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Risk and Uncertainty: Macroeconomic Perspective

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Abstract

The paper discusses main concepts and definitions related to macroeconomic uncertainty as operational concept. It proposes classifications of uncertainty according to areas of application and measurements. Properties of different methodologies of assessing uncertainty used in empirical analysis are discussed. The paper also analyses positive and negative aspects of particular methods and illustrates one of the most relevant problems, which is the biasness of the experts' based assessments, by the analysis of the National Bank of Poland Survey of Professional Forecasters. A simple uncertainty indicator based on forecast errors for the analysis of inflation uncertainty in Poland is computed and evaluated.

1. Introduction

In recent years there has been a significant increase in research aiming at measuring and quantification of macroeconomic uncertainty. Seminal works on macroeconomic uncertainty have been published as early as in 1920's. However, for a long time, the topic of assessing such uncertainties has been overlooked and works concentrated on a more narrow investigation into risks associated with particular measurable indicators, e.g. in inflation (the risk of missing inflation target) and exchange rate (risk of falling outside exchange rate realignment) and similar. As the dynamics of such indicators was usually noticeable, such risk analysis was regarded as useful for practical purposes. During the last decade, however, in a number of countries there has been little inflation movement, stagnant unemployment and the exchange rates have been anchored in relatively narrow intervals. At the same time, there was a more general perception of macroeconomic uncertainty which resulted, among other things, in rather large discrepancies between macroeconomic forecasts.

The relevance of this, not directly observable, phenomenon of macroeconomic uncertainty is substantial. Its outcome has often been described as the *real options effect*, that is the fact that the general feeling of uncertainty can affect timing of investment and, as a consequence, also consumption decisions (see e.g. Bloom, 2000; Bloom, Bond and Van Reenen, 2007). As these effects are harmful (decisions undertaken under uncertainty are suboptimal), their influence on wider macroeconomic landscape are detrimental as hiring is depressed, dissimulating employment and affecting growth. Moreover, if agents are risk averse, it increases precautionary savings, which also negatively affects growth. Finally, increased uncertainty leads to tightening financial constraints, for instance by widening the gap between saving and lending rates.

This renewed interest resulted in a stream of new research projects aiming at more precise defining, modelling and evaluating of uncertainty. There are, at present, at least three main research groups working on this topic. For the sake of this study they are dubbed the Chicago-Stanford group (lead by Baker, Bloom and Davis), the 'Columbia-New York' group (Jurado, Ludvigson and Ng) and Leicester-UCL-CREST group (Charemza, Díaz, Francq, Makarova and Zakoian,) and UCL 'Center for decision-making uncertainty' (Tuckett, Smith, Chong, Nikolic and Ormerod). There is also a stream of papers coming from other academic centres. Many of them are discussed further in this text.

Abundance of output resulting from these and other projects creates certain misunderstandings, due to definitional differences and varying measurement approach. In particular, there are numerous different measures of uncertainty proposed in the literature which might be applied interchangeably or separately and might contain similar or different messages. In the light of this, the purpose of this paper is to provide an overview of conceptual and empirical approaches that are used to formulate and assess (measure) economic uncertainty. This overview should not be considered as a 'complete' however, as the area is currently quickly developing. Also, a simple measure of macroeconomic uncertainty for Poland will be evaluated and interpreted.

The structure of the paper is as follows. Section 2 discusses the main concepts and definitions relevant for the empirical studies of macroeconomic uncertainty. Section 3 gives classifications and properties of the particular concepts used in empirical analysis. Section 4 analyses positive and negative aspects of particular approaches and illustrates one of the most relevant problems, which is the biasness of the experts' based assessments, by the

analysis of the National Bank of Poland Survey of Professional Forecasters. Section 5 shows the results of applying a simple uncertainty indicator based on forecast errors for modelling inflation uncertainty for Poland. Section 6 concludes and provides some suggestions for further research.

2. Risk and uncertainty

For the purpose of macroeconomic inference, it is relevant to distinguish between the concepts of Knightian and non-Knightian uncertainties. In the seminal publication, Knight (1921) stated that:

But Uncertainty must be taken in a sense radically distinct from the familiar notion of Risk, from which it has never been properly separated. The term "risk," as loosely used in everyday speech and in economic discussion, really covers two things which, functionally at least, in their causal relations to the phenomena of economic organization, are categorically different. ... The essential fact is that "risk" means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomenon depending on which of the two is really present and operating. There are other ambiguities in the term "risk" as well, which will be pointed out; but this is the most important. It will appear that a measurable uncertainty, or "risk" proper, as we shall use the term, is so far different from an unmeasurable one that it is not in effect an uncertainty at all. We shall accordingly restrict the term "uncertainty" to cases of the non-quantitative type. It is this "true" uncertainty, and not risk, as has been argued, which forms the basis of a valid theory of profit and accounts for the divergence between actual and theoretical competition

