Methods Available to Monetary Policy Makers to Deal with Uncertainty*

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Abstract

Three sources – research on monetary policy under uncertainty, the managerial literature, and the real-life strategies of five inflation targeters – have been used to survey methods that are available to monetary policy makers to deal with uncertainty. The methods have been compared within a framework that is based on a decision matrix. The comparative framework has been designed in order to encompass different representations of uncertainty employed by various central banks. The results of comparative analysis suggest that central banks use models, intuition, judgement as well as traditional managerial methods to deal with uncertainty. This finding helps understanding why economic research cannot fully explain differences between monetary policy actions and outcomes of model simulations. The results of the comparative analysis also suggest that central banks have not so far fully utilised the whole spectrum of methods available to them. Economic research, other banks' strategies as well as decision analysis may be interesting sources of inspiration when designing the decision-making process. It is emphasised that central banks introducing inflation targeting should pay equal attention to both building their forecasting models as well as selecting methods to deal with uncertainty. In the case of emerging economies where uncertainty can be much higher than in advanced economies, neglecting uncertainty may increase probability of policy errors significantly.

Key words: Inflation targeting – Uncertainty – Decision matrix – Survey of methods

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I. Introduction

Methods to deal with uncertainty are important to monetary policy makers targeting inflation. Inflation targeting is a forward-looking strategy that aims at setting interest rates to minimise the expected sequence of deviations of inflation from the target. In a world of decision-making, this means that monetary policy makers aim at what is called a "good" decision since they select the policy reaction that yields the best expected outcome. In order to decide which policy reaction is the "good" one, monetary policy makers need to consider a variety of alternative scenarios, their probabilities as well as impacts of possible policy reactions. Monetary policy makers employ two types of methods for this purpose. First, they employ methods to analyse data and produce forecasts under specific assumptions. For example, developing a forecasting model is a typical method of the first type. It has been often reported that the forecasting model improves consistency of policy debates[1]. Second, they employ methods to deal with uncertainty. Uncertainty can be often related to various components of the forecasting model and to crucial assumptions of the benchmark forecast, and consequently, cannot be easily represented inside the model. Voting by members of the Boards or Monetary policy committees is a typical method of the second type. It has been demonstrated that sharing views about all available information within a group can improve quality of decisions[2].

This paper puts emphasis on the fact that although monetary policy makers need both types of methods for their decisions, the second type has not received equal attention. Economic research often describes inflation targeting as inflation-forecast targeting where the forecast is fully based on a model and normally distributed shocks[3]. However, monetary policy makers stress that they do not follow simplistic normative recommendations produced by models[4]. Monetary policy makers also emphasise that economic research focusing on the implication of uncertainty for monetary policy[5] mainly analyses consequences of a very limited subset of uncertainties[6]. While the research focuses on uncertainties that can be easily represented with simple statistical distributions in the model, real policy debates are influenced by more substantial uncertainties[7]. Although recent research has made significant progress in this direction by approximating monetary policy decisions with Bayesian models that work with

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[1] Blinder (1998), Budd (1998), and Vickers (1998) claim that the central forecast based on the model helps organising policy discussions.

[2] King (2002) supports this view and suggests that differences in views between individual members of the Monetary Policy Committee help improving decisions. Blinder, Morgan (2000), Clemen, Winkler (forthcoming) and Lombardelli, Proudman, Talbot (2002) all demonstrate that groups make better decisions than individuals.

[3] Battini, Haldane (1999) and Svensson (1996) illustrate features of inflation targeting in this set-up.

[4] Monetary policy makers also emphasise that it is not possible to use policy rules for normative recommendations. Issing (2002) points out that central banks must use frameworks that are much more complex than policy rules.

[5] Hund, Orr (1999) and Salmon, Martin (1999) summarise research related to implications of uncertainty for monetary policy.

[6] They use the definition of risk and uncertainty that can be found in Knight (1921) to illustrate this point. According to this definition, monetary policy makers face a risk if they know a reliable estimate of its probability distribution prior their decision. They are faced with uncertainty if a relevant probability distribution cannot be easily estimated.

[7] Blinder (1999), Freedman (1999) and Issing (1999) draw attention to the fact that economic research does not solve the problems of Knightian uncertainty that is very difficult to approximate with statistical distributions and that is often related to the forecasting model itself.

more complex distributions and with robust control methods related to model uncertainty[8], the research does not explicitly analyse methods to deal with uncertainty. For example, methods of attaching subjective probabilities are not subject to research. The research also does not suggest how monetary policy makers form their priors about Bayesian distributions. In addition, methods employed to deal with uncertainty often receive less attention than methods of the first type when monetary policy strategies are described. Specifically, when forecasting systems are designed and analysed, methods to deal with uncertainty are not described in as much detail as the modelling framework[9]. At the same time, economic research provides enough evidence that monetary policy makers consider more factors than the model-based forecasts and easily represented uncertainties. Otherwise, it would not be so difficult to explain their decisions with model simulations and policy rules[10]. The missing part in the picture is consideration of all types of uncertainty. Monetary policy makers are aware of the fact that forecasting the future is very complicated, and consequently, they employ a variety of methods to deal with uncertainty, however informal or implicit this may be.

This paper has been motivated by the fact that there may be costs involved if the methods employed by inflation targeters to deal with uncertainty are not treated explicitly. First, monetary policy may not be fully transparent. This is specially a problem in periods when uncertainty plays a more prominent role in decision-making than usual. Lack of transparency can reduce the efficiency of monetary policy actions[11]. In addition, lower transparency can mislead economic research that analyses monetary policy under uncertainty[12]. Second, central banks cannot compare notes about these methods as easily as they can about their forecasting models. As a result, the methods dealing with uncertainty might not be employed as effectively as they could. Third, central banks that start targeting inflation may underestimate the importance of these methods. These are usually central banks in emerging economies where uncertainties about future economic developments are much larger than in advanced market economies and where more attention should be paid to uncertainty.

These potential costs can be prevented. One possibility is suggested in this paper. A framework for comparing methods to deal with uncertainty is developed in line with the decision analysis. Decision analysis is used as a starting point because it has been employed by decision-makers leading important institutions in many areas in order to make good

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[8] Cogley, Morozov, Sargent (2003) and Sims (2002) draw a parallel between behaviour of monetary policy makers and Bayesian econometrics. Tetlow, von zur Muehlen (2000) apply robust control methods to deal with model uncertainty. Cagliarini, Heath (2000) show that in papers on robust control methods an inadequate decision rule is used. Similarly, Goodhart (2003) suggests that minimising the costs of the worst possible scenario cannot approximate behaviour of monetary policy makers. Both Cagliarini, Heath (2000) as well as Tetlow, von zur Muehlen (2000) emphasise that results of their analysis depend on models selected for the analysis.

[9] Pagan (2002) and Robertson (2000) compare forecasting systems of several central banks from developed countries. Laxton, Scott (2000) suggest how to build a forecasting system for a central bank in emerging economy. Methods to deal with uncertainty have not been emphasised in either case.

[10] Orphanides (1998), Smets (1999) and Tetlow, von zur Muehlen (2000) focus on explaining differences between behaviour of monetary policy makers and actions suggested by policy rules by analysing implications of different types of uncertainty.

[11] Geraats (2001) summarises arguments for higher transparency.

[12] One can observe from current debate –as for example outlined by Cagliarini, Heath (2000) and Tetlow, von zur Muehlen (2000) – that it is not easy for researchers to approximate methods used by monetary policy makers to deal with uncertainty.

decisions under uncertainty[13]. This comparative framework is then used for describing methods that are available to deal with uncertainty according to three distinct sources – the economic literature on monetary policy under uncertainty, the managerial literature on decision analysis, and the real-life strategies of five inflation targeters[14]. The resulting study can be used by inflation targeters to compare their methods employed to deal with uncertainty to those employed by other central banks, other decision-makers and to the suggestions of economic research. The study can also help new inflation targeters to design their decision-making process.

The rest of the paper is organised as follows. In the next section, the role of methods dealing with uncertainty is discussed in more detail. In the third section, the general structure of decision matrix is described and the matrix is constructed for the monetary policy case. In the fourth section, the comparative framework for methods dealing with uncertainty is developed according to the structure of the decision matrix. In the following five sections, methods that are available to monetary policy makers to deal with uncertainty at each stage of the decision making process are surveyed. The tenth section summarises the implications that a specific selection of methods dealing with uncertainty can have for external communication. Concluding remarks recapitulate major similarities and differences between methods employed by central banks. Lessons that can be learnt from economic research and from decision analysis are outlined. Several specific topics for further research are suggested.

II. Role of Methods Dealing with Uncertainty

The description of monetary decision-making process is very similar to other areas of decision-making[15]. After experts analyse all available data and produce a central forecast with their modelling tools, monetary policy makers face considerable uncertainty related to assumptions of the central forecast and various limitations of the employed analytical and modelling tools. Monetary policy makers must apply a combination of various methods in order to overcome this problem and make good decisions. Specifically, if their judgement suggests that policy implications of the central forecast do not correspond to the good decision, they may require experts to produce alternative forecast. This means that monetary policy makers use two types of methods during their decision-making process: (i) methods to analyse data and to produce forecasts and (ii) methods to deal with uncertainty. Both types of methods have an important role. Hence, neither should be neglected during the monetary decision-making process. Both types of the methods should be described to the general public in order to avoid costs of lowered transparency[16]. Specifically, if methods dealing with uncertainty are neglected in external communication, the general public can be lead to thinking that the central forecast is fully unconditional and that any deviation of actual inflation from the forecast is the result of a monetary policy error. Consequently, the credibility of the inflation targeting strategy can be diminished.

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[13] Beroggi (1998) Clemen (1996) and Skinner (1999) provide good introduction to decision theory and decision analysis.

[14] Smidkova (2003) describes the background of the survey in more detail. For summary, see Appendix II.

[15] Smidkova (2003) suggests that although monetary policy makers are not always viewed as decision-makers, methods to deal with uncertainty designed for decision makers leading important institutions in other areas are relevant for monetary policy as well.

[16] Costs of lower transparency are illustrated in Geraats (2001).

Methods of first type ensure that all available information is assessed in a systematic way, and the policy debate is consistent. Policy makers emphasise that producing the model-based central forecast is a very good way of organising the internal policy debate and obtaining the benchmark case around which the opinions of individual policy makers can be formed[17]. Methods of the second type ensure that uncertainty is not neglected and policy interest rates are not changed solely according to the central inflation forecast. Otherwise, changes in policy interest rates could be too large or too small with respect to optimal policy responses[18]. Methods dealing with uncertainty also prevent the problems with overstated uncertainty. If too many potential uncertainties are considered[19], alternative forecasts can be too far away from each other and they cannot give monetary policy makers a clear picture of how to set interest rates. In both cases, sub-optimal policy reactions can burden the economy with otherwise avoidable costs, for example, with excessive output volatility.

