Monetary policy-making under uncertainty

Uncertainty is a characteristic of the real world that plays an important part in the decision-making process of all economic agents. This also applies to central banks, which need to take policy decisions in an environment of considerable uncertainty regarding current and future economic conditions and the functioning of the economy. The relevance of uncertainty has been recognised in the design and implementation of monetary policy for a long time. In recent years advances in academic research have attempted to shed new light on the implications of uncertainty for monetary policy-making. This article provides an overview of the concepts discussed in the literature with a bearing on the conduct of monetary policy.

Three broad forms of uncertainty are identified and their implications examined. The first relates to the imperfect knowledge of the "state" of the economy, that is, the current economic conditions and developments. This issue is linked to the availability and quality of information on economic developments. The second is related to the "structure" of the economy, that is, the relations describing the behaviour of economic agents that shape the transmission mechanism of monetary policy. The third aspect arises from strategic interactions between central banks and private agents, which affect market expectations and the behaviour of economic agents.

It is argued that the presence of these three forms of uncertainty lends support to monetary policy strategies characterised by three basic features. First, an orientation towards the medium term, which eschews attempts at fine-tuning economic developments at shorter horizons. Second, a diversified approach to the analysis of information, which is robust to different views (or paradigms) about the functioning of the economy. Third, a clear and overriding focus on the objective of price stability as a credible anchor for expectations. The ECB's stability-oriented monetary policy strategy provides an example of a strategy which reflects these features and which can – in turn – be seen as an answer to the three main sources of uncertainty identified in this article. This article thus complements the article entitled "The two pillars of the ECB's monetary policy strategy" published in the November 2000 issue of the ECB Monthly Bulletin.

1 Introduction

The presence of uncertainty has important implications for monetary policy-making. This has been recognised in academic research for a long time and has generated a considerable body of literature that attempts to analyse and to evaluate monetary policy-making under uncertainty.[1] In the light of this, this article first identifies different categories of uncertainty that all central banks face. In this regard, the situation of the ECB is by no means unique, although the specific features of the euro area create additional challenges. The article then summarises the general findings that have emerged from the literature concerning the appropriate conduct of monetary policy in an uncertain environment. Finally, it examines the implications for the ECB's monetary policy strategy.

2 Different sources of uncertainty that affect monetary policy-making

In this section, three broad categories of uncertainty are discussed: uncertainty about the state of the economy, uncertainty about the structure of the economy and uncertainty arising from strategic interactions between central banks and private agents.

1 *Recent contributions to this literature were presented at the conference on "Monetary policy-making under uncertainty" organised by the ECB and the Center for Financial Studies (CFS) in December 1999. These contributions and a summary of the conference proceedings can be found on the ECB's website at http://www.ecb.int.*

Uncertainty about the state of the economy

A challenge that faces all central banks is to assess accurately the prevailing economic conditions, which are sometimes referred to as the state of the economy. Such an assessment is essential, as it helps to identify the nature of shocks hitting the economy and the resulting risks to price stability. It thereby forms the basis of the monetary policy decisions needed to ensure price stability over the medium term. Uncertainty surrounding the analysis of current economic conditions arises at two levels.

First, the information that underlies this analysis is often imperfect. Such imperfections concern data on a broad range of monetary, financial and economic variables. The availability and the quality of these data, including their timeliness and reliability, vary across different types of data (see the box opposite). Some data, such as certain financial market prices, are available on a continuous and timely basis and are normally not revised. However, most economic and financial data are only available with some delay and can be revised following their initial release. Such revisions typically arise from further information becoming available (including the updating of weights and samples), from the correction of measurement errors or, albeit less frequently, from reclassifications and changes of methods and definitions. The first of these factors, of course, reflects the potential trade-off between timeliness and reliability.

In the case of the euro area, the data for the Harmonised Index of Consumer Prices (HICP) are available at a monthly frequency, in a timely fashion, and are normally not revised. Data on monetary aggregates – while subject to some revision – can also be compiled at a monthly frequency and with only a short delay from the balance sheets of Monetary Financial Institutions. These data are available earlier (and with less uncertainty) than most information on economic activity. Moreover, the fact that monetary aggregates are measured directly rather than indirectly by means of surveys or similar techniques greatly enhances their reliability.

However, while the quality, including timeliness, of both HICP data and monetary and financial data is high, further improvements are still needed. In some other areas, timeliness can certainly be improved, and, in many cases, there are problems with data quality that lead to sometimes considerable revisions at the euro area level. These issues are addressed notably in the Action Plan on EMU statistical requirements prepared by the European Commission in close co-ordination with the ECB and presented to the ECOFIN Council in September 2000.