Knight (1921), pp. 19-20; also online edition

<http://www.econlib.org/library/Knight/knRUP1.html#Pt.I,Ch.I> , I.I.26

Developing from this statement, the *Knightian uncertainty* is understood in macroeconomics as a concept related to an aggregate and is not directly measurable. It is unobservable by nature, but proxies can be developed in order to assess, at least, its changes in time. Macroeconomic uncertainty is defined by Jurado, Ludvigson and Ng (2013) as 'the conditional volatility of a disturbance that is unforecastable from the perspective of economic agents'. Consequently, the concept of *non-Knightian uncertainty* is associated with the phenomena which might be observable *ex-post*, like inflation or exchange rate. According to the reasoning of Knight (1921) above, the non-Knightian uncertainty should be called *risk*. However, in current economic parlance the concept of risk is somewhat narrower. It is common to say about the 'risk that inflation will be outside the target bands' or the risk that 'unemployment will exceed its NAIRU level', so that *risk* is associated with the probability of reaching or missing a particular mark. Also the term 'risk' is commonly used in finance indicating chances of actual returns on an asset being different from expected return. In order to avoid confusion, in this work the *non-Knightian uncertainty* refers to the uncertainty of a phenomenon which is potentially measurable in the sense that a probability distribution of *ex-ante* realisations can be defined, but the marks (values of interest) are not defined. A simple non-Knightian uncertainty measure can be defined as a dispersion of such distribution. In such sense it is often used either colloquially or, for constructing probability forecasts. As the marks in such probability forecasts are not defined, it can therefore be conceptually regarded in a similar way to the Knightian uncertainty. It becomes a *risk* after such marks are explicitly known and addressed.

The decomposition of uncertainty proposed by Walker *et al.* (2003) can also be applied. It distinguishes between the *epistemic uncertainty*, generated by incomplete knowledge of the system by the experts and *variability uncertainty*, associated with unpredictable randomness. The variability uncertainty is often identified (or regarded as a close concept) with the *ontological uncertainty* (see e.g. Lane and Maxfield, 2005). Further discussion and adaptation of Walker's classification for inferring about inflation uncertainty is given in Kowalczyk, (2013). However, it has been criticised on the grounds of incompleteness and tautology (see Norton, Brown and Mysiak, 2006, where a review of other concepts is given).

3. Classification and measurement of macroeconomic uncertainties

Macroeconomic uncertainty can be classified further according to the application area and method of measurement. Regarding the area of application the classification can be as follows:

- (1) Policy uncertainty, that is the uncertainty related to the circumstances surrounding undertakings and outcomes of particular policy actions. The main development here is the Economic Policy Index (EPU) by Baker, Bloom and Davies (2013). Due to its easy availability and transparency it has already a substantial number of follow-on papers (see further in the text for references). The way of construction is described in more detail further in the paper.
- (2) Sentiment-related uncertainty, where sentiment is understood in the Keynesian 'animal spirit' sense (see Benhabib, Wang and Wen, 2013; Bird, Choi and Yeung, 2014; Tuckett *et al.*, 2014). There are also some commercially produced indices, like *Economic Sentiment and Uncertainty Index*. However, as the relation of these concepts to macroeconomic uncertainty is still under research, they are not further discussed in this paper.
- (3) Macroeconomic (in a wide sense) and financial uncertainty which relates to the assessment of the state of uncertainty, either as (a) macroeconomics as an aggregate, or (b) its particular components. Regarding (a), the most influential is paper by Jurado, Ludvigson and Ng (2013), resulting in development of a comprehensive measure of the state of the uncertainty of the US economy in the forecasting perspective, assessed separately for different forecast horizons. Its details are also discussed further in the paper. In this category there is also one of historically first indicators of uncertainty, Chicago Board Options Exchange Market Volatility Index (VIX), which, although formally designed for measurement of uncertainties related to financial market only, has been widely used as a proxy for the entire macroeconomic uncertainty (see e.g. Bloom, 2009; for other approaches see e.g. Haddow *et al.* 2013; for a critique see Bekaert, Hoerova and Duca, 2013). These concepts are based on the idea of Knightian uncertainty, as they refer to the entire sphere of macroeconomics. Regarding (b), that is the uncertainty related to particular disaggregates and indicators, like inflation, labour market (usually hiring and unemployment, see e.g. Ernst and Viegelahn, 2014), output, consumption, exchange rate *etc.*, it is usually regarded as the non-Knightian concept, as direct measurements of these disaggregates are available.

The methods of assessing uncertainties can be classified into three groups:

1. Measuring uncertainty by assessing the disagreement between the forecasters (*uncertainty by disagreement*).

2. Measuring uncertainty through some output of formal models (*uncertainty by model*).
3. Mixed approach and other aggregate measures.

