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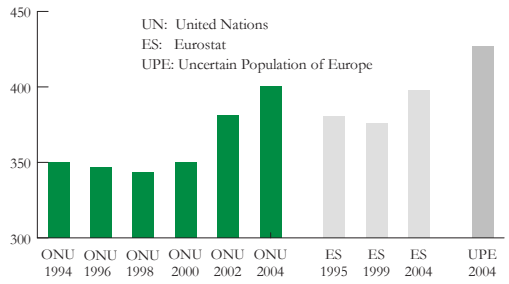
THE WORLD ECONOMY IN THE LONG RUN: BEWARE OF DEMOGRAPHIC UNCERTAINTY!

Economic decisions on long term issues are based upon uncertain demographic projections, for which it is crucial to assign probability. The stochastic projection method allows to get such a probability distribution of future demographic paths. In this study, we consider the level of uncertainty in each of the ten major regions of the world, and their correlation across regions. The method we use assumes that we should expect forecast errors that are of the same order of magnitude as in the past. We produce stochastic simulations of the world population and illustrate the economic consequences with simulations performed with the INGENUE 2 macroeconomic model. We show that the assumptions regarding interregional correlations of forecast errors are important in a multi-regional framework: they have a large impact on the uncertainty of the demographic and macroeconomic variables, and they could modify substantially the macroeconomic adjustments.

While demographics have long been identified as a key variable in long term macro-economic prospects, most of the analyses so far have relied on deterministic population forecasts. But, as several papers testify, demographic developments are uncertain.[1] Revision of population forecasts over time is common practice and reflects the uncertainty surrounding demographic projections. For instance, between 1994 and 2000, the UN predicted a total population in Western Europe around 350 million people in 2050 (Figure 1). Then the UN undertook a sharp upward revision, mainly driven by higher assumptions for life expectancy and net migration, delivering a forecast of 400 millions in its latest 2004 projection. Eurostat gave an almost identical number the same year after a substantial upward revision. However an alternative forecast performed by independent demographers in the frame of the European project UPE[2] gives a higher number of 427 millions.[3] The difference is primarily due to an assumption of faster decline in mortality, and higher level of net migration. Both can be justified by considering biases in past official forecasts.

Demographic uncertainty is usually described via scenario-based variants. Demographers have traditionally used alternative (high and low) variants that bracket the point forecast. The high variant results from high fertility, low mortality and high net migration, whereas the low variant has the opposite rates. The area between the high and low variants is supposed to reflect the uncertainty surrounding the point forecast, considered as the most plausible path.[4] Nevertheless, from a statistical point of view, this does not correspond to a predictive distribution: in particular, with this methodology, it is not possible to assign a probability to a specific projection. Furthermore, there is no guarantee that the high and low variants for different ages, or for different future years, correspond to the same level of uncertainty. So, without a

Figure 1 – Population prospects for EEA countries in 2050 (millions)



1. See N. Keilman, H. Cruijsen & J. Alho, "Changing Views of Future Demographic Trends" and J. Alho, H. Cruijsen & N. Keilman, "Empirically-based specification of forecast uncertainty" in J. Alho, S. Hougaard Jensen & J. Lassila, editors (2007), *Uncertain Demographics and Fiscal Sustainability*, Cambridge University Press, forthcoming.
2. This result is based on stochastic population forecasts. See the UPE website for information about these forecasts : http://www.stat.fi/tup/euupe/
3. See M. Alders, N. Keilman & H. Cruijsen (2006), "Assumptions for long-term stochastic population forecasts in 18 European countries", *European Journal of Population*, forthcoming.
4. Concerning the UN projections, the high and low variants take into account alternative assumptions for the fertility rate only.

quantitative yardstick, it is difficult – essentially impossible – to come up with a set of high-low intervals that would be consistent in the probabilistic sense. As a consequence, the standard approach has several important shortcomings as a means of describing forecast uncertainty.

Nevertheless, many investment and economic policy decisions (such as pension systems sustainability and energy policy) rely on long term population and GDP projections. So, it is crucial to provide probabilistic prediction intervals for these projections in order to get a better assessment of the possible future demographic and economic paths. Such prediction intervals could be computed on the basis of stochastic population projections. We produce stochastic simulations of the world population and illustrate the macroeconomic consequences of demographic uncertainty in a multi-regional setting with simulations performed with the computable, general equilibrium, multi-regional overlapping-generations model INGENUE 2.[5]

