

# How can population pyramids be used to explore the past?

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## Why should econophysicists analyze past events?

Before coming to our topic we should perhaps answer an obvious question that is related to our title. Why should econophysicists care about the past? The answer is simple. The past is the *laboratory* which allows us to test our understanding of social phenomena. This answer may perhaps seem surprising at first sight. It can best be explained through a parallel with astrophysics.

Let us consider an astrophysicist who has built a theory of triple star systems that he wants to test. What will he do? His first step will be to identify a sample of triple star systems in a star catalogue, for instance the Hipparcos or the PPM star catalogue. In a second step he will perform on these systems the observations that are required for testing the theory. Likewise an econophysicist who wants to test a theory of (for instance) peasant uprisings will first identify a number of such events in the past history of countries with which he is familiar. In a

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*In the present article, Prof. Roehner will try to convince the reader that, provided one respects some basic rules, one can also apply the same methodology in the social sciences.*

second step he will need some reliable quantitative data about these events. Most often peasant uprisings have been militarily defeated by the armies of the government against which the rebellion was initially directed<sup>1)</sup>. The numbers of people killed during and after such conflicts provide rough estimates of the magnitude of such phenomena.

In other words, provided they contain some reliable data, history books serve the same purpose for econophysicists as star catalogues for astrophysicists. This point now begins to be well understood. It is probably for this kind of reason that the last book written by A.-L. Barabási, a well-known expert in network science, contains a meticulous description of a peasant uprising that occurred in the 16th century in Transylvania (now in Rumania) which is Barabási's home region. To be sure, the description of one uprising is far from constituting a catalogue of uprisings but one may expect that Barabási's very active group will produce such a catalogue within the next years.

In physics and in astronomy, every time a new and more accurate observation device has been invented it has led to major progress. Galileo's telescope constitutes one of the early examples. More recently, the invention of the multi-wire proportional chamber by the physicist Georges Charpak was a major step forward in experimental particle physics as recognized by a Nobel award in 1992.

<sup>1)</sup> The outcome of the civil war in China (1930-1949) was one of a small handful of exceptions.

To improve the accuracy of observations about births and deaths in major historical events is the central objective of this paper. What is presently the accuracy of such data? A specific example will convince us that this accuracy indeed greatly needs to be improved.

How many civilians died in Iraq through violent death during the invasion of 2003 and in the 4 years afterward? A comparison of three estimates obtained through different surveys and methodologies reveals huge discrepancies. The total numbers of deaths were found to be equal to 600,000, 200,000 and 50,000 respectively (Browstein et al 2008, p. 446). What is even worse is the fact that a comparison of the methods which were used by these study groups does not reveal why these estimates are so different. The authors observe that there is an ongoing discussion and that convincing arguments have been put forward which suggest that the highest estimate may either overestimate or underestimate the real death toll.

How can an analysis based on population pyramids be of some help in such a situation? Because it relies on data for different age-groups such an analysis allows us to separate different sorts of death such as infant mortality, death of adult males, old age mortality. Once the mortality in a “normal” population has been discounted one will be able to identify and estimate the excess-mortality due to the occupation (whether by violent deaths or not)<sup>2)</sup>.

The paper is organized as follows. First we recall the definition of a population pyramid and introduce the important distinction between static and dynamic analysis. Before beginning to use population pyramid data we discuss their reliability and accuracy. From a physicist’s perspective this is a crucial step. Then, we explain how population pyramids allow us to measure birth rates. The response of birth rates to several kinds of “special events” is illustrated through various examples. Finally, we propose an agenda for further research. An appendix which provides useful information about population pyramid and census databases closes the paper.

## How can population pyramids serve to explore the past?

A population pyramid gives the structure by age and sex of a population. Various examples are given in Fig. 3a,b,c,d and Fig. 5.

<sup>2)</sup> Naturally, population pyramid data must be accompanied by data about emigration because population pyramids make no distinction between permanent emigration and death.