Uncertainty by disagreement

The general idea that the degree of uncertainty can be represented by some measure of dispersion between individual forecasters (experts) who formulate their separate judgements regarding a particular macroeconomic indicator is attributed to Zarnovitz and Lambros (1987) and followed, most notably, by Bomberger (1996). It quickly attracted discussion (see Rich and Butler, 1998; Bomberger, 1999) and has rarely been used in its original form, but led to numerous improvements and modifications (see, *inter alia* Lahiri and Liu, 2006; Clements, 2008; Lahiri and Sheng, 2010; Siklos, 2013). The popularity of this approach increased with the development of the probabilistic experts' forecasts, when the forecasters formulated their judgement not only about expected values of the forecasted variables, but also about the probabilities of their realisation, usually given in the form of histograms or confidence intervals. It was also stimulated by the increase in the availability of panel-type data of individual forecasts, like the Survey of Professional Forecasters, SPF, initially for US and later for other countries as well. These make the forecasting more feasible but, on the other hand, creates an additional methodological challenge on how to combine the uncertainty about means and uncertainty about the entire distribution. The milestone paper within this area has been paper by Giordani and Söderlind (2003), who came up with the formula that uncertainty should be expressed by a variance of means of individual forecasts plus a mean of their variances. The problem of combining individual probabilistic forecasts proved to be attractive enough to stimulate a series of papers, such as Diebold, Tay and Wallis (1999), Clements and Harvey, (2011), Lahiri, Peng and Sheng (2014) and others. Properties of uncertainty measures based on SPFs are currently widely discussed in the academic literature, (see, *inter alia*, Kowalczyk, Łyziak and Stanisławska, 2013). In particular, Clements (2014a) analyses *ex-post* and *ex-ante* performance of measures of uncertainty based on SPF for different time horizons.

Referring to the classification of Walker *et al.* (2003), uncertainty by disagreement is, in its pure form (that is where the individual forecaster formulate point forecasts), epistemic uncertainty, generated by incomplete knowledge of the system by the experts. In its more comprehensive form, where the forecasters formulate their statements about uncertainty itself, it also contains an element of inherent variability uncertainty.

Uncertainty by model

There are essentially three types of methods aimed at evaluating uncertainties with the use of empirical models. The first one is determined by the construction of a model which is designed to generate uncertainties. In this category predominate ARCH/GARCH type models, which conditionally-autoregressive errors are associated with uncertainties (see e.g. Elder, 2004; Kontonikas, 2004; Daal, Naka and Sanchez, 2005; Elder *et al.*, 2005; Fountas, Karanasos and Kim, 2006; Henry, Olekalns and Suardi, 2007; Fountas, 2010; Neanidis and Savva, 2011), stochastic volatility models (e.g. Berument, Yalcin and Yildirim, 2009) and models derived on the basis of RiskMetrix measures (Hartmann and Herwartz, 2012).

The second approach is based on the explicit assumption that a model is subject to uncertainty regarding the parameters, variables, data, coverage, *etc.*. This itself generates

uncertainty as an outcome. (see, *inter alia* Onatski and Williams, 2003; Orlik and Veldkamp, 2013; Fritsche and Glass, 2014).

The third way of deriving uncertainty from models is to use a sensible forecasting model, or model combinations (not necessarily econometric), and base the assessment of uncertainty on the distribution of *ex-post* forecast errors (*uncertainty by error*). An obvious measure of uncertainty is variance of such distribution (for recent developments see, e.g. Jordà, Knüppel and Marcellino, 2013; Knüppel, 2014). This approach is not well supported so far by economic theory (with exception of Charemza, Díaz and Makarova, 2014b), but is popular among the practitioners, especially in central banks.

Mixed approaches

Methods of evaluating uncertainty by disagreement between professional forecasts and from forecast errors are, in their pure forms, rarely used by practitioners. Often there is a mix between these two approaches which are also combined with some prior insights (e.g. experts' judgements). This 'mixed approach' has been used by the forecasters in a number of central banks for producing probabilistic forecasts, in particular in central banks of Canada, Chile, Czech Republic, Hungary and Sweden. It is also used at the European Central Bank.¹ The growing and the most recent literature on a various approached in this direction include, *inter alia* Engelberg, Manski and Williams (2009), Faust and Wright (2009), Monti (2010), Rich and Tracy (2010), Kowalczyk, Łyziak and Stanisławska (2013), Clark, Krüger and Ravazzolo (2014), Jain, Jo and Sekkel (2014).

A particular place in this group is for Lahiri, Peng and Sheng (2014), who used forecast errors of individual forecaster in a panel of forecasters, implicitly assuming that each individual forecast has been produced from a separate model. This is in fact a combination of uncertainty by model with uncertainty by disagreement.

Uncertainty by model, by error or their combinations belongs to the class of non-Knightian uncertainties, as the models have to be related to a measurable phenomenon. They cannot, therefore, be used directly for assessing the general state of uncertainty in a macroeconomy. This has to be done with the use of the concept of Knightian macroeconomics uncertainty which related to non-measurable general state of the economy. There are, so far, two main approaches to quantify this potentially non-measurable phenomenon.

One approach is by Jurado, Ludvigson and Ng (2013), who use large scale dynamic factor model with stochastic volatility to extract joint forecastable component from 279 macroeconomic and financial indicators (for US only) allowing for idiosyncratic shocks in each of the indices. This analysis is complemented by analysis of common variation of uncertainty at firm level by examination of panel of 155 firms.