Second, data on monetary, financial and other economic indicators can be distinguished from unobservable "synthetic" indicator variables that have been proposed as a way of structuring and summarising a possibly large amount of the observable data. Examples of such indicators are potential output as a measure of the economy's productive capacity and the output gap (i.e. the deviation of actual from potential output) as a measure of the degree of capacity utilisation in the economy. Other examples of unobservable indicators include various notions of equilibrium real interest rates, equilibrium exchange rates and various measures of excess liquidity conditions.

The uncertainty surrounding these unobservable indicator variables may be expected to be significantly greater than for observable information, since these indicators have to be estimated. These estimates are not only affected by uncertainty with respect to the data that are used in the estimation, but can also be significantly affected by the statistical methods that are employed for estimation. Moreover, the concepts on which their definitions are based may be controversial. With respect to the uncertainties regarding the notion of potential output and the output gap, see, for example,

Box

Timeliness and reliability of statistics

A broad range of monetary, economic and financial data is used in the assessment of the outlook for price developments. The availability and quality of these data are essential for ensuring that appropriate monetary policy decisions are taken. Indeed, availability and quality are issues of concern to all users of statistics. In the case of euro area statistics, which are aggregated from national statistics, defining harmonised methods and practices is an additional issue of importance.

In this box, timeliness and reliability, which are regarded as integral parts of the quality of the data, are briefly discussed. All other things being equal, faster data availability is desirable, but there is generally a trade-off between timeliness and reliability. For instance, indicators designated as "flash estimates" are released on a very timely basis. However, this may be achieved by the use of only partial information, which increases the risk of significant revisions in later releases. How the balance between timeliness and reliability can best be resolved varies between indicators, depending on factors such as their importance in economic assessment, their frequency, their level of aggregation and their volatility.

Timeliness

As regards the timely availability of data, it is important that data are released with a short lag following the end of the reference period. Some data, such as those on market interest rates or stock prices, are available in "real time". However, most other data become available with various lags, which partly depend on the frequency of the indicator.

Qualitative survey data are often available within a few days following the end of the month to which they refer, or even during this month. Price indicators for the euro area (such as the HICP) and monetary aggregates are usually available within a month following the end of the period to which they refer. Data on euro area producer prices are released after slightly more than one month. With regard to labour market indicators, the data on unemployment are generally released around one month after the end of the month of reference. Other euro area data, such as those on wages, employment and the labour force, tend to be less timely. Quantitative indicators related to the real economy, such as monthly industrial production or quarterly national accounts, are usually available with delays of two to three months. There are similar publication lags for monthly data on euro area external trade. Finally, the timeliness of fiscal data, most of which are released at annual frequency, varies significantly across countries. Sufficient geographical coverage of the euro area needs to be available before euro area aggregates can be compiled. Thus, national data may be released for some Member States before their counterpart for the euro area becomes available.

Reliability

It is particularly important for the reliability of euro area data that harmonised statistical concepts are used across Member States. For national statistics, many aspects influence data reliability, such as adequate coverage and estimation methods that ensure an accurate description of the underlying economic phenomenon. For instance, the coverage of goods and services included in the HICP has been extended since the introduction of the HICP in 1997 in order better to reflect the composition of consumers' purchases.

Large and frequent revisions to initial and subsequent releases undermine reliability. Revisions of first releases are mainly due to new or more complete information, but other factors, such as the introduction of conceptual improvements, seasonal adjustments or adjustments within an accounting framework, are also potential reasons for revisions. Depending on the indicator, different magnitudes of revisions may be considered acceptable.

For the euro area, HICP data are normally not revised and revisions to M3 data tend to be small. Since mid-1998, when euro area national accounts were first released, revisions to quarter-on-quarter growth rates of real GDP have tended to be more substantial. The difference between the highest and the lowest estimate of quarter-on-quarter growth in a given quarter has averaged 0.2 percentage point, with usually larger revisions in terms of the components of GDP. Revisions have generally been largest between Eurostat's first and second releases, as data available at the time of the first release have usually covered around 75% of the euro area. As, by the time of the second release, more information is available from national statistical institutes, revisions to further releases have been smaller on average. Member States are currently working towards an earlier release of national accounts, which should improve the coverage of the first estimates for the euro area released by Eurostat, and therefore their reliability.

the article entitled "Potential output growth and output gaps: concept, uses and estimates" in the October 2000 issue of the ECB Monthly Bulletin.

