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Forecasting environmental migration to the United Kingdom, 2010-2060: an exploration using Bayesian models

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ABSTRACT

Over the next fifty years the potential impact on human livelihoods of environmental change could be considerable. One possible response may be increased levels of human mobility. This paper offers a first quantification of the levels of environmental migration to the United Kingdom that might be expected. The authors apply Bijak and Wiśniowski's (2010) methodology for forecasting migration using Bayesian models. They seek to advance the conceptual understanding of forecasting in three ways. First, the paper is believed to be the first time that the Bayesian modelling approach has been attempted in relation to environmental mobility. Second, the paper examines the plausibility of Bayesian modelling of UK immigration by cross-checking expert responses to a Delphi survey with the expectations about environmental mobility evident in the recent research literature. Third, the values and assumptions of the expert evidence provided in the Delphi survey are interrogated to illustrate the limited set of conditions under which the forecasts of environmental mobility, as set out in this paper, are likely to hold.

KEYWORDS

Bayesian forecasting, Delphi survey, environmental mobility, UK immigration

EDITORIAL NOTE

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FORECASTING ENVIRONMENTAL MIGRATION TO THE UNITED KINGDOM, 2010-2060: AN EXPLORATION USING BAYESIAN MODELS

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1. INTRODUCTION

It seems highly likely that environmental change will impact significantly of the distribution of world population over the next fifty years (Stern, 2007; House of Commons, 2008). Increased levels of human mobility may be one possible response to climate change (Black et al., 2011a; Pecoud and Geiger, 2011), but there is huge uncertainty about precisely how many people will move and about the destinations that they will choose. Recent research (Piguet et al., 2011; Government Office for Science (GOS), 2011) contradicts earlier assertions that climate change will produce mass environmental migration (Myers, 1993, Stern 2007). This recent wave of research suggests that where environmental movement occurs, it will be focused mainly in the poorer nations of the world, and that regions such as north-west Europe will receive few migrants compared with the scale of environmentally-driven short distance moves that will take place in Asia and Africa (Black et al., 2011b; de Haas, 2011).

The research reported in this paper seeks, for the first time, to offer some quantitative estimates of the scale of environmental migration to the United Kingdom. The analysis combines expert opinion with time series datasets to produce a Bayesian forecast of so-called environmental migration to the UK by 2060. It is argued that more important than the empirical dimensions of the forecast, is the approach taken by the research team. This demonstrates first, that there can be value in seeking expert opinion in areas where other evidence is lacking. Second, it points to the folly of giving too much weight to single ballpark estimates of environmental mobility, and instead underscores the value in examining both the sources of uncertainty in forecasts of this kind and the values and assumptions of experts in making migration forecasts. Whilst the authors are perfectly aware of the difficulties with conceptualisation and definition of 'environmental migration' (see also GOS, 2011), the current study attempts to reflect the surrounding ambiguities in a formal manner, through the uncertainty of the relevant estimates and predictions.

The paper opens with a brief summary of what the research literature suggests about mobility trends in relation to environmental change. There subsequently follows a discussion of the researchers' methodology. It then considers in detail the results of the Bayesian forecast, before turning to evaluate how the results might be interpreted. Is it plausible, as the median forecast implies, that there will be very little additional

environmental migration directed towards the UK over the next 50 years? What are the policy implications of such outcomes?

2. EXPECTATIONS OF HUMAN MOBILITY IN AN ERA OF ENVIRONMENTAL CHANGE

The frequency and severity of extreme environmental events seem set to increase over the next fifty years (GOS, 2011). Although there seems a broad consensus of scientific opinion linking the observation of increased environmental hazards to climate change, there is less agreement about what the likely impacts will be on a range of human activities including human migration (Gemenne, 2011; Piguet et al. 2011; Warner, 2009). Early estimates by environmentalists (Myers, 1993) focused on forecasting the numbers of people who would be displaced because they were living in areas deemed to be at high risk of an identifiable environmental process linked to global warming (such as sea level rise). This literature has been widely reviewed and we do not rehearse the arguments once again here (Black et al., 2011b; Gemenne, 2011).

Only in the last few years has a systematic attempt been made to gather field evidence on the nature of environmentally-linked mobility (Castles, 2011; Kniveton et al., 2008; Warner et al., 2009). Reviews of this literature show that most environmentally-linked mobility is short distance and within country and that perhaps the greatest risk is human immobility in the face of environmental change (Findlay, 2011). The recent migration systems emphasis in the study of human mobility in an era of environmental change has led to recognition of the complex and entangled nature of migration motivations and to the recommendation that researchers should focus on understanding the role of environmental forces in impacting existing migration regimes, both directly and indirectly (Black et al., 2011a, 2011b), as opposed to making estimates based on the populations of areas at highest risks of rapid environmental change. This multi-causal approach also recognises the diversity of mobility responses that can emerge in association with different types of environmental events. Piguet et al. (2011), for example, make the important distinction between temporary moves (three months or less) following an environmental event, short-term displacement (three months to a year), and migration (one year or more), and note the different mobility responses to hazards such as

hurricanes and typhoons from those witnessed in relation to slow onset disasters such as drought-linked famines (see also Laczko et al. 2009).

