen (2002) shows in the context of a two-period model with a New Keynesian Phillips curve (characterized by forward-looking inflation expectations) that clear CBC about central bankers' intentions faces a trade-off between reputation building (credibility) and output stabilization. The private sector uses the output gap (only imperfectly controlled by the central bank through an unobservable policy instrument) as a signal to form its inflation expectations in the next period. As in Faust and Svensson (2001), higher transparency (regarding control errors) renders the signal more accurate, and, by raising the sensitivity of inflation expectations, increases the costs to reputation of deviating from the inflation target. Hence, there are benefits from increasing transparency: The credibility of the central bank increases and the inflation biases will be reduced. On the other hand, the trade-off between inflation and output may worsen, as Jensen shows. Transparency here may actually be a policy-distorting straitjacket if the central bank enjoys low-inflation credibility and there is need for active monetary stabilization policy. The intuition behind this argument is that, with forward-looking inflation expectations, the higher the degree of transparency, the smaller the impact of an inflation surprise on output.[46]

[45] This will be dealt with in more detail in section 4.2 below.

[46] In contrast, Woodford (2003, 2005) strongly opposes the view that taking the market by surprise is a prerequisite for effectiveness in monetary policy. For him, monetary policy is effective only when the central bank can shape the beliefs of market participants. By improving its signals about policy actions and policy targets, the central bank can enable the private sector to anticipate future central bank actions more accurately, thereby increasing the effectiveness of its monetary policy.

In addition, as Mishkin ((2004), p. 26) emphasized: "...some suggestions for increased transparency, particularly a central bank announcement of its objective function or projections of the path of the policy interest rate, will complicate the communication process and weaken support for a central bank focus on long-run objectives. *Transparency can indeed go too far*."[47]
And Geraats (2006c) argues that though central banks should be clear about their inflation targets, they should communicate output targets with ambiguity: "... central bankers should speak, but with mystique." (Geraats, (2006c), p. 21)

(b) The **Feasibility** of Transparency and Clear CBC:
It might also be argued that transparency is desirable, but not feasible. Goodhart (2001) and Cukierman (2005), for example, both stress central banks' own ignorance about parameters of the loss function: i.e. the relative weighting of output stabilization, the output gap and output targets may be unknown to central bankers themselves (for more detail, see section 4.2 below).
The question arises here again whether and how central banks/bankers should signal their own ignorance. This will be dealt with in more detail below in section 4.3.

(ii) Communication of Strategy

Various controversial issues have been at the forefront of the academic discussion here. One major issue refers to publishing forecasts and the future course of policy; another major issue is communicating about asset price (boom-and-bust) possibilities.

A. Publishing Forecasts and the Future Course of Policy
The public's forward-looking expectations are based on assessments of future monetary policy. It has often been stressed that central banks have to signal the future course of monetary policy in order to steer the public's expectations (see, e.g., Woodford, (2005)).

(1) In practice, numerous central banks (not only those that target inflation) publish inflation/output-gap forecasts today. However, only a few central banks publish forecasts that are conditioned on their likely future policy.

[47] My emphasis. In general, the theoretical literature on central bank transparency has so far produced a variety of partly contradictory results, depending upon model assumptions and the particular information asymmetry under consideration.

(2) However, the majority of recent **theoretical findings** on this subject suggest that publishing conditioned forecasts would be desirable.

(a) The **Desirability** of Transparency and Clear CBC:
Svensson (2002) and Woodford (2005), for example, argue that central banks should publish projections of the policy interest path. By doing this, they argue, the public's understanding of monetary policy can be improved, it can be helped to evaluate the quality of central banks' forecasts, and the incentives of the central banks to produce good forecasts would be increased. For them, monetary policy is principally the 'management of expectations' (Woodford, (2005), p. 3). As a consequence, there is good reason for a central bank to commit itself to a systematic approach to policy. Publishing and justifying the central bank's best forecast of inflation, output, and the instrument rate is argued to be the most effective way to manage expectations. It should provide the best internal central bank incentives to get it right, and provide the best information for external evaluation, and therefore the best accountability.

(b) The **Feasibility** of Transparency and Clear CBC:
Though the above arguments for desirability appear to be convincing, various problems or hindrances may arise: Publishing forecasts and the future course of policy may complicate the decision-making process (Goodhart, (2001)), and the public may underestimate the risks of forecasts and may pay too much attention to information provided by the central banks (Morris and Shin, (2002)). Morris and Shin (2002) show that, if private subjects do not have sufficient private information, disclosure of public information is always beneficial; but if valuable private information already exists, the welfare effect of increased disclosure of public information is not unambiguous.[48]

B. Communication on Potential Asset Price Boom-and-Busts

There have been many dangerous-looking asset and house price booms in many countries over the world during the last decade or so. There has also been a lively debate about the optimal monetary reaction to these asset and house price booms.[49] Rapidly rising asset (or house) prices may create serious challenges for CBC. Rising asset prices may be a threat to monetary policy objectives if asset prices reach unsustainable levels. But not all asset price booms result in busts, and asset price busts are not always followed by severe consequences for inflation, output or financial stability (see Detken and

[48] However, see Svensson (2006) for a critical discussion of this argument.

[49] See, e.g., Funke, Kißmer and Wagner (2006).

Smets, (2004)). In addition, it is difficult to identify costly asset price booms ex ante. Even if the identification problem was solved, it is difficult to discover the optimal monetary policy. Even if both problems were solved, it may be difficult to communicate the optimal policy to the public if this policy involves a reaction with respect to rising asset prices.

Nevertheless, central bankers have to act; and they have a choice between two main policy options if they observe rapidly rising asset (house) prices. They can choose either a pro-active strategy or a reactive strategy. When following a pro-active strategy, policy takes into account how the policy instrument can influence the probability of a future crisis. The basic idea here is to counter pre-emptively the build-up of a crisis scenario by responding to an asset price boom. In contrast, when following a reactive strategy, policy takes the probability of a future crisis as given. The basic idea here is to avoid immediate costs that are associated with a pre-emptive response by mitigating only the consequences of an expected or actual asset price bust. The conventional wisdom (among academics and central bankers) today appears to be that central bankers should adopt a reactive strategy. In many cases, the reactive strategy is supposed to be consistent with a policy of 'benign neglect' towards asset price booms. Monetary policy here only reacts if and when an asset price crash occurs.

(1) In central banking **practice**, we have seen different routes taken during the recent past.
At the **Fed** under Greenspan, external CBC seemed to be consistent with 'benign neglect', whereas internal CBC appeared to be inconsistent with 'benign neglect' (see Cecchetti, (2003)).
At the **ECB**, the monetary pillar appears to play a strategic role in fighting the danger of asset price bubbles (see Issing, (2005b)).
At the **BoE**, strategic changes have been considered, particularly with respect to extending the forecast horizon, (see, e.g., Bean, (2003), King, (2002)).

