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ELICITATION OF EXPERT KNOWLEDGE FOR MIGRATION FORECASTING USING A DELPHI SURVEY

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Abstract: The paper presents the application of the Delphi survey method for eliciting expert knowledge to be used in forecasting immigration flows to selected European countries. The adopted perspective for the analysis is the one of Bayesian statistics, where the expert knowledge can serve as a basis for formulating prior distributions, which are further combined with the data in order to produce forecasts. This paper aims at presenting the Delphi technique, the construction of the survey and then the translation of the answers obtained from the experts to prior distributions.

Keywords: Migration forecasting, Delphi, Bayesian, Europe, Austria, Czech Republic, France, Hungary, Italy, Poland, Portugal

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Contents

1. Introduction

The aim of the paper is to present an application of the Delphi survey as a technique of the expert knowledge elicitation. The expert opinions and beliefs elicited by means of the Delphi were subsequently applied in the Bayesian forecasts of immigration into selected European countries. The exercise was carried out within the project '*Mediterranean and Eastern European Countries as new immigration destinations in the European Union*' (IDEA).

One of the tasks of the project consisted in providing forecasts of immigration into several European countries (Austria, the Czech Republic, France, Greece, Hungary, Italy, Poland, Portugal and Spain) in the horizon of 2025, based on the quantitative data, as well as on the country-specific expert knowledge. The forecasts ultimately served the overall aim of the project, that is a comparative analysis of migration patterns in these countries[1]. However, Greece has not been included in the forecasting exercise due to the lack of data on international migration flows and Spain due to unavailability of the expert information at the time of preparing this report.

The variables forecasted in the study were immigration inflows, both total and the ones from up to three most important sources of immigration (or citizenship groups, depending on data availability). Additionally, the impact of two economic (GDP per capita growth and unemployment rate of the receiving counties) and two demographic (natural population growth rate and productive age group share) covariates on the immigration was investigated. For handling the problem of combination of the subjective expertise and the data the Bayesian approach was employed.

The expert judgements or opinions can be treated as prior knowledge represented by the prior probability distributions that is then combined with data reflected in the likelihood function by means of the Bayes theorem. Informative priors, which take into account the hardly predictable nature of migration, seem to reflect the uncertainty associated with the processes in question better than hardly- or non-informative distributions, which let the (flawed) data alone speak for themselves (Bijak, 2008). The expert subjective knowledge, that in the study was translated into prior distributions for particular parameters of the forecasting models and for probabilities on the model space, was elicited by means of a Delphi survey. Details concerning models employed in the analysis that served as a basis of the preparation of the questionnaire and then the elicitation process are provided in Bijak and Wiśniowski (2009). Hereafter we use the notation introduced therein.

Apart from the current Introduction, the report is structured in three sections. Section 2 is an introduction to the Delphi technique and the issues specifically related to the current study. In Section 3, the description of the questionnaire used for the expert knowledge acquisition is

[1] More information on the project can be found on http://www.idea6fp.uw.edu.pl.

provided and the elicitation procedure is explained. The last section concludes. In the Appendix to the paper a sample country-specific survey is presented.

2. A Delphi survey among experts

This section aims to present the Delphi method, which in a simplified form has been applied in the current study. As mentioned before, the proposed forecasting methodology for the IDEA project encompasses the elicitation of *a priori* expert knowledge on immigration processes concerning seven European countries taking part in the forecasting exercise. The expert knowledge constitutes a vital element of predictions, being eventually applied within a formal Bayesian forecasting model.

2.1. Introduction to the Delphi method

In general, Delphi is a technique that obtains data and opinions through surveys carried out via mail, which originally stems from the applications in the US military (see eg. Dalkey, 1967). The key features of the Delphi method are (Armstrong, 1985; Rowe and Wright, 1999):

- The respondents are experts in the subject under consideration.
- The respondents are anonymous.
- Judgements are obtained iteratively: experts are asked the same questions more than once.
- Feedback for the respondents is provided: the respondents are informed about the results of the preceding round. They can formulate their opinions in order to reach a consensus. The respondents with extreme answers may be asked for the reasons for their views.
- The answers can be statistically aggregated.

The anonymity of the respondents ensures that the opinions are expressed without the social pressure of the majority or the dominant individuals in the group. The iterative procedure (two or more rounds) and the feedback concerning the general results of the previous rounds give the experts the opportunity to change their opinions in order to achieve compromise, again anonymously. The feedback comprises a simple statistical summary of the preceding round answers. It may provide additional information, such as the arguments of the respondents whose answers are extreme with respect to the average.

On the other hand, Armstrong (1985) points out that, admittedly, adding rounds brings greater accuracy and consensus with respect to the outcome, yet it is uncertain whether the gains could be greater if the number of experts was increased. Moreover, in their Delphi evaluation review, Rowe and Wright (1999) suggest that the greater number of rounds may result in a correction of the opinions to conform with the group without changing the opinion. They advise that the number of rounds should be three. This number suffices to achieve stability of the responses and reduces the risk of conformism (Rowe and Wright, 1999). The Delphi

survey used in the current study comprised of two survey rounds (which is the least acceptable number), instead of the ideal three rounds, mainly due to the constrained availability of resources.

2.2. Formulation of the questions

In general, the Delphi technique requires preparation of a survey according to the rules that take into account insights from cognitive psychology, so as to ensure unambiguous answers. Rowe and Wright (2001: *passim*) provide evidence for a strong influence of question formulation on the answers obtained. Hence, most importantly, the questionnaires should contain a clear definition of the subject in the question. The key hints on question formulation are (*idem*):

- The question should be long enough to ensure its correct interpretation by the respondent, yet it should not be complicated and overloaded with information, but instead phrased in simple language.
- Questions should not contain emotive phrases, to avoid connotations and prejudices.
- The wording of the question, especially with respect to numbers, is also important, as it may induce the anchoring or bias effects.
- Questions should not incorporate too much or irrelevant information. With too much knowledge provided, the respondents may tend toward discarding it, and the irrelevant information may be considered relevant. Armstrong (1985: 104) suggests that "lack of information is better than worthless information."
- When the questions are formulated, it is also recommended to pre-test them with someone in order to ensure that they have the intended meaning.

In the current research problem, the questions concern predicting future immigration flows and, in particular, the structural parameters of the models employed in the analysis. A novel application of the Delphi approach in the study consists in the aim to combine the prior knowledge elicited from the experts with the quantitative data, in order to obtain forecasts. Originally, the Delphi survey alone was used as a tool for prediction-making (for a migration forecasting example, see e.g. Drbohlav, 1996).