The environmentalist perspective continues to inform much of the contemporary debate on climate change (Stern, 2007) and the implications for human mobility. In looking to the future it tends to uphold the popular perception that many millions of people will leave areas adversely affected by climate change, possibly in favour of more secure lives in the global north. By contrast, recent research on migration regimes affected by environmental change points to high levels of immobility, and challenges the view that environmental change will result in significant international migration flows into many of the wealthier countries (de Hass, 2011; Findlay, 2011). Instead Black et al. (2011a) and GOS (2011) suggest that migration over the decades ahead may shift more people into those areas that are at greatest environment risk in the poorer countries of the world, such as low lying large urban areas in the developing world (Seto, 2011).

The literature reviewed above presents an interesting challenge when applied to the question of how immigration to the UK will change in an era of environmental change. On the one hand, the environmentalist perspective would lead to concern that over the decades ahead the scale of environmentally-linked immigration would increase substantially and come to account for an ever-greater proportion of new arrivals in the country. On the other hand, the migration regimes perspective might point to a rather different future, with attention focussing instead on the pattern of the UK's current migration linkages and the prospects of environmental change in countries close to the UK resulting in population displacement. Remarkably, given the significance of the issue, the research literature offers very little evidence to inform these very different views of future environmental mobility to the UK. Most recent environmental mobility research has focussed on other parts of the world (for example, Kniveton et al., 2011; Lilleor et al., 2011) where concerns about the current impact of climate change are perceived to be greater. One possible exception is the recent study by Fielding (2011), but his study (looking at the effects of environmental change over the next fifty years on inter-regional migration in UK) is limited to internal mobility and thus cannot answer questions about the effects of climate change on future environmentally-linked immigration to Britain. This leads therefore to the central goals of this paper: to forecast environmental migration to the UK over the

next 50 years and to evaluate the plausibility of these forecasts given the limited nature of the evidence available on the topic.

3. RESEARCH METHODOLOGY

The key feature of the researchers' methodology is bringing together expert knowledge and historical data series to generate estimates of gross immigration, and environmentally-related migration, as well as measures of uncertainty associated with these forecasts. The methodology used a Delphi survey of experts embedded within the Bayesian statistical modelling framework, as depicted in Figure 1 and described in more detail in the next section (for an introductory-level exposition of Bayesian statistics, see e.g. Bernardo 2003).

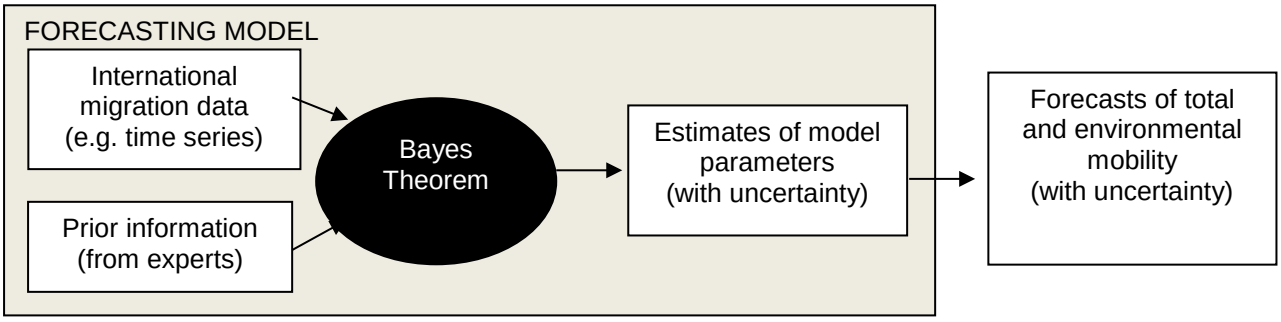

Figure 1 The Bayesian approach for forecasting environmental mobility

3.1. BAYESIAN MODELLING

The data series used in the Bayesian modelling drew on ONS (Office for National Statistics) figures on total immigration to the UK from 1975 onwards. The Bayesian approach used in this analysis has two main advantages over conventional approaches to migration forecasting. First, in using probability distributions to handle uncertainties attached to the predictions, the forecasts go beyond the normal presentation of one number predicted for each year and instead create a probability fan which indicates the degree of uncertainty around the mean or median (Abel et al., 2010). Second, Bayesian models have the capacity to formally allow for expert opinions to be built into projections in the form of prior distributions (Bernardo, 2003). Prior distributions in Bayesian modelling inform the parameters of the statistical model and are independent of any existing data. In this case it is subjective expert opinion which constitutes the prior distributions. To this end, the most important aspects of the Delphi questionnaire used in this study were the questions

relating to future volumes of immigration and immigration related to environmental change. Central to the construction of Bayesian model forecasts is consideration of subjective definition of probability, which in this case equates to the respondents' confidence in the accuracy of their answers.

The modelling framework used in this paper is to predict immigration to UK solely based on its past history using a univariate autoregressive (AR) model. An extensive treatment of suites of such models in the context of population predictions has been provided in Abel et al. (2010), where all the methodological particulars are discussed in more detail. For the purpose of the current study, an AR model based on the k-year history of immigration, AR(k), is defined as:

$$m_t = \mu + \sum_{i=1}^{k} \left[\phi_i \cdot \left(m_{t-i} - \mu\right)\right] + \varepsilon_t \,.$$

where m_t refers to total immigration in year t, taken as a first difference of the logarithms of migration volumes.

