

**INE-Spain strategy on population estimates and
projections facing the challenge of statistical
measure of population**

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Abstract

National Statistics Institute of Spain presents new actions focused on improving the available statistical sources of demographic information and providing accurate population figures and punctual, detailed and consistent information on current demographic evolution, in a context of general concerns about the current and future evolution of the population pyramid.

Keywords

Demographic flows; population now cast; demographic projections

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INE-Spain strategy on population estimates and projections: facing the challenge of the statistical measure of population

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Abstract

The first years of the XXIst century are representing a period of exceptional relevance for Spain demographic evolution and thus for the demographic statistics. They are being a burning issue of the academic, social and political debate, focused on the pressing interest in knowing the volume and structure of the resident population and its most foreseeable evolution, at least, in the near future.

Such exceptionality is deeply determinated by the extraordinary intensity of the foreign immigration flux since the end of the nineties, which has greatly altered its demographic structure and behaviours. It has also become Spain in one of the more significant cases of sociodemographic transformation over the Old World, getting a place between the countries with higher percentage of foreign resident population, lightly exceeded by USA, and behind Canada and Australia.

Therefore, this new context has arisen a crucial challenge over the INE work plans: the traditional approach to the statistical measures of population trough classics censuses and occasional long term population projections should be replaced by a more modern strategy of continue monitoring of demographic changes which results could be integrated in updated current population estimates and demographic projections. Consequently, new INE action plan are based on:

- Giving the best statistical approach to the current resident population in every moment (monthly series): Population Now Cast.*
- Making continuous forecast of the future demographic and population evolution: Short Term Population Projections (annually updated) and Long Term Population Projections (updated every three years).*

We can label Spain Population Now Cast as a synthesis statistic, that integrates results from different primary sources of information in order to get consistent estimates of the resident population in Spain and its regions, at every present moment. Population Now Cast uses the most updated information about the recent demographic evolution (Monthly Demographic Now Cast) and its results are brokendown by basic demographic characteristics (sex, generation, age and citizenship). For all these reasons, we could assert that Population Now Cast

represents over the demography field of official statistics a similar role as National Accounts over economics statistics: a systematic and detailed representation in an integrated and consistent system of stocks and flux of the resident population as a whole.

In addition, taking Population Now Cast for January 1st of the current year as starting point, INE produces:

- Short Term Population Projections, for the following ten years, according to the foreseeable hypothesis of demographic events evolution. It lets users follow the current demographic progress in Spain, its regions and provinces, through permanent updated results to the last available information. INE provides it since 2008 and its results are disseminated in an annual basis.*
- Long Term Population Projections of Spain resident population, for forty years, as simulation exercise about future population, under the hypothesis of continuity in recent demographic trends. It will be carried out every three years.*

From a methodological side, Spain population projections are based on the implementation of component method using a complex multiregional model¹ which makes possible the total consistency between all considered territorial levels and a complete coherence among demographics flux and population stocks for every demographic breakdowns (sex, generation and age). It becomes the projective exercise in a complete demographic projection, including population stocks and demographics events between its results.

In addition, Spain Population Now Cast represents a genuine and advance application of component method (multiregional model¹), adapted to the ambitious objective of offering monthly population and current demographic trends estimates. It consists of a multiregional calculus of a one year projection (auxiliary projection) and a linear interpolation mechanism that guarantees a perfect consistence between population stocks of every date of the current year and monthly demographic flows estimated.

Population Now Cast is considered as the best statistical approach to the current resident population in Spain. For this reason it constitutes the reference population figures for all the other INE products (households surveys, socioeconomic indicators, national accounts, etc.) and the official population figures that Spain transmits to international organisms such as Eurostat, International Monetary Fund and UN.

¹ Based on Willekens, F.J. and Drewe, P. (1984) "A multiregional model for regional demographic projection", in Heide, H. y Willekens, F.J. (ed) *Demographic Research and Spatial Policy*, Academic Press, London.

1 Introduction

Since the middle of the last century the main concern about the challenges of national offices of statistics had been strongly biased toward economy field. The development of harmonized and standard account systems and indicators, which give a detailed and systematic measure of the economy as a whole (production, investment and consume flows, capital and labour force stocks, prices evolution, etc.), was professed as the leading goal for national office and international statistical authorities. A huge catalogue of statistical action and products found their meeting point in the development of national accounts systems during the last quarter of the XXth century.

On the other hand, the worries about demographic field of statistics has been arisen with a limited relevance, focused on the measurement of vital events (births and deaths) and the historic and long term evolution of fertility and mortality. Only once in a while, attention was paid on the question "How many are we?" with occasion of every population census.

However, during the last years a general interest about the current and future evolution of the population has emerged. In particular, Spanish media have gathered in many occasions a generalized worrying about it, as a symbol of an intense political, academic and social debate.

Firstly, the consolidation of Spain as a significant migratory destiny during the first decade of the new century should be pointed out as the main reason for such growing interest. Nonetheless, this was only the light that drove to a winding rode: How can we deal with the inexorable population ageing? Is migration the key solution for our depressed population pyramid? What about fertility? Are our current fertility levels enough to have a feasible demographic future?

Secondly, the changeable current demographic evolution, mainly due to the unpredictable behaviour of the international migration phenomena, broke the classic strategy of giving national population figures through sporadic population census and population projections for the post-census period.

And thirdly, all of these issues are decisive questions for the purpose of the macroeconomic analysis and research . In fact, we should not forget that, over an above its own relevance, the strong sensitivity of the current and long term evolution of several economic indicators determinates, nowadays, the fundamental motivation for improving the capacities of the official statistics to monitor and explain the demographic change.

These are the reasons why National Statistics Institute of Spain and, in general, the national offices of statistics, have opened the XXIth century with a new pressing and unavoidable targets over the field of demography:

- 1.The improvement of the statistical sources of demographic information, broadening the detail and quality of their results and reducing the traditional delay in producing data.

2. A definitive rise in the confidence of the statistical system in giving accurate population figures and punctual, detailed and consistent information over the current demographic evolution and every component of the demographic change (fertility, mortality and migrations).