(2) Theoretical studies have found ambiguous results about the optimal monetary response to asset (house) price booms. One alternative response is so-called 'benign neglect'. The question arises whether a strategy of this nature should be made transparent. If the central bank communicates 'benign neglect' (including the promise to help out when bubbles burst), then moral hazard may be produced:

– In the boom phase, the so-called "Greenspan put" (Miller et al., (2001)) may arise; i.e., the observed risk premium in the stock market may be reduced by one-sided intervention policy on the part of the central bank,

which leads investors into the erroneous belief that they are insured against downside risk. Miller et al. propose in the case of overvalued markets a clear "...announcement that prices are irrational and that the market will not in fact be supported at any level" (p. 19). This would include the risk of a market collapse.
Another alternative would be for shareholders to abandon their erroneous beliefs and thus learn that the insurance was an illusion. This could lead to a gradual disappearance of the bubble, as Miller et al. (2001) show in a stylized example.

– In the bust phase, the "risk of interest rate gap"[50] (Illing, (2004)) may occur; i.e. a policy attempting to soften ex post the impact of negative systemic shocks on one asset market (e.g. the stock market) may encourage investors to build up even more serious imbalances on another asset market (e.g. house market), thus aggravating the underlying risks. In the end, the central bank has to stabilize the economy by raising interest rates. Illing recommends that the central bank helps orderly unwinding financial imbalances through a strategy where highly leveraged private investors only should be given very precise signals so they can unwind their positions, whereas all the other private agents do not get information in order to prevent triggering of destabilization of the financial system. As he admits, this requires a highly awkward communication strategy ('creative ambiguity').

In addition, optimal reactive policy differs from 'benign neglect' if the public's forward-looking expectations are important. In this case, even a purely reactive policy adjusts policy instruments during asset price booms, as has recently been shown by Berger, Kißmer and Wagner (2007). Communication here needs to be two-way: policymakers may be forced to react to a deterioration of public's forward-looking expectations in the boom period.[51]

(iii) Communication of the Decision-Making Process

(1) In practice, there are central banks that are collegial in communication and individualistic in decision-making (prime example: the Bank of England), and other central banks that are individualistic in communication

[50] In an interest rate gap a central bank has to deal with the following dilemma: If it raises the interest rate too much, a credit crunch on the domestic market may be the consequence. If it leaves the interest rate too low, it risks the amplification of existing imbalances.

[51] Other challenges refer to the fact that central banks have simultaneously to address various audiences. Hence, trade-offs may arise, the same message may be understood differently and CBC will need to be strategic. See, e.g., Issing (2005a).

and collegial in decision-making (example: the US Fed), whereas the ECB is collegial in both communication and decision-making (see Blinder, (2006), Ehrmann and Fratzscher, (2005)).

(2) Against this empirical background, recent **theoretical studies** have shown that "one-size-doesn't-fit-all"; i.e. the optimal nature of CBC depends on the framework within which it operates (Blinder, (2006)).[52] In other words, it is unlikely that there is a single best approach to central bank communication.

Nevertheless, Ehrmann and Fratzscher (2005) found that the ECB and the Fed have been more effective than the BoE. They analyzed the strategies and effectiveness of communication by the US Fed, the Bank of England, and the ECB. They found that effectiveness of communication is not independent of the decision-making process in the respective committee. As argued above, the US Fed has an individualistic communication, but a collegial decision-making, whereas the Bank of England has collegial communications, but individualistic decision-making; and the ECB is collegial both in communication and decision-making. Ehrmann and Fratzscher analyze empirically how these differences impact the effectiveness of communication. They find that predictability of policy and the reaction of financial markets to communication is highest for the US Fed and the ECB and lower for the Bank of England's MPC.
On the other hand, the ECB has often been blamed for its opaque communication (e.g., Jansen and de Haan, (2004)), and with regard to the US Fed, Reinhart and Sack (2006) showed that the greatest financial market effects have been associated with FOMC statements and testimonies. In contrast, speeches of individual members have had little impact. Their results support the view that there are advantages to collegial CBC.

4.2 Uncertainty and Central Bank Communication

In section 3.1 above, we have already mentioned that over the past few years an increasing emphasis has been laid on uncertainty (including in the sense of ambiguity or ignorance) as a feature of the monetary policy landscape. First this has occasionally been done by central bankers highlighting that they have to act under much stronger circumstances of uncertainty than those assumed

[52] In the words of Rachel Lomax (deputy governor of the Bank of England): "Institutional and political arrangements matter. What works in one environment may not work elsewhere." (Lomax, (2005), p. 16).

in theoretical models of monetary policy.[53] With a certain time lag, academics have also begun to consider or mention "incalculable" (or, Knightian) uncertainty in theorizing about central banking.[54] The questions that arise here are what this "stronger uncertainty" exactly means, whether (and how) central bankers should signal this strong uncertainty or "ignorance" to the public (on the latter question see section 4.3. below), and, last not least, whether the opaqueness of central bankers prevalent in practice can be explained by this "ignorance".

4.2.1 Opacity of Central Banks

We have seen that that there is a consensus view in monetary economics today that transparency is desirable, on the one hand because it enhances the democratic accountability of central banks, and on the other hand because it provides better control of the public's expectations by the central banks. However, we have also emphasized some controversial issues above, which may call for less than complete transparency. In addition, central banks are not very clear in practice about their conduct of monetary policy. So far, to my knowledge, no central bank has made clear statements about its objective function.[55] In spite of the publication of inflation reports, minutes, speeches etc., central banks have given very little information to the public about the

[53] For example, Issing already 1999 emphasized that "while the academic profession has made tremendous progress in analysing risk in well-defined stochastic economies, the "Knightian" uncertainty that confronts central bankers is altogether of another dimension (...)." (Issing, (2002)) Also Greenspan recently argued that "(...) uncertainty is not just a pervasive feature of the monetary policy landscape; it is the defining characteristic of that landscape." (Greenspan, (2004), p. 36; see also the citations in Blinder and Reis, (2005)). See also in section 3.1 above.