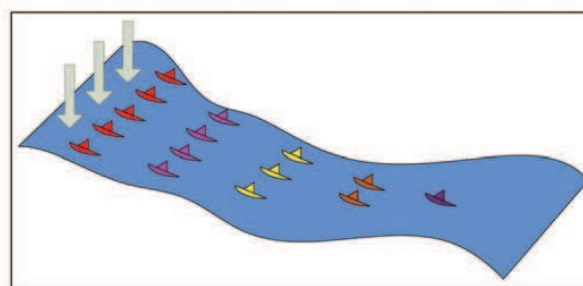
## A spatial parallel of aging

In physics one is more used to movement in space and time than to aging processes. So it may be worthwhile to describe a spatial parallel of the aging process which may be more suggestive to physicists. Fig. 1 pictures a parallel in which age has been replaced by a spatial variable.

Let us imagine that from a bridge on which she is standing a young girl drops small paper boats into a river. At 10am she drops a batch of 25 boats of red color. At 10:10 she drops a second batch consisting of 28 blue boats, at 10:20 she drops a third batch of 21 boats and so on with each batch of boats corresponding to a different color. Once in the water, the paper boats are carried downstream by the current. At intervals some of the boat sink, either because affected by a whirlpool or perhaps because they landed in the water on the side and quickly took in water. This analogy will help us to explain a distinction which plays an important role in demography.

The aging process of a population can be analyzed in two different ways, static or dynamic. In demography the dynamic viewpoint is called “cohort analysis”. This important distinction has a clear interpretation in the paper boat analogy.

- The static viewpoint corresponds to population pyramids. At a given moment one takes a picture of the



**Fig. 1: Spatial analogy of the process of aging.** The blue color represents the water of a river. At one point shown by the vertical arrows, small paper boats are dropped into the water in several successive batches. Each batch (represented by a different color) has approximately the same number of boats except for some random fluctuations which represent the more or less random fluctuations of birth rates. Once in the water, the boats begin to move downstream but as a result of various accidents their number decreases in the course of time until eventually all of them have sunk. In demography, each row of boats is called a cohort. The observation of one specific row in its movement downstream is called cohort analysis. Such an analysis should be distinguished from the static, instantaneous picture provided by population pyramids.

flotilla of paperboats and one counts the number of boats of each color. It should be noted that between two successive rows there is no clear connection because the numbers in successive batches are fairly random.

- In the cohort analysis one concentrates on a specific batch as it moves down the stream. Whereas the static view is an instantaneous snapshot, the cohort viewpoint requires an observation over a long time interval from the moment when the boats fall together in the water to the moment when the last boat of this batch sinks; in demography such an observation must cover over one century. Instead of the expression “cohort analysis” which is fairly abstract we will rather use the expressions “downstream” or “along the stream” analysis which make reference to the river analogy.

### Stability of downstream changes versus instability of birth rates

As we will see later on, birth rates are highly fluctuating. Wars, periods of high food prices, displacements of population may bring about a reduction in birth rates. On the contrary, after the end of wars or during periods of economic prosperity birth rates will tend to increase. In parallel with births, babies and small children who are much more vulnerable than adults to external events will also be affected to a greater degree.

Apart from this and for reasons we do not yet understand, there are dramatic changes in fertility rates (i.e. number of children per woman) which have strong effects on birth rates. For instance, between 1990 and 2002, Poland experienced a dramatic reduction in its fertility rate from 2.0 to 1.35. Similar changes occurred during the same decade in several other countries such as for instance Italy, South Korea, Spain or Ukraine.

It is for these different reasons that in our stream analogy the number of boats in successive batches was taken as a random variable.

On the contrary, once a generation has reached the age of 5 its reduction rate in the course of time will be fairly stable, only determined by the overall standard of living and availability of healthcare. In short, when we follow a given age group downstream we would expect a very smooth and predictable evolution. However, there are two kinds of circumstances which will disrupt this smooth evolution.

- Unexpected events which produce mass mortality such as wars, epidemics or earthquakes. It is precisely in such

events that we are interested. It is because they will appear as sharp falls on a fairly smooth curve that they can be identified and measured.