These two aims lead official statistic to see unavoidable the promotion of systematic systems of demographic information that, with a similar role than national accounts systems in economic statistics, integrates consistent information about population stocks and demographic flows provided by such improved sources, giving to the society updated and timely information about the current demographic change and its future implications, and closing the coherent circle of information.

Such feeling marks the course of action of the new plans of the National Statistical Institute of Spain over the present and the future of the demographic statistics. A first approach to this modern conception of the demographic information system is defined in the new national strategy over the field of population estimates and projections, together with a first package of improvements of the demographic information infrastructure and sources.

2. Demographic sources: catalogue for a new infrastructure of demographic information

2.1 Vital Statistics

Vital Statistics is an statistical action with a long tradition in the Spanish system, which quantify the births, deaths and marriages happened in Spain an its regions along a calendar year, disaggregated by basic characteristics. Definitive figures for the reference year t are available in December of the year $t+1$.

For every national office, Vital Statistics are a fundamental tool for the retrospective analysis of basic demographics phenomena (mainly fertility and mortality), which population projections exercises are traditionally based on. Nevertheless, the delay in availability of definitive figures could be stressed as one important limitation of theses statistical product nowadays, in a context of quickly changing demographic evolution.

2.2 Population register (Padrón)

Municipal population registers are the administrative file where every inhabitant of the municipality should be registered . They are built, kept and revised by the local authority and they are obliged to transmit to INE all variations in the register on a monthly basis, that allows INE to centralize the management and coordination of local registers, following the Spanish law.

Nowadays, beyond its administrative purpose and restrictions, *Padrón* represents, from a statistical point of view, an essential element of the national statistical system, principally regarding the continuing monitoring of the migration flows, which set INE in a exceptional situation for its capacities to measure migration flows over the European and international context, spite the extraordinary dimension of the migration event in Spain.

2.3 Basic Demographic Indicators

Collection of indicators which describes the retrospective evolution of basic demographic phenomena (fertility, mortality and nupciality), brokendown by basic demographic characteristics and by regions and provinces. Special mention should be done for the annual calculation of **life tables**, through a new and advanced methodology since the last year.

All of them are carried out using final figures of the Vital Statistics, so definitive data are available one year after the end of reference calendar year too.

2.4 Monthly Demographic Now Cast

The National Statistics Institute of Spain started the development of this project in 2007, with the eagerness to enhance the demographic information provided to society, under this new perspective of great general interest on demography and its socioeconomic impact. In particular, Monthly Demographic Now Cast brings into demographic statistics field a monthly base, very innovative, but traditional in economy statistics.

One of the more significant conditions in carrying out accurate population estimates and updated projections, specially in a context of strong instability of demographic evolution, is the availability of statistical information about the most recent evolution of demographic phenomena. Although it is quite clear that basic demographic sources have reached important achievements in their quality, the delay in the availability of definitive results continues being insufficient to face such changeable reality. Beyond the monthly analysis, we find the main reason to exist of Monthly Demographic Now Cast here: the reduction in the delay of availability of basic demographic information since the reference dates.

2.4.1 GENERAL METHODOLOGY

Regarding to methodology, we can assert that the own nature of these monthly demographic estimates has nothing to do with classic a traditional techniques of demographic analysis and prospecting. They are not based on observed regularities or trends in demographic behaviours, but on measuring certain regularities in information circuit, that is to say, in their administrative path from original sources (Civil Registers in case of vital events and *Local Padrón* in case of migrations) to INE databases.

Basically, the estimation in a given moment of the total events happened in a given month, is carried out taking the partial number of such events arrived until the estimation time in INE databases and an *expanding coefficient* based on the past regularity in the delay in the arrival of this information from its original administrative source. In other words, such *expanding coefficient* replies the monthly rhythm in the arrival of information of the previous year:

Defining the variable delay as the number of months that an event happened in a given month takes in arriving to INE databases and giving $E_{m,a-1}$ the total events (births, deaths, marriages, migrations, etc.) happened during the month m of the year $a-1$ and given $E_{m,a-1}^r$ the partial number of such events received in INE database until the *delay* r , we define the *expanding coefficient* corresponding to the month m of the year a in the *delay* r :

$$CE_{m,a}^r = \frac{E_{m,a-1}}{E_{m,a-1}^r}$$

Then, given $E_{m,a,k}^r$ the total number of events happened during the month m of the year a , in a subpopulation determined by demographic characteristics k received in INE databases until the *delay* r , the estimate of the total events happened in the month m of the year a in subpopulation k , $\hat{E}_{m,a,k}$, is:

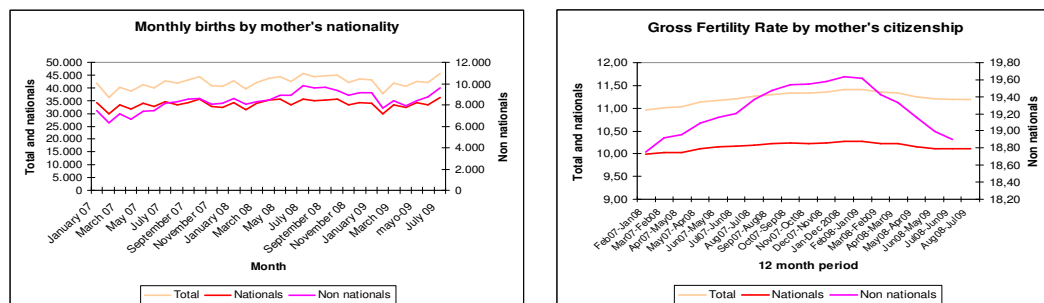
$$\hat{E}_{m,a,k} = CE_{m,a}^r \cdot E_{m,a,k}^r$$

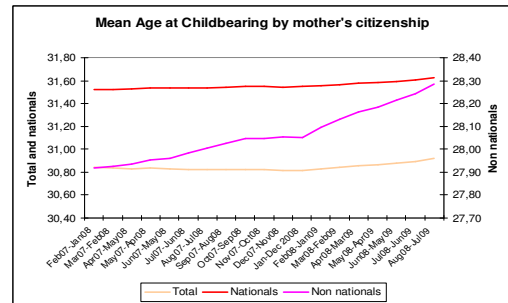
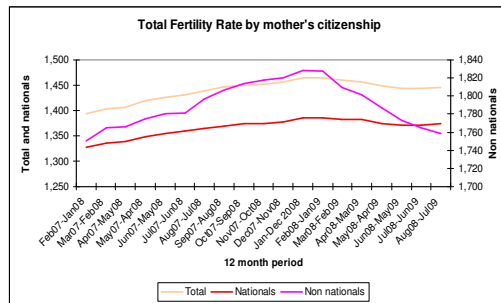
Besides, opposite the appearing randomness of administrative process, the designed methodology betrays itself extremely robust, keeping in mind that few months after the reference date most of events have been registered in INE databases. In fact, the number of estimated events is minimum. Furthermore, we should emphasize other decisive feature of these advanced estimates: the estimation error is decreasing with the gap between the reference month and the month of estimation. So Monthly Demographic Now Cast are convergent to definitive results of basic demographic statistics.