[54] For example, Feldstein remarked that "(...) dealing with uncertainty is the essence of making monetary policy." (Feldstein, (2004), p. 42). Meltzer even highlighted the prevalence of Knightian uncertainty: "Uncertainty, in Frank Knight's sense, is not a central problem; it is the central problem." (Meltzer, (2005), p. 101) Walsh argued that, in the modern theories of monetary policy, "the central bank is assumed to know the true model of the economy and observe accurately all relevant variables. The sources and properties of economic disturbance are also taken to be known. Uncertainty arises only due to the unknown future realizations of these disturbances. (...) In practice, policy choices are made in the face of tremendous uncertainty about the true structure of economy, the impact policy actions have on the economy, and even about the current state of the economy." (Walsh, (2004), p. 2)

[55] The typical objective function assumed in theoretical models of central banking is like the following: $L_t = (\pi_t - \pi^*)^2 + \alpha(y_t - \bar{y}_t)^2$, where π_t and y_t denote inflation and output in period t, π^* the inflation target, $\bar{y}$ the potential output and α the relative weight on output-gap stabilization. The objective function is quadratic since it is assumed that the central bank is equally averse to positive and negative deviations from output and inflation targets. In order to take the future into account an intertemporal loss function of the following type is usually considered: $V = E_t \sum_{t=0}^{\infty} \beta^t L_t$, where β is a discount factor and E_t denotes expectations based on information in period t.

relative weight (α) that is attributed by them to the stabilization of the output gap in comparison to the stabilization of the inflation gap. Neither have they given information about the shape of central bank losses as a function of those two arguments, nor about the discount factor between current and future objectives (β). However, knowledge/transparency particularly regarding the parameter α is essential for the assessment of monetary policy by the public; and it would also be essential for the transparent implementation of targeting rules of the kind recommended by Svensson (2003).

With respect to the shape of central bank losses, current academic wisdom assuming that the shape of losses is quadratic appears not to be consistent with the practice of central banking.[56] In practice, as recent empirical evidence suggests, central banks apparently have responded more strongly to anticipated negative output gaps compared to a positive output gap of the same absolute size. This kind of asymmetry is argued to imply that the loss function of the central bank exhibits a precautionary demand for expansions[57] (see Cukierman and Gerlach, (2003); Ruge-Murcia, (2003)).[58] Central banks themselves are largely silent on this apparent difference in attitude. I am not aware of any central bank that has published a statement explicitly saying that its losses are quadratic (or non-quadratic) in the output gap.

4.2.2 Reasons Behind This Opacity

The question is what may be the reason behind this opacity of central banks with respect to this point. We may guess that this is due mainly to central banks' limited knowledge (and hence, uncertainty) about the economy. The latter implies feasibility constraints on transparency that are more serious than is assumed in stylized models of the transmission mechanism.

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[56] The main reason for using quadratic approximation for the loss function in monetary theory is analytical tractability and the nice properties of quadratic loss functions, being the applicability of the certainty equivalence and separation principles under this specific condition. *Certainty equivalence* means that the optimal monetary policy can be modeled by employing an efficient estimate of the state of the economy as if it was known with certainty. For applied work, it is desired for decisions in an uncertainty context to have a model where uncertainty is treated in such a way that the decision problems are as simple as the equivalent ones in a certainty framework. *Separation* signifies that the filtering and the optimization problems can be solved separately. This significantly simplifies the calculation of optimal policies, and it removes the need to know the whole shape of the loss function.

[57] Cukierman and Gerlach (2003) argue that this may lead to an equilibrium that exhibits an inflation bias, even if the output target of the central bank equals the potential output.

[58] Blinder ((1998), pp. 19, 20) also stated that: "In most situations the central bank will take far more political heat when it tightens preemptively to avoid higher inflation than when it eases preemptively to avoid higher unemployment."

One aspect may be the poor knowledge of central bankers about the "true" potential output. This imposes severe objective limits on the ability of central banks to be transparent about the output gap. Central banks may even detect (or suppose) circumstances in which excessive transparency is (assumed to be) actually detrimental (see below in section 4.3)). Be that as it may, central banks are likely to shy away from making a long term commitment to a relative output gap weight to be attached to a highly uncertain output gap measure. Because of such measurement problems, Orphanides (2003) even recommended taking the output gap completely out of the loss function.

Another reason for opacity about the relative weight on output gap stabilization in the loss function of a central bank may be that monetary policy today is usually made by a committee, in which not all members share the same *alpha*, i.e. do not have the same priorities. Knowledge of this could lead the public to the possibly wrong conclusion that the monetary policy process is more uncertain than it really is. Hence, central banks shy away from being transparent about this diversity about the relative weight of *alpha*. Moreover, they may fear that committee members, knowing that their personal views will become public information, may be driven in their statements and in their voting behavior by short term political and personal career considerations (Cukierman, (2005)).

Against this background, Alex Cukierman, for example, comes to the following conclusion (Cukierman, (2005), pp. 3–4): "since sufficiently high transparency is now in place and is part of the orthodoxy, time has come to take a more realistic, and perhaps, more balanced look at the limits of its feasibility and of its desirability."

However, it may be argued that transparency has by far not yet reached the desirable optimal level at most central banks. Nevertheless, against the background of feasibility constraints, the above objection is apparently (or, should be) taken serious by central banks that have to determine their degree of transparency about their monetary policy and their own uncertainty or ignorance. We have seen above that central bankers are conceding (or daring to concede) more and more that they have to choose monetary policy under conditions of "real", i.e., Knightian uncertainty (see footnote 53). However, it is not clear yet what this means for the desirability and feasibility of the central banks' transparency.

On the other hand, we can assume that the kind of thinking about uncertainty affects the choice of strategy and communication of central banks. For

example, it is guessed that Greenspan's view of "Knightian uncertainty" led him to value flexibility as a higher priority than commitment and therefore never to announce a commitment to any particular target inflation rate (Mankiw, (2006)).[59]

4.2.3 The Role of Low Probability Extreme Events

The increasing emphasis of "real" uncertainty by central bankers may also partly be based on the increasing significance of the financial stability objective in central banking in the era after the Asian crisis.[60] There is a fear of the outbreak of financial crises that represent low-probability extreme events that threaten central banks as a potential danger. The question arises here of whether central banks should be open about (potential or planned) deviations from simple rules in the event of low-probability extreme events, i.e. whether it may be desirable for a central bank to specify in advance the (imagined) contingencies and its (planned) course of action, particularly in case of low-probability extreme events (e.g., asset or house-price bubbles etc.), and whether a central bank should disseminate its private information about such threats in real time.

It may be regarded as "counterproductive and highly risky to publish advance signals about potential problems in parts of the financial systems... (This) may induce a run on the banks (...), may even trigger a crisis (...). (The) publication of advance warnings may be misinterpreted by the public and lead to a panic." (Cukierman, (2005), pp. 15–16)

This argues for withholding advance signals about problems in the financial system. However, there are also other opinions arguing for transparency. The International Monetary Fund (IMF), for example, advocates greater transparency, in both economic policy and in data on economic and financial developments, as this is supposed to be critical for smoothly functioning national economies and a stronger international monetary system (IMF, (2006)). In this regard, the IMF has adopted several measures that aim to improve the transparency of its members' policy and data, putting forward that the publication of staff reports and the like could strengthen the

[59] Mankiw described Greenspan's policy as "covert inflation targeting" (Mankiw, (2006), p. 183). This, however, may be questioned, as inflation targeting is (or should be) more than just aiming for a measured inflation rate of a specific number.

[60] "Since I have been on the Committee, we have spent at least half our allotted forecasting time debating longer term issues, such as the effect of structural change in the labour market and the relationship between house price inflation and consumption." (Lomax, (2005), p. 4).