Since the aim of this paper is to compare methods that are available to monetary policy makers to deal with uncertainty, the distinction between the two types of methods has been necessary. Although in the following sections these methods are described independently from the methods used to produce the forecast, in practice both types of methods may be either relatively independent or very closely interconnected. For example, the forecasting model can be used to illustrate the most likely scenario, and subsequently, risks can be attached to this central forecast verbally during the monetary policy meeting. Alternatively, the central forecast can be re-done several times according to risks attached to each version in order to represent implications of a policy reaction that is close to the good decision. Sometimes, central banks can opt for a compromise solution. For example, if monetary policy decisions are taken on a monthly basis, a full forecasting exercise can be run on a quarterly basis and methods dealing with uncertainty can be used in order to assess a new distribution of risks between two forecasting exercises. It is also worth noting that the importance of methods dealing with uncertainty does not remain unchanged over time. It depends on the forecasting errors of the core model, frequency of the structural breaks, size of the expected shocks and on divergence in views of individual monetary policy makers and experts.

III. The Decision Matrix

The framework for comparison of methods employed to deal with uncertainty should be quite general since methods can differ quite substantially. We suggest basing the comparative framework on the structure of the so-called "decision matrix" a tool designed by decision analysis to support decisions under uncertainty[20]. The decision matrix describes all important components of the decision-making process and helps organising together very different types of information that are all necessary for taking good decisions. For example, alternative assumptions and subjective probabilities are represented with columns of the matrix and possible policy reactions with the rows of the matrix. The decision matrix can also encompass

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[17] Blinder (1998), Budd (1998), and Vickers (1998) give arguments why monetary policy makers organise their decision-making process around the central forecast based on the model.

[18] Brainard (1967) makes a case for more conservative monetary policy under uncertainty. Leiderman (1999) makes case for more aggressive monetary policy under uncertainty.

[19] For example, methods dealing with uncertainty should eliminate the problem of low probability events that is described in Svensson (2003).

[20] According to Anderson, Sweeney, Williams (2000), the decision matrix is also called pay-off table or pay-off matrix since elements of this matrix are usually represented with calculated pay-offs.

different representations of uncertainty used by central banks such as a two scenario approach or fan charts. These propositions are illustrated in Appendix I[21].

The decision matrix can include all information considered by monetary policy makers: variant forecasts, subjective probabilities of alternative scenarios and pay-offs derived from their loss functions. We use this framework to illustrate that monetary policy makers organise their decision-making process similarly to other decision-makers leading important institutions in other areas, however informal or implicit this may be. This does not mean that all elements of the decision matrix are calculated mechanically by central banks prior to their monetary policy decisions. It only means that all information is considered prior to decisions. Following examples illustrate three possible approaches to dealing with uncertainty within the framework of decision matrix. The calculations are explained in more detail in Appendix I.

In the first case, the decision matrix consists of one column only and the major emphasis is put on the most likely scenario (Table III.1). The central forecast was produced with the core model, working with a fixed-rate assumption. In addition, the model was used to estimate implications of two additional possible policy reactions. It is worth noting that a similar approach can be used if the model includes endogenous monetary policy. In that case, three different reaction functions can be used that represent neutral, slow and aggressive responsiveness of monetary policy to shocks[22]. In our example, each outcome was evaluated by a loss function. As a result, the decision matrix consists of three pay-offs. It implies that only a partial policy assessment can be done. If we select the policy reaction that yields the best pay-off, we will leave interest rates unchanged.

Table III.1 – One-Column Decision Matrix: "The Best of the Most Probable" Rule

Probability		***Most likely case***	
Alternative assumptions **Possible reactions**		**Neutral inflation pressures**	
Reduction in interest rates		1.216	
No change in interest rates		1.212*	
Increase in interest rates		1.215	

Note: Pay-offs are values of the loss function. Hence, the best pay-off is the one with the lowest value. See Appendix I for calculations.
*) This is the pay-off of the central forecast.

In the second case, the decision matrix incorporates much more information (Table III.2). Uncertainty related to the most likely case is represented by two alternative sets of assumptions that were specified by experts in order to represent deflation and inflation risks. Alternative sets of assumptions may have included, for example, different paths for exogenous variables or different model equations. For each set of assumptions, implications of three possible policy reactions were estimated and the pay-offs calculated. As a result, we can consider nine pay-offs. The pay-offs indicate that risks were very asymmetric. However, the decision matrix is still incomplete since we do not know the probabilities of alternative sets of assumptions. In this case, we can use one of the decision rules not requiring this

[21] Calculations presented in Appendix I are based on the small forecasting model of the Czech economy, data set and assessments of the Czech economic outlook from July 2001.
[22] Both approaches to inflation forecasting are possible. Don (2001) argues that a conditional forecast is more suitable for institutions that can affect the whole economy and that an unconditional forecast causes a difficult decision problem for them. Archer (2003) claims that central banks should base their forecasts on models with endogenous monetary policy. The survey summarised in Appendix II show that central banks use both approaches in reality.

information[23]. For example, the least risky policy reaction can be selected. This is the approach taken by papers using the robustness control method for analysis of implications of uncertainty. As a result, we will decrease interest rates.

Table III.2 – Incomplete Decision Matrix: "Maximin" Rule

Probability				
Alternative sets of assumptions **Possible reactions**	**Deflation pressures**	**Neutral pressures**	**Inflation pressures**	**Worst pay-off**
Reduction in interest rates	13.207	1.216	1.431	13.207
No change in interest rates	13.432	1.212*	1.300	13.432
Increase in interest rates	13.663	1.215	1.175	13.663

Note: Pay-offs are values of the loss function. Maximin decision rule finds the worst pay-off for each possible policy reaction and selects the reaction with the minimal worst pay-of. See Appendix I for calculations.
*) This is the pay-off of the central forecast.

In the third case, the decision matrix is complete. It combines all types of available information (Table III.3). In addition to previously considered information, we have now attached our own subjective probabilities to all alternative sets of assumptions. It is worth noting that the set of neutral assumptions on which the central forecast was based usually represents the most likely case, but it need not to be the case. The subjective probabilities can be derived in various ways. For example, we could have asked a group of experts to vote, and then construct probabilities according to number of votes that each set of assumptions had been given. With the complete decision matrix, we can use different decision rules to determine the adequate level of interest rates. Specifically, we are able to select the reaction with the best expected pay-off. According to this rule, which is sometimes called a "rational" rule, we will increase interest rates.

Table III.3 – Decision Matrix: "The Best Expected Value" Rule

Probability	***0.1***	***0.5***	***0.4***	
Alternative assumptions **Possible reactions**	**Deflation pressures**	**Neutral pressures**	**Inflation pressures**	**Expected pay-off**
Reduction in interest rates	13.207	1.216	1.431	2.501
No change in interest rates	13.432	1.212*	1.300	2.469
Increase in interest rates	13.663	1.215	1.175	2.444

Note: Pay-offs are values of the loss function. See Appendix I for calculations.
*) This is the pay-off of the central forecast.

The three examples illustrate the importance of treating uncertainty explicitly. Specifically, if the decision matrix is incomplete as a result of neglected uncertainty, a policy reaction that does not have the best expected pay-off is selected. If the decision matrix is complete as a result of considering a variety of alternative forecasts, policy reactions and attaching subjective probabilities, a good decision is made. The difference in decisions is caused by significant asymmetric uncertainty and by subjective probabilities that evaluate one of the alternative sets of scenarios as very likely. This documents that methods dealing with uncertainty may be important for monetary policy makers in situations when the certainty

[23] Smidkova (2003) gives more examples of decision rules that do not require subjective probabilities.

equivalence principle does not hold[24]. If alternative sets of assumptions are asymmetric, probabilities of alternative sets of assumptions are significant and asymmetric or the core model is non-linear then methods dealing with uncertainty will be influential. In addition, asymmetric loss functions or a prevailing divergence of inflation and output from the targeted values will have similar impact[25].

It is worth noting that although calculations in our examples look simple, information represented by various components of the decision matrix is not always easily obtained. Specifically, it is not straightforward at all to define alternative sets of assumptions. Although there are model-based methods available to help with this task, such as sensitivity analysis or impulse response analysis, their definition relies enormously on the intuition and judgement of experts and monetary policy makers.

IV. The Comparative Framework

The main purpose of the following sections is to present in a comprehensible way findings of the survey of methods available to monetary policy makers to deal with uncertainty[26]. Three distinct sources have been used to compile the survey. First, economic research on monetary policy under uncertainty employs the certainty equivalence principle to draw implications of different types of uncertainty for monetary policy decisions. Subsequently, the research findings are used to explain differences between actual decisions and decisions predicted by the model. The findings confirm that monetary policy makers consider uncertainty to a significant extent[27]. Economic research also provides background for dealing with certain types uncertainties that can be incorporated into the model framework[28].

Secondly, the "real-life" methods of five inflation targeters document that monetary policy makers do not limit themselves to producing the central forecast when deciding about interest rates. They typically rely on a combination of various methods to deal with uncertainty. For example, several central banks attach subjective distributions to the central forecast in order to produce fan charts. Several banks use alternative scenarios to deal with uncertainty about

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[24]In line with Brainard (1967), the certainty benchmark is defined as the policy reaction that would be optimal under certainty. Under uncertainty, optimal policy reaction is different. According to the certainty equivalence principle, certain types of uncertainty, such as linear symmetric risks, do not change optimal policy.

[25] Srour (1999) provides an analysis of implications of different types of uncertainty (linear, non-linear, parameter, model) for monetary policy. Don (2001) illustrates that if there are several users of the forecast, their loss functions should be aggregated in order to derive the optimal policy reaction. However, this aggregation is not easy and can result for example into asymmetric loss function. Issing (2002) stress that strategic uncertainty that is related to expectations has serious and complex implications for monetary policy. The disinflation process in emerging economies can have this type of effect.

[26] The background of the survey is described in Smidkova (2003).

[27] Hall, Salmon, Yates, Batini (1999) and Srour (1999) demonstrate that implications of different types of uncertainty for monetary policy are not the same. Hunt, Orr (1999) and Levin, Wieland, Williams (1999) illustrate that uncertainty is the reason behind differences between actions taken by monetary policy makers and actions suggested by policy rules.

[28] Cogley, Morozov, Sargent (2003), Sims (2001) and Wallis (forthcoming) offer sophisticated econometric tools to deal with uncertainty that can be expressed within the model.

important external factors such as commodity prices. And some let a group of experts vote about the policy recommendation prior to the meeting of the monetary policy makers[29].

Thirdly, various methods offered by decision theory and decision analysis have been examined. This part of the survey has been focused more on methods that are less mathematically rigorous and more rely on intuition and judgement, such as the Delphi method, since the methods that are rooted in mathematics, such as Bayesian techniques, are already covered by economic research. Many decision analysis tools work with subjective evaluation of uncertainties and are aimed at reaching good decisions in an uncertain world[30]. Some forecasters have already used the decision theory framework to recommend methods of presenting the forecast uncertainty to decision makers[31].