Once the questions have been formulated, the experts for the survey can be selected. Although the evidence suggests that the expertise alone is not of a great value in forecasting (Armstrong 1985), the current task is, however, to elicit the expert judgements that will be used as a prior knowledge (expressed in the form of probability distributions) for further research, namely for combining it with the data. In general, the choice of experts should be carried out according to the following rules (for details, see Rowe and Wright, 2001):

- The experts should have the appropriate domain of knowledge.
- The combined experts' knowledge should encompass the whole problem domain, not only a particular field. Hence, heterogeneous groups of experts are preferred.

- The group should be between 5 and 20 experts. It is argued that more respondents may cause the information overload, conflicting opinions or irrelevant arguments. The number of experts should depend on the resources available and the quality of feedback expected from them, however this range is arbitrary.

One particularity of the forecasting task presented in the current study is that several questions concern subjective probabilities. That means that the experts are asked, how they perceive the future in terms of subjective beliefs or convictions about the behaviour of a particular variable, in our case, the inflow of migrants to the expert's country of expertise. Hence, the formulation of the questions requires attention with regard to proper perception of the very concept of probability.

The research on the assessment of probabilities shows that the *direct* methods sometimes can be inconsistent with *indirect* ones (see Goodwin and Wright, 1998). For instance, the estimates of odds ratios (of the form $a : b$), which are not normalised and thus may have no upper bound, tend to be more extreme than the probabilities specified within a [0, 1] interval. People also tend to view the uncertainty not expressed as subjective probabilities but rather as frequencies (Gigerenzer, 1994; Kadane and Wolfson, 1998). Moreover, people perceive problems as unique, not as the instances of a wider class of events. They pay attention to the particular and specific characteristics of the subject under consideration and forget about the context and the analogies to similar events. Gigenrenzer (1994) advises that questions about probabilities should be formulated as questions about proportions, so as to provide the wider context of the subject. This method allows also for elimination of the overconfidence of the respondent in his or her subjective probability. Only when the event under consideration is truly unique, the subjective probability should be employed directly by using the judgemental heuristics (for references, see Rowe and Wright, 2001).

The problem of overconfidence arises also when the coherence of the probabilities is considered. For two mutually exclusive and exhaustive events the probabilities should sum up to one. The general tendency is, however, that the greater the number of such exclusive and exhaustive events, the greater the chance that the sum of such 'probabilities' exceeds 100% (Armstrong, 1985). Nevertheless, the latter problem can be overcome by the means of a simple standardization of the values provided by the respondents.

Another problem that arises while assessing the judgements about probabilities and probability distributions is overconfidence of the respondents in providing too narrow uncertainty ranges. The starting question about the mean or median of the distribution may lead to the anchoring of the answer, lowering the variability and difficulties in assessment of the tails of the distribution (see e.g. Kadane and Wolfson, 1998; Rowe and Wright, 2001). The assessment of the variability may require detailed technical considerations, such as variance decomposition (e.g. O'Hagan, 1998), although in the current study a different approach is followed, described in more detail in the next subsection together with the whole questionnaire. Furthermore, in order to provide some intuition for the experts about the ideas

included in the questions concerning the model parameters and their probability distribution characteristics, a visual presentation of the behaviour of the variables under consideration or the possible answers to the questions (such as the shape and direction of the trend) was proposed.

3. Elicitation of prior information

3.1. General information

In the current study, the *a priori* expert knowledge has been elicited from between six and fourteen respondents per country. The survey-based elicitation process consisted of two rounds, so as to allow for corrections and possible convergence of the initial judgements, hence, following a Delphi framework described in the previous section.

The survey concerned process characteristics (parameters of the forecasting models), rather than the processes as such (future values of migration volumes). This solution was found more straightforward, as it does not require additional re-calculations in order to transform the expert-based predictive probability distributions into the prior ones. Besides, the inference on the future values will ultimately combine data and expert knowledge, so that the predictive distributions obtained *a posteriori* would anyway differ from the ones elicited from the experts, which may lead to interpretational difficulties. In any case, the aim was to elicit expert knowledge using a natural language (or terms close to it) and visualisations of certain concept, rather than formal terms.

Unlike in the implicit assumptions made in many Bayesian literature examples (cf. Kadane and Wolfson, 1998; Dey and Liu, 2007), in the presented study expert knowledge has been elicited from migration specialists of various background, but predominantly from non-statisticians (for a thorough overview of elicitation issues in this context, see O'Hagan, 1998, and O'Hagan *et al.*, 2006)[2]. For the current study, this implied very strong limitations on the use of formal terms in such a survey (for example, 'distribution', 'variance', 'probability', 'stationarity', 'quantile', etc.). However, with respect to migration research, the area seems uncharted. As it has been noted by A. O'Hagan (1998: 22), "[…] to elicit a genuine prior distribution […] is a complex business demanding a substantial effort on the part of both the statistician and the person whose prior beliefs are to be elicited. A Bayesian who wishes to take this task seriously finds little guidance in published work that is directly relevant to the task that he or she faces."

The questionnaires for each of the IDEA countries were prepared using the same layout, which allowed for handling the country-specific information, such as definitions of an

[2] Another example of a purely 'non-statistical' elicitation can be found in the study of Szreder and Osiewalski (1992), who analysed the instances of supply shortages in the then-socialist economy of Poland.

immigrant or data collection practices. Besides, two versions of the questionnaires were prepared: English only, and a bilingual one, including, apart from the English text, a translation of it into the national language. Due to the fact that the questions concern the distributions of possible model parameters, our aim was to provide the respondents with some intuition about the possible answers using the visual presentations. In general, the questions concerned the general tendency of immigration to a particular country, the shape of the process, its volatility, the possible impact of some economic and demographic variables on immigration, as well as main directions of migration inflows. The questionnaire is described in more detail below. A sample questionnaire is presented in the Appendix to the paper.