Fund's capacity to induce timely action by members to prevent crises (IMF, (2003)). Glennester and Shin (2003) find that the reforms, the IMF introduced to promote transparency, have created more informed markets. Petersen and Sullivan (2005) note that a inadequate transparency by international organizations as well as national governmental units is a contributing factor to the serious financial disturbances that have plagued the global economy in the recent past. Meanwhile, the lack of accurate and timely information on financial developments aggravates the financial weaknesses and contributes to the emergence of crises situations, indicating that the cost of withholding information can be high (e.g., if an asset price bubble bursts and a costly financial crisis breaks out).

If central banks see a major task of monetary policy to be dealing with low-probability extreme events (or even no-probability events, i.e., Knightian uncertainty),[61] the question arises of whether simple rules (such as simple Taylor type rules) then are appropriate. The central bank will like to deviate from such rules in the case of such extreme events or contingencies. However, the problem is that the central bank will have difficulties defining ex ante exactly the probability of a low-probability extreme event of this type (or even cannot imagine the event at the moment), and/or – even if it can determine the probability of the occurrence of the event – it may have problems determining the associated cost in the case of occurrence of this event (example: ex-ante costs of terrorist attacks). Svensson (2003) recommended for such cases a so-called "general targeting rule" in which only the target variables, the targets and the loss function are specified, but without any commitment to a particular reaction function.

We have seen above, however, that even being clear and transparent about the loss function is not an easy task. This has to be seen against the background of the described uncertainty/ignorance of central bankers, and it again raises the question of how open a central bank should be about its own "ignorance".

[61] It has to be remembered that central banks "first came into being in order to avert financial crises and the related extreme fluctuation in interest rates. They were, and still are, expected to fulfill this function by acting as lenders of last resort in the face of extreme events that could endanger financial stability." (Cukierman, (2005), p. 15).

4.3 How Open Should a Central Bank Be About Its Own Ignorance?

We have already emphasized above that central banks operate under substantial uncertainty with respect to
- the measurement or reliability of economic variables or data ("data uncertainty")
- the structure of the economy ("parameter and model uncertainty")
- the consequences of their actions ("strategic uncertainty")
- their own internal forecasts and objectives

(see above in sections 3.1 and 4.2).

The main questions arising here are:
1) Do central banks signal this uncertainty/ignorance to the public and how do they do this?
2) Should central banks signal this uncertainty/ignorance to the public and how should they do this?

4.3.1 (How) Do Central Banks Signal Their Ignorance to the Public?

As we have argued above, over the past ten years or so central banks have become more open about their inflation targets and their monetary policy course, and many of them today regularly publish inflation forecasts. However, there is still an opaque concern about output fluctuations ('real stability'), and only a few central banks publish forecasts that are conditioned on their likely future policy. This has (as we have argued) to be seen against the background of the probable ignorance of central banks about parameters of the loss function and other uncertainties surrounding central banking.

We can differentiate between two types of uncertainty: (i) the asymmetry between the knowledge of the central bank and market participants, and (ii) the uncertainty with which that knowledge is held. Furthermore, there is an interdependence between the central bank's knowledge, and uncertainty, and those of the market participants, as each enter into the expectations of the others. The decisions of both types of agents are based on an understanding of the causal mechanisms at work in the economy, and of the likely effects of monetary policy action. Formal economic models, and econometric analyses, provide a mechanism for central banks' expressing and communicating their own understanding of these causal mechanisms.

4.3.1.1 Emphasis of Judgment

Central banks are confronted with the question of how open they should be about their model uncertainty. Model uncertainty captures the fact that central bankers are not necessarily confident enough to rely on prognoses that rely on a single model, and therefore compare these with prognoses that are based on alternative models, and furthermore, with information that was acquired through different processes (see above in section 3.1)). If central banks are transparent or open on this, and thus inform private subjects about the fact that they derive their forecasts from several stochastic models, but do not (or cannot) teach them exactly how this is done (because flooding them with technical details which they do not understand will not improve the understanding on the part of the general public), the uncertainty of the private subjects about central bank behavior might increase. If a central bank goes on to concede (i) that it is ignorant about (for example) the right relative weight factors to be attributed to the various models from which the forecasts are derived, and (ii) that possibly no one model within the model portfolio of the central bank may provide an adequate base for monetary policy (full transparency would have to include this information as well), the uncertainty of the market participants about the effectiveness of monetary policy and the competence of central bankers may be increased further.

Against this background, central banks today at most generally emphasize that their monetary policy decisions are based not only on forecasts derived from econometrical analyses (formal methods), but also on information acquired through informal methods such as judgment and intuition.[62] Model uncertainty implies that decision-making requires the exercise of judgment. One question here is how to reveal the *collective* judgment of a monetary policy committee. The main, as yet unsolved, challenge, however, is to analytically combine both, the formal and the informal, bases of central banks' decision-making within one analytical model:[63] Up to now, quantifiable risk (calculable uncertainty) is captured by inflation (and output

[62] Not many central banks are very open on this yet. Openness about uncertainty is anyway a relatively recent feature in central banking, and not yet widely spread among central banks. A relatively open central bank in this respect is the Bank of England (at least during the past few years).

[63] For the short term, first solution attempts have recently been offered (Svensson, (2005)). It appears to be (even) more difficult to analytically combine bases related to different time horizons. This also corresponds to a recent appeal by Axel Weber and others (from the Bundesbank and the ECB) to strengthen the effort to find a single analytical framework for uniting the foundations of the first and the second pillar of the ECB's monetary policy strategy. So far, only the first pillar is analytically founded by model-based theory.

gap) forecasts, whereas unquantifiable risk (non-calculable uncertainty) is caught by "verbal explanations" (in the Minutes, Inflation Reports etc.), without a common analytical foundation of the two bases. This tension (if perceived by the public) between these two bases creates, or increases, signal uncertainty[64] with respect to central bank pronouncements.

4.3.1.2 Publication of Fan Charts

One prominent way for a central bank to signal its own uncertainty or ignorance is to publish so-called "fan charts" for the path of interest rates. By doing this, a central bank tries to make clear that it is not committing itself to a definite path, but that the expected evolution will depend on a variety of contingencies, which can at best be assigned probabilities. Insofar, the fan chart is seen as "an effective device for communication about the uncertainty around the published interest-rate path" (Woodford, (2005)).

The Bank of England, for example, has published its projections in the form of "fan charts", since February 1996.[65] A fan chart displays a range of bands around a central forecast.

The fan charts of the Bank of England, which are published quarterly, are so constructed that the colored bands cover 90 % of the area (nine bands, and a 10% probability of the actual inflation rate falling within each band), so there is a 10 %-chance that the inflation will be outside the colored zone (Bank of England, (2002), pp. 48–49).