- When we follow an age-group downstream mass emigration or immigration will also produce rapid changes. In fact, the data make no distinction between people who died or people who moved away. In both cases, they just disappear from the census statistics.

### What is the reliability and accuracy of census data?

It is a distinctive feature of physicists to care about the quality of the data that they use. Social scientists and particularly economists do not. This can be illustrated by two facts: (i) Even though the accuracy of data is much higher in physics than in the social sciences, physicists publish them with error bars whereas social scientists do not. (ii) By browsing through papers published in economic journals one quickly comes to realize that usually only 2 or 3 lines are devoted to discussing the origin, reliability and accuracy of the data that will be used. Yet, if the data are flawed the analysis will be faulty, confusing and useless. This makes the question of data accuracy a matter of cardinal importance. That is why we will give close attention to the various pitfalls that may occur.

Population pyramids rely on census data. Among statistical data recorded by government agencies, census data are considered as particularly reliable and accurate. There are two main reasons for this.

- Because censuses were among the first operations that were carried out, statistical agencies were able to develop adequate procedures and improve them in the course of time.
- In contrast to macroeconomic data (e.g. statistics of Gross Domestic Product) which require heterogeneous variables to be aggregated (a process often referred to as the problem of “adding apple to oranges”) population statistics only involve the addition of data of a single kind.

In spite of this, population data (as indeed any data based on observation) should be considered carefully and viewed with a critical eye.

Basically, population pyramids by country and province require information about residence and age. Are these variables easy to define and to collect?

## Residence

As is well known, the specification of the residence poses some problems for certain categories of citizens who move frequently such as for instance the personnel of the navy or army. Such problems can be solved by setting up clear rules and definitions. Let me give an illustration. At first sight, the big dip in the male population shown in Fig. 2 may look surprising. It becomes clear once one knows that in the 1990s the North Korean government has made the choice of counting the military personnel separately from the rest of the population<sup>3</sup>.

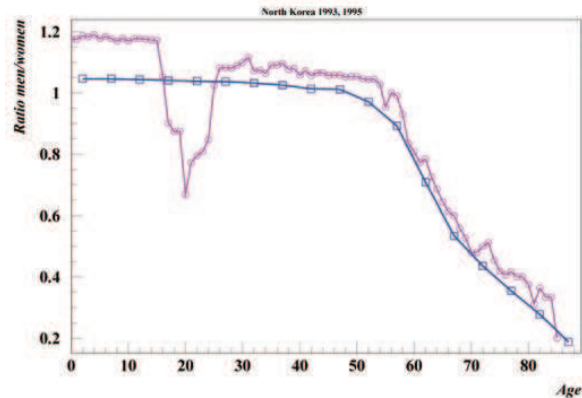
## Age

One may think that for age there should be less problems than for place of residence. Observation shows otherwise. This can be illustrated by the following examples.

- The population pyramid of France based on the census of 1851 (Fig. 3a) shows big steps for the ages of 30, 40, 50, 60 and 70 years. For instance the population for the 50-year age group is almost twice the populations of the 49- or 51-year age groups. Why is this so? A comparison with population pyramids of the same period in other countries such as Canada or the United States (especially at state level<sup>4</sup>) shows the same feature. On the contrary, twentieth century data do not exhibit such a feature. The most likely explanation is that this feature comes from the recording procedure. First, one must realize that French people who were 50 in 1851 were born in 1801 at a time when the registration of births by state agencies was just beginning. As a result, many of them did not know their age with precision. To the question “How old are you” asked by the census officer, they may have answered “Around 50” which was then recorded as 50 on the census form. In short, by giving the closest round number as a proxy of their age people favored multiples of 10 but also (albeit to a smaller extent) multiples of 5.
- In the case of India (Fig. 3b), in addition to the multiples of 10, the steps for ages which end with 2 or 8 are also larger than expected. The number 8 is considered as a “good” number in China. Is it the same in India? We do not know.
- As mentioned above, the bias in favor of multiples of 10 and 5 also occurs for the 1850 census in the US state of

<sup>3</sup>) Most countries do not include in their censuses the personnel of armed forces who are located overseas; counting apart the military based in the country is more uncommon.