Regional Uncertainty

Our stochastic projections of population are performed for each of the 10 regions of the INGENUE 2 model (see the list in Table 1). On the basis of these simulations, we could get a predictive distribution for the period 2000-2050 around the point forecast that is included in the baseline scenario of the economic model.[6] In stochastic population forecasts, future fertility and mortality rates and net migration are considered as random variables.[7] These estimates depend on the volatility of population development during the past half century (see Box). For some regions (such as Western Europe and North America) this period has been relatively calm, so the level of uncertainty as specified in Table 1 is lower than other estimates based on longer time periods. For other regions, the period may have been unusually turbulent. For instance, the degree of uncertainty for the Russian area is high: the standard deviation around the mean value (coefficient of variation) that we reproduce for 2050 is ± 26%.[8]

Demography is a key variable in long term macro-economic analysis (potential GDP growth projections); as a consequence, demographic uncertainty could translate into macroeconomic uncertainty. In order to illustrate this point, we focus on two

Table 1 – Coefficients of variation used for the calibration of the uncertainty scale parameters

North America	Western Europe	Eastern Europe	Japan	South America
6%	5%	6%	13%	12%
Mediterranean area	Africa	Russian area	Chinese area	Indian area
24%	17%	26%	11%	11%

Source: Authors' calculations, from National Research Council (2000): *Beyond Six Billion*.

regions of the model: Western Europe and the Russian area, where the uncertainty is assumed to be the highest in the next decades.[9]

Western Europe will age rapidly in the coming decades (Table 2): the median of the dependency ratio (defined as the number of retirees in percentage of total working age population) is expected to increase from 0.50 in 2010 to 0.99 in 2050, with a 90% prediction interval of [0.88, 1.13]. The Russian area will age by as much, from 0.31 to 0.82 in 2050, but starting from a lower level. However, a major difference is that, in this latter region, the 90% prediction interval ranges from 0.46 to 1.30 in 2050. Furthermore, notice that the dispersion is already high in 2030.

Table 2 – Percentiles of the predictive distribution of the dependency ratios in Western Europe and Russian area

		P5	P25	P50	P75	P95
Western Europe						
	2010	0.49	0.5	0.5	0.5	0.5
	2030	0.77	0.79	0.81	0.83	0.85
	2050	0.88	0.95	0.99	1.04	1.13
Russian area						
	2010	0.28	0.3	0.31	0.32	0.33
	2030	0.33	0.43	0.5	0.56	0.63
	2050	0.46	0.66	0.82	1	1.3

Source: Authors' calculations.

The uncertainty surrounding the GDP growth rate is higher for the Russian area than for Western Europe as a result of the higher uncertainty concerning the population forecasts in the former region (Figure 2). The median of the predictive distribution of GDP growth decreases in Western Europe from 1.9% in 2010 to 0.7% in 2050 with a 90% prediction interval of [0.3%, 1.0%]. Throughout the period 2000-2030 the uncertainty in birth rates has a modest impact on the size of the working age population. Therefore the growth rate of GDP stays in a close range around its mean with a 95% probability. The picture changes dramatically thereafter. High or low fertility

5. The INGENUE 2 model was developed at CEPII, Paris, in collaboration with CEPREMAP and OFCE by Michel Aglietta and Vladimir Borgy (CEPII), Jean Chateau (OECD), Michel Juillard (CEPREMAP), Jacques Le Cacheux, Gilles Le Garrec and Vincent Touzé (OFCE). For a complete description of the model and detailed definitions of world regions, see Ingenue (2007), "INGENUE 2: A long term intertemporal world model for the 21st century", *CEPII Working Paper*, forthcoming. This *Lettre du CEPII* is based on research carried out in the EU funded research project DEMWEL. For a complete presentation, see J.Alho & V.Borgy (2007), "Global Ageing and Macroeconomic Consequences of Demographic Uncertainty in a Multi-regional Model", *CEPII Working Paper*, forthcoming.

6. The baseline scenario of the INGENUE 2 model and the stochastic simulations performed are based on the UN demographic projection published in 2001: *World Population Prospects. The 2000 Revision: volume I: Comprehensive Tables*, New York, United Nations.

7. The methodological features of stochastic population forecasts are explained in Alho, Cruijsen and Keilman (2007) (*cf.* footnote 1).

8. The interpretation of such probability statements, and methods for developing them, are discussed in some detail by Alho and Spencer (2005), *Statistical demography and forecasting*, New York: Springer, pp. 238-264.

9. Western Europe includes EU15, Malta, Sweden, Norway and Iceland. Russian world includes Russia, Ukraine, Belarus and Moldova.