In order to interpret the state of the economy and its implications for future price stability, it is essential that central banks examine the available data and the indicators to identify the nature and persistence of the particular shocks that are driving observed economic developments. Whether shocks occur on the demand or supply side of the economy, whether they originate from domestic or foreign sources, and whether they are judged to be transitory or long-lasting will all have a bearing on the assessment of the state of the economy and the appropriate monetary policy response. While some shocks, such as unexpected changes in oil prices, are directly observed, others, like changes to preferences and technology, are not.

A prominent example of the latter relates to the possible emergence of a "New Economy". Such developments may change the economy's productive capacity either permanently or for a sustained period, but are intrinsically difficult to identify on the basis of historical information, thereby adding considerably to the uncertainties surrounding monetary policy-making.

Uncertainty about the structure of the economy

In addition to, and intimately linked with, the uncertainty about the state of the economy, central banks also have limited knowledge about the structure and functioning of the economy. A good understanding of how economic shocks are propagated over time and how monetary policies are transmitted to future price developments allows the central bank to take appropriate policy decisions to counteract possible threats to price stability in a forward-looking manner.

In the face of a lasting shock to oil prices, for example, it is important for monetary policy to understand how this shock will affect the economy. On the supply side, a lasting increase in oil prices will lead over time to increases in raw materials prices, intermediate input prices and producer prices along the chain of production, and thereby to increases in costs and a reduction in profitability. As regards the demand side, an increase in oil prices will have a direct effect on consumer prices, which stems from the increase in overall energy prices, as well as an indirect effect, which arises from the pass-through of producer to consumer prices. Moreover, an oil price increase, through its impact on the terms of trade, will also reduce available aggregate income. It is important to quantify the individual effects arising from the initial shock to oil prices since they jointly influence the risks to price stability over the medium term.

Uncertainty about the structure of the economy arises from two sources. First, there is fundamental uncertainty about which models provide suitable descriptions of the structural relationships in the economy. While various models have helped to deepen understanding of the economy, none has yet provided a fully satisfactory, unified and uncontroversial description of the transmission process. This reflects not only the complexity of the various transmission channels within modern market economies, but also the fact that there is no consensus among economists about how these economies work. Since each model per se constitutes a simplification which abstracts from relevant aspects of reality, central banks always face the problem of deciding which model or class of models is most suitable to use given the prevailing economic circumstances. As a result, central banks cannot afford to rely on a single model of the economy, but need to have available a number of alternative modelling tools.

For example, among the many structural relationships that determine the transmission of monetary policy, knowledge of the relationship between inflation and its determinants remains limited, although considerable research has been undertaken. There is a widespread consensus that inflation is a monetary phenomenon in the long run. At the same time, there is a multiplicity of different approaches to modelling the inflation process at short and medium-term horizons. Two main modelling traditions (or "paradigms") can be distinguished. One approach assigns an important role to monetary developments in determining future inflation. In other models, such as Phillips curve models, excess demand in goods and labour markets is the main driving force behind changes in prices and wages.

Second, even if there were a consensus on a suitable model of the economy, considerable uncertainty would remain regarding the strength of the structural relationships within that particular model. This form of uncertainty relates to the parameters of the structural relationships that need to be estimated. Inevitably, available parameter estimates are always affected by data imperfections and by the particular econometric techniques that are employed for estimation. An even more fundamental problem is that parameters may vary over time as a result of structural change in the economy. These sources of parameter uncertainty hinder economic analysis insofar as they make an assessment of relationships between economic variables more difficult.

Uncertainty about parameters confronts all central banks, but seems particularly relevant for empirical models of the euro area since their estimation has to rely on historical back data which stem from the period prior to the formation of Economic and Monetary Union (EMU), when the member countries experienced different monetary policy regimes within different institutional settings. Moreover, to the extent that models are estimated for the euro area as a whole using data which are aggregated across member countries, conducting empirical analysis into structural relationships may also be subject to aggregation problems. Such problems relate to the methods being used for aggregating data for the member countries, which may, in some cases, not be sufficiently harmonised, as well as to the aggregation of structural relationships themselves, which may differ across countries and thereby result in complex, possibly non-linear relationships at the euro area level.

Strategic uncertainty

Another form of uncertainty facing central banks is sometimes referred to as strategic uncertainty. This form of uncertainty relates to the interaction between private agents and policy-makers and, in particular, to the role of expectations, which may crucially influence the transmission of monetary policy. It is important to realise that the central bank is confronted with some degree of uncertainty about the reaction of economic agents and financial markets to its own policy decisions

and announcements. Conversely, economic agents may be unsure about the motivations, actions and intentions of central banks.