<sup>4</sup>) For instance, at the census of 1850 in Georgia the age-group of 30 has a size four times larger than those for 29 or 31.



**Fig. 2: Sex ratio by age in North Korea.** The big dip in one of the curve is due to the fact that the military have not been included in the census of 1993. The blue curve which refers to 5-year age-groups has been corrected for this effect on the basis of previous censuses. At this point it is not clear why it gives a ratio which is lower than the other curve in ages from 0 to 18. Sources: *United Nations: population by single years of age; United Nations: World Population Prospects, 2008 revision.*

Georgia (Fig. 3c). In this case there are in addition substantial random fluctuations due to the fact that the pyramid is based on a 1% sample of the total population.

- The case of Chile (Fig. 3d) is somewhat different in the sense that in this case the steps which are enlarged are those which end with 2. The age groups for 32, 42, 52, 62, 72 have a size which is systematically larger than the adjacent age groups. The difference is not as big as in the previous examples but it is nevertheless significant. For instance, the 42-year age group is 30% larger than the 41 or 43 age-groups. How can one explain this feature? This can possibly be explained by assuming that the census agent did not ask the age but the year of birth. Thus, because the census was done in 1992, if a person born around 1950 rounds the number to 1950 that would produce an excess of people who were 42 year old in 1992.

Whatever the exact reasons of these discrepancies, they are very damageable for any precise analysis. To some extent they can be eliminated by constructing broader age-groups for the following age-intervals:

$$(0.5, 10.5) (10.5, 20.5) (20.5, 30.5) \dots$$

In this way, one has age-groups of equal amplitude and the big steps at 10, 20, 30,... will be divided uniformly between the two adjacent decades. Of course, such a treatment will probably not be sufficient to make a very irregular pyramid (such as the one for India) acceptable.



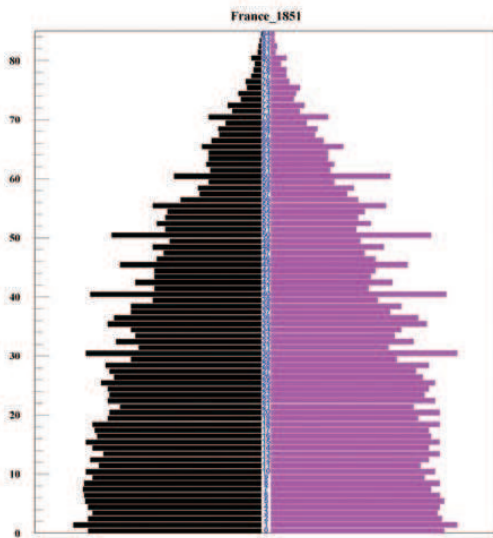


Fig. 3a: Population pyramid of France in 1851. The steps of ages that are multiples of 10 are larger than they should be. Source: *Annuaire statistique de la France, Annuaire rétrospectif (1966)*

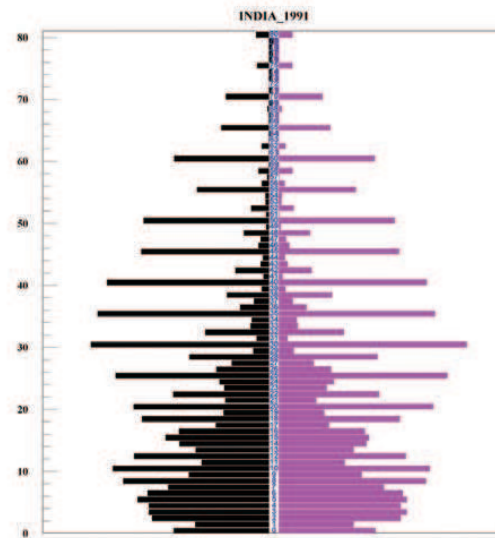


Fig. 3b: Population pyramid of India in 1991. The steps ages which are multiples of 10 or which end with 2 and 8 are much larger than expected. Source: *United Nations: Population by single years of age.*