Another approach relates to measurement of economic policy uncertainty rather than to macroeconomic or financial uncertainty and is pioneering by Baker, Bloom and Davis (2013) who developed the Economic Policy Uncertainty index (EPU). The EPU index (unlike the macroeconomic uncertainty measure by Jurado, Ludvigson and Ng above), is available not only for US, but also for Canada, China, Eurozone, France, Germany, India, Italy, Spain and UK. For US it consists of three components, the main of which is frequency of newspapers references to economic policy uncertainty, other two components are based on tax

¹ According to information given at websites of particular central banks.

provision and disagreement among professional forecasters. A variation of the EPU index based on news only is also published. News based EPU index considers number of articles that include words 'economic or economy' and 'uncertain or uncertainty' and 'regulation or deficit, or foreign reserve or congress or legislation or White House' in 10 major US newspapers. The index, therefore, captures the uncertainty related to who, what and when undertakes economic policy actions and what might be an economic effect of this policy. The EPU index provides good proxy for economic policy-related uncertainty and is widely used in applied research for identification of policy uncertainty shocks (see e.g. Colombo, 2013; Aastveit, 2014; Bernal, Gnabo and Guilmin, 2014; Istrefi and Piloiz, 2014).

For different countries the ways of constructing EPU index varies. For instance, for China the newspaper count is based on the Hong Kong English language newspapers rather than Chinese ones and for Europe it excludes disagreement between the forecasters. It is shown in Charemza, Díaz and Makarova (2014a) that for most countries it correlates significantly with simple measures of uncertainty based on forecast errors (except for China and Canada).

4. Pros and cons of different measures of uncertainty

The main three techniques of accounting for uncertainty, by disagreement, by model and, in particular, by error, have their own advantages and disadvantages. They are briefly discussed below.

Uncertainty by disagreement is a truly *ex-ante* measure and can therefore be used for assessing future state of the economy. It is based on the transparent and intuitive assumptions and it is easy to interpret. It can also be associated with particular periods of time in a natural way, as the surveys are usually well grounded in time, both in terms of the periods when the forecast is made and the period for which it is made. There has been recently a substantial methodological and technical progress in this type of research, so that the quality of survey based methods is improving.

Nevertheless it also has some disadvantages. It is costly and creates obvious difficulties in completing a competent panel of experts. As the most professional forecasts are recently probabilistic (the panellists are asked about the distributions of expected phenomena rather than their point values), still relatively unsearched problem of the psychological ability of an individual to express probability statements in an unbiased way has to be addressed. There is some empirical evidence, and also results of psychological experiments, suggesting that this might not be possible (see e.g. Bolger and Harvey, 1995; Soll and Klaymen; 2004; Hansson; Juslin and Winman, 2008; So, 2013). Also Clements (2014a) argues that, in the context of survey forecasting, the panellists tend to overestimate the short-term uncertainty and underestimate the long-term one. This result contradicts, to an extent, the psychological literature quoted above making the problem even more complex.

However, the crucial problem here seems to be the joint bias of forecasts formulated by different forecasters. The potential for an existence of such bias is rather obvious, as the panellists either have access to identical sources of information, which influence them in a similar way, or may know each other and their formal or informal discussions about the state of the economy may inadvertently cause correlation of their individual forecasts. In another words, the disagreement in survey point forecasts reflects the differences in opinion rather than uncertainty (Diether, Malloy and Scherbina, 2002; Mankiw, Reis and Wolfers, 2003). The consequence of this can be dire, as it results in a relatively small dispersion between the

means of the forecasters' distribution and a substantial bias, which reduces the usefulness of the results.