Finally, it should be clarified that, in case of migrations, such simple methodology is not enough. Basically, it is due to the fact that Monthly Demographic Now Cast has the variations observed in local population registers like original source, as it has been mentioned before. However, under-record of external emigrations movements is a general lack of national population registers. As a consequence, some additional statistical procedure are needed to complete the estimation process, for example: statistical imputation of the exact date of departure for emigrations counted through administrative corrections in population register and, therefore, not declared by the emigrant; estimation procedures of final resolution of expiry registration processes; and use of auxiliary sampling actions in estimating the part of the flow not covered by the *Padrón*.

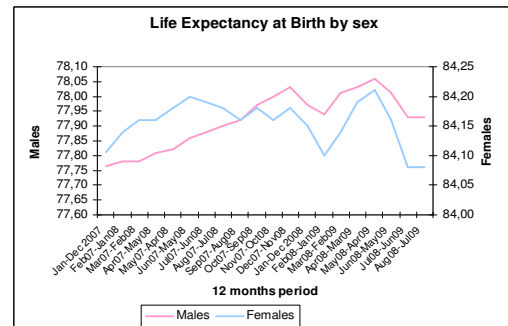
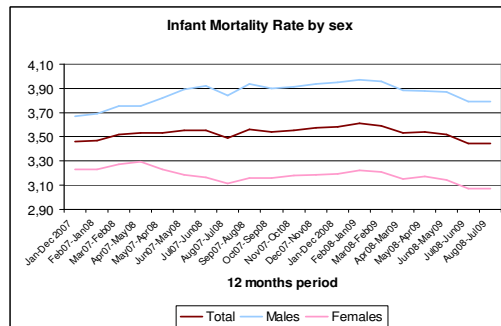
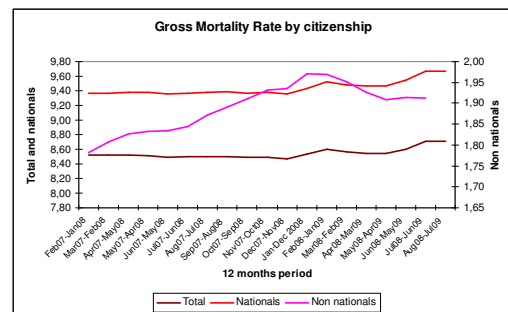
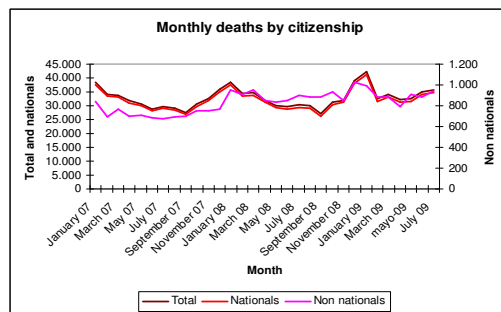
2.4.3 MONTHLY DEMOGRAPHIC NOW CAST RESULTS

Births and fertility indicators. Last updated results:

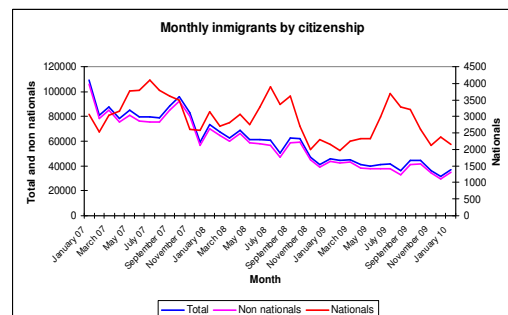
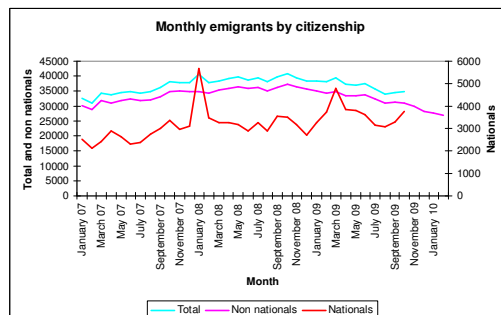


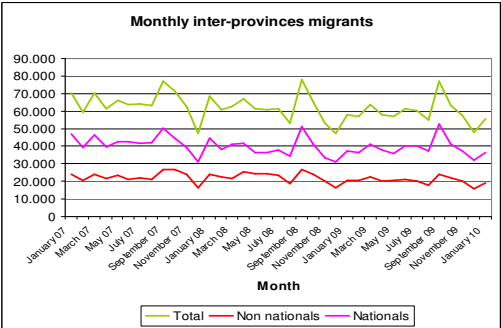
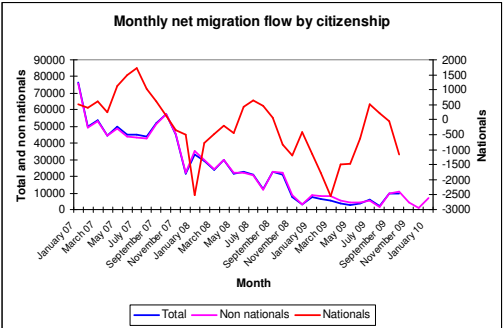


Deaths and mortality indicators. Last updated results:



Monthly migration flows. Last updated results:





3 The integration of demographic information: population estimates and projections

There is no doubt that the exposed improvements in demographic data have increased the quantity and quality of available information about the past and most recent demographic progress of Spain population. However, a decisive challenge for modern demographic statistics will be to integrate all statistical inputs in a systematic and coherent system of information which let national statistics offices explain every component of the demographic change and, even so, work out the value of such determinant information. Definitely, the internal coherence and consistency of information contribute to get it reliable enough for users and general public. In fact, the experience of national offices in rising an harmonized National Accounts Systems as integrating and summarizing instrument of economic information, generally and well accepted by public and private users and analysts as official economic data, is the better witness of such assertion.