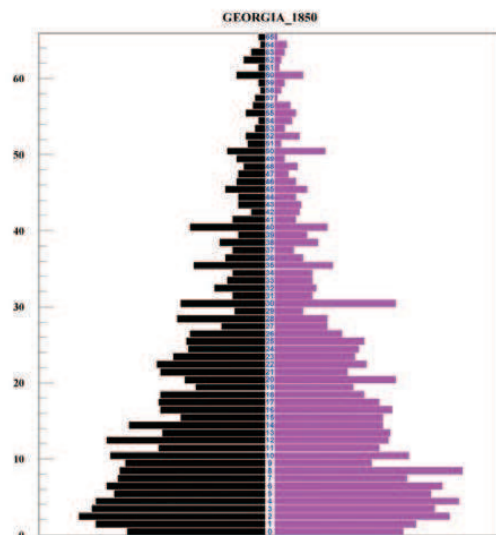


Fig. 3c: Population pyramid of the US state of Georgia in 1850. The steps of ages that are multiples of 10 are larger than expected. Source: *IPUMS (USA).*

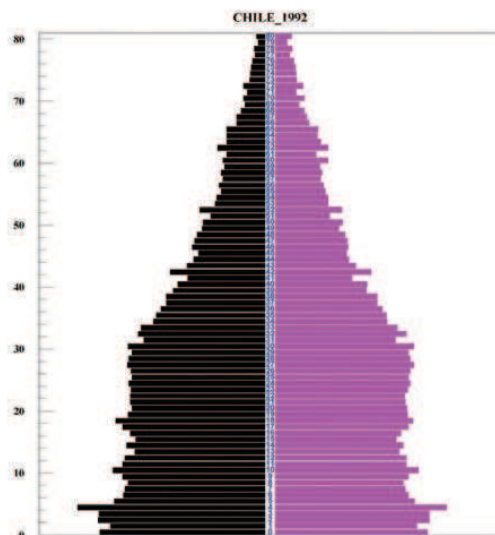
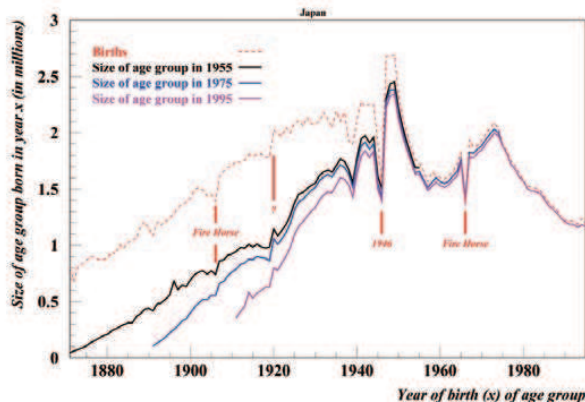


Fig. 3d: Population pyramid of Chile in 1992. The steps of ages 32, 42, 52, 62, 72 are larger than expected. Source: *United Nations: Population by single years of age.*

## How to estimate birth numbers from population pyramids?

Birth and death rates are the two main demographic variables. Both can be estimated by using the information contained in population pyramids but birth rates are much easier to estimate than death rates. In this section we discuss how this can be done and how reliable such estimates are.