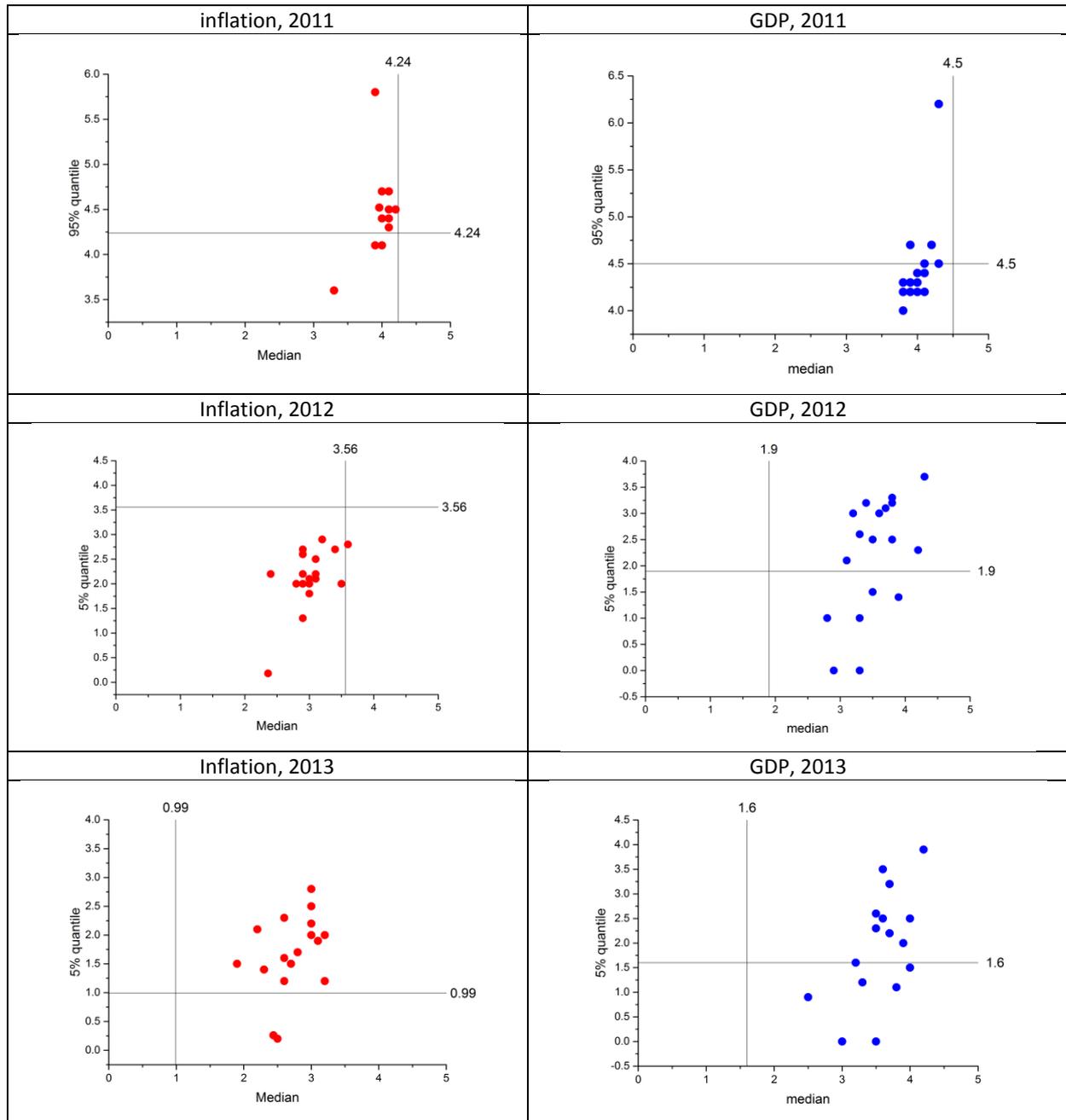
This is illustrated by Figure 1, which shows the outcomes of forecasting the average Polish annual inflation and GDP made in the third quarter of 2011 by 18 experts who participated in the National Bank of Poland (NBP) Survey of Professional Forecasters. The forecasts were made for 2011, 2012 and 2013. The forecasters expressed their predictions by reporting median and 5% and 95% percentiles of their perceived distributions. Medians of these distributions are shown on the horizontal axis and on the vertical axis there are these quantiles which are closer to the actual value of the average headline inflation or GDP in forecasted years (95% for 2011, as the median forecasts underestimated both inflation and GDP and 95% for 2012-2013, as median forecasts for these years were too high). The actually recorded (*ex-post*) values of inflation and GDP in each year are marked by vertical and horizontal lines. Figure 1 indicates consistent bias of the median forecast. For each year, and for both inflation and GDP, all forecasts, except of a single case of inflation forecast for 2012, were at the same side of the observed inflation (to the left for 2011 and to the right for 2012-2013), showing that the forecasters almost unanimously underestimated or overestimated inflation and GDP. For 2013 the bias of the inflation forecasts was so strong that only two forecasters included observed inflation within their 90% confidence band. For all others the probability of average inflation being at the level of 0.99% (that is recorded for 2013) was smaller than 10%. At the same time, standard deviations showing discrepancies among the forecasters were remarkably small. This implicitly suggests the high dependency between the forecasters. Similar phenomenon is typical for other surveys of professional forecasters made in other countries.

Two other methods of assessing uncertainty: by model and by error, also have their advantages and disadvantages. They usually do not require other data than publically available, they represent well past dependencies and are, to an extent, independent from psychologically induced fads and rumours. Current methods give an opportunity to identify the ontological and epistemic elements leading to some approximation of *ex-ante* uncertainties (see Charemza, Díaz and Makarova, 2014b). Among the disadvantages the most relevant one seems to be the model dependence. The uncertainty by error and some of the uncertainty by model methods are assuming a perfect model. Clearly this can always be disputed. Also, there are often problems with associating the uncertainty with particular timing. As uncertainty by error requires collecting data related to a considerable period of time, there is a question of time invariance, in the *ex-post* and, in particular, in the *ex-ante* context, when the uncertainty is used for the assessment of probabilistic forecasts.

5. Empirical assessment of uncertainty for Poland

This section presents a simple measure of macroeconomic uncertainty computed for Poland with the use of monthly inflation data. It is based on the uncertainty by error principle, called herein the *Econometric Forecast Uncertainty* (EFU) measure. It was originally proposed by Charemza, Díaz and Makarova (2014b), and is slightly modified in this paper. Its computation is the following:

Figure 1. Forecasts of annual average inflation and GDP in the 3rd Quarter of 2011 according to the NBP Survey of Professional Forecasters



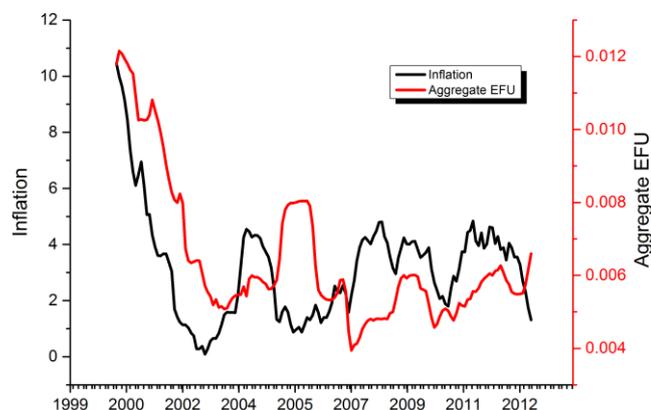
Source: based on data from NBP *Survey of Professional Forecasters*, <http://amakro.nbp.pl/amakro-static/pages/datasets.nbp?cid=1056>

The monthly inflation data for Poland has been downloaded from: <http://stats.oecd.org/>. Among various types of time series models a relatively simple seasonal autoregressive moving average model (SARMA) model has been estimated using first 80 observations of the sample, that is monthly data from November 1993 till June 2000. Other, more complicated, models have also been considered, but it has been decided in favour a univariate autoregressive model bearing in mind its generally superior forecasting properties (see e.g.