A first attempt to lead Spanish demographic statistics towards such modern concept crystallizes in the new INE strategy on populations estimates and projections, formally stated in National Plan of Statistics 209-2012 and the respective Annual Programs², which is based on:

1. The development of current population estimates continuously updated with the last available information about demographic developments: Spain Population Now Cast.
2. A new way of focusing the production of future population projections in a periodic basis: Short Term and Long Term Population Projections.

Both represent a first approach to the objective of getting a more integrated system of demographic information.

3.1 Current population estimates

Population Now Cast is the statistical action that INE has developed during the last years to face the challenge of measuring the current resident population in our country and in every region and province, once the unexpected intensity of immigration phenomena shook the past quiet demographic evolution. Both, the National Statistics System and external users of official statistics, required population figures permanently updated with the present demographic reality. Population Now Cast was the answer from INE.

This statistical product has some general features, which determinate its significance as well as set its own limits:

1. Population Now Cast constitutes a synthesis statistic, which uses several primary sources of information, whose results are integrated in the estimation

² http://www.ine.es/en/normativa/leyes/plan/legplan_en.htm

mechanism giving place to consistent estimates of the resident population stock at the present moment and of the estimated demographic flows which determinate the population evolution, all of them broken down by basic characteristics like sex, year of birth and age.

2. Population Now Cast makes use of the most updated available information on the recent demographic evolution: Vital Statistics, registered variations in *Padrón* and, specially, the last results of the Monthly Demographic Now Cast.

3. Population Now Cast are calculated every quarter, few days after the end of the quarter, providing the estimation of the resident population referred to the first day of every month of the quarter and to the first day of the following quarter. This immediacy respect to the reference date gives the character of **advanced population figures** to these estimates.

4. Population Now Cast methodology guarantees the complete consistency between population stock at every date of the current year and the estimated demographic flows happened during the time being of the year.

5. Population Now Cast results are not subject to revision, unless there are enough evidence about significant deviations from real population evolution.

6. Population Now Cast is considered as the most accurate estimate of the current population residing in Spain and its regions and provinces. That is the reason why it works as the reference population figures for all INE production and it is transmitted to international institutions (Eurostat, United Nations, International Monetary Fund, etc.) as Spain population figures for any purpose.

In conclusion, the own character of synthesis statistics, the use of all available information about recent demographic evolution and the total coherence between estimated population figures and demographic flows confer to the Population Now Cast over the field of demographic statistics a similar role than national accounts systems over the field of business statistics: beyond evident conceptual differences they both are a detailed and systematic representation of the demographic and economic reality, respectively, as a whole, through a consistence balance of stocks and flows.

3.1.1 PRODUCTION AND DISSEMINATION CALENDAR

Both, the internal demand of homogeneous population figures which works as reference for all INE statistical products and the strong requirement on the updating of such figures to the current demographic evolution, impose a really demanding timetable for carrying out the development of Population Now Cast. Those are the reasons why INE produces Population Now Cast results during the first days after the end of every quarter, with reference to the last day and to several intermediate dates of the quarter. In other words:

Population Now Cast referred to the first day of the months $m+1$ and $m+2$ of the quarter q and to the first day of the month m of the quarter $q+1$ is calculated and disseminated at the first days of the quarter $q+1$.

3.1.2 GENERAL METHODOLOGY: ADAPTED COMPONENTS METHOD

The design of Population Now Cast general methodology was deeply determined by three main requirements:

- a) The availability of results in a quarterly basis, with reference at different intermediate date of the reference quarter.
- b) The absolute immediacy of the time of calculation and dissemination respect to the dates of reference.
- c) Population Now Cast results are definitive, so they are immovable points of the estimates series along the current year.

Keeping in mind these three general premises, Population Now Cast are carried out through a genuine adaptation of the component method , which consists of providing population figures with reference to the first day of a month ^m of the current year in two steps:

1. For every month of the quarter, performing an auxiliary population with horizon in the January 1st of the following year. This projection is performed through the component method, according to a multiregional model³, which keeps a necessary consistence between demographic flows and population stocks and among all territorial levels.

Besides, the migration input of this auxiliary projection consist of a linear extrapolation to the whole year of estimated monthly migration flows along the current year until the time of estimation.

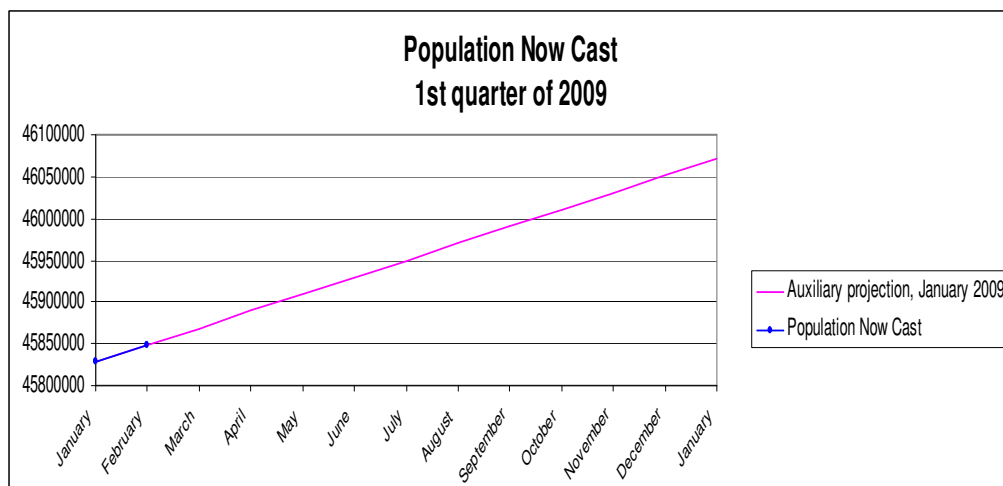
2. Calculating a linear interpolation between the Population Now Cast on January 1st of the current year and the result of the auxiliary projection for January 1st of the following year.