Since a relatively broad range of methods has been compiled from the survey, it has been important to organise the survey around a suitable comparative framework in order to make the findings clearer. Therefore methods dealing with uncertainty compiled from the survey have been grouped together according to components of the decision matrix to which they are related. Hence, it is easy to see which methods can be incorporated into different components of the monetary decision-making process. It is worth noting that this approach differs from ones that try to incorporate all components of the decision-making process into the model, such as robust control methods or Bayesian models. We try to show various methods that can be employed to deal with uncertainty, including ones based on judgement and intuition, instead of modelling the whole process from the observer's perspective.

During the work on the survey, it has become clear that it is important to distinguish two stages of the decision-making process. In the first stage, experts produce the forecast and conduct robustness analysis. The outcome of the first phase can be presented as the so-called robustness matrix[32]. Each simulation exercise based on one set of assumptions including a monetary policy action can be represented as one element of the robustness matrix that illustrates the divergence of inflation forecast from target under a specific set of assumptions. In addition, the subjective probabilities of alternative sets of assumptions attached by a group of experts to each set of assumptions can be also components of the robustness matrix. If experts recommend a policy reaction, this is represented with a corresponding decision rule. Although we speak about experts, monetary policy makers can be also members of the expert group. For example, monetary policy makers may participate in debates about alternative sets of assumptions. The elements of robustness matrix are presented by experts to monetary policy makers. Consequently, information contained in the robustness matrix is explicit.

In the second stage, monetary policy makers make use of all information represented by the robustness matrix. In addition, they use all other information available to them, their judgement, intuition and preferences in order to derive their own expected pay-offs before deciding about interest rates. This implies that the decision matrix need not be identical to the

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[29] Results of the survey on the country-specific methods to deal with uncertainty are reported in Šmídková (2003). Appendix II gives summary of the findings for the purposes of this paper.

[30] Clemen (1996), Skinner (1999) and Wright, Goodwin (1998) give examples of tools that work with subjective probabilities such as decision matrix, decision tree and pay-off table.

[31] Don (2001) uses decision theory terminology and argues that the role of the forecast is to help to reach competent decisions.

[32] Rosenhead, Mingers (2001) use the robustness matrix in order to organise results of the robustness analysis.

robustness matrix and that it can remain implicit. The components of the decision matrix are derived by individual policy makers for their own use. However, various components of the decision matrix can be revealed to experts and general public after decision, for example by publishing votes. Although monetary policy makers decide about interest rates according to their own expected pay-offs, it is still beneficial for them to have information about expert views on subjective probabilities and pay-offs. Monetary policy makers can benefit from knowing the complete robustness matrix because it represents expert knowledge that is difficult to express within the model framework. According to decision analysis, averaging of assessments of several experts can improve the quality of the forecast. Similarly, averaging of assessments obtained from different methods can be also beneficial. When monetary policy makers work with the complete robustness matrix, they employ both types of averaging simultaneously and are more likely to make good decisions[33].

Central banks often design their decision-making process as iterative[34]. This implies that some components of the decision-making process are repeated several times. Specifically, after the central forecast and robustness analysis is conducted by experts, monetary policy makers may conclude that the resulting picture of the economy is too different from their views and that they would have to do major adjustments in the second stage of the decision-making process. In other words, the decision matrix would be too different from the robustness one. As a result, they may ask experts to change the assumptions of central forecast, and subsequently, all information represented in the robustness matrix. It follows that the iterations aim at modifying assumptions of the central forecast in order to better reflect the scenario with the best expected outcome. Without these iterations, the central forecast could not play a prominent role in the actual decision and in external communication. Asymmetric risks attached to the central forecast are one possible reason for initiating changes in assumptions of the central forecast[35]. However, producing the central forecast with balanced risks through the iterative process is not easy, and consequently, the full forecasting rounds are typically less frequent than actual monetary policy decisions. As a result, some methods dealing with uncertainty, such as attaching subjective probabilities, can play more prominent role between the two full forecasting rounds.

Due to its iterative nature, the monetary decision-making process need not to be organised in the same order as reported in the paper where each of the sections corresponds to one component of the decision matrix. In line with the structure of the decision matrix, we group the methods into the following five sections (sections V-IX):

[33] Clemen, Winkler (forthcoming) show that adding an expert to the group as well as adding methods improves the quality of decisions with diminishing returns and that adding the expert helps more than working with and additional method of analysis.

[34] All five inflation targeters from the survey report strategies that are similar to iterations. For example, the Swedish Riksbank describes its decision-making process as follows. The main scenario and risks are mostly prepared by experts. If the Board disagrees with the outcome of the process, the main scenario or inflation forecast distribution can be adjusted.

[35] Monetary policy makers emphasise that asymmetry in risks poses a serious problem to them. They may try to reduce the potential asymmetry in risks during the monetary decision-making process. These observations have been made by C. Goodhart and L. Niedermayer.

1) the central forecast
2) elements of the robustness matrix
3) the pay-offs attached by expert group
4) subjective probabilities attached by expert group
5) deciding about interest rates by monetary policy makers.

V. Producing Central Forecast

The central forecast corresponds to the central element of the robustness matrix. When it is produced, there are three methods to deal with uncertainty available (See Table V.1). First, a broad set of information about the core model can be compiled. For example, an extensive sensitivity tests can be reported, including ones reflecting sensitivity of the inflation forecast to the level of interest rates or to the specification of the reaction function. Secondly, estimates of the uncertainties that can be easily represented within the core model can be attached to the central forecast. Thirdly, a list of potential uncertainties can be compiled by experts while they work on the central forecast. The list should consist of uncertainties that are remarkable but are more difficult to represent within the core model. All three methods aim at enlarging (and organising) a supplementary set of information that is produced together with the central forecast. This stage is crucial since the larger the set of supplementary information is, the more methods to deal with uncertainty can be employed at the later stages of the process.

These three methods vary according to the tool that is being used in order to produce the central forecast. Specifically, the more sophisticated the forecasting tool is, the broader the set of supplementary information that can be produced. For example, the model-based forecasts offer a possibility to consistently describe results of sensitivity analysis while expert forecasts do not. In addition, stochastic models can provide estimates of some types of uncertainties. At the same time, the larger sophistication is costly in terms of know-how, and consequently, in terms of more complicated debate. Perhaps, this trade-off may be the reason why central banks in our survey have stayed so far in the middle ground as far as the forecasting tool is concerned while research papers have moved the technology frontier further. The example of the CNB indicates that central banks from emerging economies may start with expert forecasts when inflation targeting is introduced, and introduce fully model-based forecasts at a later stage.

Table V.1 – Producing Central Forecast

	Stochastic forecast	Model forecast	Expert forecast
Description	Central forecast is stochastic (based on model). Estimates of some uncertainties attached to the core model	Central forecast is model-based (with monetary policy endogenous or exogenous)	Central forecast is produced by experts. Experts report estimates of forecasting errors
Examples	CMS, HSYB, KW	BoC, RBNZ, SR, BoE, CNB* (since 2002)	CNB* (prior to 2002)
Supplementary information (data)	Analysis of data series, comparison of assumptions on exogenous variables to distributions derived from past data		
Supplementary information (forecasting tool)	Sensitivity analysis, estimation statistics (if model was estimated), past forecasting errors		Past forecasting errors
Supplementary information (uncertainty)	Shocks represent some uncertainties	None	
Treatment of uncertainties	Some uncertainties explicitly treated	Central forecast creates benchmark for later stages	Uncertainty implicitly treated
List of uncertainties	List of potential uncertainties produced during the work on the central forecast		
Major pros	Model gives framework for discussion. Full information set available for the next stages. Estimates of some uncertainties available.	Model gives framework for discussion. Full information set available for the next stages. Central forecast gives clear benchmark to assess uncertainties.	Robust to the core model uncertainty Robust to problems with data (noise, short series) Know-how of modelling not necessary
Major cons	Requires know-how of stochastic modelling. Explicitly represented uncertainties may interfere with further methods to deal with uncertainty.	Central forecast does not necessarily indicate the optimal policy response. Requires know-how of modelling.	Incomplete information set makes it difficult to assess uncertainty in the next stages. Implicit treatment of uncertainty makes further policy debate difficult.

Note: Abbreviations: BoE – Bank of England, BoC – Bank of Canada, CNB –Czech National Bank, RBNZ – Reserve Bank of New Zealand, SR – Swedish Riksbank. CMS- Cogley, Morozov, Sargent (2003), HSYB- Hall, Salmon, Yates, Batini (1999), KW – Wallis (forthcoming).
*) In this case, the method has not been applied to its full extent (explanation given in brackets).

VI. Deriving Elements of the Robustness Matrix

By conducting robustness analysis related to the central forecast is produced, experts produce information that corresponds to elements of the robustness matrix. By defining alternative policy assumptions, they specify the rows of the matrix. Similarly, by selecting the alternative sets of assumptions, they specify columns of the robustness matrix. By producing alternative forecasts, experts (informally) produce all elements of the robustness matrix. This whole part of decision-making process is designed to deal with uncertainty. First, experts define the least certain components of the central forecast and group them into several alternative sets of assumptions. Second, experts produce the alternative forecasts in order to illustrate distributions of uncertainties that are relevant for the actual decision (See Table VI.1). If the robustness analysis is neglected, illustrations of relevant uncertainties are not available, and there may be an insufficient background for making good decisions. The robustness analysis is conducted in several steps. In the first step, a list of relevant uncertainties must be compiled. Economic research suggests that including all uncertainties that can be represented within the core model can be an option. However, this approach can lead to problems with overstated uncertainty and does not so far offer a unified methodology for dealing with uncertainties that are more difficult to describe. Since monetary policy makers are faced also with off-model uncertainty[36], they cannot rely solely on methods developed so far by economic research and they have to specify their list of relevant uncertainties by using less formal approaches. Therefore it is very difficult to describe this step. Generally, all supplementary information complied previously can be used together with the expert judgement and intuition. There are various approaches available. For example, it is possible to develop a rule of thumb. Every potential uncertainty that could change the inflation forecast by x % or more could automatically qualify to the list of relevant uncertainties. Alternatively, it is possible to rely on intuition and to illustrate several economic problems that are currently debated (even in this case a relevant uncertainty should have a large potential impact on the inflation forecast and have non-negligible probability)[37]. The following examples illustrate the potential candidates for list of relevant uncertainties:

- assumptions about an influential exogenous variable whose future path is uncertain
- residuals in an equation that is influential in the model and has large errors
- a functional form of an influential equation that is subject to a structural break
- a role of the influential equation that is over-written by off-model information
- influential model components (e.g. long-run solution) that are not consensual.

