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Uncertainty in demographic projections and its consequences for the user[1]

Some introductory thoughts on the uncertainty

1. Prigogine (1996) in its work entitled " La fin des certitudes " asks on our capacity to predict the future in these terms: " Is the future given or is it in perpetual construction? " . If the future is " given ", it can then be predicted with a relatively high degree of accuracy and the degree of uncertainty will be rather weak [2]. If, on the other hand, the future is " in perpetual construction " , it can not be predicted and the degree of uncertainty will be raised.

2. In the field of population, the future is not " given ". It is by nature uncertain. Its prediction is then difficult. Predicted trends are often extrapolations of past trends observed until the date of the setting up of the projection while the future may present reversals of trends or unexpected irregularities. Consequently, one may formulate a large number of different hypotheses and combine them to predict the future of the population, but there is no projection " correct " in the absolute.

3. Because they are tainted by a part of uncertainty, demographic projections have to be carefully used. In the opposite case, bad political measure or inadequate planing choices could be taken.

Demographic projections, why?

4. We should note that demographic forecasts are used for many purposes (see for example Romaniuc, 1990). Firstly, *" official " projections* have for purpose to help with planning (for example school, sanitary planning, housing demand....) or to help to take political measure (concerning migration or family policy, for example). " Official " projection results are supposed to show the most plausible demographic trends in the future. Almost all authors of official demographic forecasts carry out several series, which combine different hypotheses (generally three: high, medium and low) of fertility, mortality and migration. These projections are generally carried out by statistical institutes at fixed times.

5. Secondly, some projections may be proposed as *simulation* in order to test the sensitivity of models to extreme or specific hypotheses or in order to reply to specific

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[2] Uncertainty has to be understood here in the sense of incapacity to predict with accuracy.

questions, such as consequences of a political measure (allocation to the third child, modification of the retirement age, repayment of medical cost) on the evolution of size and age composition of the population and consequently on financial or social costs,... or which is the minimal level of fertility that maintains constant the level of population ageing.

6. Finally, " *normative* " *projections* may be carried out to evaluate impacts on the population evolution of, for example, a modification of the migratory flows or of behaviours concerning family constitution. One calls them *demographic scenarios*. The latter translate demographic evolution that could be realised under some conditions.

Sources of uncertainty in demographic projections

7. Whatever the methodology and purposes of the projections, the prospective approach is tainted by forecast errors. These ones are the manifestation of uncertainty, or of our incapacity to predict the evolution of population size and structure. Forecast errors may be due to our imperfect knowledge of the present and the past or to our imperfect perception of the future (see for example Keyfitz, 1977).

8. Concerning errors due to our bad knowledge of the *present*, we can distinguish those referring to problems of measure (more precisely data quality) and those relative to the misunderstanding of the underlying mechanism explaining the level of demographic events. In the first case, errors on sizes and age compositions of the population at starting point of projections may occur, as well as errors of registration , recording or codification of age or date of events. Inoue and Yu (1979) have shown that United Nations projections established until 1968 were mainly influenced by information on population and growth rates until the starting point. Although the quality of data at the starting point has improved (according to these authors, from 1968, the main source of error was linked to fertility hypotheses), there is no doubt that they may still have a role in forecast errors. With regard to underlying mechanisms explaining current fertility, mortality and migrations levels, we should note that theories which could explain these levels according to the socio-economic, cultural or health context are still missing. For this reason, the demographer who elaborates projections is found lacking of guidelines when he has to discuss future evolution of these phenomena.

9. Errors come also from problems encountered in the reconstitution of the *past* demographic trends. Thus, discontinuities may exist in time series taken for the setting up of fertility, mortality or migrations hypotheses, due to changes in definitions, classifications of events (for example, classification of causes of death) or modifications in the exhaustivity of statistical sources.

10. It is necessary to notice that the availability of data on the past and the present play an important role on the quality of the projection. The demographer that has precise data, concerning, for example, the cause of death or the birth order, will have some advantage compared to the demographer which would have only raw data. Similarly, the more the delay between observation and availability of the data lengthens, the more it is difficult to grasp precisely the present, and the more the quality of the projection decreases. Finally, the availability of data covering a long period improves forecast quality. Smith and Sincich (1990) show that increasing the length of the basis period up to 10 years improves significantly forecast accuracy. Further increases generally gives little additional effect. Finally, the uncertainty finds its source in our inaptitude to perceive the future evolution of the socio-

economic context, and the consequences of this evolution on the occurrence of demographic phenomena. Furthermore, the uncertainty in hypotheses concerning reversals of tendency (emergence of new pathologies, health progress, new social norms concerning fertility, new modes of constitution of unions, modifications in the international migration flows...) is another factor of forecast errors. As discussed by Taymann and Swanson (1996) for the United States, demographers do not often take the risk to forecast a demographic decrease or an abrupt change of the evolution, preferring to opt for a continuity of trends.