Such procedure guarantees that the demographic change happened (estimated) during the current year is completely consistent with flows of births, deaths and migrations.

For example, we can go over the calculation process of Population Now Cast corresponding to the first quarter of 2009, developed at the beginning of April of 2009. At this moment we had already got the Population Now Cast figures referred to 1st January of 2009 since the last estimation period (fourth quarter of 2008), which works as our starting point . We follow the estimation process through annual auxiliary projections and linear interpolations in the following graphics and table:

³ Willekens, F.J. y Drewe, P. (1984) "A multiregional model for regional demographic projection", en Heide, H. y Willekens, F.J. (ed) *Demographic Research and Spatial Policy*, Academic Press, Londres.

Population Now Cast at 1st February of 2009



Population Now Cast at 1st February of 2009

Estimated February migration flows	
Inmigrants	Emigrants
45.223	33.689

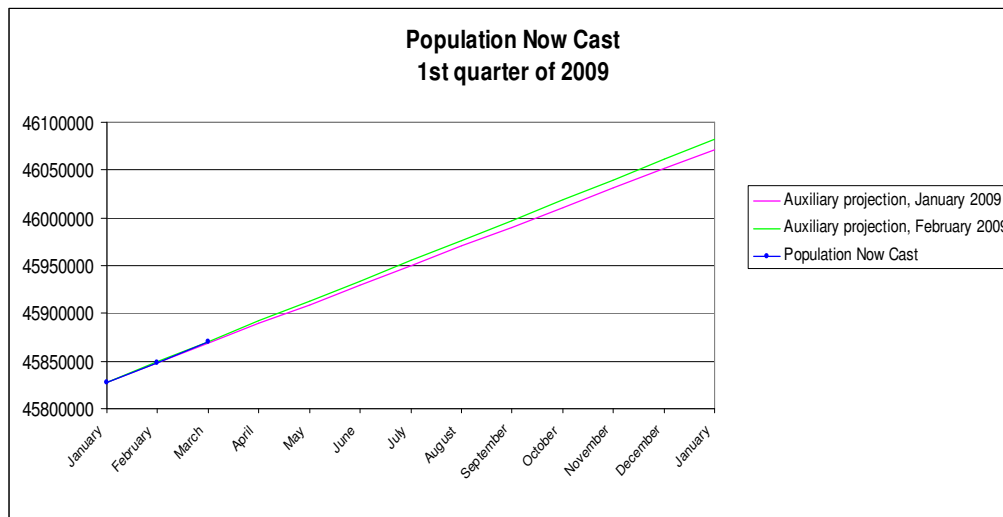
Auxiliary projection of January 2009

1st January 2009 population	Births-Deaths	Inmigrants	Emigrants	1st January 2010 population(*)
45.828.172	104.962	542.676	404.265	46.071.545

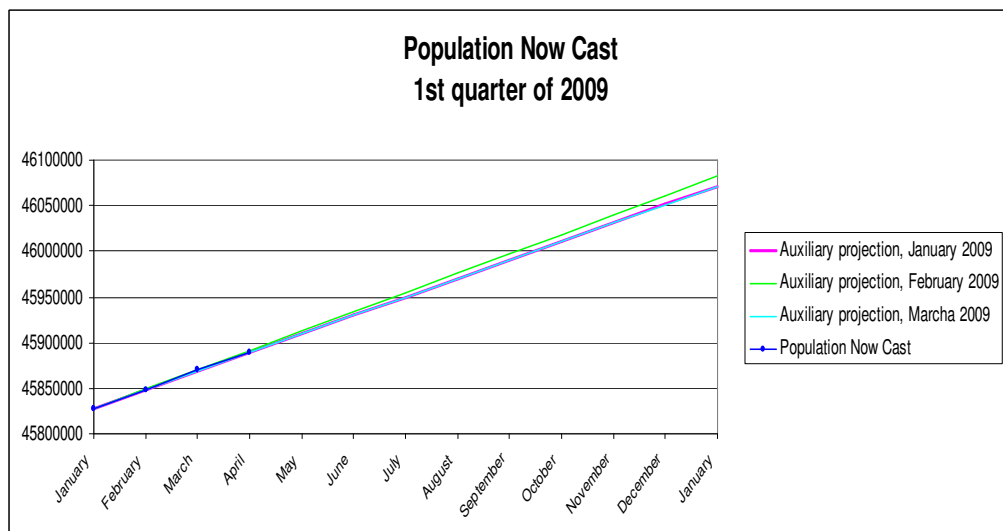
(*) Auxiliary projected figures

Population Now Cast at 1st February 2009	45.848.453
Demographic change during January 2009	20.281
Births-Deaths	8.747
Inmigrants	45.223
Emigrants	33.689

Population Now Cast at 1st March of 2009



Population Now Cast at 1st April of 2009



3.1.3 SPECIAL MENTION OF ESTIMATION PROCEDURE OF MONTHLY MIGRANTS FLOWS

Regarding Population Now Cast, one of the essential elements is the estimation of monthly migration flow along the current year, taking into account that:

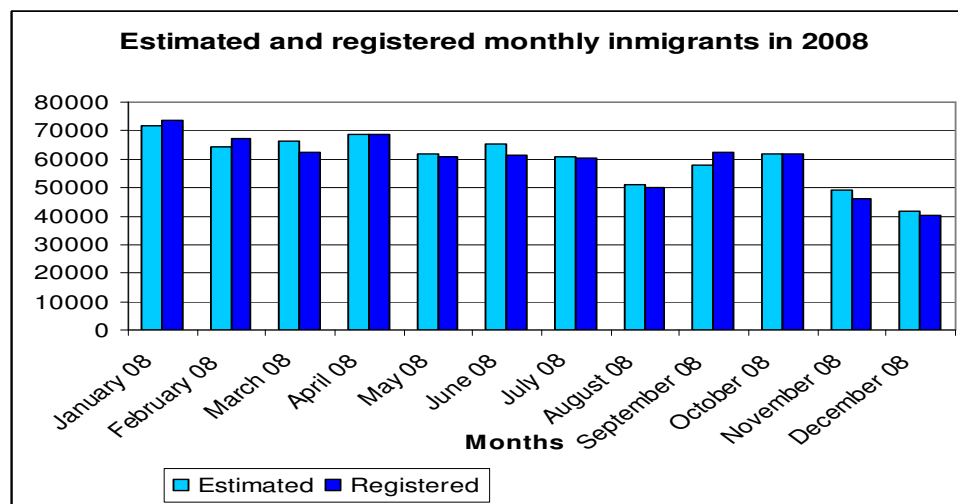
1. Nowadays, this is the most significant component of the demographic change.