In general, the task of monetary policy-making will tend to be facilitated if strategic uncertainty is reduced in both directions, i.e. if economic agents as well as central banks exhibit stable, reliable and broadly predictable patterns of behaviour. A clear definition of the overriding policy objective and the announcement of a strategy to guide and explain policy choices are key instruments to reduce strategic uncertainty and to enhance credibility on the part of the central bank.

A key concern for central banks has therefore always been to maintain credibility with respect to their ability and commitment to achieve their policy goals. Credibility tends to induce a virtuous circle. If economic agents can confidently rely on the central bank to keep prices stable over the medium term, then they will themselves be more likely to exhibit behaviour that is more stable, more oriented to long-term relationships and more conducive to the maintenance of price stability.

In particular, if inflation expectations on the part of the public, social partners and financial markets remain firmly anchored at levels consistent with price stability in the face of temporary shocks to price developments, monetary policy tends to be more effective in maintaining price stability over the medium term. Moreover, if the behaviour of central banks is well anticipated by the markets, financial market prices may move in a direction supportive of the maintenance of price stability in a self-correcting manner and may thus actively reduce the need for strong movements in central bank policy instruments.

Thus, in the face of considerable uncertainty about the economy it is important that central banks do not themselves become a source of additional uncertainty in this regard. This supports the case for a clear, steady, consistent and reliable focus on the overriding objective of price stability over the medium term and cautions against overly ambitious – and potentially destabilising – attempts at fine-tuning economic developments at shorter horizons.

3 Some lessons from economic research

This section presents a review of some of the main arguments that have been made in the economic literature regarding the implications of different forms of uncertainty for monetary policy-making.

Earlier views

The implications of the existence of uncertainty for the optimal setting of monetary policy instruments have been recognised in economic literature for at least half a century. Already in the late 1940s and early 1950s it was recognised that reliable information about the long and variable lags in the transmission of monetary policy is typically not available. This led a number of academic economists to warn strongly against the implementation of policies that aim at fine-tuning economic activity. It was argued that these policies may be counterproductive if the limitations in the knowledge of the monetary transmission mechanism are not taken into account. They favoured a "non-activist" approach to monetary policy-making that places less emphasis on stabilising short-term economic developments and relies on monetary growth as a guide to policy-making with a medium-term orientation.

Despite existing scepticism about the usefulness of activist policies in the presence of long and variable lags, academic research in the 1950s and 1960s relied rather confidently on the knowledge of the monetary transmission process available at that time. One important finding of this research is that

the prescriptions for setting a particular policy instrument do not depend on unforeseen shocks if they affect the economy in particularly simple ways. Different implications arise, however, if uncertainty enters the economic structure in more complex (and more realistic) ways. For example, uncertainty about key parameters describing the transmission of monetary policy provides a rationale for an "attenuated" approach to monetary policy-making in the sense of reacting less vigorously to incoming information than would be optimal if such uncertainty did not exist. This result, which is known as "Brainard's conservatism principle", has been used as one explanation of the commonly observed central bankers' practice of moving interest rates in a gradualist fashion. However, it has been known from the outset that this principle is not universally robust, but rather depends on the relationships between all the uncertain parameters of the economic structure.

More recent views: data, parameter and model uncertainty

Recently, academic interest in optimal monetary policy-making under uncertainty has revived. The associated literature has focused extensively on two of the three broader forms of uncertainty classified above, namely data uncertainty on the one hand and parameter and model uncertainty on the other. References to the literature and an illustration are provided in an annex to this article.

Data uncertainty

The relevance of data uncertainty arising from measurement error in key macroeconomic variables provides backing for the earlier cases of an attenuated and non-activist approach to policy-making. Recent research has shown that central banks should moderate the responsiveness of the policy instrument to initial data releases when these data are expected to be subject to measurement error. The reason is that, when a measurement error occurs, a strong policy response to mismeasured data will induce unnecessary fluctuations in the interest rate, resulting in unintended movements in output and inflation. In addition, the adverse effects arising from imperfect data should be mitigated by using the whole set of available information to cross-check the imperfect data against all other relevant sources of information and gauge the extent to which the data may be subject to measurement error. The weight given to the individual information variables will depend on how precisely those variables are measured themselves.

In recent studies, considerable attention has been focused on the uncertainty regarding one particular economic variable, namely potential output. This is understandable, given that potential output (particularly the relationship between actual and potential output, i.e. the output gap) is often considered to be an important variable in determining the strength of inflationary pressures. The adverse effects of errors in estimating potential output can be more long-lasting and greater than those arising from the mismeasurement of other data. This is because estimates of potential output – a variable that can never be directly observed – are typically subject to very large revisions, even many years later.