The symbol μ denotes the overall mean level of m_t; the parameters ϕ_i for $i = 1, ..., k$, refer to the ensemble of coefficients of autoregression of m_t with its past history up to k periods (years) before. Finally, ε_t denotes an error term, conventionally assumed to follow a univariate Normal distribution with mean 0 and variance σ^2, N(0, σ^2). All ε_t are assumed to be independent and identically distributed (iid).

In this study, migration history up to eight years before was examined by way of a set of nine models, ranging from the Independent Normal (IN) model, equivalent to AR(0), through AR(1), etc. to AR(8). For every one of them, in terms of prior distributions, it was assumed that as well as μ, all relevant parameters ϕ_i follow a Normal distribution N(0,1). Standard deviation of the error term, σ, was assumed to follow a Normal distribution N(0,100), truncated at zero to ensure the positivity of the values of σ. This assumption is rather vague and reflects lack of strong beliefs a priori with respect to the error of immigration forecasts. In the current study, full Bayesian inference was applied for all ϕ_i, σ, and μ, although in the last-mentioned case, the forecasts drew on expert-based trajectories obtained from the Delphi survey, as described in the next section. A fully expert-based approach was also applied to obtain the predictions of the share of environmental migrations. This was necessary in

the absence of any systematic time-series dataset on environmental immigration to the UK.

Given that in this exercise nine different models are considered, in order to allow for their goodness of fit with the empirical data, the procedure of Bayesian model selection and averaging was applied (Raftery 1995). In this approach, models themselves are being assigned prior probabilities, adding up to unity, which are subsequently updated according to how much support from data a particular model has. The resulting *posterior probabilities*, also adding up to one, can be then used to select the best fitting model (i.e. the one with the highest probability), or to *average* forecasts yielded by different models, using these probabilities as weights. In the current case, the nine models were assumed a priori to be equi-probable, without preference to any one of them, so the prior probability of each of them equalled 11.1% (i.e. 1/9).

In computing the posterior probabilities of particular models given the data, the *bridge sampler* algorithm was applied (Meng & Wong 1996). Additionally, two measures of goodness of fit of models, also used in classical (frequentist) statistics, were calculated: the Akaike Information Criterion (AIC) and the Bayesian (Schwartz) Information Criterion (BIC). These measures are described in more detail in Congdon (2003: 32–33), whereas a discussion of the general methodology of Bayesian model selection in the context of a series of AR(*k*) models is provided in Abel et al. (2010). The Bayesian calculations were based on 10,000 iterations of the estimation algorithm, with 1,000 initial iterations discarded.

3.2. ELICITATION OF EXPERT OPINION

In order to construct the prior distributions for the forecasting model, expert information on environmental mobility was obtained through engaging in a two-round Delphi survey. This produced information that shaped the model parameters. Expert views may be gathered in a variety of ways (O'Hagan, 2011), but one well-established approach in situations involving long-range forecasts of uncertain futures has been the Delphi survey method (Hill and Fowles, 1975; Linstone and Turoff, 1975). This perspective involves asking experts their views on a particular topic (round 1) and then bringing them together as a panel (round 2) to explore the reasons

why they gave the answers that they did and then giving them the opportunity to amend their responses in the light of the opinions of the other experts. This is a recognised approach to handling uncertainty in a forecasting context (Schmidt, 1997) and has been previously used in migration modelling (Bijak and Wiśniowski, 2010). As has been highlighted by the literature on elicitation, obtaining information about uncertainty is universally difficult (Szreder and Osiewalski, 1992; Kadane and Wolfson, 1998; Dey and Liu, 2007; O'Hagan, 2011) and so far no completely satisfactory solution has been developed.

In this instance the views of 27 experts were canvassed, with heterogeneous backgrounds, which is a desirable feature of a Delphi exercise. Eleven of the experts were demographers (migration and demographic specialists) and sixteen were stakeholders in the Government Office for Science Foresight Project (2011) on *Migration and Global Environmental Change*. Round 1 involved survey respondents independently completing a questionnaire on current and future environmental migration trends to the UK. From the point of view of forecasting, two groups of questions were most relevant. The first comprised questions aimed at eliciting target distributions of total immigration, as well as of the shares of environmental migration, for 2030 and 2060. Additionally, one question dealt with the share of environmental migration in 2010, since currently no relevant data are available. In this way, we also tried to reflect the ambiguity surrounding the very concept and definition of 'environmental migration'. The second group of questions dealt with the impact of particular demo-economic covariates.

In round 2 the aggregated results were presented to the same panel of experts at a specially convened meeting held in London in March 2011. An important part of the research process involved considering what types of moves might qualify as being linked to environmental change. Audio recordings were taken during the round 2 meeting and some quotations from these discussions are included in this paper to provide an understanding of the reasoning behind the choices made by the experts in their predictions. This approach is considered valuable since participants are given the opportunity to discuss their responses and then either affirm or change their initial estimates.