3.2. Construction of the questionnaire

The questionnaire consisted of fifteen questions (the sample is presented in the Appendix):

- The first question concerned the long-term (until 2025) general tendency (direction) of the future immigration flows. The figures indicating the shape of the trend (constant, as well as increasing or decreasing linear, logarithmic and logistic), along which the flows would follow, were presented. The experts were asked to choose one from the figures or to describe other type of trend.
- The second question aimed at the elicitation of the stationarity[3] characteristics of the immigration process, treated as a stochastic one. Three figures presented the example immigration processes that indicated the stationary (white noise), non-stationary (random walk) and explosive characteristics. The experts were asked to provide the chances (in terms of percentages) of occurrence of a given process or to describe their own characteristic and assign a subjective probability to it.
- The third question concerned the volatility characteristics of the future immigration process, or, more technically, how the variance of the immigration process would behave. Two example figures presented the idea of constant (stable) and stochastic (changing over time) volatility. As in the question 2 the experts were asked to provide their estimates of the probabilities of occurrence with the possibility to describe their own characteristic.
- In the fourth question the experts were asked for the estimates of the future deviations of the immigration processes from the assumed (for a given country) average immigration levels, in terms of percentage points, to be chosen from a range 10 – 1,000% or to provide their own. This question concerned the standard deviation level of the process.
- The aim of question 5 was to bring the estimate of the volatility of the variance level provided in the antecedent question. This volatility was required as a characteristic of the prior distribution for the variance (see detailed description in Section 3.3). This was achieved by asking the experts for their certainty concerning the answer given in question

[3] A stochastic process $\{y_t,\ t=1,2,3,\ldots\}$ is called (covariance-) stationary in a weak sense if and only if its expected value and variance exist, are finite and are independent of time, and the covariance of y_t and y_s is a finite function of the term $|t - s|$ and not of t nor s alone (Greene 2003: 612). In lay terms, one can think of stationarity as 'stability' of the mean and variance of the process, which is the reason of its similar behaviour in different periods of time.

4. The certainty was measured on a 11-degree scale ranging from 0 (very uncertain) to 10 (almost sure).

- Questions 6 to 9 concerned the additional economic and demographic variables possibly influencing the future immigration processes (see Section 3.3 in Bijak and Wiśniowski, 2009). The questions aimed at providing the estimate of the character of the impact of these variables on immigration. Specifically, in the subsequent questions the experts were asked, whether faster economic growth ('stimulant'), decreasing unemployment rate, decline in natural population growth and the decrease in the share of the productive age group ('inhibitors') would be associated with proportional, even faster or even slower immigration growth, with immigration decline, or whether the particular variable is not relevant for immigration process (one option to be chosen).
- In question 10 the experts were asked to provide up to three variables (in the order of importance) in their opinion potentially influencing the future immigration processes other than the ones listed in questions 6–9.
- Question 11 aimed at providing the direction of the impact of the variables described in question 10. The experts were asked to indicate whether the certain behaviour of the variable would cause the immigration to increase or decline (expressed in terms of positive and negative impact).
- Question 12 concerned three most important future source countries (directions) of inflow of the immigrants (or citizenships in the case of Hungary and France). The experts were asked to provide up to three, in their opinion, most important source countries with an indication (if relevant), whether these would likely be returning migrants.
- In question 13 the experts were asked to evaluate the expected future tendency of the directions of inflows listed in the previous question by choosing one from the options: increasing, decreasing, stable, or to describe more complex pattern.
- Question 14 aimed at providing the professional background of the experts (information not relevant for and not used in the forecasting exercise).
- Question 15 was an open-ended one, where the experts could provide the comments (concerning the merit, as well as the questionnaire itself), additional explanations or justifications for their answers with the possibility to indicate, whether their comments could be shared with the other experts in the following round.

In addition to the above-mentioned questions, the second-round questionnaire contained summaries of first-round answers in the form of histograms (question 1, as well as 4 through 9), probabilities expressed as percentages (questions 2 and 3), or tables (questions 10 through 13). Besides, two new questions were added in the second round:

- Question N1 aimed at the assessment of the characteristics of the logistic trend (if an expert indicated so in the preceding first question), namely the likely upper asymptotic value (an upper bound) of the future immigration level and the inflection point of the trend curve.
- Question N2 concerned the impact of the most common variable listed in the first-round answers on the future immigration flow (in most cases it was the immigration

policy). The question was formulated in the same manner as questions 6–9. In the second round the questions 10 and 11 were omitted as they served as a basis for the question N2 (summaries of the answers from the first round were also provided).

The experts' answers to the questions were summarised and then used to formulate the prior probability distributions of the models (*idem*). The translation of the answers to the quantitative characteristics of the densities are presented in the next subsection.

3.3. Translation of the answers into probability distributions

Herein we describe, how the knowledge elicited from the experts was transformed into the probability densities. Note that the models and all the prior distributions of the parameters are presented in detail in Bijak and Wiśniowski (2009), the enumeration of the equations regards the enumeration therein.

Firstly, the constants, c, were included in every model to handle the mean value of the (log-transformed) immigration levels. The priors for every country but Poland (explained in detail below) were normal with mean 0. The precision for constants in the autoregressive models were diffuse, however the information concerning the immigration policy was used. The tighter policy the majority of experts indicated in their answers to question N2 (options 'slower' or 'proportional growth'), the less diffuse prior (greater precision) was set for the constant. In the case of pro-immigration policy, hardly-informative priors were set (precision was smaller)[4]. The priors for constants in the random walk models were, in almost all cases, concentrated in 0 due to the undesirable characteristics of the process (technically, an infinite RW process with drift has an infinite expected value), and the resulting absurdity of the produced forecasts (exploding immigration flows). On one hand, this can be viewed as a drawback of the analysis, but on the other hand, as confirmed by the results (*idem*), the characteristics of the random walk process allow to capture the specific variability in the immigration data very well.

The deterministic trend indicated by the vast majority of experts in all countries but Poland was logarithmic. The trend was included in the AR models only due to the general characteristics of the non-stationary RW process, mentioned in the previous paragraph. As almost all experts in all countries pointed out the increasing tendencies of the immigration flows, the priors set for the parameters γ in the AR models are normal with mean 0.5 and variance 1. This hyper-parameters ensure a distribution with about 30% of the probability mass below 0. The exception was the Czech Republic, where the prior set for γ was diffuse, in order to ensure reasonable results.

[4] We are perfectly aware that the adopted solution is to a large degree arbitrary. As it was difficult to formulate the policy-related question and operationalise the answers, we decided to propose a simple solution that we found sensible (tighter policy – less room for change). However, except for several cases of the random walk models, these distributions appeared not to matter so much – the priors were relatively diffuse and the data changed them anyway.

In the case of Poland, the logistic trend was suggested by the experts (*idem*, Section 3.3.1). The logarithm of α in equation (2) served then as a constant, with the prior (assumed normal) elicited from the answers to the question N1: the upper bound for immigration was set to about 90,000, thus the mean of the prior was ln(90,000), and the precision defined according to the precision estimated from the experts' answers sample. The value of t^* in the equation (3) was elicited from question N1 as year 2019 (a year in which the increase would begin to slow down). The prior for the coefficient γ was assumed to follow a Beta distribution with parameters 20 and 2, and was informative, mostly due to the computational and convergence issues.