Aron and Muellbauer, 2013; Clements, 2014b). Forecasts have been made recursively, starting from the initial period and then by updating the estimation period by one observation at a time and re-estimating the model. Each time forecast from 1 to up to 12 months ahead has been made. For each forecast horizon, and individual EFU measure have been computed as a 24-months moving standard deviation of the forecasts. The individual EFU measures (that is, for the different forecast horizons) have then been aggregated with the use of Samuelson discount function, discussed in the context of temporal aggregation by al Nowaihi and Dhami (2008). Details of computation and algorithms are available on request.

Figure 2 shows the aggregate EFU index plotted together with the time series of inflation. It demonstrates a general tendency of the uncertainty first to decline, in line with the tendency of inflation to fall, then to rise in the period from February to May 2006, and then to decline again and stabilise. It is interesting that at the beginning of 2006 inflation and uncertainty were moving in opposite directions. It appears to be the consequence of the fact that the temporary increase in inflation after Poland had joined the European Union on the 1st of May 2004 lasted shorter than expected. It started to fall in 2005, but uncertainty actually rose at this time, as fall in inflation was not grounded within inflationary fundamentals (and was, in fact, not foreseen by most of the analysts).

Figure 2. Aggregate EFU and annual inflation in Poland, 2000-2013.



6. Conclusions and reflections

The paper provides an overview of the problems related to defining and practical applications of different measures of macroeconomic uncertainty. It evaluates similarities and differences between particular approaches and attempts to identify the most relevant problems which are in need of resolving. It seems that one of the issues that require further investigation is clarification of the differences between the concepts of uncertainty free from policy influence and that which results from such influence. To an extent this has been tackled by Clements (2014a) by his distinction between the *ex-post* and *ex-ante* uncertainty and also by Charemza, Díaz and Makarova (2014b) by their evaluation of uncertainty free from epistemic element. However, these issues, important from the point of view of conducting efficient economic policy, are far from being resolved.

Further research should also concentrate on finding the consensus between the survey-based and model-based approaches. Important development here is by Lahiri, Peng and Sheng (2014) and Rich and Tracy (2010), but, again, further work is needed in this respect.

Finally, efforts should be directed towards construction of an aggregate measure of non-Knightian uncertainty. Current developments by Baker, Bloom and Davis (2013) and Jurado, Ludvigson and Ng (2013) are ground-breaking. However, the ways aggregation between particular individual measures of uncertainty is made is arbitrary and depend on a number of aggregation assumptions. It might be possible to apply some more general aggregation rules which would depend less on such assumptions and, consequently, be more widely accepted and applied.

References

- Aastveit, K.A., G. J. Natvikz and S. Sola (2014), 'Economic uncertainty and the effectiveness of monetary policy', Norges Bank Working Paper, 2013/17.
- al-Nowaihi, A. and S. Dhami (2008), 'Discounting by intervals: an inconsistent theory of intertemporal choice?', Department of Economics, University of Leicester Working Paper No. 08/10.
- Aron, J. and J. Muellbauer (2013), 'New method of forecasting inflation, applied to the US', *Oxford Bulletin of Economics and Statistics* **75**, 637-659.
- Baker, S. R., N. Bloom and S. J. Davis (2013), 'Measuring economic policy uncertainty', Stanford University and University of Chicago Booth School of Business, <http://cep.lse.ac.uk/seminarpapers/04-06-13-SD.pdf>.
- Bekaert, G., M. Hoerova and M. Duca (2013), 'Risk, uncertainty and monetary policy', ECB Working Paper No. 1565.
- Benhabib, J., P. Wang and Y. Wen (2013). 'Uncertainty and sentiment-driven equilibria', NBER Working Papers No. 18878.
- Bernal, O., J.-Y. Gnabo and G. Guilmin (2014), 'Economic policy uncertainty and risk spillovers in the Eurozone', paper submitted to the IFABS Conference, Lisbon.
- Berument, H., Y. Yalcin and J. Yildirim (2009), 'The effect of inflation uncertainty on inflation: stochastic volatility in mean model with a dynamic framework', *Economic Modelling* **26**, 1201-1207.
- Bird, R., D. F. S. Choi and D. Yeung (2014), 'Market uncertainty, market sentiment, and the post-earnings announcement drift', *Review of Quantitative Finance and Accounting* **43**, 45-73.
- Bloom, N. (2000), 'The real options effect of uncertainty on investment and labour demand', Institute for Fiscal Studies, Working Paper 00/15.
- Bloom, N. (2009), 'The impact of uncertainty shocks', *Econometrica* **77**, 623-685.
- Bloom, N., S. Bond, and J. Van Reenen (2007), 'Uncertainty and investment dynamics', *Review of Economic Studies*, **74**, 391-415.