The questions on the target values of the immigration to the UK, as well as of the shares of migration related to environmental reasons, were elicited in a straightforward fashion. The indicated values were treated as means of respective probability distributions, which were assumed to be log-normal for total immigration volumes (allowing positive values) and of Beta type for shares (allowing only values from the range between 0 and 1). Additionally, for each of the interim periods (2011–2029 and 2031–2059), the shares of environmental migration suggested by the experts were linearly interpolated.

Since both log-normal and Beta distributions require two parameters to be specified, the second ones were computed based on the answers to the questions about the confidence of experts about the values or shares quoted before. The measures of confidence were obtained on a 100 point scale, ranging from 1 (very unsure) up to 100 (very sure). These questions were asked for all point estimates of future levels of migration and percentages of environmental migrants, and have been subsequently judgmentally mapped onto the scale of the variables in question, to match either the order of magnitude of the total number of immigrants, or of the share of environmentally-related migration.

The mapping procedure was as follows: first of all, in each case, a total variance was calculated. This was done initially by calculating the overall weighted average of all individuals' mean response, where the respondent's confidence answers were used as weights. The total variance was then derived as the summation of the squared difference between this weighted average and each respondent's mean (scaled by the confidence level), divided by the total number of respondents. An individual's variance term, in its log-normal distribution, was then calculated by dividing the total variance by respondent's reported level of confidence. Individual means and derived variance were used as method-of-moments estimates (obtained by matching the empirical mean and variance with their analytical forms, depending on the parameters) to calculate Beta distribution parameter for the share of environmental immigrants.

The 100-point scale was intended to provide a subjective measure of uncertainty surrounding future levels provided in the preceding questions. This question was not aimed at eliciting confidence intervals. Given the heterogeneity of

the expert panel, we could not assume that a question requiring statistical background would be understood consistently across the respondents. Instead, a subjective score with a wide range of options (1 to 100) was intended to allow the experts more flexibility and scope for manoeuvre between both Delphi rounds. During the second round of the Delphi some respondents raised issues with the use of the 1 to 100 scale, and the placing of their level of uncertainty, especially in the middle of the range. These concerns are legitimate. However, as pointed out by the literature on elicitation, obtaining information about uncertainty is universally difficult and so far no consensus has emerged in the academy as to the ideal solution. In addition, during the second round of the Delphi survey, when faced with all responses from the first round, the participants were able to move towards a shared understanding of the scale and the underlying concept of subjective uncertainty. In some cases respondents may have also adjusted their uncertainty in light of discussions. In general, the aim of choosing a point scale subjective measure of uncertainty was thus to obtain a shared understanding of its meaning by the second round of the Delphi survey, despite differences in the methodological background of the experts. Hence, the second round responses to questions on uncertainty reflect subjective views of individual respondents relative to the whole expert panel. It is worth stressing that Bayesian forecasts are characterised by inevitably subjective elements, since they are conditional on expert opinion being linked to the past history obtained from the data series.

The ultimate distributions for the target parameters in question were derived by 'averaging' individual distributions – log-normal for volumes and Beta for rates – obtained for particular experts. In formal probabilistic terms, the final distributions were mixtures of expert-specific ones, where each expert was given an equal weight (probability) of inclusion in the final output.

As researchers, we would wish to acknowledge that the approach we have taken has a number of methodological limitations. One is that, despite being considered experts in the field, the participants had imperfect knowledge and their input, upon which the model parameters are based, is inherently subjective, and the resulting forecasts are therefore only as good as the experts' knowledge allows. Another issue is in interpreting the expert answers to the survey. Some participants commented that terms such environmental migrants were ambiguous and that the use

of a 0–100 per cent confidence scale was confusing. It is thus possible that respondents interpreted these in different ways and that these ambiguities impacted on the findings since it would have resulted in the questions being answered in an inconsistent manner. Finally, the limited availability of appropriate time-series data on past migration trends and the complete absence of any data on environmental migration limit the analysis. Despite our reservations on these matters, it remains the case that this paper offers for the first time quantifiable estimates of environmental movement into the UK and of the uncertainty levels associated with these forecasts, which also reflect the expert ambiguities. For this reason we would maintain the paper is not only original but highly significant in its contribution to the debate over the relation between environmental change and migration.

4. FORECASTS OF ENVIRONMENTAL MIGRATION

By applying the methodology outlined above, univariate forecasts of total and environmental migration to the UK, based on autoregressive models, were obtained. The forecasts of the total immigration are weighted averages (technically speaking, mixtures) of predictions yielded by particular models, from IN and AR(1) up to AR(8). The weights used were the posterior probabilities of particular models, obtained from the bridge sampler algorithm of Meng and Wong (1996). In this example, the averaged model was 58.5% influenced by the Independent Normal ('AR(0)') model, 21.3% by AR(2), and 16.1% by AR(1), with a trace impact of AR(3) and AR(4). Noteworthy, other goodness-of-fit criteria also pointed to models with high posterior probability: the Akaike Information Criterion (AIC) pointed to AR(2), while the Bayesian Information Criterion (BIC) to AR(1).

In order to derive forecasts of environmental migration, the expert-based predicted distributions of relevant shares were juxtaposed with the results for the overall immigration. The resulting forecasts of total and environmental immigration to the UK are illustrated respectively in Figures 2 and 3.