In the case of the parameters ϕ of the AR models, the normal priors were set according to the information from the answers to the question 2, parts A (stationary process, with $|\phi|< 1$) and C (explosive process, $\phi >1$). The random walk cases ($\phi=1$) in part B was treated separately, while the processes with $\phi \leq -1$ had negligible probability mass attached to them, and could be therefore ignored without a loss of generality. The answers from A and C were normalised to represent the probability mass below and above 1 respectively and then the values of the mean and precision were found using grid-searching algorithm.

The priors for the precision parameter of the model, $\tau=\sigma^{-2}$, were assumed to follow the Gamma distributions, $\Gamma(r, \mu)$. The shape parameter, r, was set to 2, which was underlain by the answers given by the experts to question 5: the average degree of experts' certainty concerning the estimates of the mean standard deviation oscillated in every country around 4–6 (medium uncertainty), hence it was justifiable to use $r = 2$ for each of them and then to control for the expected value of the precision using the scale parameter μ. Had the answers been different, than either $r = 1$, or $r = 3$ would be used, respectively depicting very high uncertainty (with answers to question 5 falling on average into the range 0–3), or, adversely, very high certainty (answers from the range 7–10).

The expected value of the precision was derived from question 4. The weighted mean of the answers, that aimed at obtaining the estimate of the standard deviation, was multiplied by 1.25 in order to eliminate the bias resulting from the usual confusion of the average absolute and standard deviations (for details see e.g. Goldstein and Taleb, 2007). The interpretation of this estimate, denote it as a, was the ratio of the standard deviation to the expected value of the underlying immigration process, according to the formula $\sqrt{Var(m_t)} = a \cdot E(m_t)$. Then, assuming the log-normal distribution of the underlying immigration process, m_t, the expected value for precision was calculated using the formula: $E(\tau) = -\log\left(1 + \frac{Var(m_t)}{(E(m_t))^2}\right)$. Finally, the value of scale parameter μ of the Gamma distribution was calculated from the equation: $E(\tau) = r / \mu$. Needless to say, the proposed procedure is merely one of the available options for operationalising the expert judgement with respect to precision. In a further sensitivity

analysis, one could alternatively use Gamma distributions with other parameters, base the results only on the outcome of question 4 (which would then indicate both mean and standard deviation of τ), after examining the correlation between the answers to questions 4 and 5[5].
The values of the hyper-parameters for priors of the SV model-specific parameters, namely K, ψ and ρ, were set in order to assure the convergence of the algorithms, however, the information delivered by them was rather vague.

The prior for dummy incorporated in the models for the Czech Republic was specified according to the change of the definition – a Normal prior was concentrated in –1 as it corresponded with a more rigorous definition of an immigrant until 2000. In the case of Portugal the prior set for a dummy was diffuse, in order to 'let the data speak for themselves'.

In the case of prior probabilities set on the model space (Bijak and Wiśniowski, 2009: Section 3.3.1), they were elicited from the answers to question 2 and 3, assuming the independence of answers to these two questions. First, the marginal probabilities for AR models, $p(M_1,M_3)$, and RW models, $p(M_2,M_4)$, were calculated from question 2 as summed averaged answers to options A and C, and averaged answers to B (taking into account answers from the open-ended option D), respectively. The probabilities for CV – $p(M_1,M_2)$, and SV – $p(M_3,M_4)$, models were derived from the averaged answers to points B and A in question 3 (again including the information from open-ended option C). Finally, the sought probabilities were calculated as presented in Table 1 (assuming the independency of the AR – RW and CV – SV models).

Table 1: Prior probabilities on the model space.

Model type		AR	RW
	Probability	$p(M_1,M_3)$	$p(M_2,M_4)$
CV	$p(M_1,M_2)$	$p(M_1) = p(M_1,M_2) \cdot p(M_1,M_3)$	$p(M_2) = p(M_1,M_2) \cdot p(M_2,M_4)$
SV	$p(M_3,M_4)$	$p(M_3) = p(M_3,M_4) \cdot p(M_1,M_3)$	$p(M_4) = p(M_3,M_4) \cdot p(M_2,M_4)$

Source: own elaboration

As far as the model of shares is concerned, the source directions of immigrants were chosen on the basis of the answers to question 12, after assigning ranks to the countries listed by the experts. The normal priors for constants were rather diffuse, with mean 0 and an arbitrary precision of 0.1 (in the case of Poland it was 1, in order to avoid high oscillation in the forecasts).

The priors set for the parameters of the matrix ϕ were normal with mean 0 and a rather vague precision, however, in some cases (e.g. Poland, Italy) it was required to concentrate the priors around zero due to the explosiveness of the process (and nonsense predictions).

[5] We are very grateful to Anna Żylicz for this suggestion.

Models for shares included trends in the cases in which the experts indicated that the shares from certain directions would behave in a specific way, e.g. would increase. The characteristics of these trends (described in *idem*, Section 3.3.2) were elicited from the answers to the question 13. The hyper-parameters for the normal priors were usually set so as to ensure the tendency indicated by experts, namely, with mean 0.5 and precision 1, 30% of the probability mass remaining below 0. The exceptions were Czech Republic, where the mean was moved to 1 (in order to allow for the future increase of the shares) and in the case of Hungary, where the mean for the shares from Romania was set to 0.1, again, in order to ensure the coherent behaviour of three directions' shares in the light of the experts' justifications. In the model of shares for Portugal, the prior for a dummy was again diffuse, centred at zero, in order to 'let the data speak for themselves'.

The Wishart priors for precision in the shares models assumed *a priori* an instantaneous independence of the shares from each other (indicated by off-diagonal zeros in the matrix **T**). The choice of the hyper-parameters for precision (diagonal of **T**) had an impact, however, on the posterior precision of the forecasts. Their values varied between the countries, so as to ensure the proper behaviour of forecasts, and in particular avoiding high oscillations of the predicted shares.

As far as the vector autoregressive (VAR) models with economic and demographic determinants are concerned (*idem*, Section 3.3.3), the prior distributions for the constants were assumed normal and diffuse. In the case of matrix of structural parameters **A**, the priors were normal. For the first parameter, α_{11}, it was obtained using the same rule as in the case of the AR models for totals, hence the normal distribution with hyper-parameters set according to the information from the answers to the question 2, parts A (stationary process, with $|\phi|< 1$) and C (explosive process, $\phi >1$), after normalisation. As far as the prior hyper-parameters for expected values of α_{12} and α_{13} are concerned, these were obtained as follows. Firstly, every answer from A to E to Questions 6–9 was assigned a prior mean given in Table 2.

Table 2: Prior means for structural parameters from answers to Questions 6–9.