In August 2004, the Bank of England decided to base its forecasts on market interest rates rather than on constant interest rates (Bank of England, (2004), Allen and Mills, (2005), Lomax, (2005)). This decision was associated with an extension of publishing forecasts from two to three years into the future. This step was seen as "a very modest step towards greater transparency" (Lomax, (2005), p. 15).

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[64] "Signal uncertainty" means that there is a lack of clarity in the signal of MPC thinking. Signal uncertainty can exist even if there was no model uncertainty, due to the fact that the success of any act of communication relies not just on the intentions of the sender but on how the signal is interpreted by the recipient. This also implies that economic communication occurs in a strategic context (see Dow et al., (2007)). In other words: "To suspicious observers, signals are always ambiguous. Once doubt exists – and how can it be fully removed? – it irremediably pervades every central bank pronouncement, no matter how hard the central bank tries to be transparent. Its signals stand to be misinterpreted or exaggerated." (Blinder et al., (2001), p. 15)

[65] "The motivation was purely to illustrate the uncertainty inherent in all economic projections." (Lomax, (2005), p. 7)

This fan chart "portrays a probability distribution that approximates to the MPC's subjective assessment of inflationary pressures evolving through time, based on a central view and the risks surrounding it" (Britton et al., (1998), p. 31). Further, "the uncertainty in the subjective assessment of inflation relates to how likely it is that the future events will differ from the central view. It is therefore a forward-looking view of the risks to the forecast, not a mechanical extrapolation of past uncertainty." (ibid. p. 32).

One objection here is that the "language quoted above is that of the Subjective Expected Utility (SEU) approach whereby, even if there is no concrete objective basis for probability estimates, these can be assigned subjectively. Here, the requirement is stronger, that the MPC arrive at a collective subjective assignation of ex ante probabilities to the risks attached to the central forecast. But there is no formal basis for doing this, given the derivation of the central forecast from a suite of models to which judgment is applied following lengthy deliberations. Rather, the fan charts apply a forward-looking modeling approach to calculating the risks attached to the central forecast on the basis of past errors; it is only the degree of skewness which is the outcome of subjective judgment (Nikolov, (2002))." (Dow et al., (2007))[66]

As mentioned before, these fan charts can only capture one part of the uncertainty surrounding central banks' monetary decisions, namely the quantifiable part (and this is done on the basis of possibly artificial, questionable methodological assumptions). This, however, would have to be reconciled with the accompanying judgment (based on intuition) that captures the unquantifiable part of central bank's uncertainty (that is unavoidable if central banks have also to deal with low-probability extreme events (associated, for example, with the task of avoidance of financial crises)). The other question is how to communicate this "judgmental gap" between econometrically based forecasts and actual decision-making of MPCs.[67]

[66] This is a typical objection raised in the Keynesian literature. Conventional judgment has often been thought of in terms of prior beliefs. Uncertainty is then a matter of belief in a proposition, measured by probability. However, this quantified probability is arrived at subjectively. A central question raised in the Keynesian literature refers to the origins of the prior subjective judgment. For (post-)Keynesians, uncertainty is defined as risk that is "unquantifiable" (Dow, (2004)). Therefore, intuition must be the final determinant of policy decisions. One of the conclusions is that judgment requires much more analytical attention than it is currently given in the literature.

[67] "No set of economic projections [owned by MPC members]... can ever be the outcome of a purely model-based operation. Judgment always plays a large role – although different people frame their judgments in more or less model-based ways." (Lomax, (2005), p. 4)

To answer this question we have to take into account that fan charts are only one channel for communicating the thinking of uncertainty of monetary policy committees. Other channels rely on the MPC Minutes, the Inflation Report, etc. We can also draw other indicators of uncertainty from these other channels:

(i) quantitative indicators (such as the 'ZEW-Wording Indikator')[68], and
(ii) qualitative indicators: these are discourse-based uncertainty indices (see, e.g., Rosa and Verga, (2005a, b), and Klaes and Sent, (2005)).[69]

4.3.2 (How) Should Central Banks Signal Their Ignorance?

The question of how a central bank should signal its own uncertainty/ignorance to the public is one of the most important, and most under-researched, questions in modern applied monetary economics. I shall here only present some first, crude ideas. As always, there are benefits and costs that have to be weighed against each other.

On the one hand, by hiding its ignorance a central bank may give the impression to the public that it knows more than it actually does. It can do this by mainly arguing with forecasts based on econometric models when it explains its monetary policy decisions. This procedure, however, is two-edged. A central bank may well succeed (in the short run) in increasing its image of competence (by creating the impression that its monetary policy decisions are based on a mainly scientific basis): It may try to hide the fact that econometric models do not fully reflect the information that has led to a particular forecast or decision. Forecasts produced by the central bank are, however, as we have argued above, based on both formal and informal methods, and on inspection of many more variables than those entering into the central bank's econometric model. That is, the central bank may try to conceal that there is a judgmental gap between model and predictions on the one hand and policy decisions on the other (Pagan, (2003), p. 4).

Giving this impression of being more "competent" than it actually is may be advantageous for the central bank, at least in the short run. However, concealing its own ignorance may also imply some risks: In particular, if

[68] On the obvious limitations of these quantitative indicators based on texts see, e.g., Cobham (2003).

[69] As central bank documents are worded extremely carefully they appear to provide excellent case material for discourse analysis.

unforeseen contingencies do eventually occur, a central bank may want to deviate from a simple rule to which it might have committed itself. This may then not be easy to explain to the public without creating the danger of being assessed as "discretionary" and "reneging".[70]

On the other hand, being fully transparent about its own ignorance, which would include conceding that monetary policymakers use constant adjustments, eyeballing and other rules of thumb, may irritate (some of) the other participants in the financial markets and, perhaps most of all, the general public. Whether, and how strongly, an irritation of this nature arises, depends on history, i.e. depends upon the prior impression created by the central bank. If the central bank has previously given the impression (i) of being more competent than it actually is and (ii) of its decisions being founded mainly on a scientific basis, then the irritation, and hence the loss of credibility, may be high. This decline in the credibility or reputation of central banks as competent authorities may also reduce their ability to steer the monetary policy process, and, in extreme cases, may even destabilize the economic development by creating bank runs, panics, etc. The greatest danger, however, of shifting from low to high transparency about its own ignorance may be for a central bank that it thereby exposes itself to the danger of losing its independence if it is no longer regarded as being competent enough by the general public. This would probably imply significant macroeconomic costs.[71]

To sum up, it is not easy for a central bank to move on this trade-off and find its optimal point of transparency. The individually optimal point on this trade-off for a single central banker is likely to be dependent upon its current (ex-ante) level of reputation of competence, which is mainly dependent upon

[70] This is a general problem that would just be aggravated by discovering that there is a judgmental gap hidden by the central bank. Mishkin ((2004), p. 11) notes that "[w]hen new information comes in and the central bank changes the policy rate from its projected path, the public may see this as reneging on its announced policy or an indication that the central bank's previous policy settings were a mistake. Thus, even when the central bank is conducting its policy in an optimal manner, deviations from its projected path may be viewed as a central bank failure and could hurt the central bank's credibility." Or in other words: "[C]entral banks need to employ consistent modes of communication and language if they are to be well understood. Abrupt changes in what is communicated, and how, always carry risks of confusion." (Lomax, (2005), p. 16).