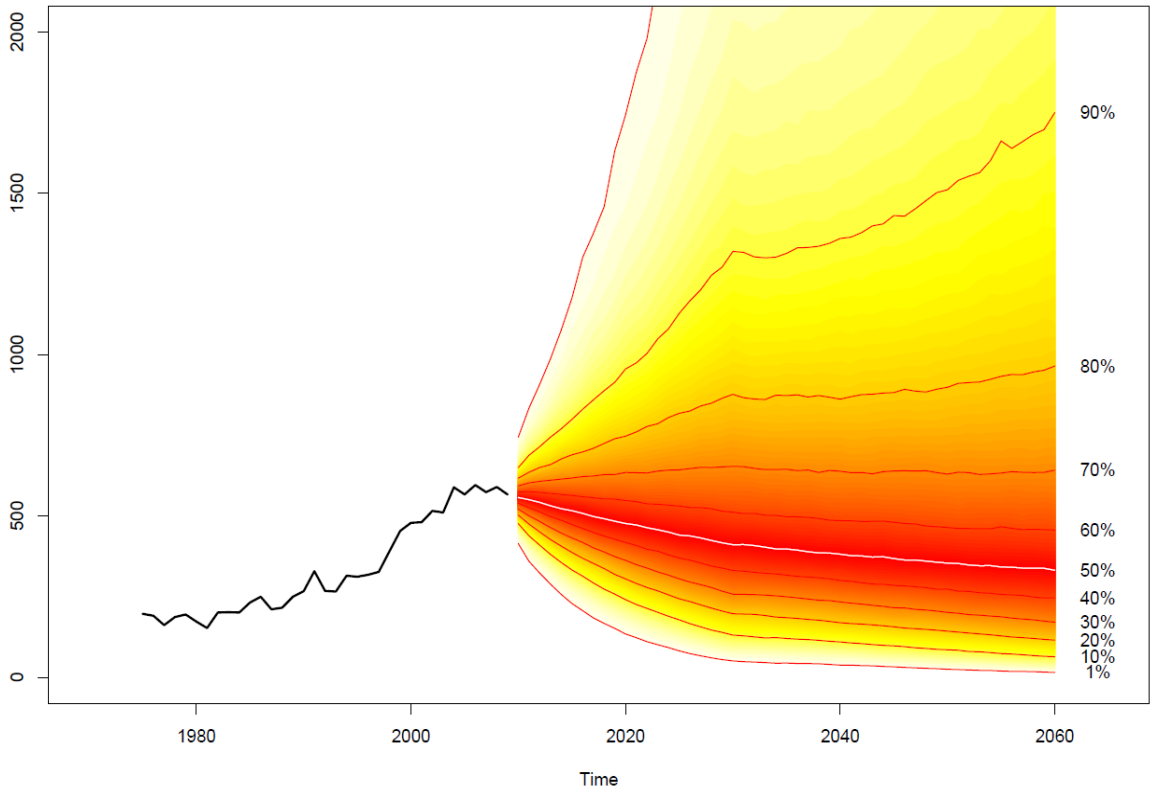

Figure 2 Forecasts of total immigration to the UK, averaged univariate models (in thousands)
Source: Data – ONS; Forecasts – own elaboration in OpenBUGS/R.
Note: White line on the forecast fan denotes the median forecast of total immigration to the UK.

The medial predictions, indicating that for 50% of the time higher values can be expected, and lower values for the remaining 50%, suggest an ever-slower-declining trend of total migration, and a long-term stability of environmental migration. Hence, in the median trajectory, overall immigration is expected to decline from the recent levels of 567,000 in 2009, to 411,000 in 2030, and then to 332,000 in 2060. At the same time, the median trajectory of the volume of environmental migration is expected first to increase slightly from the expert-based estimate of 19,600 thousand in 2010, to 26,800 in 2030, and then decline to 24,900 by 2060. With respect to environmental migration, Figure 3 clearly shows a discontinuity of the trend around 2030, resulting from the values having to conform both to overall migration totals, as well as to the shares of environmental migration envisaged for 2030 by the experts. The values are the result of the impact of the history of migration and its impact on the forecasts through the parameters of the forecasting model. In addition, respondent's answers for the mean levels are weighted by their associated uncertainty levels in the prior distributions.