In the second step, alternative forecast assumptions are constructed that correspond to the list of relevant uncertainties, and they are grouped together into several sets. The grouping determines how many columns the (informal) robustness matrix has and also what the role of the central forecast is in the decision-making process. It is worth noting that alternative sets of assumptions are not necessarily connected to the stochastic assessment of uncertainties, if this was used previously. The construction of the alternative sets of assumptions may be more or less complicated. There is an obvious trade-off. On one hand, a large number of sets is easy to generate since each uncertainty can be treated separately, while a small number of sets is more difficult to construct since it requires quite substantial debate about a suitable grouping. On the other hand, a large number of sets is more difficult to discuss, while a small number of sets helps an efficient policy debate. Due to this trade-off, central banks and other forecasting institutions use between 2-5 alternative scenarios, preferring clearly more efficient debate[38]. Central banks use a small number of the alternative scenarios even when they use probability distributions for representing uncertainty. These distributions are constructed mainly in order

[36] Issing (2002) gives examples of the problems faced by monetary policy makers that cannot be dealt with the so far available modelling methods.

[37] It is worth noting that the process of deciding which uncertainties are relevant should eliminate those that are not very likely and those that are not very influential. As a result, the problem of the problem of low probability large extreme events that is analysed in Svensson (2003) should be eliminated.

[38] Don (2001) also recommends a small number of scenarios in his paper about forecasting.

to communicate uncertainty externally. As said above, some research papers suggest that a large number of alternative sets of assumptions can be approximated with Bayesian probability distributions. However, this approach cannot be viewed as a substitute for expert judgement about relevant uncertainties. For example, it does not solve yet some problems with the model uncertainty and uncertainty about future paths of exogenous variables.

Table VI.1 – Defining Alternative Sets of Assumptions

	Distribution	**Benchmark & Alternatives**	**Several alternatives**
Description	(1)Distributions around the central forecast are specified (2)Distribution around the central inflation forecast approximates impact of several alternative sets of assumptions	Several alternative sets of assumptions specified with respect to the central forecast E.g. one alternative set of assumptions is specified on each side of the central forecast	Several alternative sets of assumptions specified, central forecast is not emphasised. E.g. two sets of assumptions are specified
Examples	KW*, CMS* (in these two studies off-model uncertainty is not considered), SR* (interval uncertainties specified for inputs of the inflation forecast) BoE, SR*	FD, BoC, CNB, RBNZ* (central forecast in the second stage)	FD, RBNZ* ("hawkish" and " dovish " sets in the initial stage)
Selection of relevant uncertainties	(1)Compilation of relevant uncertainties not necessary	These methods, including distribution around the forecast (2), require compiling the list of relevant uncertainties	
Grouping alternative assumptions into sets	Grouping of assumptions must reflect the assumed form of distribution	Grouping of assumptions into sets must reflect the central inflation forecast	Grouping of assumptions into sets need not reflect central forecast
Major pros	(1)Does not limit number of sets of alternative assumptions. (1)+(2) Outcome is valuable for external communication.	Gives good background for decision by opening possibilities on both sides (inflationary and deflationary). Can approximate very atypical distributions (e.g. more alternatives on one side)	Simplicity of grouping (everybody can have his own alternative set). Uncertainties can be treated as independent. No need to emphasise the most likely case.
Major cons	(1) Relies too much on the core model and pre-specified distribution. (1)+(2) It is more difficult for experts to attach subjective probabilities	Difficult to group assumptions into sets with respect to the central forecast. Uncertainties should not be treated independently (the total uncertainty can be over-estimated).	Difficult to use between the full forecasting rounds (if the most likely case is not known). The matrix can have too many columns. Difficult to use for external communication.

Note: Abbreviations: BoE – Bank of England, BoC – Bank of Canada, CNB –Czech National Bank, RBNZ – Reserve Bank of New Zealand, SR – Swedish Riksbank. CMS- Cogley, Morozov, Sargent (2003), FD- Don (2001), HSYB- Hall, Salmon, Yates, Batini (1999), KW – Wallis (forthcoming).
*) In this case, the method has not been applied to the full extent (explanation given in brackets).

As far as grouping of alternative sets of assumptions is concerned, the survey does not indicate similar clustering of the real-life strategies in the middle ground as was the case with the first stage. Also, economic research supports all three possible representations of the alternative sets. Advantages of three possibilities are more equally distributed than in the first stage. One may assume that central banks select the possibility that is more suitable for their institutional settings and that is a good complement to tools used in the subsequent stages. However, central banks tend to emphasise the central forecast more than research papers because for them the external communication matters as well as the quality of their decisions.

In the third step, elements of the robustness matrix are constructed. This can be done in two ways: either by running the full forecasting exercise several times or by estimating the impact of new assumptions on the key forecasted variables. The former approach gives an advantage of fully comparable outcomes. It may be more time consuming. The latter approach may be less time consuming since it does not require the full forecasting round per each element of the robustness matrix. Another advantage of the latter approach is that the supplementary set of information need not rely on one (core) forecasting model. Several central banks report using a suite of models to deal with model uncertainty. The multipliers estimated with the core model can be modified by expert judgement according to results from other models. The second approach has also costs because it requires an adequate supplementary set of information to be constructed. Specifically, judgements or estimates of the impact of changes in assumptions and of changes in policy interest rates on the forecasted variables must be known. Also, certain changes in assumptions, such as changes in the model itself, cannot be analysed fully by the latter approach. It is possible that the first approach is used during the full forecasting round, while the second one for decisions between two rounds. Both approaches provide sufficient information content to represent the pay-offs of all alternatives.

VII. Representing the Pay-offs by Experts

After conducting the robustness analysis, experts can represent the results in a way that provides the best possible support for monetary policy decision (See Table VII.1). The easiest way to represent results is to produce a standard set of graphs or tables per each element of the robustness matrix. This simple tool provides enough information to allow monetary policy makers to compare the outcomes of alternative scenarios and attach their own pay-offs to them. Alternatively, experts can assess outcomes themselves, for example by calculating values of loss function, in order to provide monetary policy makers with an explicit representation of the pay-offs. This additional exercise makes the results of the robustness analysis clearer. It is worth noting that priors about the pay-offs are to some extent also provided by experts if the core model works with endogenous monetary policy.

Considering uncertainty when working with pay-offs is important since the real-life inflation targeting strategies usually do not work with a point inflation target only. The strategies themselves have built-in tools to deal with uncertainty such as interval targets or a list of caveats[39]. This implies that monetary policy makers sometimes need to compare the inflation forecast with the mid-point of the target as well as the upper and lower bands of the target. Consequently, if no explicit pay-offs are calculated by experts, it may be quite complicated for monetary policy makers to consider outcomes of the robustness analysis as well as variations in the target or targeted index. Economic research suggests that this problem can be

[39] Mahadeva, Sterne (2000) describe a variety of inflation-targeting frameworks.

solved by calculating the so-called event probability. However, in this case, monetary policy makers would be again faced with difficulties when dealing with off-model uncertainties. Decision analysis recommends calculating the explicit pay-offs with the loss function in order to simplify the assessment of outcomes. On one hand, in this case, an additional uncertainty may be added to the whole process due to a specification of a loss function. On the other hand, some central banks assume endogenous monetary policy in their forecasting models, and hence they are faced with this additional uncertainty anyway.

The survey shows that the problems with comparing several variants represented by many tables and considering caveats and targeted bands at the same time are probably not so serious in reality because central banks do not report working with explicit pay-offs for the sake of simplification. It is worth noting that for central banks that forecast with models working with endogenous monetary policy, calculating the explicit pay-offs by experts would not be a significant deviation from the currently applied methodology. Policy rules already indicate what the expert views are on the weights of inflation and output in the loss function.

Table VII.1 – Calculating Pay-Offs by Experts

	Event probability	Loss function	No explicit pay-offs
Description	Elements of the matrix contain probabilities of inflation being inside the targeted range, available for stochastic models only	Each element of the decision matrix contains value of loss function	Each element of the robustness matrix is represented with a table/chart illustrating divergence of inflation from target
Examples	KW	DA, BoC*, CNB*, RBNZ* (in all three cases, models with endogenous policy reveal something about loss function of experts)	BoE, SR, BoC*, CNB*, RBNZ*
Dealing with targeted range	The whole targeted range represented	Components of the target must be treated explicitly	Target pictured with all components (midpoint +bands, if any)
Dealing with caveats	Caveats can be used to modify distributions	Caveats must be treated explicitly	Caveats can be expressed graphically as an additional information (e.g. by adjusting the forecast)
Major pros	Comparison of outcomes and interpretation of pay-offs easy Policy makers can use expert priors	Comparison of outcomes relatively easy Policy makers can use expert priors	Easy to produce, no additional uncertainty imposed (about loss function)
Major cons	So far very difficult to produce	Experts must agree on the formula (loss function, role of the target and caveats)	Difficult to assess if robustness matrix large or if a range is targeted Policy makers have no priors available

Note: Abbreviations: BoE – Bank of England, BoC – Bank of Canada, CNB –Czech National Bank, RBNZ – Reserve Bank of New Zealand, SR – Swedish Riksbank. DA –decision analysis. KW – Wallis (forthcoming).
*) In this case, the method has not been applied to the full extent (explanation given in brackets).

VIII. Attaching Subjective Probabilities by Experts

After conducting robustness analysis, experts can also attach subjective probabilities to alternative sets of assumptions (See Table VIII.1). These probabilities are represented with an upper row of the robustness matrix. Subjective probabilities can be later used by monetary policy makers as additional information before the actual decision about interest rates. If this stage is omitted, monetary policy makers work with an incomplete robustness matrix and they derive their subjective probabilities and expected pay-offs without employing the know-how of the experts fully. During this stage, statistical methods cannot be employed since most of the assumptions in the alternative sets are likely to represent the uncertainty that cannot be easily represented by objective distributions. That is why economic research does not offer a complete solution. Experts can use some of the tools suggested by decision analysis. The most sophisticated tool offered by decision analysis to policy makers is to ask the expert group to reach a consensus about subjective probabilities. Alternatively, the experts can attach subjective probabilities individually and these can then be averaged. The easiest way followed by several central banks is to allow experts to work with subjective probabilities implicitly and to reveal them indirectly to monetary policy makers by suggesting a policy recommendation. In this case, experts usually vote about policy recommendation. If monetary policy makers have access to the voting pattern, they can learn some information about the implicit subjective probabilities.

No matter which tool is employed, it is always important to select the expert group carefully in order to deal with uncertainty efficiently. The expert group should have both an adequate size as well as a well-designed structure. Specifically, experts should not have the same background (e.g. it makes no sense to have only the modelling team voting). In addition to the modellers, other experts in the group should be able to offer detailed knowledge about problems that are on the list of relevant uncertainties. It follows that the formation of the expert group may not be easy[40]. Also, there is a rule of thumb that each set of assumptions should be able to get at least 2-3 votes. The composition of the group matters because individual views about subjective probabilities are according to decision analysis subject to biases[41]. The most common mistakes when assessing subjective probabilities are wishful thinking (the best outcome is attached the highest probability), experience bias (the alternative that was observed in the past is attached the highest probability), and overconfidence (neglecting that subjective probabilities can be wrong).