Answer	A	B	C	D	E
Prior mean	1.5	1.0	0.5	–1.0	0

Source: own elaboration

Secondly, the hyper-mean was a weighted mean of the answers given by the experts to particular questions, with positive sign in the case of the 'stimulant' (GDP growth) and negative sign in the case of the 'inhibitors' (the other variables) of the immigration processes. Then, the hyper-variance was set arbitrarily to 4.0, which was rather concentrated, however still allowed for the data to 'speak for themselves.' The other parameters were centred in 0. The diagonal ($\alpha_{22}$and α_{33}) parameters had diffuse priors (precision was set to 0.01), while for the off-diagonal elements precision was set arbitrarily to 1 (still the results were rather insensitive to this parameterisation).

The prior distribution for the precision matrix $\mathbf{T}=\mathbf{\Sigma}^{-1}$ was assumed to follow Wishart distribution. The hyper-parameters were matrix **P** and k=3 degrees of freedom. Using the facts that $E(\mathbf{T})=3\mathbf{P}^{-1}$ and that **P** can be decomposed into $\mathbf{P}/k=\mathbf{DRD}$, **D** – a diagonal matrix with elements interpreted as prior standard deviations and **R** – a matrix interpreted as prior Pearson's correlation coefficients (for details see e.g. Bijak, 2008: 117), matrix **P** was constructed as follows. The first element of **D** was set so as to reflect the standard deviation resulting from the experts' answers to Question 4, and the remaining elements were set to 1. In the case of matrix **R**, every answer from A to E to Questions 6–9 was assigned a prior mean (of the corresponding correlation coefficient) given in Table 3.

Table 3: Prior means for precision parameters from answers to Questions 6–9.

Answer	A	B	C	D	E
Prior mean	0.5	1.0	0.5	–0.5	0

Source: own elaboration

Then the weighted means with signs set according to the role of the variable ('stimulant' or 'inhibitor') for every variable represented the prior correlation. Needless to say, the diagonal parameters of **R** were ones.

Tables 4, 5 and 6 present the summary characteristics of the prior distributions used for models of total immigration, origin-specific shares, as well as the impact of demographic and economic variables impact, respectively. They sum up briefly, whether the applied distribution was informative and whether it was based on the expert knowledge.

Table 4: Prior distributions for model of total immigration flows – a summary.

Parameter	Distribution	Informative	Expert knowledge
c	Normal	Yes/No*	Yes/No*
ϕ	Normal	Yes	Yes
γ	Normal (Beta)**	Yes	Yes (No)**
$\tau = \sigma^{-2}$	Gamma	Yes	Yes
K	Normal	Yes	No
ψ	Normal	Yes	No
ρ^{-2}	Gamma	Yes	No
dummy	Normal	Yes/No	No

* Depending on the model type and/or stability of forecasts.
** Prior distribution for the logistic trend coefficient.
Source: own elaboration

Table 5: Prior distributions for model of shares of the immigration flows – a summary.

Parameter	Distribution	Informative	Expert knowledge
$\mathbf{c}$	Normal	No	No
$\boldsymbol{\phi}$	Normal	Yes/No*	No
$\mathbf{T}$	Wishart	Yes	No
$\mathbf{b}$	Normal	Yes	Yes

* Concentrated distributions in such cases, where the forecasts were unstable.
Source: own elaboration

Table 6: Prior distributions for models of impact of the economic and demographic variables – a summary.

Parameter	Distribution	Informative	Expert knowledge
$\mathbf{c}$	Normal	No	No
$\mathbf{A}$	Normal	Yes/No*	Yes/No*
$\mathbf{T}$	Wishart	Yes/No*	Yes/No*

* Informative and based on expert knowledge in the case of the immigration equations.
Source: own elaboration

4. Concluding remarks

In the methodological aspect, a part of the forecasting exercise presented in the current study, that comprised of the Delphi survey preparation and expert knowledge elicitation, was aimed at providing qualitative input to the forecasting models. We believe that the combination of qualitative and quantitative information, within the formal Bayesian framework, is a step towards greater synergy and coherence in migration predictions. The methodological novelty of the proposed approach consists in taking advantage of the features of the Delphi survey to obtain the subjective, qualitative expert knowledge that served as a supplementary information in the preparation of the forecasts.

It should be kept in mind, however, that despite some general rules of the survey preparation the researcher should follow, its construction is heavily case-specific. In the current application several problems were identified. First of all, the purpose of the survey was to obtain information concerning the model parameters and their characteristics, while it was aimed primarily at non-statisticians, what implied limitations on the usage of the formal terms. Secondly, despite the cautious iterative construction and pre-testing of the survey, as well as providing respondents with some intuitions of the basic concepts, there have been some misunderstandings and misinterpretations of the questions among experts and there could have been misinterpretations of the answers. The reason for this may have its roots in the translation of the questions into country-specific national languages. It could has also been a case that the expert's underlying model, upon which he or she formulated opinions about future immigration, had been different from the one used in the study. Finally, the questions concerning the probabilities and probability distributions could have led to the interpretational problems.

Summarising, the Delphi survey has proven to be a very useful tool for the elicitation of the prior knowledge for the Bayesian model. Nevertheless, the translation of the answers to the prior distributions requires making sometimes strong assumptions about the parameters (especially the precision) and the interrelationships among them. Hence a careful sensitivity analysis with respect to the usage of the subjective information should be a vital point of any analysis of such a kind. The sensitivity analysis of the presented elicited prior distributions was a subject of investigation in the second part of a forecasting task (see Bijak and Wiśniowski, 2009).

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As the current study was to a significant degree based on the expert information, we would like to wholeheartedly thank all the migration experts from the European countries relevant to the IDEA project, who, despite the complexity of the method and ambiguity of some of the questions, decided to devote their time and judgement and participated in the Delphi survey. It is their involvement that enabled the innovative character of the research presented in this report. More information on the project can be found on http://www.idea6fp.uw.edu.pl.

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■

Appendix

A.1 Sample Delphi questionnaire - Austria

Mediterranean and Eastern European Countries as new immigration destinations in the European Union (IDEA)

EC 6th Framework Project SSP CIS8-CT-2004-44446
Work Package 4: Migration Scenarios

Delphi survey on immigration patterns for 2007–2025: 2nd round

(English version)

Welcome to the second round of the IDEA survey!