2. In general, international migration is one of the principal lack of the official statistics.

3. The monthly migration flow estimates gives a very important relevance to Population Now Cast in national system, which provides the only advanced flash estimate of the current demographic evolution.

As it has been explained before, Population Now Cast is produced for every quarter, few days after the end of the quarter. This timetable imposes a high challenge in estimation of immigration flow during the months of reference. Basically, Monthly Demographic Now Cast are timely enough in providing accurate estimates of Spanish and foreign migration fluxes during the two first month of the quarter. The migration flow of the third month is estimated through a detailed analysis of the trend and seasonal behaviour of the monthly migration series.

This simple procedures are really robust, thus the comparison between 2008 monthly immigrants flows provided by Population Now Cast and updated information of finally registered ones shows:



3.2 Population Projections

3.2.1 HOW SHOULD A POPULATION PROJECTION BE FOCUSED LIKE?

Availability of future population evolution perspectives implies an element of structural relevance in any socioeconomic analysis or planning activity, either from the public or private sector. In fact, it is one of the statistical actions with a longer tradition for national statistics office and international statistics

institutions. Until now, INE has satisfied this aim providing projections with occasion of each new census, after population census figures were available.

However, the use and public understanding of this kind of exercises is one of the more controversial aspect of official demographic statistics. Often, users wonder: Should we take it as a real forecasting? What is the statistical error associated to the results? Could we give a measure of reliability? Which possible scenarios should we used?...definitely, How can you guess the future?

On the other hand, nowadays we stay in front of one of the more serious demands raised in official statistics. The extreme worries about the unstoppable growth of the world population, even above of natural resources, and the demographic future of European and occidental countries, deeply branded by a increasing population ageing, result of the continuous extensions in life expectancy and accentuated by generalized low levels of fertility, makes the production of statistical simulation of future population an unavoidable goal for official statistical organisms.

Therefore, official statistics are obliged to give a convincing answer to this strong social and political requirement. But, it should be done with a useful and pragmatic approach, avoiding the utopia of forecasting future population and, at the same time, providing clear messages to society about future demographic risks. Precisely, these are the guidelines that have leaded the design of a new national strategy on providing population projections, based on three main principles:

1. A population projection is not a forecasting. Then, non statistical errors should be associated to results.
2. A population projection should be an statistical simulation of future population according some hypothesis on demographic evolution.
3. The most important use of a population projection is to warn the public opinion about the future consequences of today's demographic structure and trends.

3.2.2 INE NEW STRATEGY ON POPULATION PROJECTIONS

Following these premises, INE has developed a new plan over the subject of population projections which is focused on carrying out Short Term and Long Term Population Projections in a periodic basis, which allows INE to provide continuous simulation of future resident population according to recent demographic trends. In fact, **Short Term Population Projections** are carried out every year, since 2008, providing a simulation of future population residing in Spain, its regions and provinces, on January 1st of the following ten years, brokendown by sex and year of birth; **Long Term Population Projections** will be carried out every three years, since 2009, providing a simulation of future population residing in Spain on January 1st of the following forty years, brokendown by sex, age and year of birth.

The periodic calendar of performance lets INE give, in a continuous way, an updated simulation of the demographic future of the country with the last available information about current evolution of demographic phenomena, in a context of significant changes. Therefore, this strategy avoids a quick obsolescence of the results that would become them useless. In addition, periodic Population Projections have as starting point the Population Now Cast for January 1st of the current year, so they are consistent with current reference population figures and complete the circle of coherence of the whole past, present and future demographic system and population series.

Both, Short Term and Long Term Population Projections are calculated through the *component* method, using a *multiregional model*⁴, which guarantees the consistency between demographic flows and population stock in all territorial level (in case of Short Term Projections) and demographic characteristics (sex and year of birth). That lets population projections results include detailed demographic events which explain future population figures evolution. In other words, we are talking about complete demographic projections, not only population projections.

3.3 Some methods of projection of the demographic evolution

As mentioned before, the calculation of Population Now Cast and Short Term and Long Term Population Projections are based on a *multiregional model*⁴, which inputs define the present or future evolution of each demographic phenomena: fertility, mortality and migrations. We should stress two comments on that:

1. Projection methods are determined by the new approach chosen in population projections: statistical simulation of present demographics behaviours and trends.
2. The chosen methods are applicable in the estimation of current demographic evolution in Population Now Cast and in the projection of future demographic evolution, based on an extrapolation of present trends, in Short Term and Long Term Population Projections too.

The designed methodology for projecting Spain fertility, mortality or internal migrations are good examples of such implications.

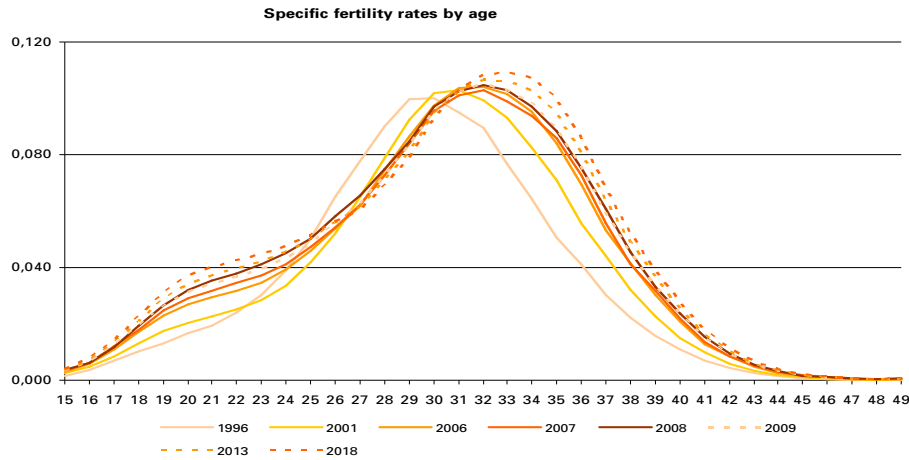
⁴ Willekens, F.J. y Drewe, P. (1984) "A multiregional model for regional demographic projection", en Heide, H. y Willekens, F.J. (ed) *Demographic Research and Spatial Policy*, Academic Press, Londres.