Parameter and model uncertainty

As already mentioned above, Brainard's conservatism principle is not universally robust, but depends on the exact form of parameter uncertainty. More recent literature has emphasised circumstances in which parameter uncertainty should lead a policy-maker to vary the policy instrument more than would be optimal in the absence of such uncertainty. Recent research, for example, has shown that uncertainty about the persistence of the inflation process can lead the policy-maker to adjust interest rates more

vigorously, since the policy-maker can reduce uncertainty about the future development of inflation this way. Similarly, when such uncertainty arises from imperfect credibility, the policy-maker may be well-advised to act more decisively.

Policy-making under parameter uncertainty is typically studied by relying on probabilistic knowledge of a well-defined range of alternative parameter values and employing the well-known laws from probability theory. However, uncertainty about model parameters or, more generally, about model structures can be so complex that this approach is very difficult to justify. A number of studies have therefore started expressing model uncertainty in the form of a variety of alternative models, which can be considered by the policy-maker to represent alternative, possibly rival descriptions of the actual economic structure. In this context, the problem can be cast in terms of ensuring "robustness" of monetary policies across models, in the sense of being capable of delivering good policy outcomes under alternative structures. This approach has considerable intuitive appeal since central banks normally avail themselves of a suite of alternative quantitative models of the economy as opposed to relying on a single all-encompassing one.

4 Implications for the ECB's monetary policy strategy

The key findings of research concerning the appropriate conduct of monetary policy in an uncertain environment are threefold. First, under a broad set of circumstances, the central bank is well advised to pursue attenuated and non-activist policies directed at the medium term when data or key features of the monetary policy transmission process are subject to uncertainty. The degree of attenuation is, in general, related to the extent and nature of the uncertainty.

Second, central bankers and academics seem to agree on the desirability of robustness of monetary policy in the presence of data and model uncertainty. This suggests that central banks should not, in general, rely exclusively on any particular individual indicator or model in isolation (be it a particular monetary aggregate, a measure of the output gap or a particular model-based inflation forecast). Instead, central banks need to cross-check information from different sources against the full set of available information. Robustness can also be taken to mean adopting policies capable of delivering reasonably good outcomes under a range of alternative plausible models of economic structures, instead of only focusing on an optimal outcome in a single dominant model.

Third, central banks have always stressed the importance of credibility for monetary policy. Credibility with respect to a well-understood objective helps to provide a clear and reliable anchor for expectations and can thus be seen as reducing strategic uncertainty in the economy.

The awareness of the presence and the implications of various forms of uncertainty is a major factor behind the design of the ECB's monetary policy strategy. As explained in many earlier publications, the ECB has provided a clear quantitative definition of its objective of price stability, namely "a year-on-year increase in the HICP for the euro area of below 2%" which is to be maintained over the medium term. This quantitative definition provides an anchor for market expectations and a yardstick against which the ECB's performance can be assessed and the ECB can be held accountable.

To achieve its objective of price stability, the ECB organises its analysis in two distinct, but complementary categories of analytical approaches, which are referred to as the two pillars of the strategy. The two-pillar structure provides the framework of analysis and the set of tools for achieving the objective of price stability. Their organisation

reflects two broad classes of modelling approaches (or paradigms) of the transmission mechanism in the absence of consensus on a single unified "true" model of the economy. Drawing on two distinct pillars helps to induce a diversified and robust approach to monetary policy-making, which involves extensive cross-checking of information across different analytical approaches.

The first pillar encompasses a set of analyses and models with primary focus on the monetary origin of inflation. They all share a common feature, namely that monetary and credit aggregates or, more generally, monetary developments play a central role in the determination of price developments over the medium term. This approach is founded on the long-term relationship between money and prices, which characterises virtually all models of monetary economies and which has been extensively illustrated in empirical studies.

The second pillar encompasses a variety of analyses and models that emphasise the interplay between predominantly non-monetary factors in the determination of inflation. Some of these factors, such as changes in oil and commodity prices, affect price developments in the shorter term. These developments are nevertheless relevant for monetary policy, since their effects may become entrenched and may, therefore, jeopardise prospects for price stability in the medium term. Other indicators, such as shortages in the labour market, which tend to result in upward pressure on labour costs, may also signal a threat to price stability in the medium term. The biannual macroeconomic projections prepared by Eurosystem staff (and published for the first time in the December 2000 issue of the ECB Monthly Bulletin) are a part of the analysis conducted under the second pillar.