1. *Thank you very much for participation in the first round of our survey concerning intuitions about trends of* ***GROSS INFLOW*** *of* ***short- and long-term (for at least 3 months) immigrants (foreigners and Austrian citizens)*** *to Austria until 2025. We are very grateful for all comments expressed therein. As the study is based on the Delphi approach, we would like to invite you to participate in its second (and last) round.*
2. *Again, you will be kindly asked to share with us with your* ***intuitive judgements*** *built on your expertise, as well as on the attached* ***synthetic responses of all experts****, that would enable us to better adjust parameters of the forecasting models.*
3. *We are perfectly aware that we are once more asking for your time and expert judgement, but nevertheless we are convinced that ultimately it will enable us to produce more reliable forecasts, the results of which we will be happy to share with you.*
4. *Below you will be provided with the questionnaire containing summarized results of the first round as well as* ***two new follow-up questions*** *(in dark blue) added in the second round. Whether you reconsidered your previous judgements and would like to change them in the second round or not,* ***please kindly fill the whole questionnaire again****. Filling it again would take much less time than in the first round (we already took into account your comments given in the first round) but would allow us to assess more accurately convergence of answers between the rounds.*
5. *Again, we would like to ensure that this survey is* ***ANONYMOUS*** *and none of the single opinion expressed therein will be used as a reference. To protect your anonymity, filled questionnaires should be submitted directly to the international coordinator (at* ***idea.delphi@uw.edu.pl****).*
6. *In case of any questions, difficulties, needs for clarification, etc., please, do not hesitate to contact directly the IDEA forecasting team in the Central European Forum for Migration and Population Research (Mr. Jakub Bijak,* j.bijak@cefmr.pan.pl*).*

Yours Sincerely,

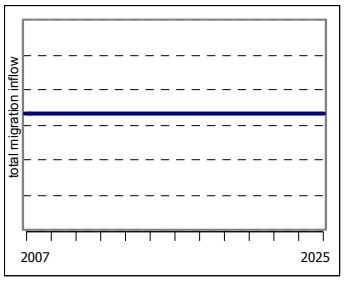
Jakub Bijak

Central European Forum
for Migration and Population Research

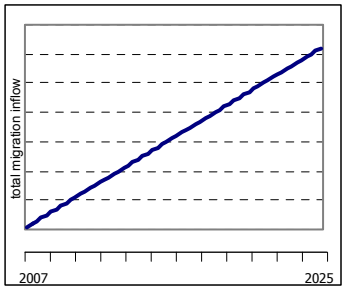
SECOND ROUND QUESTIONNAIRE: AUSTRIA

1. Thinking about the current circumstances and taking into account possibly relevant factors, what would you expect to be the likely general long-term tendency of total gross immigration to Austria until the year 2025? Please, choose **ONE** option below.

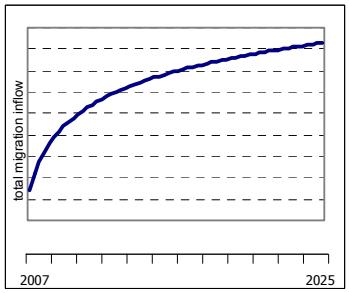
☐ 1A) Constant



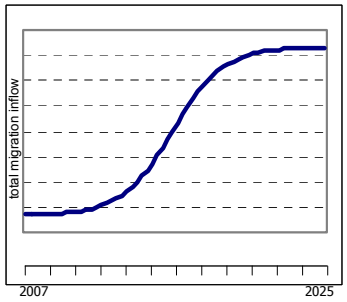
☐ 1B) Linear increase



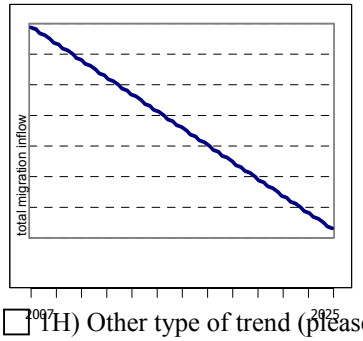
☐ 1C) Ever-slower increase



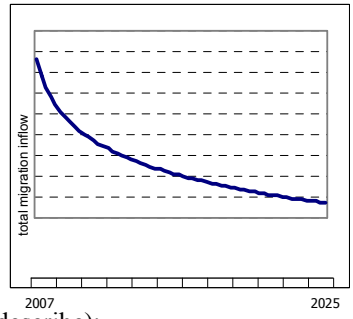
☐ 1D) S-shaped increase



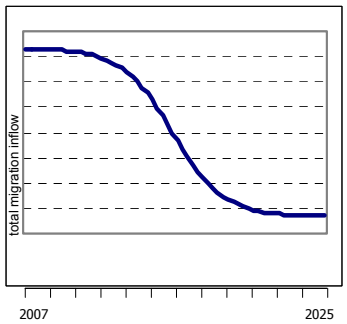
☐ 1E) Linear decrease



☐ 1F) Ever-slower decrease

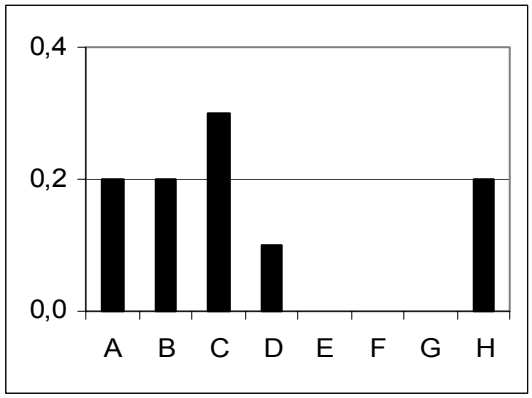


☐ 1G) S-shaped decrease



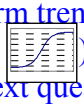
☐ 1H) Other type of trend (please describe):

First-round results (frequencies of answers)



Answers H: see the comments on the last page

FIRST FOLLOW-UP QUESTION in the second round:

N1. Please, answer **ONLY** if you think that the long-term trend of total immigration to Austria will be reflected by an S-shaped increase () or decrease () of migration inflows: (Otherwise go to next question)

N1A. How large will be the overall increase / decrease of migration since 2007?

- About times of the initial levels.

N1B. Around what year will the increase / decrease begin to slow down?

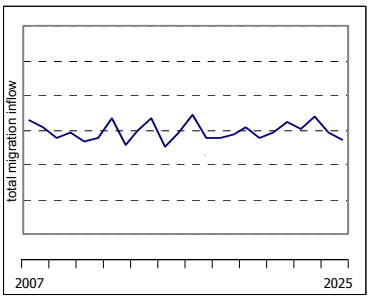
- Around the year .

Additional comments (if preferred):

2. Assuming the tendency indicated in Question 1, what you would expect the variability of this total gross immigration process to be until 2025? Please, express your subjective intuition on what are the chances (in terms of percentages) of occurrence of the options illustrated in the pictures below.