Consequences on the quality of demographic projections

11. Sources of uncertainty presented above can have more or less important consequences on the precision and accuracy level of demographic projections. This level varies according to different characteristics [3].

12. *Errors in data* (on population structure, level and / or tendency of occurrence of demographic events) can have important repercussions on demographic projections when the latter are calculated by extrapolation of observed trends.

13. *Size of population*. Probabilities of occurrence of demographic events are generally known with a relative certainty when the forecasts are concerning the population at a national level. On the other hand, even on a short-run forecast for small populations (sub-populations) can be rather uncertain because of the random fluctuation in probabilities of occurrence at the individual level (Sykes, 1969; Pollard, 1973). Thus, as Taymann, Schafer and Carter (1998) note, there is an inverse relationship between population size and forecast accuracy.

14. *Temporal range*. Furthermore, errors tend to grow with the temporal range of the projection (Ascher, 1978; Stoto, 1983; Armstrong, 1985, Smith, 1987 and Long, 1992). Keyfitz (1981) writes that “ beyond of a quarter of century, one is incapable to tell what the population size and structure will be ”.

15. Concerning the *population structure*, on the one hand, total numbers estimated for the future of generations born before the starting point of the projection will be obviously modified only by the possible errors of observation and by the difficulty to predict mortality and spatial mobility of this population. On the other hand, the population that will be born during the period of projection will be affected moreover by hypotheses about fertility of their mothers which influenced the most frequently the projections’ uncertainty. Alho (1992) writes that the uncertainty due to hypotheses about migration and mortality of populations already born before the beginning of the projection can be ignored in the propagation of errors although this uncertainty is not insignificant. However, contrary to what Alho (1992) writes, several authors think that one of the most difficult demographic phenomenon to predict is probably migration, more affected than other phenomena by economic conditions, by international legislation or, moreover, by national political decision. The decline of fertility has been the main factor of ageing in transitional populations (Coale, 1972). Nevertheless, given the high levels of life expectancy currently reached in industrialised countries, mortality becomes an important factor of population ageing (Duchêne and Wunsch, 1990 and 1991).

[3] This does not apply only to demographic projections, but also to other forecasts, for example economic forecasts (See Bouthevillain and Mathis, 1995)

16. *Social situation*. Moreover, uncertainty in projections may change according to whether one is in a stable situation (social, political or demographic) or if one observes strong fluctuations or changes of trends. The example of Russia, whose political and social changes were followed by rapid reversals of male mortality trends, shows how we must be careful during the drawing up of demographic projections for countries subject to new political or social situations.

17. *Heavy trends or soft trends*. Uncertainty linked to demographic estimates may remain relatively low when we are interested in stable trends (“ heavy ” trends). For example, the short- or middle-range evolution of the numbers of 65 years and older is influenced by mortality, and incidentally by migration. Moreover demographic ageing can be considered as a “ heavy ” tendency in Northern countries, because it appears unalterable at least in the next fifty years. On the other hand, the evolution of the population aged less than 30 depends all at once on fertility of women in or entering in reproductive ages, and also on migration of these women and of the young adults. Those demographic phenomena cannot be considered as following “ heavy ” trends.

18. *Compensation of errors*. Finally some errors coming from the uncertainty may compensate each other, as Shaw (1994) has shown for British projections [4]. Demographic projections are the result of a set of information (concerning rates of fertility, mortality and migrations by age, or even the transitional matrix between households types) resulting from the combination of hypotheses.

The measure of errors of prevision

19. Theil (1958 and 1966) has built the first statistical tools for the evaluation of forecast errors. Ahlburg (1995) has listed the main measures used and their respective limits and advantages. One can retain, among others :

- the mean absolute error (MAE), appropriate if the loss function (cost of errors) is linear in absolute terms
- the mean absolute percentage error (MAPE), appropriate if the cost of errors is linear in percentages [5]
- the mean of squares errors (MSE) or the root mean of squares errors (RMSE) are adequate if big errors are very costly. Although these measures are the most frequently used, they do not allow comparisons between models and between different temporal horizons
- the root mean of squares percentage error (RMSPE)
- the indicator of Theil (the RMSE divided by the RMSE of an alternative method of projection) which allows to compare two methods of forecasting.