[71] Even widely publicized inflation reports may produce risks, or significant macroeconomic costs, insofar as they may sensitize rational inattentive individuals to inflation, and this may lead to wider fluctuations in inflationary expectations. In the presence of forward-looking elements in price formation, this may worsen the policy trade-off between stabilization of inflation and of output (Cukierman, (2005)).

the central bank's prior policy. It may be fruitful for a central bank (under normal circumstances) to concede from the beginning that there are feasibility constraints on transparency and transparent communication, as well as on sticking to commitments to simple rules, against the background of potential low-probability events that cannot be included adequately in simple rules of this kind. By doing this, it may well lose some of its reputation of being competent, but it will gain credibility. As/if the gain in credibility is more long-term than the loss in reputation, honesty (and transparency) may prove beneficial, at least for an institution (like the central bank) that is not (or, should not be) too short-sighted.[72]

[72] However, not only the degree of short-sightedness of the central bank is important here, but also that of the public (and hence of the government) plays a role, since a perceived loss in competence of the central bank may produce a call from the public (or the government) for a reduction in the central bank's independence. A reduction in the central bank's independence, however, would be associated with significant losses, not only for central bankers, but also throughout the economy.

5 Summary

This Study has argued, that, over the past decades, theory and practice of monetary policy have changed significantly. In particular, monetary policy economics has increased its focus on information and information asymmetries between the monetary authorities and markets, as well as (more recently) on uncertainty. As a result of this, the ineffectiveness theory of the "new classical macroeconomics" (NCM) has lost support in the course of the further development or synthesis of the NCM with new Keynesian macroeconomics in the form of the "new neoclassical synthesis" (NNS), at least for the short term. The foundation for this is the inclusion of micro based nominal rigidities. If we then integrate uncertainty as well, in certain circumstances the ineffectiveness theory is also questionable with regard to the longer term as well. A difference should be made here between traditional, Bayesian uncertainty analysis and a Keynesian/post-Keynesian uncertainty analysis. Recently, the latter has suddenly been taken seriously in the mainstream as well, following years in which it was "ignored". I have introduced some example of this from the sphere of the theory of monetary policy. At present, it is not at all clear where this development will lead in the future and what implications this will have. Nonetheless, it appears that it will become a highly interesting research field for the coming years that will be worthwhile paying close attention to. Nor is it clear yet which consequences this will have for optimal strategy, communication und institutional design of central banks. At least, recent (still infant) research indicates that simple rules, transparency and central banking by committees might be optimal consequences from this. However, still a lot of further research is necessary to get a clearer view on this.

This may lead some to argue for "sceptical eclecticism" instead of scientific ambitions (in the form of single-minded devotion to any particular model) in central banking (e.g., Laidler, (2007)). However, this should not lead to an "anything goes" attitude. To build on advances in the theory of monetary policy is important as the latter may function as a benchmark and point of focus for practitioners even if they not slavishly could/should follow advices derived from theory. Judgement matters, as a complementary component, and that's what makes central banking to an "art".

6 Annex

Annex A: Theoretical background on the compromise variant (on sections 3.1.3 and 3.2.2) *(with Daniel Schulz)*

The theoretical concept of uncertainty can be implemented with different mathematical concepts, as is shown in detail in Camerer and Weber (1992). One possibility, which is taken up in sections 3.1.3 and 3.2.2, does not assume any expected probabilities and instead permits unambiguous but, as a generalization of a probability measurement, "non-additive probabilities" (also known as "capacities"). A capacity is a set function from the potential set P(S) of a finite stochastic decision space S in the closed interval [0,1], which allocates a weight between 0 and 1 to every event. For a capacity v only one scaling property ($v(\varnothing) = 0$ and $v(S) = 1$) and one monotonicity property applies, so that $v(A) \leq v(B)$ for each pair $A, B \in P(S)$ with $A \subset B$. With a standard probability measure the monotonicity follows directly from the additive property. A non-additive property means $v(A \cup B) \neq v(A) + v(B) - v(A \cap B)$. Significant consequences of this are:

1. Two equivalently equal events have the same probability or capacity ($v(A) = v(B)$), but they do not have to have the same capacity as two events C and D that are also equivalently equal, but whose estimate is based on more information.
2. $v(A)$ and $v(B)$ measure the probability of events as an implication of the evidence, against which $1 - v(A) - v(B)$ measures the trust in the probabilities as weighting of the evidence. With a probability measure the probability of an event measures both dimensions of the evidence, which had already surprised Keynes (Camerer and Weber, (1992), p. 327).

However, the use of capacities also involves difficulties, e.g. the maximizing of u(x) no longer necessarily corresponds to the minimizing of –u(x). Other problems can be found in Camerer and Weber ((1992), p. 351).
The integral above a capacity also has to be redefined. I want to refer here only to the key term Choquet integral, which coincides with the Riemann integral for a probability measure. The compromise shown above is a consequence of this approach, in that the capacity through which the Choquet integral is then calculated is derived from the belief function (that represents the degree of uncertainty) of the decision makers.

Annex B: Reputation models (on section 3.2.1)

A simplified model structure with a two-period approach is shown below:

(B.1) $$L_t = 0.5\pi_t^2 - b(y_t - y^T)$$

(B.2) $$y_t = c(\pi_t - \pi_t^e).$$

(B.1) is the standard loss function in inflation (π) and output (y). The optimal inflation rate is set to zero here, y^T is the target level for output. The parameter b indicates the importance of output relative to inflation stabilization. The greater the parameter the more important is output stabilization. Rational expectations are assumed.

(B.2) describes the aggregated supply function. It says that supply only deviates from its equilibrium value as a result of inflation surprises (shocks are abstracted from here). c is a positive constant. The expectation value of the output is zero and is therefore less than the target value.

There are two possible types of politicians, and private individuals do not know beforehand which type is at present in office. Type 1 shares the preferences of private individuals and attempts to minimize:

(B.3) $$L = L_1 + \delta L_2.$$

The parameter δ expresses the relevance of the second period in social welfare. In contrast, type 2 is not concerned with the output target and therefore sets the rate of inflation at zero in period 1 and period 2. (It is assumed that it can do this as well.) Even if it is not certain which politician is in office, the corresponding probabilities are known. With probability z it is the politician of type 1, and with probability (1 – z) the one of type 2.