The three key messages from research, outlined above, are all reflected in the design of the strategy. First, by putting emphasis on the medium term as the time frame within which price stability is to be attained, the strategy implicitly leads to a lower weight being attached to short-run developments in indicators that are more likely to be noisy and subject to statistical uncertainty and data revisions. More generally, each indicator, under both pillars, needs to be looked at in conjunction with its record of reliability, and the uncertainty surrounding such indicators must be taken into account in their interpretation. In particular, this also applies to the staff economic projections as one form of analysis conducted under the second pillar. Presenting such projections in the form of ranges for the outcomes of economic variables – where the ranges are determined on the basis of past errors in such projections – is one way of conveying this uncertainty.

Second, the examination of monetary and economic developments under the first and second pillars provides a robust framework that allows for the cross-checking of relevant information across different modelling approaches. The strategy avoids reliance on any single indicator, model or forecast which is likely to be highly sensitive to uncertainty about the data or the structure of the economy. Thus, the strategy recognises that central banks – and economists in general – do not have full knowledge of any single "true" model and cannot afford to rely on a single model without the risk of making major policy errors. The strategy is also consistent with findings in the literature, which suggest, other things being equal, that policy should be based to a lesser extent on unobservable and less reliable indicators like the output gap, compared with those that can be observed more directly and measured more accurately, such as many monetary and financial variables.

Third, the quantitative definition of price stability is a clear and visible expression of the ECB's commitment to achieving its primary policy objective over the medium term. This public commitment should enhance credibility and reduce uncertainty

about medium-term price developments. The medium-term and forward-looking orientation of the ECB's strategy takes account of central banks' limited knowledge of the long and variable lags in the transmission mechanism. It also acknowledges that monetary policy cannot – and should not attempt to – control price developments at shorter horizons.

5 Concluding remarks

This article has identified and examined three broad categories of uncertainty relevant for monetary policy-making that all central banks in the world are facing. In this sense, the situation of the ECB is by no means unique. In the euro area, however, these uncertainties may be heightened by the implications of the regime shift associated with the formation of EMU and reflect the specific features of the euro area. This creates additional challenges for the monetary policy of the ECB. First, when assessing the prevailing economic conditions, the ECB has to focus on aggregate euro area-wide data, where availability and quality are in some areas still limited. Second, when taking monetary policy decisions, the ECB is confronted with a lack of knowledge about the structure of the euro area economy, which itself is likely to change in the new institutional setting of EMU. Third, the ECB as a new institution has to be particularly transparent and predictable to prevent monetary policy itself becoming a source of uncertainty.

The main features of the ECB's strategy – the quantitative definition of price stability, its medium-term orientation and its two-pillar structure – reflect an honest recognition of limited knowledge of the economy and uncertainty about "long and variable lags" in the transmission of monetary policy and the importance of credibility. These issues have been stressed by central banks and academics for a long time. Recent work on the implications of data, model and parameter uncertainty supports, on the whole, a robust and diversified approach to monetary policy-making, like that adopted by the ECB. In particular, the two-pillar strategy of the ECB, with first a prominent role for money and second an analysis of a wide range of other economic and financial indicators, provides a robust framework for a broadly based assessment of risks to price stability. This strategy is well equipped to deal with the various forms of uncertainty that all central banks face and also meets the particular challenges arising in the euro area. The inevitable data uncertainty associated with the estimation and measurement of key macroeconomic variables supports the ECB's medium-term orientation and its rejection of fine-tuning economic developments. At the same time, the limited availability and reliability of data in some areas of economic statistics make clear the need for further improvements to the euro area statistical framework. Particular effort is currently being devoted to this aim.

With respect to uncertainty about the structure of the euro area economy, the two pillars of the ECB's strategy provide a diversified approach to analysing the large amount of data used in the decision-making process. This diversified approach explicitly accounts for the use of a variety of alternative models suitable for analysing the propagation of shocks and the transmission of monetary policy. Considering classes of models (or paradigms) which differ in some fundamental way, rather than relying on a single approach or indicator, reduces the risk of policy errors. The ECB's strategy thereby facilitates the adoption of a robust monetary policy that is capable of delivering good policy outcomes under all main sources of uncertainty.

Annex: Monetary policy-making under uncertainty: more recent results

The more recent results on monetary policy-making under uncertainty emerged from a number of studies that analysed the performance of monetary policy when economic data are subject to mismeasurement and when there is uncertainty about the appropriate specification of economic models.