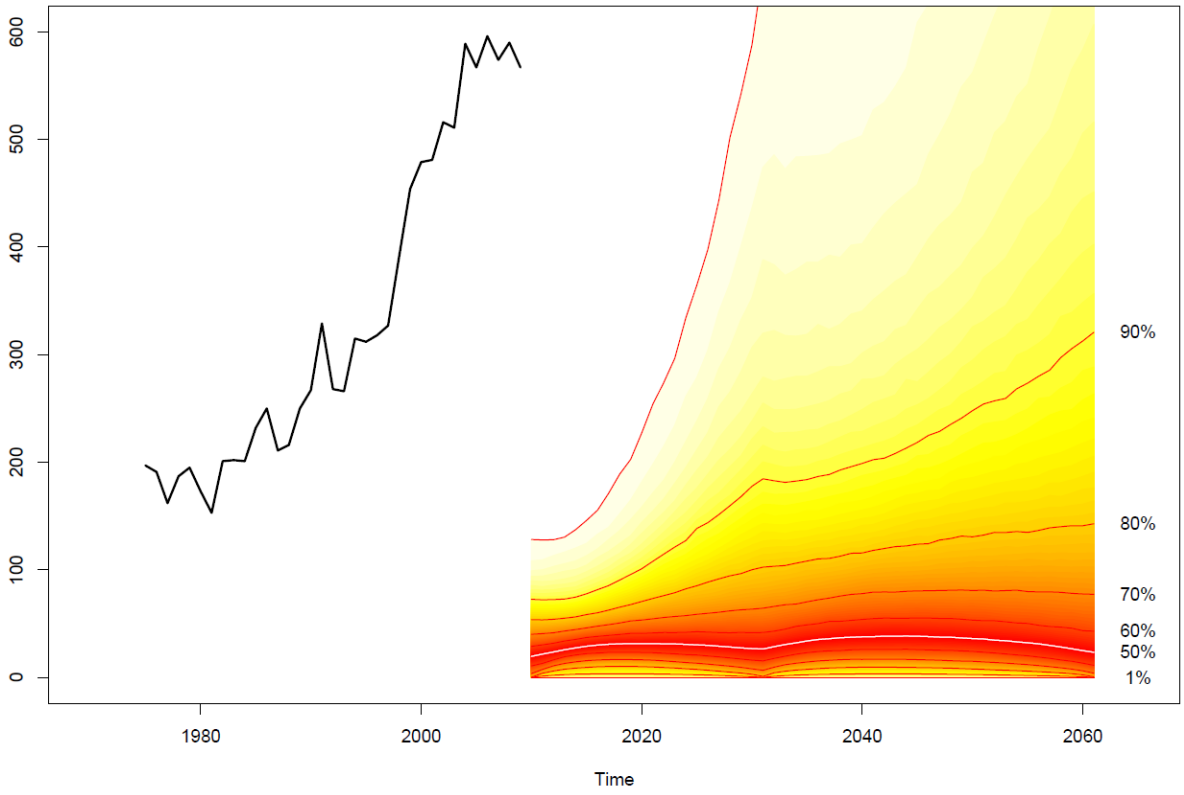

Figure 3 Forecasts of environmental immigration to the UK, averaged models (in thousands)
Source: Data – ONS; Forecasts – own elaboration in OpenBUGS/R.
Note: Black line denotes historical total immigration – the same series as in Figure 2 (rescaled). White line on the forecast fan denotes the median prediction of environmental immigration to the UK.

Figure 3 is ground-breaking in providing for the very first time some expert-based estimates of the volume of environmental migration to the UK that might occur year on year over the next 50 years. It not only shows the possible levels of environmental mobility, but perhaps more significantly it predicts that there will not be a continuous increase in the number of environmental immigrants, refuting the suggestions of some environmentalists of an exponential rise in environmentally-driven population movement by 2060. Of course, the values shown in the diagram (while being the best estimate available to decision makers) are only as good as the knowledge base of the Delphi panel experts and the univariate modelling procedure that has been employed to generate this forecast. Nevertheless, by recognising that the panel of experts was selected to represent the best available knowledge on the topic in 2011, and that the model has taken into account the panellists self-defined uncertainty about current and future levels of environmental mobility, the forecast provides the best possible estimates ever generated of the possible scale of environmental mobility.

This provides an important baseline for policy makers to work with until better estimates can be obtained.

The predictive uncertainty shown in Figure 2 is – as expected – quite high. For example, the 80% intervals[1], related to chances of one in ten that in any particular year the actual total immigration to the UK will be above the given range, and one in ten that it will be below, are estimated to be between 131.1 thousand and 1.32 million immigrants in 2030, and between 64.0 thousand and 1.75 million in 2060. It has to be stressed that these intervals, and in general the probability bounds refer to particular years, and not to the whole long-term trajectories of such a volatile process as migration.

By definition, the volume of environmental migration must fall below the value of the total. Thus, in 2030 between 0.6 and 177.7 thousand immigrations to the UK could be caused by environmental drivers, while in 2060, this range could be between 0.6 and 312.7 thousand. In the short term, the uncertainty assessment seem plausible; however, due to the nature of the processes under study, as well as of the forecasting models, the intervals beyond 2020 or 2030 clearly become too wide, especially at the upper end. From this point of view, the statistical migration forecasts can be useful within the horizon of about ten years (see also Bijak and Wiśniowski 2010). Beyond that the exploration of possible futures should be ideally complemented by the means of other tools, such as scenarios, examples of which are available from the GOS (2011) study. The results of our forecasting exercise presented in the next section should be interpreted with these caveats in mind.

[1] Probabilistic population forecasters tend to prefer 80% predictive intervals over, for example, 95% ones, main arguments being that the former are more robust and less affected by the extremes, and do not unnecessarily amplify the impression of uncertainty (Lutz et al. 2004: 37). Besides, as argued by Bijak (2010: 107), "such intervals can also provide additional warning to the forecast users, as the probability that the process will fall beyond their limits from time to time cannot be neglected."