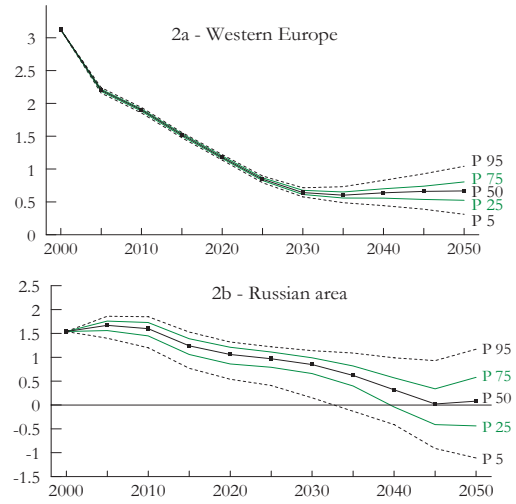
Box – Stochastic population projections at a world level : methodological issues

In order to run the stochastic population forecasts in the 10 regions of the INGENUE 2 model, we used the program PEP (*Program for Error Propagation*) developed by Juha Alho. Stochastic cohort-component forecasts are formally similar to conventional population forecast, but future fertility and mortality rates and net migration are considered as random variables. The stochastic simulations rely on a deterministic point forecast (the parameters of these forecasts will then be affected by random shocks). Since we assume no migration between regions, the uncertainty of forecasting derives from fertility and mortality alone. As discussed in Alho, Cruijsen and Keilman (2007)* a direct empirical assessment of forecast uncertainty is a practical possibility in many countries, notably in the EU. However, for the broad regions of the world, only partial estimates are available. Thus, a different strategy had to be adopted. To specify the uncertainty parameters we used two sources of information. First, as regards relative level of uncertainty across age and sex, we used the empirical estimates for the 18 European countries estimated in the frame of the UPE project. Second, these estimates are proportionally calibrated to match the empirical findings concerning the overall level of uncertainty in total population size, as given in the book '*Beyond Six Billion*'.

Cf. footnote 1. - ** National Research Council (2000), *Beyond Six Billion: Forecasting the Worlds Population*, Washington DC : National Academy Press, chapter 7.

rates are conveyed into the labour force twenty years after. In the Russian area the median decreases sharply from 1.6% in 2010 to 0.1% in 2050. The uncertainty is substantially higher than in Western Europe with a 90% prediction interval of [-1.1%, 1.2%]. So, we are unable to say with a 90% prediction interval if the growth of potential GDP in the Russian area will be +1% or -1% in 2050![10]

Figure 2 – Percentiles of the predictive distribution of GDP growth 2000-2050 (percent, annual rate)



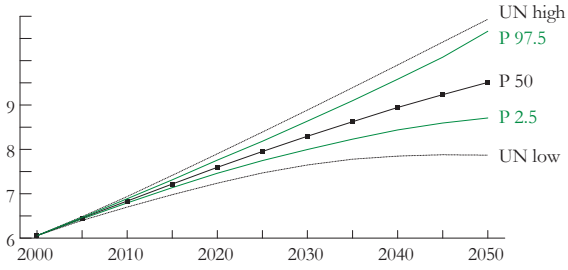
Source: Authors' calculations.

Population and Globalisation

Figure 3 depicts a stochastic forecast for the world population on the basis of 400 simulations performed with 95% prediction intervals that assume (unrealistically) complete independence across regions. The median of the predictive distribution for the world population in 2050 is 9.51 billion. According to these estimates, there is a 50% probability that the world population in 2050 is between 9.18 and 9.87 billion people.

This result is based on stochastic simulations that assume complete independence of errors across regions. In a multi-regional setting, the question of the correlation between the stochastic population forecast errors is of major interest. For instance, we could think that some specific events at the origin of these errors (for instance an epidemic or an unexpected medical research innovation) could affect simultaneously all the regions. Given that reliable empirical estimates of correlation were not available, we ran stochastic simulations with PEP in such a way that we could perform sensitivity analyses concerning the level of interregional correlation of forecast errors.[11] Introducing an interregional correlation of 0.1 across the ten regions has an effect of broadening the prediction interval as compared to standard errors that assumed independence. With the assumption of the interregional correlation of 0.1, the 95% prediction interval is larger than in the case assuming independence between the regions, and ranges between 8.45 and 10.77 billion (Table 3). The 95% prediction interval is even larger when we assume an interregional correlation of 0.2 as it reaches [8.23, 10.89] billion. One must note that, in all the cases, the UN high and low variants are outside from the prediction interval, illustrating that the probability they could occur is very low.

Figure 3 – Stochastic forecasts of the world population and UN high/low variants (billions)



Source: Authors' calculations and UN (2001), *World Population Prospects*.