The case for attenuation and non-activism

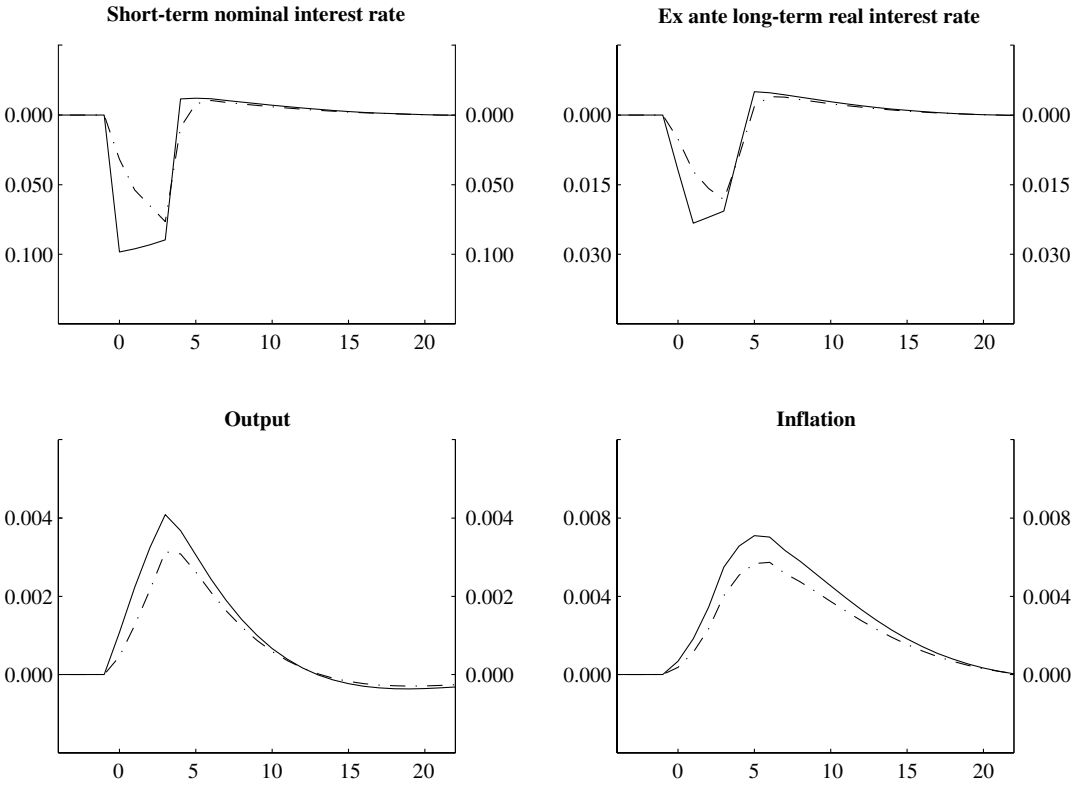
When economic data are subject to measurement error, recent studies provide two basic prescriptions.[2] First, the direct response of monetary policy to initial data releases should be attenuated, and, second, policy-makers should make efficient use of the whole set of available information by cross-checking imperfectly measured data against all other relevant sources of information and gauging the extent to which the initial data are subject to mismeasurement.

The chart below provides a numerical example where both prescriptions are intimately related. The example illustrates the consequences of a measurement error in

2 *See Athanasios Orphanides (1998), "Monetary policy evaluation with noisy information", Finance and Economics Discussion Series, 1998-50, Board of Governors of the Federal Reserve System, and Lars E. O. Svensson and Michael Woodford (2000), "Indicator variables for optimal policy", ECB Working Paper No. 12.*

Chart

Responses to a persistent measurement error in output



Note: The simulations are based on the relative real wage contracting specification, which is referred to as the RW specification in ECB Working Paper No. 30. Short-term nominal and ex ante long-term real interest rates are annual rates, given as percentages. Output is the log difference from the baseline, as a percentage. Inflation is the log change in the output deflator over four quarters, as a percentage.

output data within a small macroeconomic model for the euro area.[3] The size of the measurement error is minus 0.2 percentage point of quarterly output and it lasts for four quarters. Within the model, monetary policy is assumed to maintain price stability by following a simple rule that links the short-term nominal interest rate to developments in inflation and deviations of observed output from potential. Changes in the short-term nominal interest rate affect aggregate demand through their impact on the ex ante long-term real interest rate.

The left panel in the top row of the chart shows the policy-maker's misguided moves in the short-term nominal interest rate resulting from the measurement error in observed output. The right panel in the top row and the two panels in the bottom row depict the resulting developments in the long-term real interest rate, output and inflation respectively. The solid line refers to the case where the policy-maker reacts directly to the observed output data. The dash-dotted line corresponds to the case where the policy-maker is conscious of prospective revisions to the observed data and forms an efficient estimate of output using all information at his disposal and then reacts to this efficient estimate rather than to observed output.