3.3.1 FERTILITY

The general method for projecting fertility of women residing in Spain consist of a modelization of retrospective series of specific fertility rates by age, using the following log-linear model:

$$f_x^t = a_x + b_x \ln(t - 1995), \text{ where } x = 15, \dots, 49 \text{ y } t = 1998, 1999, \dots$$

Being f_x^t the specific fertility rate at age x during de year t , provided by Basic Demographic Indicators and by Monthly Demographic Now Cast for the last 12 months period available. The model parameters, a_x and b_x , are estimated trough *linear least squares*. Next graph shows specific mortality rate observed (1998-2007), estimated by Monthly Demographic Now Cast (2008) and projected in Short Term Population Projection 2009-2049 (2009-2018).



The projection of fertility in lower territorial level (provinces) is carried out using a log-linear modelization of the differential in fertility intensity (Total Fertility Rate, TFR) and fertility calendar (Mean Age at Childbearing, MAC, and Intercuartilic Range, *IR*) of provinces respect to the whole country:

$$DF_{Province}^t = \alpha_{Province} + \beta_{Province} \ln(t - 1993), \text{ } t = 1998, 1999, \dots, \text{ being } DF_{Province}^t = \frac{TFR_{Province}^t}{TFR_{Spain}^t}$$

$$MAC_{Province}^t = \alpha_{Province} + \beta_{Province} \ln(t - 1993), \text{ where } t = 1998, 1999, \dots$$

$$IR_{Province}^t = \alpha_{Province} + \beta_{Province} \ln(t - 1993), \text{ where } t = 1998, 1999, \dots$$

From these parameters, specific fertility rates per every province are developed using *the Gompertz Relational model*, following the methodological proposal of Zeng Yi and others⁵:

$$Y\left(\frac{F(x,t)}{ISF(t)}\right) = \alpha_t + \beta_t \cdot Y\left(\frac{\tilde{F}(x,t-1)}{ISF(t-1)}\right)$$

Where:

$$F(x,t) = \sum_{i=15}^x f_i^{Province,t}, \text{ being } f_i^{Province,t} \text{ specific fertility rate at age } i \text{ in the province during the year } t; \tilde{F}(x,t-1) = \sum_{i=15}^x \tilde{f}_i^{Province,t-1}, \text{ being } \tilde{f}_i^{Province,t} \text{ the smoothed specific fertility rate at age } i \text{ in the province during the year } t; Y(x) = -\ln(-\ln(x));$$

$$\alpha_t = Y(0,5) - \beta_t \cdot Y\left(\frac{F(MAC_{Province}^{t-1}, t-1)}{TFR_{Province}^{t-1}}\right); \beta_t = \frac{IR_{Province}^{t-1}}{\hat{IR}_{Province}^t}.$$

3.3.2 MORTALITY

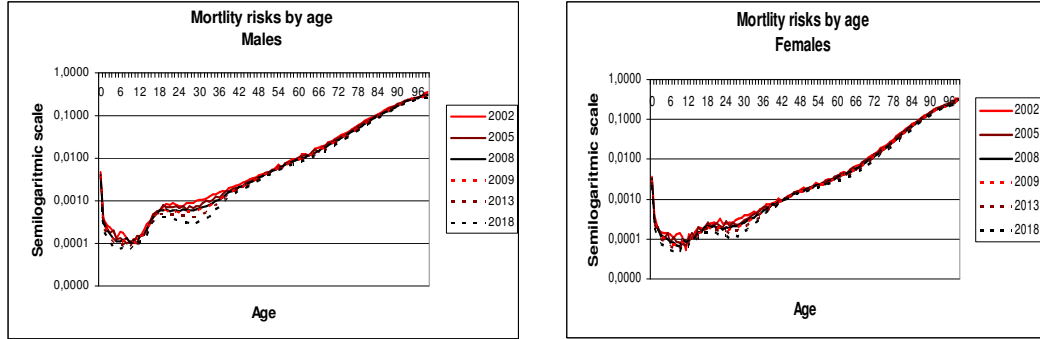
The method for projecting mortality is based on an extrapolation of recent trends in mortality risks by sex and age, according to an exponential modelization of the retrospective smoothed path of them:

$$\tilde{q}_{s,x}^t = e^{\alpha_{s,x} + \beta_{s,x}t}, \quad x = 0,1,2,\dots,99,100+. \text{ For } x \geq 1, t = 1991,1992,\dots; \text{ for } x = 0, t = 1998,1999,\dots$$

Where $\tilde{q}_{s,x}^t$ is the mortality risk of people with sex s and age x during the year t provided by Spain Mortality Tables and by Monthly Demographic Now Cast for the most recent 12 months period available. Model parameters, $\alpha_{s,x}$ and $\beta_{s,x}$, are estimated through *least squares method*.

An intermediate smoothing process of series $\hat{\beta}_{s,x}$ and reestimation of the first parameter $\alpha_{s,x}$ is required in order to guarantee a soft transition between last observed years and projected ones.

⁵ Zeng Yi, Wang Zhenglian, Ma Zhongdong y Chen Chunjun. 2000. "A simple method for projecting or estimating and: An extension of the Brass Relational Gompertz Fertility Model", Population Research and Policy Review 19:525–549.