5. DISCUSSION OF BAYESIAN FORECASTS IN RELATION TO EXPERT VIEWS

Based on the Bayesian forecasts obtained from extrapolating immigration data augmented by expert opinion, Figure 3 suggests that probably environmental immigration to UK will not change much over the next 50 years from current levels. It is possible that there may be a very slight rise over the next few decades, but that the trend is unlikely to be one involving ever-increasing numbers. Instead, the median forecast suggests that the total volume of environmental immigration (while hovering between 25,000 and 27,000 people between 2030 and 2060) is not set to expand exponentially as Britain moves forward into an era of significant climate change.

In addition, environmental migration will most likely remain a small percentage of the overall migration inflow into the UK. The median environmental flows in 2030 and 2060 correspond to respectively 6.5% and 7.5% of the median total immigration flow. In addition to these estimates, Figure 3 provides policy makers with the challenge of considering how to respond to unlikely outcomes as well as to the more probable estimates around the median line.

How plausible are these forecasts? The plausibility of the results can be considered in two ways. First, do they conform to the expectations of academic literature about the future directions and volume of environmental mobility? Second, the significance attached to them, depends on the credibility given to the reasons provided by the experts in the Delphi panel for the reasoning behind the information which they provided.

The attempt to review the academic literature in the early part of this paper, led to the conclusion that there has been little evidence that climate change has produced international environmental mobility so far (Castles, 2011), and that immobility rather than mobility is the norm (Findlay, 2011). Where environmental forces do produce international migration it seems likely that they will principally be between neighbouring countries, with most of the mobility confined to the developing world. De Haas (2011) believes that even Europe's southern borders will not be the scene of mass environmental migration. All the evidence from the research literature therefore seems compatible with the forecasts presented in this paper of low levels of

environmentally-linked mobility to the UK over the next 50 years, with no significant upward trend in the volume of movement.

Turning to the reasons given by the experts for their forecasts, a number of interesting points emerge. First, the expert panel anticipated a minor decline in UK immigration by 2030. This expectation revolved around perceptions that the relative attractiveness of the UK as a migrant destination would recede over time and that tighter controls on immigration would be an effective barrier. Two comments from panel members amplify this view.

> *'My expectation would be that a lot of the future growth poles globally are going to be in the emerging economies and not in OECD economies. And I would also make the assumption that British immigration policy will not allow in so many migrants… so it is not just a simple matter of economics, we'll still see some immigration but I suspect that it will be lower'.*
>
> *(Expert A, London, March 2011)*

> *'I focused on how desirable this country will be in 50 years from now and for me it is going to be a less desirable country. Southeast Asia will develop so it will become more attractive but I believe that people will continue to see this country as a desirable place to live in. But you also have to take into consideration the impact of this government and movements in other countries to control migration; so I do not think that immigration to the UK will change that much'.*
>
> *(Expert B, London, March 2011)*

These comments indicate that one reason that environmental mobility forecasts for the UK appear stable over time (rather than increasing rapidly) is because the demographic and other experts in the Delphi panel held the views first, that the overall flow of immigration to the UK up to 2060 would not be higher than at present, but rather would involve a slow downward trend because of the UK's declining attractiveness relative to other destinations and, second, that this trend was predicated on the assumption that efforts to impose strict immigration controls would to some extent shape these trends. Since environmental mobility was by definition nested within the overall pattern of migration, the volume of such moves was inevitably shaped by this overall judgement.

Turning to views of current levels of environmental mobility towards the UK, experts confirmed the view of the academic literature that there was currently very little immigration to the UK due to environmental change. Consider the following comment:

> *'I am of the view that we get very few, if any, environmental migrants and that's because I think that migration is overwhelmingly an economic decision or outcome'*
>
> *(Expert C, London, March 2011)*

By the end of round two of the Delphi survey it was clear that there was strong agreement amongst the experts on this, and a high degree of confidence was attached to this position.

Looking forward 20 years, the view of the experts was that environmental change would become a more important contributor in proportional terms to immigration to UK than at present (but because overall immigration was falling this did not imply an absolute increase). Even those who felt that there would be an upward trend did not expect it to account for more than 20 per cent of total immigration (80% of responses estimated environmental mobility to be below 20% of the total). Interestingly, those who were most confident in their forecasts, were also those most likely to give low estimates of future environmental mobility to the UK.

This view was based on assumptions about how migration systems operate. The case was not that there would be minimal human displacement at a global level arising from environmental hazards, but that those moving for environmental and other reasons would mainly move short distances within the less wealthy countries, and even those moving longer distances would be entrained in migration flows to destinations other than the UK. For example:

> *'What are the things that actually drive people to move from their country or their immediate surroundings to a country that is much further away? If you look at the flooding that happened in X (Asian country) … people .. got displaced and many of them don't want to go back even though that is where they have got a potential livelihood … but their decision is not to migrate to UK unless they already have links here. Their coping strategy is to say, I have*

family members close by that can provide me with temporary shelter while I get on my feet. …So my point is that migration is there, but it is not to the UK.'

(Expert D, London, March 2011)

The same logic, in line with the literature on how migrants select specific destinations, suggests that much environmental mobility towards the UK will be European in origin. This is so, first because this is the origin of most current UK immigration and, second, because this is the region within which environmental change might impact on populations who are currently likely to select the UK as a destination (e.g. agricultural workers from other parts of Europe).