20. In order to attach confidence intervals to current United Nations (UN) projections, Keyfitz (1981) and Stoto (1983) have proceeded to the ex-post analysis of errors in UN projections for different countries. They provide confidence intervals only for the total size of the population: the standard deviation of errors on the rate of increase varies between 0.3%

[4] Fertility and mortality were overestimated, while international migrations were underestimated

[5] This indicator has been proposed beside the mean algebraic percent error or MALPE by Smith (1987), The National Academy of Sciences (1980) and Isserman (1977). The first indicator (MAPE) calculates the average of errors without taking into account their sign (+ or -) while the second one (MALPE) takes this sign into account

per year in developed countries and 0.5% per year in developing countries. Another conclusion of Keyfitz's (1981) and Stoto's (1983) studies is that the rate of population growth is, in one case of three, situated outside the interval delimited by low and high variants. Lee (1990) has completed the Keyfitz's and Stoto's analysis by reviewing long-range projections (from fifty to several hundred years) brought up by Frejka (1981): Lee obtains an average relative error on the rate of increase around 1% per year.

21. On the basis of regularly updated projections in Norway and The Netherlands, Keilman (1995) examines ex-post errors in fertility and mortality estimates with a model that distinguishes period effects (year of calendar), duration effects (range of the projection) and jump-off year effects. Details of the modelling and the estimation have been presented by Keilman (1990).

22. The application of ex-post errors to new projections presupposes that today specialists will make the same errors or will neglect the same discontinuities than those who have calculated previous projections. This assumption is a bit pessimistic. It is probably possible to reduce uncertainty if one could proceed to a regular control of the adequacy between the future projected and reality.

23. These methods allow only the comparison between projection and reality, once the latter is observed, that is to say *ex-post*. For the user, availability of information on possible errors and linked uncertainty is nevertheless important. This information must be available at the moment of the use of the projection and not ex-post.

Methods to quantify the uncertainty at the elaboration of the projection

24. Different methods allow to take uncertainty into account and to quantify it at the time that the projection has been made:

- the use of several scenarios or combinations of hypotheses, in order to present how size and composition may evolve according to the possible futures of fertility, mortality and migration
- the calculation of stochastic projections
- and the elaboration of probabilistic projections based on expert opinions

25. Generally, national institutes propose different *scenarios*, in order to show the different paths which the population and demographic processes may follow. This method leads to some problems. Firstly, when variants define a too large interval of possible results, the information is of few interest. Secondly, users of these projections (and especially planners) tend to retain only one scenario, generally the one considered as the likeliest. They can hardly take uncertainty into account when they use the results of the projection to take a social or legislative decision.

26. Lee and Tuljapurkar (1994) present an overview of methods for making *stochastic population forecasts*, notably using Leslie Matrix with fitted models of vital rates. Pfaumer (1988), among others, has drawn vital rates according to an assumed probability distribution and has estimated parameters of the model in view to establish stochastic simulations for the United States. He has shown that after a century, the standard error of the forecast is 8% of the expected value. According to Lee and Tuljapurkar (1994), the distribution used by Pfaumer to simulate fertility is too narrow; furthermore, and still according to Lee and Tuljapurkar

(1994), Pfaumer does not assume autocorrelation in fertility, which leads to severe understatement of the uncertainty.

27. Methods aiming to attribute, to each scenario, a probability of realisation, have a long history since they have appeared in years 1960 (see Hatene, 1993). Lutz, Sanderson and Scherbov (1996) expose a method of *probabilistic population projections based on expert opinion* both on the future courses of fertility, mortality and migration, and on the extent of their uncertainty. This intuitive approach, built on subjective probabilities, is a variant of the Delphi method (proposed by Dalkey and Helmer, 1963), used for example for energy demand or future technological development scenarios (see for example Mirenowicz et al., 1990; Héraud et al., 1997) [6].

28. Results provided by Lutz, Sanderson and Scherbov (1996) concerning, among others, the range of variation in 95 percent confidence intervals obtained from 1000 simulations, question about the interest of probabilistic population projections based on expert opinion [7]. Perhaps those methods aim to make forecasters a bit less sure of their results. But the subjectivity necessary to propose hypotheses, of which they are well aware, is sufficient to increase their mistrust.

Some recommendations to encourage users to take uncertainty into account

29. Uncertainty, and possible errors of prevision, question about the most "correct" possible use of population projections. Demographers are generally aware of the limits and problems due to uncertainty in forecasting. However, they take rarely into account these limits and problems. Mostly, demographers let the users take the median variant which is considered as the most probable population evolution in the future if not as the *real* population evolution. This way to consider and to use demographic projections is simplistic: taken into account all the scenarios can give a better view of uncertainty and its consequences. Moreover, this way is to optimistic too. No projection can give a perfect idea of the future. As well as Whiston (1979) says, “ Forecasting are made with the intention of providing an input to the process of policy-making. *It cannot predict the future* ” .

30. Projections are probably too often considered by the users as a perfect or correct view of the future. We should admit that users are seldom implicated in the process of projection elaboration and, for this reason, they are misinformed on uncertainty which characterise this production. Some recommendation can be made in order to encourage users to take uncertainty into account.