The projection of mortality incidence in every province is based on the relational method proposed by W. Brass, called *Brass' logits*⁶, which bind the territorial level to the national results:

Being $I_{s,x}^{Province}$ and $I_{s,x}^{Spain}$ the survivor series by sex s and age x ($x = 40, \dots, 95$) of mortality tables of the corresponding province and Spain, respectively, and its *logistic transformation*, the following *linear model* is estimated trough *least squares method*:

$$\text{Logit } I_{s,x}^{Province} = \frac{1}{2} \ln \left(\frac{I_{s,0}^{Province} - I_{s,x}^{Province}}{I_{s,x}^{Province}} \right)$$

$$\text{Logit } I_{s,x}^{Spain} = \frac{1}{2} \ln \left(\frac{I_0^{Spain} - I_{s,x}^{Spain}}{I_{s,x}^{Spain}} \right)$$

$$\text{Logit } I_{s,x}^{Province} = \alpha_s^{Province} + \beta_s^{Province} \times \text{Logit } I_{s,x}^{Spain}$$

3.3.3 INTERNAL MIGRATIONS

The specific inter-provinces, i and j , migration rate by sex s and age x could be factorized in:

$$m_{s,x,i,j}^t = \text{TMRint}_{i,s}^t \cdot c_{i,s,x}^t \cdot a_{s,x,i,j}^t$$

Where $\text{TMRint}_{i,s}^t$ is the Total Internal Migration Rate from the province i of people with sex s during the year t ; $c_{i,s,x}^t$ is the calendar of internal migration by age x of people of sex s residing in the province i during the year t ; and $a_{s,x,i,j}^t$ is matrix of percentage provincial interchanges in every sex s and age x during de year t .

⁶ William Brass, (1975), *Methods for estimating fertility and mortality from limited and defective data*.

Then projection method is based in a genuine regression model with delays in dependant variable, which modelizes the evolution of internal mobility intensity with relation to the foreign immigrants flow (INM) of the same year and the year before and the own trend of the dependent variable.

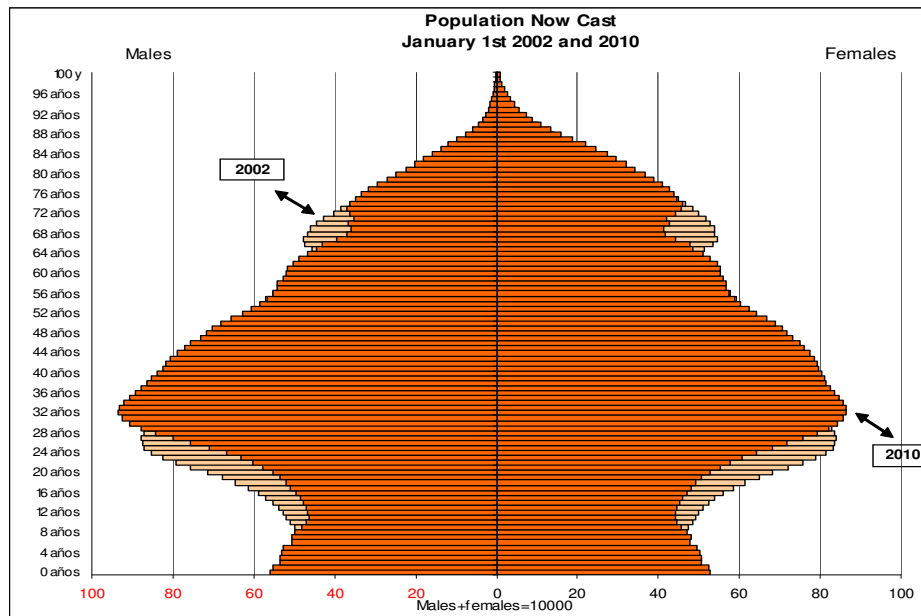
$$\text{TMR int}_{i,s}^t = \beta_0 + \beta_1 \text{TMR int}_{i,s}^{t-1} + \beta_2 \text{INM}_{i,s}^t + \beta_3 \text{INM}_{i,s}^{t-1}$$

The *least squared* estimated parameters of the model are consistent, since autocorrelation in errors are refused with statistical evidence.

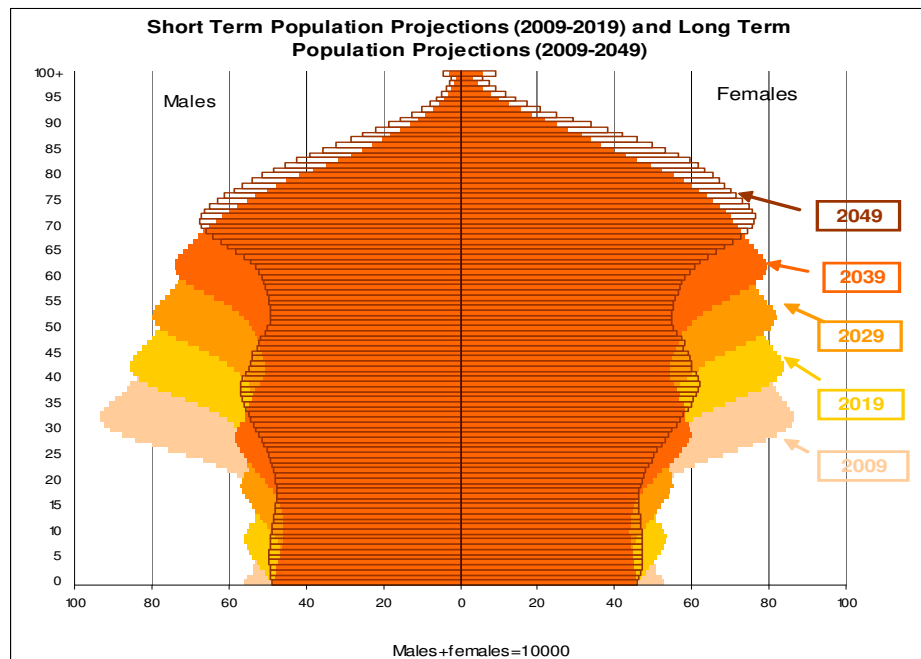
The projection process is completed with the calculation of projected calendars of internal migration $c_{i,s,x}^t$ and the matrix of percentage provincial interchanges $a_{s,x,i,j}^t$ through average data of the last four observed years.

Annex

Recent evolution of Spain population pyramid



Simulated future evolution of Spain pyramid population



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