All the above-described tools employ some methods to deal with these biases. Specifically, the averaging of individual opinions across the heterogeneous group of experts can be used in order to reduce biases. The averaging can be done by experts or by a monetary policy maker who listens to their debate. The latter method is sometimes referred to as the BOGSAT (bunch of guys sitting around talking) method. Alternatively the expert group can vote anonymously on a set of proposed subjective probabilities and then the group must discuss the outcome of this initial voting and agree on consensual probabilities. This method is called the Delphi method[42]. It is probably the most efficient method in reducing the biases but it can be very time consuming. However, even simpler tools, such as averaging of individually attached probabilities, can still reduce a significant portion of biases. It is worth noting that all these methods can be also employed by monetary policy makers in the second stage of the decision-making process.

Interestingly, no central bank in our survey reports that explicit subjective probabilities attached by a group of experts to alternative sets of assumptions are fully incorporated into the decision-making process. In three cases, averaged or consensual probabilities are revealed to monetary policy makers indirectly during procedures related to the specification of alternative sets of assumptions. In two cases, experts keep subjective probabilities implicit, with the exception of the central forecast that is in all cases built as the most likely case. An interesting strategy is to let the group of experts vote about policy recommendations. Although this voting reveals something about subjective probabilities, it is not possible for monetary policy

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[40] The comment that the formation of the expert group is not an easy task has been made by M. King. In the case of a significant model uncertainty, researchers that have a deep knowledge of alternative models can help. In the case of data uncertainty, statisticians that analyse a specific data in a very detailed way can improve the discussion. The comment that the formation of the expert group is not an easy task has been made by M. King.

[41] Clemen (1996) and Wright, Goodwin (1998) summarize possible biases that can affect specifications of subjective probabilities.

[42] Armstrong (1985) explains the Delphi method, initially developed by the RAND Corporation in 1969 for technological forecasting, in more detail.

makers to separate this information from information about an implicit loss function of experts. As a result, monetary policy makers are unable to distinguish whether experts had applied the “best expected value” rule that should lead to a good decision. As a result, this policy recommendation may not have as significant value added for monetary policy makers as it could.

Table VIII.1 Attaching Subjective Probabilities

	Consensual Probabilities Derived	**Probabilities Attached by Individual Experts**	**Probabilities Are Implicit**
Description	Group of experts must reach consensus about subjective probabilities	Individual experts attach their subjective probabilities, these are then aggregated	Experts work with implicit probabilities (they may say explicitly which case is the most likely one)
Examples	DA, BoE*, SR* (building of distribution around the central forecast and iterations ensure that probabilities are revealed indirectly)	DA, RBNZ* (averaged probabilities can be derived indirectly from “hawkish” and “ dovish ” sets and the central forecast)	CNB, BoC, BoE*, SR* RBNZ*
Work with subjective probabilities	Experts use managerial method (e.g. Delphi method) to reach consensus. Experts can use some modelling tool as a mean of communication to reach consensus (e.g. fan chart)	Experts attach probabilities individually, these are then aggregated (averaging, weighted averaging). Experts can also vote about sets of assumptions (number of votes for each set implies probability)	Experts work with them only implicitly and reveal them indirectly by their recommendation. Experts can vote about policy recommendation
Work with decision rules	All decision rules available to experts for policy recommendation	All decision rules available to experts for policy recommendation	Experts cannot use all decision rules explicitly
Major pros	Robustness matrix is complete. Monetary policy makers have full set of information prior to their decision. Biases in expert judgement are detected and reduced.	Robustness matrix is complete. Monetary policy makers have full set of information prior to their decision. Biases in expert judgement are reduced by averaging.	The easiest option, it takes one short meeting to vote
Major cons	Time consuming and sometimes frustrating	Biases reduced only indirectly by averaging Differences between expert opinions are not explained.	Expected inflation cannot be calculated by experts. If uncertainty high, recommendation does not necessarily lead to a good decision Policy makers have no priors about probabilities.

Note: Abbreviations: BoE – Bank of England, BoC – Bank of Canada, CNB –Czech National Bank, RBNZ – Reserve Bank of New Zealand, SR – Swedish Riksbank. DA –decision analysis.
*) In this case, the method has not been applied to the full extent (explanation given in brackets).

IX. The Interest Rate Decision

In the second stage of the decision-making process, monetary policy makers use all information presented to them by experts, all additional information they have and their judgement in order to take the final decision about interest rates. One can associate this stage with transformation of the (informal) robustness matrix into a decision matrix. If monetary policy makers have an important piece of additional information or their judgement does not correspond to conclusions of experts, the two matrixes can differ significantly. The two matrixes are also likely to be dissimilar if the robustness matrix was incomplete. This implies that although the experts can use various methods to deal with uncertainty, some method should be also employed during the second stage of the decision-making process. As above mentioned, monetary policy makers can employ similar methods to deal with uncertainty that can be used by experts during the previous stage (See Table IX.1).

The system of voting by members of the decision-making body is respected as an important method to deal with uncertainty, according to decision analysis. Interestingly, the voting is rarely mentioned among methods that central banks claim to use to deal with uncertainty. However, all central banks use voting of monetary policy makers as an important weapon in their battle against uncertainty. The methods go across the whole spectrum from one decision maker relying on a strong group of advisers to consensual decision-making. It is worth remembering that iterations, used to improve the forecast, can be to some extent a substitute for the consensus method. If several stages of the decision-making process are repeated, the central forecast can move closer to the best expected outcome. In this case, the likelihood that the robustness matrix and the decision matrix are similar increases.

There are trade-offs when designing the voting system of the decision-making body. The more the voting system helps in dealing with uncertainty, the less transparent it is for external observers. Hence, more sophisticated methods should be complemented with additional communication tools. Specifically, if the Governor decides about monetary policy interest rates himself, external observers can extract additional information from his decision. The observers can combine their knowledge of the published forecast with their guesses about the Governor's loss function and subjective probabilities. Subsequently, they can form their views about future policy actions more easily. If the decision-making body consists of several members who decide individually, external observers can only make guesses about the aggregated loss function and aggregated probabilities from the interest rate decision. If one member of the decision-making body is absent from the policy meeting, the aggregate loss function and the aggregate subjective probabilities that are behind the final decision are likely to change. In this case, publishing the votes improves the knowledge about individual loss functions and subjective probabilities that are more stable than aggregates and hence easier to predict. If the decision-making body makes consensual decisions, individual loss functions and subjective probabilities are very difficult to extract for external observers. In this case, some additional information such as indication of the future policy bias, may be needed to improve external communication.

Table IX.1–Interest Rate Decision

	Board Members Reach Consensus	Board Members Vote Individually	Governor decides
Description	Policy makers must reach consensus about the best policy reaction, they consider all available information + their individual judgements +judgements of other board members	Policy makers vote considering all available information, including expert views on probabilities and pay-offs, and their individual judgements	Governor decides considering all available information, including expert views on probabilities and pay-offs, and his own judgement
Examples	DA (Delphi), BoC, BoE*, SR* (in both cases, there is an iterative debate about distribution around central forecast)	DA (heterogeneous group of experts), CNB, BoE*, SR*	DA (BOGSAT), RBNZ
Work with subjective probabilities	Implicit subjective probabilities of the individual members are revealed indirectly to other members during debate	Implicit probabilities of the individual members are averaged	Implicit subjective probabilities of the Governor used
Work with the pay-offs	Implicit pay-offs of the individual members are revealed indirectly to other members during debate	Implicit pay-offs of the individual members are averaged	Implicit pay-offs of the Governor used
Major pros	Indirect revealing of pay-offs and probabilities to other decision makers and consensus are respected methods to deal with uncertainty.	Averaging of probabilities and pay-offs helps to deal with uncertainty.	Easy and transparent (pay-offs and probabilities of the Governor are indirectly revealed)
Major cons	Time consuming Transparency lower since pay-offs and probabilities are not revealed externally (policy bias can be indicated to compensate).	Differences between board members' opinions are only averaged. If voting pattern not announced, transparency not so high.	If experts are not valuable partners in policy debate, no additional method to deal with uncertainty added in the second stage of the decision-making process

Note: Abbreviations: BoE – Bank of England, BoC – Bank of Canada, CNB –Czech National Bank, RBNZ – Reserve Bank of New Zealand, SR – Swedish Riksbank. DA –decision analysis. CMS-Cogley, Morozov, Sargent (2003), FD- Don (2001), HSYB- Hall, Salmon, Yates, Batini (1999), KW – Wallis (forthcoming).

*) In this case, the method has not been applied to the full extent (explanation given in brackets).

X. External Communication

Although the paper focuses on methods to deal with uncertainty for the purposes of decision-making, it is worth making a few remarks about external communication as well. Methods dealing with uncertainty often produce useful inputs to communication strategy. It is also often the case that they are selected because their outcomes can be used for the purposes of external communication. After the decision is taken, monetary policy makers targeting inflation need to communicate why decision was taken and also describe risks attached to the forecasts. Risks are often communicated in order to emphasise that the probability of hitting precisely the mid-point of the inflation target is very low[43]. For the purposes of explaining the reasons behind the actual decision about policy interest rates, it is important to describe those components of the decision matrix that supports the decision. Specifically, if the economic outlook expected by monetary policy makers does not correspond to the forecast produced by experts, for example due to different subjective probabilities, this is usually explained in the minutes from the meeting.

Central banks employ various communication strategies to describe the reasons behind the decision as well as risks attached to the inflation forecast (See Table X.I). In order to describe all relevant components of the decision matrix, including the central forecast, central banks publish a combination of various information. None of them describes the whole decision matrix to general public. All central banks describe risks attached to the central forecast, verbally or numerically. These observations correspond to the above-mentioned aims of external communication. In addition to risks and reasons of the actual decision, some central banks also publish information about disagreement among individual policy makers that is sometimes viewed by the general public as an additional signal of the forthcoming changes in interest rates.

Table X.1–Examples of Communicating Risks and Uncertainty After Decision

Component of Decision Matrix	Communication method	Example
Central forecast with risks	Staff estimates of risks (expert estimate) are published together with the central inflation forecast	CNB
Elements of decision matrix	Alternative forecasts are sometimes published as well as simulations with alternative reaction function	BoC
Subjective probabilities	Fan chart is published for inflation that incorporates subjective probabilities	SR
Pay-offs (loss functions)	Votes of individual members of the MPC are part of the Minutes of the meeting	BoE

Note: Abbreviations: BoE – Bank of England, BoC – Bank of Canada, CNB –Czech National Bank, SR – Swedish Riksbank.

XI. Concluding Remarks

- Methods of producing the benchmark forecast as well as methods to deal with uncertainty are equally important. Monetary policy makers need both in order to make good decisions. It can be costly if uncertainty is treated only implicitly. The paper offers one possibility of reducing the potential costs by analysing different methods that are available to monetary policy makers to deal with uncertainty during the whole decision process. The survey of methods to deal with uncertainty looked at approaches employed by central banks, methods suggested by economic research and methods suggested by decision analysis.