How does the type 1 politician now behave? The inflation expectations are given for him and he therefore minimises L_2 over π_2:

(B.4) $$\frac{dL_2}{d\pi_2} = \pi_2 - cb = 0.$$

He therefore selects in any case the discretionary rate $\pi = cb$ in the second period. In the first period, however, he will take into account the effect that his selected rate of inflation has on the inflation expectations, and possibly set $\pi = 0$. This is done so that the private individuals do not know in period 2

either which politician is in office. They simply observe an inflation rate of zero and still do not know which politician is in office. However, if a politician selects a rate of inflation greater than zero, the private individuals will adjust their expectations, because they now know with certainty that type 1 is in office, and expect the discretionary rate of inflation for period 2 (private individuals adjust their expectations because of the observed rate of inflation, in order words, they learn). In the first period, if he deviates, type 1 will select the discretionary rate of inflation, so that the following value results for the loss function:

$$\begin{aligned} L_{\pi_1=cb} &= 0.5c^2b^2 - b\left(c^2b - c\pi_1^e - y^T\right) + 0.5c^2b^2\delta + b\delta y^T \\ &= cb\pi_1^e + 0.5c^2b^2(\delta - 1) + b(1+\delta)y^T. \end{aligned} \tag{B.5}$$

The alternative for type 1 consists of "hiding" behind type 2 and setting the rate of inflation at zero. It can be shown that, circumstances permitting he "randomizes" in the equilibrium between cb and zero, i.e. he chooses between both in accordance with the random principle. Let q be the probability with which the type 1 politician selects $\pi_1 = 0$. The inflation expectation of private individuals for π_2 can be calculated from this. This is done through Bayesian updating. If private individuals now observe $\pi_1 = 0$, this can mean either that type 2 is in office, which is the case with a probability of (1 – z), or that the type 1 politician is in office but is behaving strategically, which happens with probability zq. The probability that type 1 is in office according to this is $\frac{qz}{qz+(1-z)}$ and this results as well in the inflation expectations of private individuals, if they observe $\pi_1 = 0$:

$$\pi_2^e = \frac{qzcb}{qz+(1-z)}. \tag{B.6}$$

The value of the loss function can now be easily calculated:

$$\begin{aligned} L_{\pi_1=0}(q) &= cb\pi_1^e + by^T + \delta\left\{0.5c^2b^2 - b\left[\frac{c^2b(1-z)}{qz+(1-z)} - y^T\right]\right\} \\ &= cb\pi_1^e + by^T(1+\delta) + \frac{c^2b^2\delta(qz-1+z)}{2(1-z+qz)}. \end{aligned} \tag{B.7}$$

As can be seen from the third term, $L_{\pi_1=0}$ increases with q. This lies in the higher inflation expectations as a result of a high value of q.

Three cases are now possible:

(*) $L_{\pi_1=0}(0) > L_{\pi_1=cb}$

(**) $L_{\pi_1=0}(1) < L_{\pi_1=cb}$

(***) $L_{\pi_1=0}(0) < L_{\pi_1=cb} < L_{\pi_1=0}(1)$.

On (*):
In this case, the loss that the politician realizes if he selects an inflation rate of zero is in any case greater than if he reveals himself immediately to be a type 1 politician and selects the discretionary rate. He will, therefore, always select the discretionary rate in the first period. The reason for this lies in a very low discount factor δ. This means that, if the weight of the second period is sufficiently low, he will in all cases reveal himself. The condition for this is that $\delta < 0.5$ [cf. (B.5) and (B.7)].

On (**):
It is now not worthwhile in any case for type 1 to reveal himself. Even if private individuals cannot draw any further conclusions regarding the type that is in office from an inflation rate of zero, it is still logical to set $\pi_1 = 0$. This case occurs if the politician includes the loss in period 2 to a sufficient extent in his calculation. Expressed mathematically this means that $\delta > 0.5(1 - z)^{-1}$ [cf. again (B.5) and (B.7)].

On (***):
From the conditions derived under (*) and (**) it follows that this possibility occurs if $0.5 < \delta < 0.5(1 - z)^{-1}$. If the private individuals expect the politician to select $\pi_1 = 0$ [$=L_{\pi_1=0}(1)$], he will select the discretionary rate, and if they expect him to select a positive inflation rate [$=L_{\pi_1=0}(0)$] he will set $\pi_1 = 0$. Consequently, the economy can only be in equilibrium if he sometimes selects $\pi_1 = cb$ and sometimes $\pi_1 = 0$. This corresponds to the randomizing referred to above. The probability q must be adjusted so that the politician is indifferent between positive and zero inflation. This probability is calculated by making (B.5) and (B.7) equal. If this is solved after q, the following results as equilibrium condition:

(B.8) $$q = \frac{(2\delta - 1)(1 - z)}{z} \text{ if } 0.5 < \delta < 0.5(1 - z)^{-1}.$$

It can be seen that the probability that type 1 realizes zero inflation is greater the more the second period (increase in δ) is taken into account.

It can be shown from the above reputation model that the influence of reputation considerations is greater if the difference between the preferred

rates of inflation of the types of politician is greater (i.e. if cb is greater) and if there is greater uncertainty regarding the type of politician (i.e. if z is closer to 0.5). Without providing detailed evidence of this here I will simply give some explanatory reasons. The theory that the influence on inflation is greater if there is greater uncertainty regarding the characteristics of politicians can be established as follows. Let us assume for the sake of simplicity that δ is one. Let us further assume that the politician type can be publicly observed. Type 1 would then always set $\pi_1 = cb$ and type 2 would always set $\pi_1 = 0$. In contrast, with incomplete information on the type of politician type 1 sets $\pi_1 = 0$ with a probability of q. The uncertainty therefore reduces the average inflation of the first period by zqcb. With $\delta = 1$ the condition for (**), namely $\delta > 0.5(1 - z)^{-1}$, implies that $q = 1$ if $z < 0.5$. For this value of z the reduction in the average inflation in the first period is therefore zcb. In contrast, (B.8) implies that $q = (1 - z)/z$ if $z > 0.5$. This means that for these values of z the reduction in the average rate of inflation in the first period is equal to $(1 - z)cb$. The maximal reduction therefore arises at $z = 0.5$ and is 0.5cb.[73]

Annex C: Robust control *(with Daniel Schulz)*

The original modelling of the robust control decision problem is also called a "robust Stackelberg problem". The political decision maker has the position of the (independent) Stackelberg leader and the households, modelled as representative agents, have the position of the Stackelberg followers, who are dependent on the leader. We will discuss the leader's decision problem first.

Generally $\mathbb{M}(m \times n; \mathbb{R})$ is the set of matrices with m lines and n columns. According to this definition a vector is an element of the set $\mathbb{M}(m \times 1; \mathbb{R})$. Let $z_t \in \mathbb{M}(n_z \times 1; \mathbb{R})$ be the vector of the leader's natural state variables that describes the state of nature at time t and is determined by the past. Let $x_t \in \mathbb{M}(n_x \times 1; \mathbb{R})$ be the vector of the model's endogenous variables that are able to change at time t. These variables include, e.g., prices and quantities that clear the markets at time t. For the sake of clarity the two vectors will be combined into one vector $y_t := \begin{bmatrix} z_t \\ x_t \end{bmatrix} \in \mathbb{M}\left((n_z + n_x) \times 1; \mathbb{R}\right)$. Let $U_t \in \mathbb{M}(n_U \times 1; \mathbb{R})$ be the vector of the leader's control variables.