31. For the user, the dimension “ population size ” or “ age distribution ”, in others terms the output of demographic projections, becomes an input for other sector-based projections answering to the main questions about the future for example: financing of the retirement insurance, housing planning, public transport planning, social budget, forecast on economic context. Consequences of uncertainty contained in demographic data depend on the weight (in mathematical terms, the *coefficient*) associated to the variable “ population ” in the sector-

[6] According to Tenière-Buchot (1972), quoted by Ducos and Menou (1992), the Delphi Method is itself derived from the Vatican method, used by the cardinals to arrive at a consensus during the pope’s election.
[7] In 2020, population size would vary in 95 percent confidence intervals from 116 to 133 millions in Eastern Europe, from 209 to 240 millions in the European part of the former Soviet Union, and from 446 to 512 millions in Western Europe (Lutz, Sanderson and Scherbov, 1996).

based modelling. Relatively weak in economic context forecasts (which are more influenced by financial or economic dimensions), this coefficient is higher in school planning in a locality for example. In the first case, uncertainty in demographic forecast may probably be neglected, because of the stronger uncertainty which taints other inputs (economic evolution, unemployment,...). In the second case, demographic uncertainty must be taken into account because of the strong weight of population future in school planning.

32. Various methods allow us to consider uncertainty where we use projection results in econometric modelling, sanitary or housing forecast or other sector-based projections. Those methods depend on the kind of demographic projection : scenarios, stochastic projections or probabilistic projection based on expert opinion.

33. As seen above, more often the scientist or planner who uses official projections has at his disposal one or more scenarios or variants (mostly three). Users can find a way to choose the likeliest scenario. Different means may help them to make a rational choice, for example (Robinson, 1981) :

- To choose the “ most likely ” scenario, in other words to take the median one. This solution seems slightly simplistic
- To choose the scenario which leads toward the worst situation (pessimist choice)
- The decision-maker can also have some information or experience which enables him to make a rational choice
- When the user has at his disposal several scenarios, he can use each of them in his sector-based modelling and not only the median one or the pessimistic one. He obtains then an information about the consequences of demographic uncertainty on his own modelling.
- Economists (but also geographers, physicians or surgeons) have since a long time discussed methods allowing help at decision making under uncertainty. When the planner has at his disposal more than one scenarios, he can choose one of them according to those methods.

34. In some cases, a wrong choice of scenario can have very costly consequences. For this reason, and even if demographic uncertainty is unavoidable, the planner has to evaluate possible errors in demographic projections and to be conscious of the possible consequences. For example, school planning in a locality requires data on population at schooling age for the next decades. Under-estimation of local school population’s growth could lead to facilities problems (lack of teachers or classrooms). An overestimation would lead to inverse effects (unemployment, under-use of classrooms). The planner who has to take a decision having considerable financial repercussions (for example the planning of a new school construction) should measure the financial consequences of demographic uncertainty, with the help of decision making methods (Tuljapurkar, 1996).

35. When the planner has at his disposal results of stochastic demographic projections or probabilistic projections based on expert opinions and from which confidence intervals may be inferred, it would become possible to refine the measure of consequences of demographic uncertainty. In the case of stochastic projections, we can calculate expected values of the cost associated to each population size, weighted by the probability of occurrence of this population size. The result in terms of cost or benefit can help to take the better social or political measure.

Conclusion

36. New analytical methods, as well as best knowledge of underlying mechanisms modifying the occurrence of fertility, mortality or migrations, may improve to some extend the quality of demographic projections: sophisticated modelling, improvement in data quality, availability of more frequent surveys can help to better forecast demographic future. However, Tayman and Swanson (1996) show that the error avoided by a sophisticated projection method compared to a simple technique is relatively weak. Smith and Sincich (1992) say moreover that the benefits of sophisticated techniques, with regards to simple techniques (extrapolations, for example), is not proved. According to Land (1986), methods like ARIMA may be useful for short-range forecasts, while classical methods based on cohort component methods are to be recommended for long-term projections ; structural modelling methods apply to simulation of the policy measures' effects. From our point of view, it may be possible to improve slightly the quality of demographic projections with the help of methods like APC models or with the use of causes of death or of birth order, and thus it may be possible to decrease uncertainty. But the cost to improve the forecast quality is probably higher than the benefit which results from it.

37. For this reason, uncertainty concerning the evolution of fertility, mortality and migratory flows will remain linked to demographic projections as to other forecasts. Tuljapurkar (1992 and 1997) suggest that users of projections is into the habit of dealing with uncertainty, notably by using stochastic projections. Stochastic projections help the decision-making by supposing that one cannot predict what will be the future, but rather give some information on the future demographic evolution.

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