[43] Issing (2003) and Budd (1998) stress that it is important to let general public know that monetary policy cannot prevent all problems.

The comparative framework was based on the decision matrix that can incorporate all different types of information important for monetary policy decisions. The matrix also encompasses various representations of uncertainty used by central banks, such as fan charts or variant forecasts.

- Central banks employ various methods dealing with uncertainty quite extensively. Alternative sets of assumptions, comparisons of variant forecasts and policy simulations, subjective probabilities and voting of the expert groups are all part of their repertoire. In this respect, monetary policy makers are similar to decision makers leading important institutions in other areas. This conclusion corresponds to claims made by monetary policy makers in their papers that the decision-process of the central bank cannot be approximated with a model-based forecast or a model-based policy rule without substantial simplifications. As a result, no rule of thumb on how to react to uncertainty can be applied. Moreover, the decision-making process often takes several iterations in order to bring assumptions of the central forecast closer to the scenario that yields the expected outcome. This implies that robust control methods when applied to analysis of monetary policy should work with decision rules that are closer to the so-called rational rule, such as the Laplace rule.
- Individual central banks do not always use same methods to deal with uncertainty. Methods of final voting cover the whole spectrum of possibilities: reaching consensus among the board members, iterative forecasting procedures, independent votes by individual members and just one decision-maker with advisers. One can also observe a large variety of methods when alternative sets of assumptions are specified. They are represented with the help of probability distributions, with variant forecasts (defined with respect to the central forecast) or with two boundary sets of assumptions that help to open the policy debate. Some components of the decision-making process are very similar in all five cases. Specifically, the central forecast of advanced inflation targeters is typically model-based, but not fully stochastic. The pay-offs are usually treated by experts implicitly but some information about them is often revealed to monetary policy makers via the policy recommendation.
- The variety of methods used by central banks does not cover the whole spectrum of methods compiled from the survey. Intuition and judgement are not incorporated into the decision-making process as formally as they are in the decision-analysis framework. Specifically, experts work with their subjective probabilities and pay-offs only implicitly in some cases while decision analysis suggests that the know-how of experts could be more utilised if they reveal this information to decision makers. Use of stochastic simulations and Bayesian techniques is less advanced in central banks than in theory papers. Economic research can help with the initial stages of the decision-making process and decision analysis can improve methods in the latter stages. Although central banks as a group cover most of the spectrum of available methods, individual central banks do not. Some central banks choose less formal methods to deal with uncertainty. It is possible that the core model is developed first after inflation targeting is introduced, and methods dealing with uncertainty are improved gradually.
- The selection of methods dealing with uncertainty for one stage of the decision-making process influences the availability of methods during the subsequent stages. For example, if robustness analysis is not conducted, the expected pay-offs cannot be computed by experts (unless the probability of the central forecast is one). The selection of methods has also implications for external communication and central banks often select internal methods to deal with uncertainty with these implications in mind.
- The full forecasting round, including complete robustness analysis, can be a time consuming process, and consequently, other components of the decision-making process

can be used more frequently. In extreme situations, monetary policy makers can decide about interest rates after updating only information that corresponds to their individual decision matrix. This may happen, for example, during times of financial or exchange-rate turbulence when monetary policy makers can hold policy meetings very frequently[44].

- The survey has been designed with the aim to compile and analyse a broad variety of methods to deal with uncertainty. In several specific areas, there is a need for further research. More central banks should be added to the survey in order to assess implications of different institutional settings, such as a multi-country structure, or different economic conditions, such as problems of emerging economies. More attention should be also paid to possibilities of constructing subjective probabilities in a more formal way during the decision-making process. Last but not least, it would be interesting to analyse implications of different methods for characteristics of the actual decisions about interest rates. For example, it has not yet been fully established whether opting for fan charts or variant forecasts affects frequency or size of changes in policy interest rates.

[44] Smidkova et al (1998) documents that policy meetings are very frequent in these circumstances.

Appendix I

The Decision Matrix Illustrated

Introduction

The decision matrix used in the third section of the paper has been based on the Czech data from July 2001. This was a period of significant uncertainty for the Czech monetary policy, and consequently, the results illustrate well methods dealing with uncertainty in a real-life situation. The robustness matrix has been constructed in the following steps. First, the central forecast has been produced together with the supplementary set of information[45]. Second, two alternative sets of assumptions have been specified in order to characterise inflation and deflation pressures with respect to the so-called neutral case. Third, the pay-offs have been calculated for each combination of alternative sets of assumption and possible policy reactions. The pay-offs have been derived from a quadratic loss function with inflation and output terms covering the time horizon relevant for the Czech monetary transmission. Fourth, several decision rules have been applied in order to formulate policy recommendations. The applied decision rules have been selected in order to illustrate the importance of subjective probabilities. The resulting robustness matrixes represent the decision matrixes under assumption that a monetary policy maker follows the expert advice.

July 2001: the underlying economic situation

Calculations are based on data available in July 2001 and on the assessment of risks recorded in the Minutes from July 2001[46]. Current evidence supports the view that July 2001 was a period of considerable uncertainty. Policy interest rates were cut in February 2001, increased in July 2001 and then cut back in November 2001 in response to changes in the central forecast as well as in risk assessments by the Board. It is worth summarising the issues that were important for policy debate in July 2001 since they will form our set of alternative

[45] All calculations presented in Appendix II are based on the simple model of the Czech economy that is occasionally used in the advisers' assessment of Situation reports of the Czech National Bank. The more extensive version of the model is described in Mahadeva, Smidkova (2000). Although the model used in the Appendix I is quite simple, in July 2001 it explained well the past behaviour of the Czech economy. Its simplicity fulfils our requirement that producing a supplementary set of information necessary for this illustration is a straightforward exercise. The model is programmed and solved in Winsolve. The model consists of the following equations (all variables are growth rates):

(1) $cp=c2*pg+(1-c2)*np$, *where cp is cpi inflation, pg are regulated prices, np is net inflation*,

(2) $np=(1-c1)*p+c1*(pfd+e)$, *where p is core inflation, pfd are international food prices and e is exchange rate*,

(3) $p=(c3-c7)*p(-1)+(1-c3)*(c4*pg+c5*(w-y)+c6*(pf+((e+e(-1))/2)))+c7*(y-ys)$, *where w is nominal wage bill, y is output, pf are foreign prices and ys is potential output*,

(4) $w=ww+cp(-4)+y(-4)$, *where ww is productivity claim made by unions,*

(5) $y=ys+c8*(g(-4)-cp(-4))+c9*(m(-4)-cp(-4))+c10*(w(-4)-cp(-4))+c11*yf+c12*(cpf+e-p)$, *where g is nominal fiscal impulse, m is money stock, yf is foreign demand and cpf is foreign cpi inflation*,

(6) $m=c13+y+cp-c14*(i-cpexp)$, *where i is nominal interest rate and cpexp is expected inflation*,

(7) $cpexp=cp$, *where cpexp are adaptive expectations*,

(8) $e=e(-1)$ or $e=c15*(e(+1)+(i-if-rp)/4)$, *where e(+1) are model consistent exchange-rate expectations, if is foreign interest rate and rp is risk premium*.

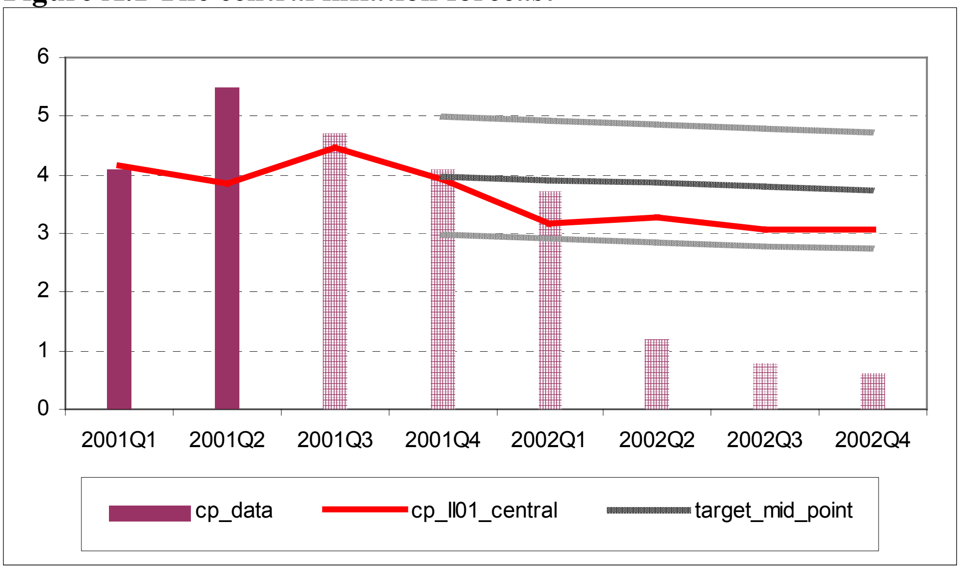
The values of the coefficients are as follows: c0=0.85, c1=0.1, c2=0.28, c3=0.5,c4=0.05, c5=0.3, c6=0.3, c7=0.5, c8=0.1, c9=0.3, c10=0.2, c11=0.3, c12=0.1, c13=0, c14=0.6, c15=0.8.

[46] Minutes of the meeting are published on the internet 12 days after each monetary policy meeting.

assumptions. Firstly, the subsequent forecasts of external variables were changing dramatically. Initially, there were expectations of upward corrections in external output and inflation in comparison to the forecast from previous months. These expectations were then subject to reverse corrections. Secondly, a real impact of government policy on inflation was different from the officially published intention. Considerable price de-regulations were expected to take place but in reality they were much slower than the official schedule suggested. Thirdly, model uncertainty was a problem. Specifically, it was difficult to model the exchange-rate of koruna that was initially expected to remain stable but it was strengthening due to large privatisation inflows. Also, the model was overestimating the wage growth due to an impact of continuing disinflation on expectations.

The central forecast and supplementary set of information
The model and the July 2001 data set, including projections for exogenous variables, have been used to produce the central forecast that represents the most likely scenario. All assumptions related to this scenario are components of the so-called neutral set of assumptions. This set consists of model equations, parameters, zero residuals, past data known in July 2001 and projections of exogenous variables done in July 2001. The neutral set is thus neutral with respect to history since assumptions are based on the past data as much as possible. The set is also neutral with respect to general knowledge since projections of exogenous variables (such as external prices) are derived from consensus forecasts. Last but not least, the set is neutral with respect to economic policies because it includes the assumptions of unchanged interest rates and exchange rate, and official scenario of government policies (such as price de-regulations). Figure A.1 shows the resulting central forecast for inflation.

Figure A.1 The central inflation forecast



Note: Variables are defined as follows. Cp_data are data (shadowed for data unknown in July 2001). CpII01_central is the central forecast for inflation. Target_mid_point is the central line of the corridor target for inflation.