[73] For the more general case $\delta > 1/2$ it can be shown that the maximum influence of reputation considerations occurs if $z = (2\delta - 1)/2\delta$, and is equal to $[(2\delta - 1)/2\delta]cb$. There is no influence with $\delta < 0.5$.

Now define the leader's one – period loss function

(C.1) $$r(y, U): = y'Qy + U'RU$$

with the well-defined symmetric matrices $Q \in \mathbb{M}\left((n_z + n_x)\times(n_z + n_x);\mathbb{R}\right)$ and $R \in \mathbb{M}(n_U \times n_U;\mathbb{R})$.

The inter-temporal maximising problem of the Stackelberg leader is then

(C.2) $$-\sum_{t=0}^{\infty}\beta^t r\left(y_t, U_t\right).$$

Find a law of motion for the solution of the vector y_t. Every kind of policy is evaluated taking into account a set of models that are indexed by a vector of specification errors W_{t+1} around its approximating model.
Basically, it is necessary to distinguish between two cases:

1. The error of the approximating model is constructed by a nonlinear, dynamic and normally distributed probability process.
2. For the proceeding analysis only the non-linear part of the error is modelled.

In the first case, W_{t+1} consists of two additive parts. The first part is a normally distributed probability process ε_{t+1}, with expectation 0 and I as covariance matrix, the elements of which are i.i.d. This process can only explain a small part of the approximation errors. In particular it does not describe any dynamic misspecification errors, such as a non-linear and time-dependent reaction to past representations of y^t. The challenge of the second part of the sum (call it w_{t+1}) is to cover these misspecification errors. Let g_t be a sequence of measurable functions. The vector process w_{t+1} is then expressed by $w_{t+1} = g_t\,(y_t, y_{t-1},...)$, which may indicate a non-linear past dependency of y_t. Write therefore $W_{t+1} = \varepsilon_{t+1} + w_{t+1}$. The vectors x_t and y_t need to be written with the expectation operator as $E_t x_t$ and $E_t y_t$.

The second case consists of $W_{t+1} = w_{t+1}$ only, and the expectation operator does not have to be used anymore. The decision rules that will be estimated in the proceedings of this section are independent of the use of ε_t and therefore it will not be quoted anymore. Now formulate a transition law to connect the movements of the natural state variables with the control variables:

(C.3) $$\begin{bmatrix} I & 0 \\ G_{12} & G_{22} \end{bmatrix}\begin{bmatrix} z_{t+1} \\ x_{t+1} \end{bmatrix} = \begin{bmatrix} \hat{A}_{11} & \hat{A}_{12} \\ \hat{A}_{21} & \hat{A}_{22} \end{bmatrix}\begin{bmatrix} z_t \\ x_t \end{bmatrix} + \hat{B}U_t + \hat{C}W_{t+1}.$$

Let $\begin{bmatrix} I & 0 \\ G_{12} & G_{22} \end{bmatrix}$ be an invertible matrix and it follows

(C.4) $$\begin{bmatrix} z_{t+1} \\ x_{t+1} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + BU_t + CW_{t+1}$$

(C.5) $$\Leftrightarrow y_{t+1} = Ay_t + BU_t + CW_{t+1}.$$

The equations for the follower are similar to the three equations estimated for the leader. The equations that represent the behaviour of the follower contain the first order conditions (Euler equations) of the households' optimisation problem. The Euler equations express the forward-looking character of the follower's behaviour.

W_{t+1} is unknown for the two players at time t because they do not have knowledge of w_{t+1}. They are only informed of an $\mathcal{N}(0, I)$–distributed probability process $\tilde{\varepsilon}_t$ with i.i.d. members of the sequence. $\tilde{\varepsilon}_t \neq \varepsilon_t$ is possible. The players by assumption recognise their approximating model as a *good* model in the following sense: The approximation errors are limited by the constraint

(C.6) $$\sum_{t=0}^{\infty} \beta^{t+1} w'_{t+1} w_{t+1} \leq \eta_0$$

with $\eta_0 > 0$ small. For the interpretation and discussion of η see Hansen and Sargent ((2006), pp. 8–11).
The leader, suspecting her approximating model, wants to make good decisions over a set of models (5) with respect to (6). These kinds of decisions are called robust against misspecification of the model.
Hansen and Sargent (2003) state for $\eta_0 > 0$ the maximisation of (2) with respect to (5) as constrained Stackelberg problem. It consists in finding a sequence of decision rules (containing U_t and W_{t+1}) as a sequence of functions with respect to the past of z^t for the decision in time t. The leader chooses one rule in time 0 and keeps on following it.
Call this rule for U_t with $\eta_0 > 0$ a robust Stackelberg plan or robust Ramsey plan.
Let us now take a look at the idea of the explicit solution. To reach this goal, solving a multiplier game is better than using a constrained game[74]. For this, we will add a Lagrange multiplier Θ to constraint (6) and express the constrained game as a Lagrange game.

[74] The motivation of this redraft is seen after the formulation of the Bellman equation.

The multiplier game of the robust Stackelberg problem is the following zero-sum game for two players

$$\max_{\{U_t\}_{t=0}^{\infty}} \min_{\{W_{t+1}\}_{t=0}^{\infty}} -\sum_{t=0}^{\infty}\beta^t \left\{r\left(y_t, U_t\right) - \beta\Theta W'_{t+1} W_{t+1}\right\} \tag{C.7}$$

with respect to (5) and $\underline{\Theta} < \Theta < \infty$.

Now formulate the Bellman equation

$$v(y) = \max_{u} \min_{W} \left\{-r(y,u) + \beta\Theta W' W + \beta v\left(y^*\right)\right\} \tag{C.8}$$

with respect to

$$y^* = Ay + Bu + CW$$

y^* is the state vector of the next period. The long-run problem is now transformed into several problems of one period.

The Bellman equation now has to be translated into a Riccati equation. Using stability properties of a shadow price from the Bellman equation and transforming the multipliers in the state variables will lead to the formulation of the Stackelberg plan. For more details see Hansen and Sargent ((2003), pp. 10f).

A similar decision rule exists for the Stackelberg follower. To construct this use θ (probably not equal to Θ) and the Bellman-Isaac conditions. The latter are needed to reach a sub-game perfect equilibrium from the solution of the Euler equations. Without the Bellman-Isaac conditions, a Markov-perfect equilibrium, calculated from the Euler equations, will not be sub-game perfect in a general 2 player game.

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