- Bolger, F. and N. Harvey (1995), 'Judging the probability that the next point of an observed time series will be below, or above, a given value', *Journal of Forecasting* **14**, 597-607.
- Bomberger, W. A. (1996), 'Disagreement as a measure of uncertainty', *Journal of Money, Credit and Banking* **28**, 381-391.
- Bomberger, W. A. (1999), 'Disagreement and uncertainty', *Journal of Money, Credit and Banking* **31**, 273-276.
- Charemza, W., C. Díaz and S. Makarova (2014a), 'Conditional term structure of the Canadian inflation forecast uncertainties: the copula approach', paper presented at the *International Association for Applied Econometrics, Annual Conference*, London.
- Charemza, W., C. Díaz and S. Makarova (2014b), 'Term structure of inflation forecast uncertainties and skew normal distributions', University of Leicester Working Paper No. 14/01.
- Clark, T. E., F. Krüger and F. Ravazzolo (2014), 'Combining survey and Bayesian VAR forecasts of US macro variables: evidence from entropic tilting', presented at the workshop *Uncertainty and Economic Forecasting*, UCL, London.
- Clements, M. P. (2008), 'Consensus and uncertainty: using forecasts probabilities of output declines', *International Journal of Forecasting* **24**, 76-86.
- Clements, M.P. (2014a), 'Forecast uncertainty – ex ante and ex post: US inflation and output growth', *Journal of Business and Economic Statistics*. **32**, 206-216.
- Clements, M. P. (2014b), 'Real-time factor model forecasting and offsetting the effect of instability', presented at the 34th *International Symposium on Forecasting*, Rotterdam.
- Clements, M. P. and D. I. Harvey (2011), 'Combining probability forecasts', *International Journal of Forecasting* **27**, 208-233.
- Colombo, V. (2013), 'Economic policy uncertainty in the US: Does it matter for the Euro area?', *Economics Letters* **121**, 39-42.
- Daal, E., A. Naka and B. Sanchez (2005), 'Re-examining inflation and inflation uncertainty in developed and emerging countries', *Economics Letters* **89**, 180-186.
- Diebold F.X., A. S. Tay and K. F. Wallis (1999), 'Evaluating density forecasts of inflation: the survey of professional forecasters', in (R. Engle and H. White, eds.) *Cointegration, causality and forecasting: Festschrift in Honor of C. W. J. Granger*, Oxford University Press.
- Diether, K. B., C. J. Malloy, and A. Scherbina (2002), 'Differences of opinion and the cross section of stock returns', *Journal of Finance* **57**, 2113-2141.
- Elder, J. (2004), 'Another perspective on the effects of inflation uncertainty', *Journal of Money, Credit and Banking* **36**, 911-928.
- Elder, R., G. Kapetanios, T. Taylor and T. Yates (2005), 'Assessing the MPC's fan charts', *Bank of England Quarterly Bulletin* **45**, 326-348.
- Engelberg, J., S. F. Manski and J. Williams (2009), 'Comparing the point predictions and subjective probability distributions of professional forecasters', *Journal of Business and Economic Statistics*. **27**, 30-41.

- Ernst, E. and C. Viegelaahn (2014), 'Hiring uncertainty: a new labour market indicator', <http://www.policyuncertainty.com/media/HiringUncertainty.pdf> .
- Faust, J. and J. H. Wright (2009), 'Comparing Greenbook and reduced form forecasts using a large real time dataset', *Journal of Business and Economic Statistics* **27**, 468-479.
- Fountas, S. (2010), 'Inflation, inflation uncertainty and growth: are they related?', *Economic Modelling* **27**, 896-899.
- Fountas, S., M. Karanasos and J. Kim (2006), 'Inflation uncertainty, output growth uncertainty and macroeconomic performance', *Oxford Bulletin of Economics and Statistics* **68**, 319-348.
- Fritsche, U. and K. Glass (2014), 'Did the real-time information content of Eurostat's macroeconomic data worsen?', presented at the workshop *Uncertainty and Economic Forecasting*, UCL, London.
- Giordani, P. and P. Söderlind (2003), 'Inflation forecast uncertainty', *European Economic Review* **47**, 1037-1059.
- Haddow, A., C. Hare, J. Hooley and T. Shakir (2013), 'Macroeconomic uncertainty: what is it, how can we measure it and why does it matter?', *Bank of England Quarterly Bulletin* **53**, 100-110.
- Hansson, P., P. Juslin and A. Winman (2008), 'The role of short-term memory capacity and task experience for overconfidence in judgement under uncertainty', *Journal of Experimental Psychology: Learning, Memory and Cognition* **34**, 1027-1042.
- Hartmann, M. and H. Herwartz (2012), 'Causal relations between inflation and inflation uncertainty-Cross sectional evidence in favour of the Friedman-Ball hypothesis', *Economics Letters* **115**, 144-147.
- Henry, Ó., N. Olekalns and S. Suardi (2007), 'Testing for rate dependence and asymmetry in inflation uncertainty: evidence from the G7 economies', *Economics Letters* **94**, 383-388.
- Istrefi, K. and A. Piloiz (2014), 'Economic policy uncertainty and inflation expectations', presented at the workshop *Uncertainty and Economic Forecasting*, UCL, London.
- Jain, M., S. Jo and R. Sekkel (2014), 'Macroeconomic uncertainty through the lens of professional forecasters', presented at the workshop *Uncertainty and Economic Forecasting*, UCL, London.
- Jordà, O., M. Knüppel and M. Marcellino (2013), 'Empirical simultaneous prediction regions for path-forecasts', *International Journal of Forecasting* **29**, 456-468.
- Jurado, K., S. C. Ludvigson and S. Ng (2013), 'Measuring uncertainty', NBER Working Paper 19456, <http://www.nber.org/papers/w19456>.
- Knight, F.H. (1921), *Risk, uncertainty and profit*, Sentry Press.
- Knüppel, M (2014), 'Efficient estimation of forecast uncertainty based on recent forecast errors', *International Journal of Forecasting* **30**, 257-267.
- Kontonikas, A. (2004), 'Inflation and inflation uncertainty in the United Kingdom, evidence from GARCH modelling', *Economic Modelling* **21**, 525-543.