The model has been used to produce the supplementary set of information that is necessary for deriving the elements of the robustness matrix. Table A.1 represents components of this set that were important for the July 2001 policy debate. The sensitivity of two important variables that enter the loss function –inflation and output growth – with respect to changes in policy interest rates was calculated from simulation results. The leverage of exogenous variables was calculated by combining information on their historic volatility and sensitivity of inflation and output to their changes. Table A.1 shows the leverages of two most influential variables – foreign demand and foreign prices.

The model uncertainty was considered. The past equation errors were calculated. Table A.1 shows the equation that had had the largest mean of residuals. As was mentioned, the central forecast works with the random walk assumption for exchange rate. The impact of including the behavioural equation for exchange-rate into the model was considered. Simulations were used to estimate the impact of this change on inflation and output growth. The government policy scenario was considered. The central forecast was based on assumption that price de-regulations would take place according to official schedule. From past experience, it was clear that de-regulations tend to be slower in reality, partially due to continuing disinflation process. This asymmetric uncertainty was considered. It is worth noting that three of the above-mentioned issues - impact of external variables, exchange-rate equations and impact of government policies – are common themes to many central banks.

Table A.1 The supplementary set of information

Changes in assumptions	**Sensitivity of inflation**	**Sensitivity of output growth**	**Is impact symmetric ?**
Increase in interest rates (25 b.p.)	-0.016	-0.055	Yes (policy multiplier)
Decrease in foreign demand (standard error)	-0.204	-0.621	Yes (volatility)
Decrease in foreign prices (standard error)	-0.879	0.090	Yes (volatility)
Wage equation corrected (downwards by average error)	-0.207	-0.263	No (average error negative)
Exch. Rate endogenous (koruna stronger)	-0.207	-0.263	No (risk premium converging)
Price de-regulations slower (by average past error)	-0.323	0.010	No (over-predicted in past)

Note: Sensitivity is reported in percentage points on a quarterly basis. For example, an increase in interest rate by 25 b.p. will reduce the inflation rate over the period of monetary transmission on average by 0.016 percentage points each quarter.

The report on central forecast and supplementary set of information could have been more extensive. It could have contained forecasts for all endogenous variables and estimates of impact of all potential changes in assumptions on all endogenous variables, together with tables reviewing pasta data volatility, past equation errors and performances of alternative model specifications. However, for illustration purposes, the less extensive Table A.1 is probably more adequate.

Alternative sets of assumptions

The assumptions of central forecast and supplementary set of information provide a benchmark for specifying the alternative sets of assumptions. At this stage, expert judgement and intuition play an important role. In our example, observations about underlying economic situation were used for selecting potential alternative assumptions. Their selection was also based on the leverage of the potential changes in assumptions on the inflation and output growth. The underlying analysis has been summarised in Table A.1. Changes in assumptions with respect to the central forecast were grouped according to their impact on inflation forecast. Hence, the two resulting sets are called “deflation pressures” and “inflation pressures". Under assumption that these changes can be viewed as independent shocks, the impact of each set of assumptions on the inflation and output growth was calculated. Table A.2 reports the results.

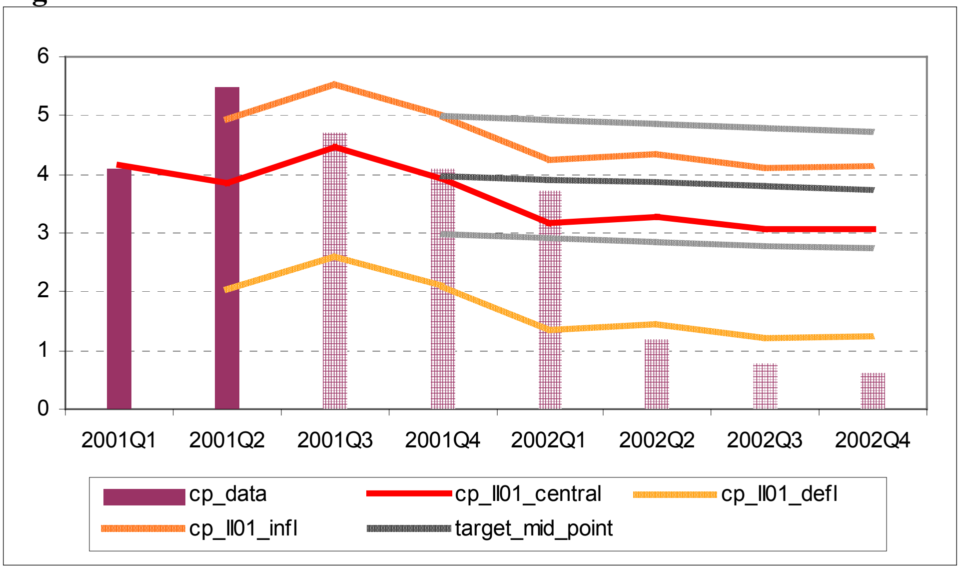
Table A.2 Two alternative sets of assumptions

Name of the set	Sensitivity of inflation	Sensitivity of output	Assumptions in the set
Deflation pressures	-1.819	-1.048	Lower foreign demand, lower foreign prices, wage corrected downwards, exchange rate endogenous, price de-regulations slower
Inflation pressures	1.083	0.532	Higher foreign demand, higher foreign prices

Note: Sensitivity is reported in percentage points on quarterly basis.

Alternative sets can be constructed differently using the same the central forecast and supplementary set of information. For example, every change in assumption can be treated as an individual set of assumptions. However, working with two sets is easier and two sets open a clearly defined space for a policy debate. Graph A.2 compares the central forecast with the two alternative outcomes.

Figure A.2 The central inflation forecast and two alternatives



Note: Variables are defined as follows. Cp_data are data (shadowed for data unknown in July 2001). CpII01_central is the central forecast for inflation. Target_mid_point is the central line of the corridor target for inflation.

Pay-offs calculated

The expert estimates of the pay-offs were calculated for all combinations of the three sets of assumptions (neutral, deflation pressures, inflation pressures) and the three possible policy reactions (no change in interest rates, increase by 25 b.p. and decrease by 25 b.p.). This can be done either by running full set of nine simulations or by working with supplementary set of information. In order to produce the expert estimates of pay-offs, the loss function was specified as follows. The quadratic loss function had the 0.7 weight on the inflation term and the 0.3 weight on the output term. The function cumulated the loss over the horizon of monetary transmission. The mid-point of the inflation target was targeted. The potential output was assumed to grow 2.8 % annually. Table A.3 reports the results.

Table A.3 The robustness matrix

Alternative sets of assumptions Possible reactions	Deflation pressures	Neutral pressures	Inflation pressures
Reduction in interest rates	13.207	1.216	1.431
No change in interest rates	13.432	1.212*	1.300
Increase in interest rates	13.663	1.215	1.175

Note: The pay-off of the central forecast is marked with *.

Subjective probabilities and policy recommendation

The robustness matrix was used to produce policy recommendations based on different approaches to subjective probabilities. The easiest approach is to work solely with the most likely case based on neutral set of assumptions. In this case, two alternative sets are neglected. The so-called "the best of the most probable" rule selects the policy reaction with the best pay-off. Table A.4 illustrates that our policy recommendation would be to leave interest rates unchanged in this case.

Table A.4 – Applying "The Best of the Most Probable" Rule

Probability		***Most likely case***	
Alternative assumptions **Possible reactions**		**Neutral inflation pressures**	
Reduction in interest rates		1.216	
No change in interest rates		1.212*	
Increase in interest rates		1.215	

Note: This table is presented in the paper as Table III.1. The best-pay-off is the one with the lowest value since the loss function is used to calculate elements of the robustness matrix.

The second approach takes things one step further. All three alternative sets are considered but no subjective probabilities are attached to them. In this case, only decision rules that do not rely on probabilities can be used. For example, the so-called "maximin" rule finds the worst pay-off for each possible policy reaction and selects the reaction with the minimal worst pay-off. This decision rule is an analogy to rules employed by the robust control methods[47]. Table A.5 illustrates that our policy recommendation would be to reduce interest rates in this case

Table A.5 – Applying "Maximin" Rule

Probability				
Alternative sets of assumptions **Possible reactions**	**Deflation pressures**	**Neutral pressures**	**Inflation pressures**	**Worst pay-off**
Reduction in interest rates	13.207	1.216	1.431	13.207
No change in interest rates	13.432	1.212*	1.300	13.432
Increase in interest rates	13.663	1.215	1.175	13.663

Note: This table is presented in the paper as Table III.2. The worst-pay-off is the one with the highest value since the loss function is used to calculate elements of the robustness matrix.

The third approach progresses even further. Subjective probabilities are attached to the alternative sets of assumptions in order to calculate expected pay-offs. The easiest way to do

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[47] Cagliarini, Heath (2000) explain that this rule is approximated with robust control methods in Tetlow, von zur Muehlen (2000). Interestingly, this decision rule is suggested by decision analysis for army officers who need to select their investment strategy. The answer is to invest into weapons that can minimise the worst possible outcome of the future war or natural catastrophes.

this is to assume that all three sets of assumptions were equally likely. The so-called Laplace rule selects the policy reaction with the best expected pay-off. Table A.6 illustrates that our policy recommendation would be to reduce interest rates in this case

Table A.6 – Applying "The Laplace" Rule

Probability	*1/3*	*1/3*	*1/3*	
Alternative sets of assumptions **Possible reactions**	**Deflation pressures**	**Neutral pressures**	**Inflation pressures**	**Expected pay-off**
Reduction in interest rates	13.207	1.216	1.431	5.284
No change in interest rates	13.432	1.212*	1.300	5.314
Increase in interest rates	13.663	1.215	1.175	5.351

Note: The expected pay-offs are (probability) weighted averages of the pay-offs in each row of the robustness matrix.

Much more effort can be invested into attaching subjective probabilities before calculating the expected pay-offs. Since we cannot have a group of experts voting about the probabilities two years after the meeting and pretend that they know only data from July 2001, the assessment of risks published in the Minutes has been used as a substitute. In July 2001, the inflation risks were given much higher emphasis during the policy debate. Table A.7 illustrates that our policy recommendation would be to increase interest rates in this case.

Table A.7 – Applying "The Best Expected Value" Rule

Probability	*0.1*	*0.5*	*0.4*	
Alternative assumptions **Possible reactions**	**Deflation pressures**	**Neutral pressures**	**Inflation pressures**	**Expected pay-off**
Reduction in interest rates	13.207	1.216	1.431	2.501
No change in interest rates	13.432	1.212*	1.300	2.469
Increase in interest rates	13.663	1.215	1.175	2.444

Note: This table is presented in the paper as Table III.3. The expected pay-offs are (probability) weighted averages of the pay-offs in each row of the robustness matrix.

Tables A.4-7 can be seen as robustness matrixes produced by experts or decision matrixes (if policy makers accepted the expert views fully).