'By 2060 from my point of view we will have more intra-European migration flows from countries likely to suffer from climate change and they are southern European countries basically because of water scarcity and issues like that. So I mean countries like the UK could be facing immigration flows coming from people that are pushed from southern Europe. That is why I have chosen a higher rank and in my mind that was due to regional migration'.

(Expert E, London, March 2011)

6. DISCUSSION AND CONCLUSIONS

The environmental mobility forecasts presented in this paper suggest that environmental immigration to UK will not rise significantly over the next few decades, although it may become a more important share of all UK immigration (Figure 3). The median forecast suggests that the total volume of environmental immigration (while hovering between 25,000 and 27,000 people between 2030 and 2060) is not set to expand exponentially. The median environmental flows in 2030 and 2060 correspond to respectively 6.5% and 7.5% of the median total immigration flow. In addition to these estimates, Figure 3 provides policy makers with the challenge of considering how to respond to unlikely outcomes as well as to the more probable estimates around the median line.

The outputs from the Bayesian models reinforce arguments about the general unpredictability of migration when we look several decades into the future, and the shortness of plausible forecast horizons (Bijak 2010). The originality of the approach outlined in this paper has been to offer an advance in forecasting environmental

migration that places uncertainty at the heart of the modeling approach and which combines expert views about generally unknown future levels of environmental mobility with known historical data series about overall migration levels. Going beyond this, our suggestion is that the value of such an approach has been enhanced rather than reduced by interrogating, using a multi-round Delphi survey, the meanings and assumptions underpinning expert evidence. As such this paper has been innovative in as far as the Delphi element of the methodology has been used not only in a conventional fashion (i.e. as a means of turning expert views into metrics that were of value for forecasting purposes), but also as a means of eliciting the values and meanings underlying the particular expert knowledge of the panel members, and thus the envelope of plausibility of the metrics.

In one sense the key result of the approach was the identification of a fan of possible environmental forecasts developed from Bayesian statistical modelling. In another sense the more important result is the recognition by the authors of the limitations of this kind of modelling exercise. The authors have argued that it does not undermine the value of their forecasts to conclude that instead of striving for (unrealistic) precision in forecasting a singular level of future environmental mobility, planners and policy makes would be better placed admitting that uncertainty is inevitable and inescapable, and to use the migration estimates in a different way from what has been conventional. Thus, while the median forecast is of interest, what it tells us mainly is the nature of the assumptions of the expert panel. Of just as great an interest are the probability fans above and below the median forecast line. They offer an opportunity for decision makers to consider the scenarios that might produce other kinds of environmental mobility outcomes. In statistical terms these might be considered to be just as likely as the median outcome, but they deviate more from the assumptions of the experts.

Looking ahead, it is useful to note that further methodological refinement of this approach could be sought in terms of examining the effect of shifting from a univariate model to more powerful models – including more sophisticated causal mechanisms and a range of different drivers – than the researchers were able to produce. Other directions for research would be to explore more sophisticated

methods for eliciting expert opinions including more rigorous interrogation of the meanings given by different experts to the term 'environmental mobility'.

Finally, the policy implications of the environmental mobility forecasts provided by this paper deserve thought. As Figure 3 has shown, it is quite likely that future environmental immigration to the UK in 2060 will not be much different from the current median estimate. The paper has argued that this is a highly plausible outcome, but it is one based on the values and assumptions held by the panel of experts. It is also entirely in line with the expectations of the small body of evidence-based literature on environmental mobility. Thus, it is an outcome that assumes that overall UK immigration levels will fall as we move into the future and that the UK will become a less desirable destination not only for migrants in general but for environmental migrants in particular. This line of reasoning leads to two conclusions of relevance to policy makers and planners.

First, plausible as are the assumptions made by the expert panel, policy makers and planners should recognise that there are no immutable laws underpinning the validity of these assumptions. Therefore there is great value in exploring the scenarios that would produce higher levels of overall migration and that might make UK more rather than less attractive to environmentally mobile people in the future. Recognition of such circumstances would help in providing an early warning of the contexts within which the UK might become a significant destination for environmental migration flows[2].

Second, if current assumptions hold, the implication is that over the next 50 years environmental mobility will focus on other destination regions. This does not absolve UK policy makers from taking action, but suggests that in place of focussing on UK border control, policy makers might usefully devote attention to international development strategies. As suggested by the recent Government Office for Science (2011) report on *Migration and Global Environmental Change*, it points to the need for international assistance to be directed to developing relevant adaptation strategies for populations in other parts of the world. This is needed on the one hand amongst

[2] For example, if an international body such as the UN were to grant legal status and rights to 'environmental refugees' equivalent to that of the current Geneva convention on political refugees, then current immigration policies in UK and elsewhere would be radically impacted

those populations of the global South living in areas of high vulnerability to climate change, but who because of poverty are immobile and unable to adapt to the impact of these changes on their livelihoods. On the other hand, this would benefit the reception areas of large cities in the global South that have been selected by many millions of people seeking a better livelihood, but who have moved to environmentally-high risk destinations in order to achieve it (Black et al., 2011b). In this context, the authors hope that the current study may help contribute to changing the focus from the developed to developing countries – potentially much more important migration actors in the times of global environmental change.

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