Please *note that the pictures below are meant* ***not*** *to present the exact path of migration processes, but to develop some intuition about general future patterns.*

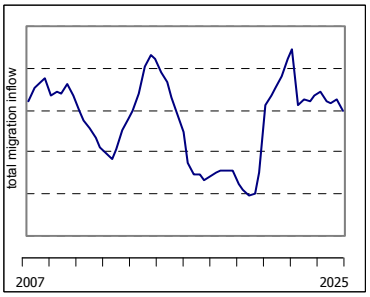
A) Stable around a trend = fluctuating immigration **volume**



Expected chances of occurrence: %

First-round results
Average: **40,9%**

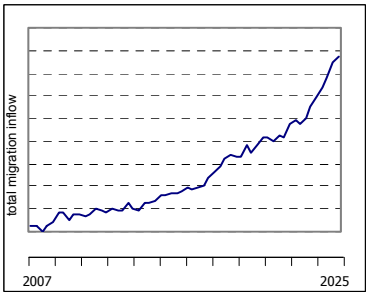
B) Random change = fluctuating immigration **change**



Expected chances of occurrence: %

First-round results
Average: **47,6%**

C) Exploding process = accelerating immigration



Expected chances of occurrence: %

First-round results
Average: **7,7%**

D) Other pattern (please describe):

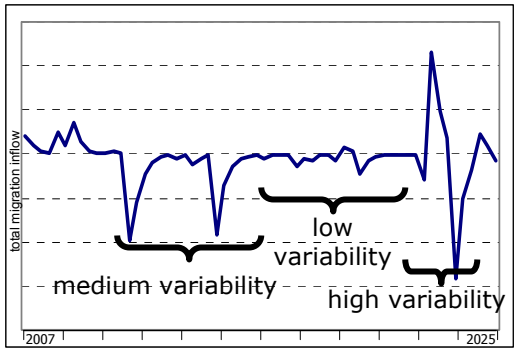
Expected chances of occurrence: %

First-round results
Average: **3,8%**

3. What would you expect the most likely pattern of variability (volatility, fluctuations) of the total immigration to be until 2025? Please, express your subjective view on what are the chances (in terms of percentages) of occurrence of the options illustrated in the pictures below.

*Please note that the pictures below are meant **not** to present the exact path of migration processes, but to develop some intuition about general future patterns.*

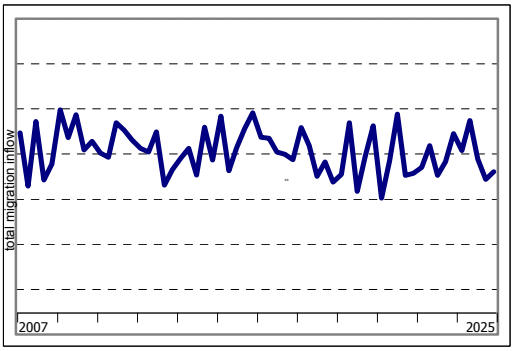
A) Periods of different variability



Expected chances of occurrence: %

First-round results
Average: **42,0%**

B) Constant (stable) variability



Expected chances of occurrence: %

First-round results
Average: **58,0%**

C) Other pattern (please describe):

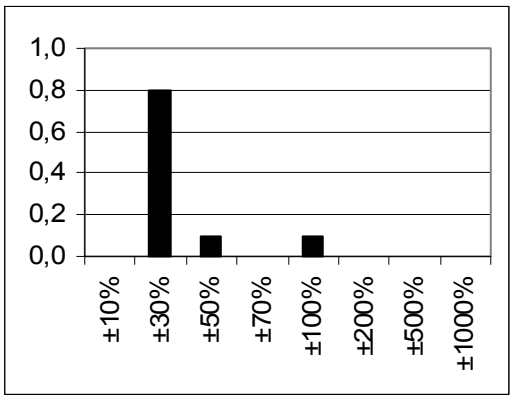
Expected chances of occurrence: %

First-round results
Average: **0%**

4. How large, in terms of the percentage of the future levels of immigration, would you expect the **deviations / fluctuations** of the total immigrations process from the trend mentioned in Question 1 to be, in the horizon of 2025? Please, check **ONE** answer, which suits your own feelings best.

☐ a) ± 10% of the average immigration level
☐ b) ± 30% of the average immigration level
☐ c) ± 50% of the average immigration level
☐ d) ± 70% of the average immigration level
☐ e) ± 100% of the average immigration level
☐ f) ± 200% of the average immigration level
☐ g) ± 500% of the average immigration level
☐ h) ± 1,000% of the average immigration level
☐ i) Other (± % of the average immigration level)

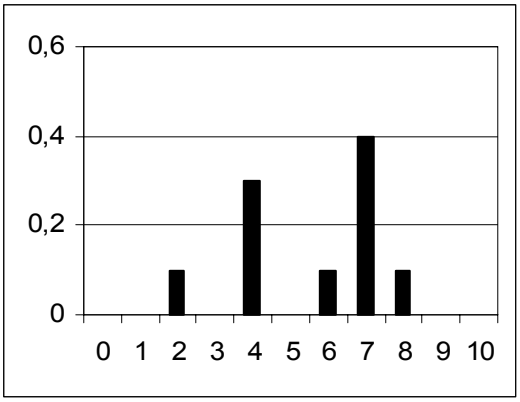
First-round results (frequencies of answers)



5. On a scale from 0 (very uncertain) to 10 (almost sure) please indicate, how certain you feel about the deviations / fluctuations mentioned in Question 4? (check **ONE** option)

(0) — (1) — (2) — (3) — (4) — (5) — (6) — (7) — (8) — (9) — (10)
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
very uncertain almost sure

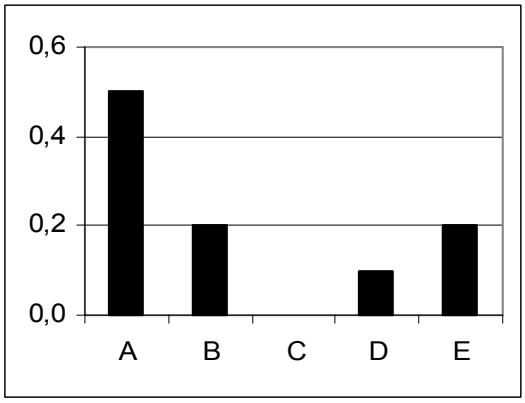
First-round results (frequencies of answers)



6. Do you think that **faster economic growth** in your country would be associated with: (please, check **ONE** option)

☐ a) proportional immigration growth?
☐ b) even faster immigration growth?
☐ c) slower immigration growth?
☐ d) immigration decline?
☐ e) Economic growth is not important for immigration in this case.