- Kowalczyk, H. (2013), 'Inflation fan charts and different dimensions of uncertainty. What if macroeconomic uncertainty is high?', National Bank of Poland Working Paper No. 157.
- Kowalczyk, H., T. Łyziak and E. Stanisławska (2013), 'A new approach to probabilistic surveys of professional forecasters and its application in the monetary policy context', National Bank of Poland Working Paper No. 142.
- Lahiri, K. and F. Liu, (2006), 'Modelling multi-period inflation uncertainty using a panel of density forecasts', *Journal of Applied Econometrics* **21**, 1199-1219.
- Lahiri, K. and X. Sheng (2010), 'Measuring forecast uncertainty by disagreement: the missing link', *Journal of Applied Econometrics* **25**, 514-538.
- Lahiri, K., H. Peng and X. Sheng (2014), 'Measuring uncertainty of a combined forecast', presented at the workshop *Uncertainty and Economic Forecasting*, UCL, London.
- Lane, D. A. and R. R. Maxfield (2005), 'Ontological uncertainty and innovation', *Journal of Evolutionary Economics* **15**, 3-50.
- Mankiw, G. N., R. Reis, and J. Wolfers (2003), 'Disagreement about Inflation expectations', in: (M. Gertler and K. Rogoff, eds.), *National Bureau of Economic Research Macroeconomics Annual*, MIT Press, Cambridge MA, 209-248.
- Monti, F. (2010), 'Combining judgment and models', *Journal of Money, Credit and Banking* **42**, 1641-1662.
- Neanidis, K. C. and C. S. Savva (2011), 'Nominal uncertainty and inflation: the role of European Union membership', *Economics Letters* **12**, 26-30.
- Norton, J. P., J. B. Brown and J. Mysiak (2006), 'To what extent, and how, might uncertainty be defined? Comments engendered by 'Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support: Walker *et al.*, Integrated Assessment **4**, 2003, *Integrated Assessment* **6**, 83-88.
- Onatski, A. and N. Williams (2003), 'Modeling Model Uncertainty', *Journal of the European Economic Association* **1**, 1087-1122.
- Orlik, A. and L. Veldkamp (2013), 'Understanding uncertainty shocks and the role of black swans', New York University Stern School of Business mimeo.
- Rich, R. and J. S. Butler (1998), 'Disagreement as a measure of uncertainty: a comment on Bomberger', *Journal of Money, Credit and Banking* **30**, 411-419.
- Rich, R. and J. Tracy (2010), 'The relationships among expected inflation, disagreement, and uncertainty: evidence from matched point and density forecasts', *The Review of Economics and Statistics* **92**, 200-207.
- Siklos, P. L. (2013), 'Sources of disagreement in inflation forecasts: an international empirical investigation', *Journal of International Economics* **90**, 218-231.
- So, E. C. (2013), 'A new approach to predicting analyst forecast errors: do investors overweight analyst forecasts?', *Journal of Financial Economics* **108**, 615-640.
- Soll, J. B. and J. Klayman (2004), 'Overconfidence in interval estimates', *Journal of Experimental Psychology: Learning, Memory and Cognition* **30**, 299-314.

- Tuckett, D., P. Ormerod, R. Smith, and R. Nyman (2014), 'Bringing social-psychological variables into economic modeling: uncertainty, animal spirits and the recovery from the Great Recession', IEA World Congress, Jordan.
- Walker, W. E., P. Harremoës, J. Rotmans, J. P. van der Sluijs, M. B. A. van Asselt, P. Janssen and M. P. Kreyer von Krauss (2003), 'Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support', *Integrated Assessment* **4**, 5-17.
- Wallis, K. F. (2004), 'An assessment of Bank of England and National Institute inflation forecast uncertainties', *National Institute Economic Review* **189**, 64-71.
- Zarnowitz, V. and L. A. Lambros (1987), 'Consensus and Uncertainty in Economic Prediction', *Journal of Political Economy*, **95**, 591-621.