It is apparent that the policy-maker's direct response to observed output induces unnecessary fluctuations in the interest rates, resulting in unintended movements in output and inflation. By contrast, when the policy-maker responds to his efficient output estimate, interest rates fluctuate less and policy performs better in terms of maintaining price stability. This is because the efficient output estimate is based on current and past observations on all estimation-relevant variables, the relative weights of which depend on how precise these variables are. As a result, the policy-maker attaches only a low weight to the imperfect output data and only gradually adapts his output estimate to incoming new information. A direct response to observed output data would have to be more attenuated in order to shelter the economy from the adverse effects of possible measurement error to the same degree.

Given that estimates of potential output are never observed and are often revised years later, the adverse effects that can arise from a misperception of potential output can be significantly greater. The relevance of this problem has been pointed out in a recent study for the United States.[4] This study shows that estimates of potential output that were available in real time to policy-makers in the 1970s may have significantly overstated the US economy's productive capacity at that time compared with revised estimates that became available much later on. Simulations of activist stabilisation policies based on these misperceived real-time estimates have been proposed as one possible explanation for the persistent rise in inflation observed in the 1970s. This finding can be interpreted as lending further support to rejecting activist monetary policies that are conditioned on intrinsically unreliable variables such as potential output.

The case for robustness

There are two approaches to studying monetary policy-making under model uncertainty which both emphasise the importance of robustness. The first seeks to design an optimal policy that is robust in the sense of sheltering the economy from the worst possible outcomes if the policy-maker's model is subject to misspecification. The second centres on robustness in the sense that a policy is capable of delivering similar outcomes in a variety of alternative models.

The first approach assumes that the policy-maker's problem is so complex that it cannot be formalised by specifying an a priori probability distribution over a range of alternative models. In this case the policy-

3 *See Günter Coenen and Volker Wieland (2000), "A small estimated euro area model with rational expectations and nominal rigidities", ECB Working Paper No. 30.*

4 *See Athanasios Orphanides (2000), "The quest for prosperity without inflation", ECB Working Paper No. 15.*

maker's problem is subject to so-called "Knightian" uncertainty. From such a perspective, model uncertainty relates to the existence of a range of unspecified alternatives surrounding a particular reference model that is considered an approximation to the true but unknown model of the economy. Two types of uncertainties can be distinguished within this setting: unstructured model uncertainty, which is manifest in arbitrarily serially correlated shocks that may result from omitted-variable misspecification, and structured model uncertainty, which arises when particular parameters are identified as the source of misspecification.[5] One interesting finding from these studies is that a more aggressive policy may be called for when the policy-maker is compelled to set his policy instrument cautiously by ensuring a minimum level of performance under the worst possible conditions.

The second approach focuses on the robustness of monetary policies across a variety of alternative models of the economy. Following this approach, one such study has recently evaluated the robustness of monetary policies across four macroeconometric models of the US economy by taking the policies that perform well in one model and measuring their performance in each of the other models.[6] The results of this study provide support for the robustness of policies that link the nominal interest rate to current outcomes of inflation and economic activity but also account for sufficient gradual adjustment of the nominal interest rate. Such policies perform well compared with others that rely on forecasts of future inflation as opposed to current information. This result shows that a model-based inflation forecast always depends in a very complex fashion on the specific structure of the underlying model. A monetary policy that is mechanistically based on a forecast obtained from a particular model may therefore result in bad outcomes if this forecast is used in any other model. This provides an additional reason why one should not rely on a single model-based forecast for monetary policy purposes; rather, any such forecast needs to be cross-checked with forecasts obtained from alternative models and information acquired using different techniques and forms of analysis.

5 *See Lars P. Hansen and Thomas J. Sargent (2000), "Robust control and filtering of forward-looking models", manuscript, University of Chicago and Stanford University; Alexei Onatski and James H. Stock (2000), "Robust monetary policy under model uncertainty in a small model of the U.S. economy", NBER Working Paper No. 7490; and Robert J. Tetlow and Peter von zur Muehlen (2000), "Robust monetary policy with misspecified models: does model uncertainty always call for attenuated policy?", Finance and Economics Discussion Series, 2000-28, Board of Governors of the Federal Reserve System.*

6 *See Andrew Levin, Volker Wieland and John C. Williams (1999), "The performance of forecast-based monetary policy rules under model uncertainty", paper presented at the ECB/CFS conference on "Monetary policy-making under uncertainty", December 1999 (see the ECB's website at http://www.ecb.int).*