10. In the INGENUE 2 model, demographic uncertainty translates into economic uncertainty through two channels: 1) uncertainty on the size of the working age population impacts directly GDP growth in each region; 2) GDP growth also reflects the consumption/saving choices of the households with perfect foresights who react to new population paths they discover at the beginning of the simulation period. This last point explains why uncertainty surrounding GDP growth in the Russian area is already high at the beginning of the 21st century.

11. Technically, we relied on the use of seeds that has been implemented in PEP. The software allows to perform simulations with independent interregional errors or with perfect correlation. The degree of correlation between the regions is then obtained by playing with the number of independent and perfectly correlated simulations. For a detailed presentation, see Chapter 9 of Alho and Spencer (2005). Previous estimations performed by J.Alho lead to a correlation of 0.1 (*cf.* "Beyond Six Billion", chapter 7).

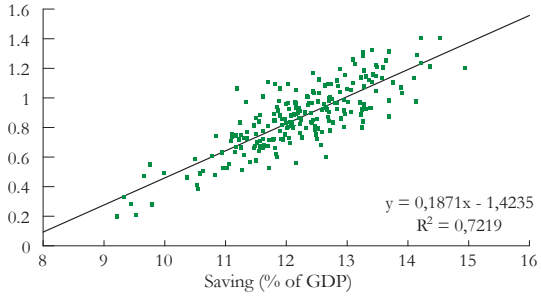
Table 3 – Percentiles of the predictive distribution of the world population in 2050 (billions), with independent or correlated forecast errors

	P2.5	P25	P50	P75	P97.5
Independance	8.71	9.18	9.51	9.87	10.66
Correlation 0.1	8.45	9.15	9.5	9.87	10.77
Correlation 0.2	8.23	9.12	9.5	9.89	10.89

Source: Authors' calculations.

The interregional correlation not only widens the prediction interval of demographic projections, it also modifies the macroeconomic adjustment at the world level. In order to illustrate this, we start from a situation that assumes complete independence of errors across regions. According to the INGENUE 2 baseline scenario, in 2025 the three industrialised ageing regions are creditors *vis-à-vis* the rest of the world (households save for their future retirement). For example, a part of the European saving could flow towards the developing regions of the world that have a more sustained growth due to the dynamics of their working age population.[12] The level of saving depends noticeably on the population structure that differs from one population simulation to another. The more pronounced is the ageing process in Western Europe, the more important is saving in this region which, for a part, will flow towards developing countries (Western Europe has a more pronounced creditor position *vis-à-vis* the rest of the world). Figure 4 plots the results of 200 simulations that assume complete independence across regions; it shows that there is a clear positive association between the current account position and the level of saving in Western Europe.

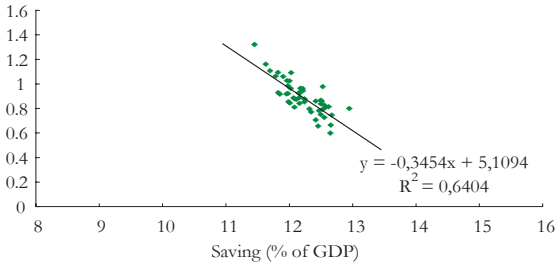
Figure 4 – Current account as a function of saving in Western Europe in 2025 under the assumption that regional forecast errors are independent



Source: Authors' calculations.

We further consider the case with perfect correlation for the interregional forecast errors: for instance, an unexpected medical research innovation could increase life expectancy (and as a consequence reinforce ageing) in all regions. Therefore, the saving behaviour, in relation with the life cycle hypothesis, would be affected in the same way in all the regions. If ageing is more pronounced everywhere, saving would be higher in all the regions, and as a matter of fact, developing regions will be less dependent on foreign capital flows coming from industrialised ageing regions. Figure 5 plots the results of 50 simulations that assume perfect correlation for the interregional forecast errors; it shows that there is now a negative correlation between the current account position and the level of saving in Western Europe.

Figure 5 – Current account as a function of saving in Western Europe in 2025 under the assumption that regional forecast errors are perfectly correlated



Source: Authors' calculations.

The main message is that demographic uncertainty does matter for the economic policy decisions. The stochastic method allows to get a probability distribution of the future demographic variables (conditionally on what is known at the jump-off time), necessary for the current economic decisions. Furthermore, interregional correlation of demographic uncertainty appears to be important in a multi-regional framework as they have a large impact not only on the uncertainty surrounding the macroeconomic variables but also on the macroeconomic behaviour of agents.

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12. In contrast, the Chinese and Indian areas are net borrowers *vis-à-vis* the rest of the world.
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