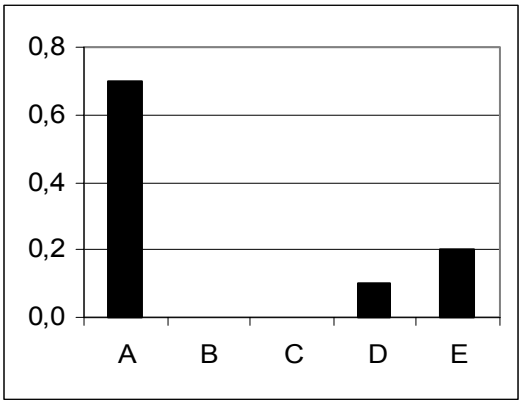
First-round results (frequencies of answers)



7. Do you think that **decreasing unemployment rate** in your country would be associated with: (please, check **ONE** option)

☐ a) proportional immigration growth?
☐ b) even faster immigration growth?
☐ c) slower immigration growth?
☐ d) immigration decline?
☐ e) Unemployment is not important for immigration in this case.

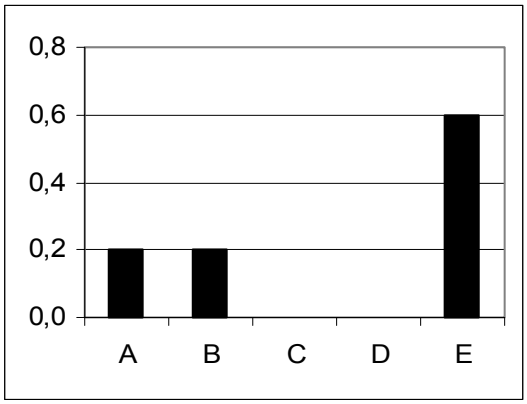
First-round results (frequencies of answers)



8. Do you think that **decline in natural population growth** (*Births – Deaths*) in your country would be associated with: (please, check **ONE** option)

☐ a) proportional immigration growth?
☐ b) even faster immigration growth?
☐ c) slower immigration growth?
☐ d) immigration decline?
☐ e) Natural growth is not important for immigration in this case.

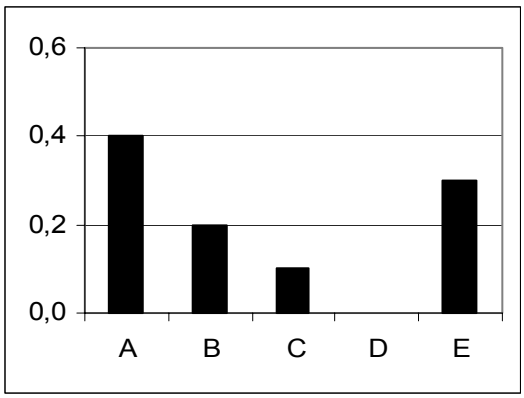
First-round results (frequencies of answers)



9. Do you think the **decrease in the share of the productive age group** in the overall population in your country, and the related **labour shortages**, would be associated with: (please, check **ONE** option)

☐ a) proportional immigration growth?
☐ b) even faster immigration growth?
☐ c) slower immigration growth?
☐ d) immigration decline?
☐ e) Productive age group is not important for immigration in this case.

First-round results (frequencies of answers)



Questions 10 and 11 are omitted, as they were used as a basis for the new Question N2.

Most frequent answers to Question 10

elements of (im)migration policy and general policy trends	**7**
"global" demand for foreign labour force (concerning minimum wage issues)	**5**
exceptional events and (un)problematic situations in other countries	**5**
EU enlargement & growth of intra-EU mobility	**5**

SECOND FOLLOW-UP QUESTION in the second round:

N2. Do you think the immigration and integration policy in Austria would be associated with: (please, check **ONE** option)

- ☐ a) proportional immigration growth?
- ☐ b) even faster immigration growth?
- ☐ c) slower immigration growth?
- ☐ d) immigration decline?
- ☐ e) Immigration policy is not important for immigration in this case.

12. According to you, which will be the most important source countries of the inflow of either immigrants or return migrants until 2025 (in both cases understood as the countries from which the migrants will be coming, not the countries of birth)? Please, list **up to** three countries in the order of importance (from 1 = highest to 3 = lowest), and indicate (by checking the box), whether the respective flow will be generated mostly by return migrants.

Note: If you consider only one or two countries important, please, list only them. If you consider some countries equally important, please list them in alphabetical order and provide us with a comment.

1.		Mostly return migrants? ☐
2.		Mostly return migrants? ☐
3.		Mostly return migrants? ☐

Comment:

First-round results (numbers of answers)
In brackets including indications from comments

Country	Count
Germany	7
Turkey	6 (7)
Serbia	3 (8)
Ukraine	2 (3)
Romania	2 (5)
Poland	1 (2)
North Africa	1
Balkans	3
former Yugoslavia	2

13. For each of three countries of immigration listed in Question 12 could you please choose whether the **shares** of these directions in the total inflow until 2025 you would expect to be, **on average**:

a) From country 1 (check **ONE** option):

☐ A) increasing
☐ B) decreasing
☐ C) stable
☐ D) if you think that the pattern will be a more complex one, please, describe it briefly below:

b) From country 2 (check **ONE** option):

☐ A) increasing
☐ B) decreasing
☐ C) stable
☐ D) if you think that the pattern will be a more complex one, please, describe it briefly below:

c) From country 3 (check **ONE** option):

☐ A) increasing
☐ B) decreasing
☐ C) stable
☐ D) if you think that the pattern will be a more complex one, please, describe it briefly below:

First-round results (numbers of answers)

In brackets including indications from comments and if country belongs to the indicated group of states

Country	Number of increasing share indications	Number of decreasing share indications	Number of stable share indications	Other
Germany	4	2	1	
Turkey	2	1	1 (1)	fluctuations: 1, increase only if Turkey joins EU: 1
Serbia	1 (4)	1	1 (3)	
Ukraine	2		(1)	
Romania	1 (4)			Slightly increasing until 2014, then sharply increasing for some years, afterwards decline: 1
Poland	1 (2)			
North Africa	1			
Balkans	3			
former Yugoslavia			2	

14. Because of the interdisciplinary character of migration studies, as well as the multiple perspectives from which the migration processes can be analyzed, would you please be so kind as to specify your general professional background: (please, select)

For possibilities not listed above:

15. If you have any comments to the questions, and / or justifications for the answers given, please, provide them in the space below, together with the question number:

Date completed:

Thank you very much for your time and judgements!

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1/2003: M. Kupiszewski, *Consequences of EU enlargement for freedom of movement between Council of Europe Member States*, ISBN 83-920313-0-X.

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