Alternative representations of uncertainty

The robustness matrix can encompass various representations of uncertainty used by different central banks. Specifically, the two extreme sets can be used to open policy debate. This implies that the central case has a zero probability attached to it when expected pay-offs are calculated. Table A.8 illustrates this "hawkish-dovish" approach that would lead to a recommendation to reduce interest rates.

Table A.8 – The Hawkish-Dovish Approach

Probability	*½*	*0*	*½*	
Alternative sets of assumptions **Possible reactions**	**Deflation pressures**	**Neutral pressures**	**Inflation pressures**	**Expected pay-off**
Reduction in interest rates	13.207	1.216	1.431	7.319
No change in interest rates	13.432	1.212*	1.300	7.366
Increase in interest rates	13.663	1.215	1.175	7.419

Note: This is an analogy to the approach used by the RBNZ.

Alternatively, subjective probabilities can be implied by an explicit estimate of a difference between the expected inflation and the central inflation forecast and by specific assumptions about a shape of the probability distribution. Table A. 9 illustrates that this “fan chart” approach would lead to a recommendation to decrease interest rates.

Table A.9 – The Fan Chart Approach

Probability	***0.483***	***0.500***	***0.017***	
Alternative sets of assumptions / **Possible reactions**	**Deflation pressures**	**Neutral pressures**	**Inflation pressures**	**Expected pay-off**
Reduction in interest rates	13.207	1.216	1.431	7.016
No change in interest rates	13.432	1.212*	1.300	7.121
Increase in interest rates	13.663	1.215	1.175	7.232

Note: The probabilities were derived in order to ensure that the difference between the central forecast and expected inflation is in line with the analysis of supplementary set of information. This is an analogy to the approach used by the Bank of England.

Tables A.4-9 illustrate that although central banks can use different ways of representing the uncertainties, they need to develop very similar supplementary sets of information in addition to their central forecasts because they need to work with all components of the robustness matrix, however implicit this may be. The only exception is the “best of most probable” approach that is the easiest one but can be too costly in terms of neglected uncertainty. It can lead to the sub-optimal decisions if - for example – alternative sets of assumptions are asymmetric or inflation and deflation scenarios are relatively probable.

Appendix II

Summary of the Survey: How Inflation Targeters Deal with Uncertainty

Short Case Studies on Dealing with Uncertainty

Five short case studies have been conducted in order to document how inflation targeting central banks deal with uncertainty. Results of the survey are reported in Šmídková (2003). This appendix gives summary of findings for the purposes of this paper. The five case studies are described in chronological order according to the year in which the respective central banks started targeting inflation: the Reserve Bank of New Zealand, the Bank of Canada, the Bank of England, the Swedish Riksbank and then the Czech National Bank. Only publicly available sources have been used to produce the case studies. Country-specific information has been obtained from Inflation Reports, Monetary Policy Statements or Monetary Policy Reports and research and policy papers published by the five central banks, see Blix, Sellin (1999), Britton, Fisher, Whitley (1998), Hrnčíř, Šmídková (2001), Macklem (2002), RBNZ Independent review of monetary policy (2000) and Vickers (1998).

The Reserve Bank of New Zealand

The Reserve Bank of New Zealand started targeting inflation in 1990, and Monetary policy statements have been published since that time. Economic projections are presented to the general public in the form of graphs that show the paths for inflation, output and other variables - such as exports - produced by the central projection for a three-year horizon. In addition, a graph with a projected path for 90-day interest rates is also published, but only one quarter in advance. It has been stressed that the inflation forecast is not a policy projection as in the cases some other central banks, because monetary policy is endogenous in the forecasting model in order to approximate the strategy of inflation forecast targeting as closely as possible. Uncertainties and risks related to the central projection and decisions on interest rates are described verbally. The central economic projection and a description of risks and uncertainties correspond to the Governor's decision. The MPC has only an advisory role, and the minutes from the monetary meetings are not published.

The internal policy debate has three stages. The first stage is focused on broadening the policy debate. Important issues that should be discussed during the policy debate are identified. In order to capture the whole range of feasible policy options and to ensure that the policy debate is robust, selected MPC members are asked to prepare brief notes advocating a "hawkish" and "dovish" policy stance. The second stage consists of a presentation of the model-based central projection with a sensitivity analysis and risk scenarios requested by the MPC. In the third stage, the debate is narrowed in order to reach conclusions, and the policy statement is drafted. The central projection plays a key role in the policy debate, but it is not the only factor affecting policy decisions.

The Bank of Canada

The Bank of Canada started targeting inflation in 1991, and monetary policy reports have been published since 1995. The inflation projection presented to the general public takes the form of a one-year point estimate with an accompanying verbal description of the general economic outlook, including the risks of the projection. The economic projection is produced as the most likely path for the economy. Although the projection is based on the model working with monetary policy rules, it is not called a forecast in order to emphasise that the point estimate of future inflation is conditional on various assumptions. In comparison to the

Bank of England or the Riksbank, the Bank of Canada communicates about uncertainty in a much less formal way using a verbal description of important risks and their potential impact on the inflation outlook and a verbal description of alternative scenarios. It is often emphasised that a multiple-model approach has been taken in order to overcome model uncertainty.

The internal process starts with the staff producing an economic projection that will be the reference points for further steps of the decision-making process. Although a suite of models is used, there is a core model for medium-term projections. In the second step, the main risks are selected by the Council, partly reflecting the staff's suggestions, and alternative scenarios are specified for alternative simulations. In addition to risk analysis, alternative policy scenarios are also considered and represented with alternative policy rules. As a result, the Council is presented with a range of projections and a range of policy simulations that can be compared to the reference projection. Then all projections and policy simulations and additional off-model information are discussed during the meeting where directors and experts can recommend a particular policy reaction. Finally, the Council meets to decide on an appropriate policy reaction, which must be consensual.

The Bank of England
The UK started targeting inflation in 1992. Inflation Reports have been published by the Bank of England since that time. The Minutes of the MPC meeting are published with the names of the MPC members and their specific votes. Economic projections presented to the general public have the form of two-year fan charts for inflation and output growth. Fan charts are constructed around a model-based central projection. The central projection corresponds to the mode of the MPC's subjective probability distribution. Inflation Reports often stress that decisions on interest rates are based on a broader set of information than used for the construction of fan charts, and that monetary policy is not automatically derived from the fan chart. While the core model works with 150 variables, information discussed on the pre-MPC briefing typically consists of 500 charts and tables and 1000 variables. Fan charts are attributed two roles. Internally, their creation facilitates monetary policy debates. Externally, they help to illustrate the degree of uncertainty faced by the MPC.

The Bank of England organises several rounds of meetings in order to produce the final projection. In the first step, the suite of models is used to produce the draft projection. The projections are run under the fixed interest rate assumption, and residual adjustments are made when necessary to correspond better to expert views or off-model information. Sometimes, alternative projections are prepared conditioned on the higher and lower values of interest rates. In the subsequent rounds, the draft projection, off-model information and assessments of risks are discussed using both "bottom up" and "top down" approaches in order to ensure that the final version represents the MPC views. After individual risks are evaluated by the MPC and the staff, they are aggregated to give the overall balance of risks that is then used to produce fan charts. As a starting point, historical distributions of exogenous variables and equation error terms are taken, but the final version represents a subjective assessment of risks. The final projection is not interpreted as the most likely path for inflation, because not all information have been included in the draft projection and subsequent risk assessment and because the projection is conditional. Votes of the MPC members are independent.

The Swedish Riksbank

The Swedish Riksbank started targeting inflation in 1993, and Inflation reports have been published since that time. The Riksbank also publishes Minutes of the monetary policy meetings. Inflation projections in the form of a two-year fan chart have been a part of the Inflation reports since 1997. The Riksbank communicates about uncertainty related to monetary policy with the help of the main scenario and a verbal description of the risk spectrum around the main scenario. The fan chart probability distribution and the table with percentage probability of different outcomes illustrate the risk spectrum graphically. The main scenario has been defined as the most likely inflation path, because this definition avoids any impact of extreme events on the decision even though the Riksbank is aware that there is a disadvantage with this choice since the whole distribution is not considered. The risk spectrum need not be symmetrical due to the introduction of skewness of the composed probability distribution. For example, there is a downside risk if the inflation forecast is more likely to overestimate future inflation.

Internally, the main scenario and the risk spectrum are created in several steps. The "bottom-up" process is used, and the main scenario and risks are mostly prepared by experts. If the Board disagrees with the outcome of the process, the main scenario or inflation forecast distribution can be adjusted. The main scenario of the inflation projection is based on the model forecast obtained from a suite of models. Then uncertainty intervals for important inflation factors are constructed. The assessments of risk factors are subjective because the stochastic approach would not allow several models, off-model information and subjective judgments on future risks to be considered. Finally, the inflation forecast distribution is composed from the uncertainty intervals with a methodology that has been developed especially for this purpose by the Riksbank. The weights of individual factors for aggregation of distributions are derived from the underlying forecasting model. The methodology is similar to that of the Bank of England – for example, it uses a two-piece normal distribution – but it works with uncertainty intervals differently.

The Czech National Bank

The CNB started targeting inflation in 1998, and Inflation Reports have been published since that time. The CNB publishes Minutes of the Monetary Policy Meetings that include the voting pattern without names of the Board members. Inflation projections take the form of a chart representing the inflation outlook for the whole horizon of monetary policy transmission. In order to illustrate the scope of uncertainty about the central forecast, the bands are attached to it, and the chart represents the band forecast. As a result, the public can compare the inflation target with the inflation forecast on one chart, both in the form of a bands. The projection of GDP growth is published as an interval forecast for the end of the year. The forecast is unconditional with respect to interest rates, and their future path, consistent with the forecast for the forthcoming twelve-month horizon, is verbally indicated on the press conference. Risks and uncertainties are assessed verbally in the Inflation report. In addition, important exogenous assumptions of the central forecast, such as development of import prices or external demand, are explicitly published in order to emphasise that if external conditions change, the path of policy interest rates will be different from the one indicated by the forecast.

The internal process of forecasting inflation has several stages. Initially, the Board meets with a group of directors, advisers and experts in order to discuss the initial assumptions of the forecast. Attention is paid to model assumptions as well as to the forecasts of external variables, and several alternative scenarios are specified. Then the central forecast emerges from the interaction of the core model with expert inputs. In the next stage, the central forecast and outcomes of alternative policy simulations are presented to the Board and the group of directors, advisers and experts, who can then require further adjustments or to suggest leaving out specific alternative policy simulations. After this meeting, the Inflation report is drafted. For the purpose of Inflation report, the bands, whose widths are calibrated by experts independently from the central forecast, are attached to the central forecast in order to illustrate the risks. During the policy meeting, the new forecast is presented. Afterwards, the Board discusses the forecast and votes on policy decision in a closed meeting, and one of the advisers records the Minutes. The Minutes focus on describing the reasons behind the decision and on illustrating the uncertainties related to the forecast. The votes of the Board members are independent, it is not necessary to reach a consensus. If no consensus is reached, the voting pattern is published in order to give additional information about uncertainty to the general public.

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