The first step of a population pyramid for year 1995 (for instance) gives of course the numbers of birth in this year. Does the population pyramid also allow us to estimate birth numbers for the years before 1995 and, if so, for how many years? For instance, the people who are 20 year-old in 1995 were born in 1975; can their number be used as a proxy for the number of people born in 1975? The answer to this



**Fig. 4: Comparison of birth numbers with the sizes of steps of population pyramids.** The fact that the 3 population pyramid curves closely follow the ups and downs of the number of births shows that, unless there are special circumstances, population pyramids provide good estimates of birth numbers. Between 1947 and 1957 the infant mortality rate was divided by 3, this explains the sudden increase in the distance between the broken and solid curves in the years before 1950. The fact that it became momentarily smaller in 1946 can be explained in only two ways (i) The birth data for 1946 may be incorrect (there is considerable uncertainty for Japanese vital rates in the years immediately after 1945) (ii) There was a massive inflow of Japanese (from Korea and Japan) with babies of less than one year. Sources: *Historical Statistics of Japan: online database of the Ministry of Internal Affairs and Communications. The birth data are from Liesner (1989)*

question depends on what happened between 1975 and 1995. If in those years there was a big disaster or a disease which greatly affected the young people, then the age-group born in 1975 will be so much reduced until it reaches the age of 20 that it cannot well reflect its initial birth size. In other words, there can be no general answer to our question. It all depends on whether there have been special circumstances or not.

It will be helpful to illustrate this argument by an example. Fig. 4 provides a comparison between birth numbers (broken line) in Japan and age-group sizes (solid lines) derived from 3 population pyramids.

First, we must say how the 3 solid line curves were derived from the age-group numbers given by the pyramids. They are in fact identical to the steps of the pyramids but instead of the age it is the birth year which is used to label the age-groups. For instance, the people of age 20 in the pyramid of 1955 were born in 1935 and in 1955 they numbered about 1.7 million. Similarly, the people of age 60

in the pyramid of 1995 were also born in 1935, but in 1995 their number has been reduced to 1.5 million. The second curve is lower than the first because some people in this age-group have died between 1955 and 1995. In a general way, the solid line curves are all lower than the broken line curve of birth numbers; the only exception would occur in case of a major immigration inflow. The only year when this may have occurred in this graph is 1946 when many Japanese people established in China or Korea came back to Japan following the end of the war.

The fact that, despite a high mortality of young men during the war, the broken and solid line curves are fairly close shows that the sizes of age-groups provide good estimates of birth numbers. This is an important rule.

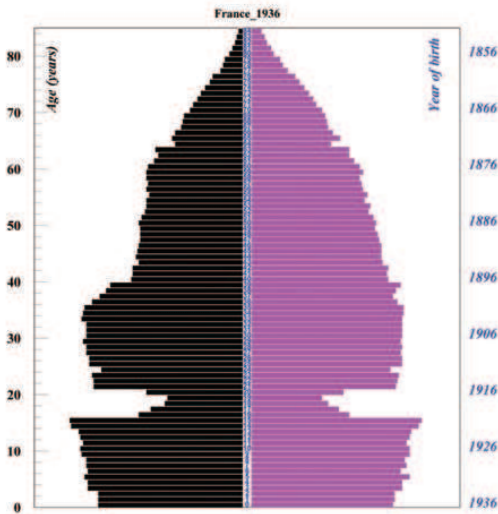
As one goes more toward the past the solid lines curves become of course lower but it can be seen that their short-term fluctuations still fairly well reflect the fluctuations of birth numbers. For instance, the sudden fall in births which occurred in 1906 is fairly well reproduced in the pyramids of 1955 and 1975. This event as well as the 3 others marked by vertical lines will be discussed in the next section.

## Statistical signature of hardship through abrupt birth falls

We have observed previously that birth rates are subject to many fluctuations. However, abrupt falls over a period of one or two years followed by a return to the level which preceded the fall most often indicate that the population suffered some form of hardship as a result of events such as war, food shortage, or other disruptions. What makes this observation of particular interest is the fact that, as we have seen, birth rates can be easily measured on population pyramids.

### Wars

**France** When one looks at the population pyramid of France in 1936 the first thing which attracts attention is a huge indentation around the age of 20. Of course, one is tempted to make a connection with World War I. However, this indentation does not correspond to the soldiers who died in the war. As a matter of fact, the indentation is the same for males and females. Another indication is provided by the fact that in 1936 the people corresponding to this notch are 20-year-old which means they were born in 1916. In short, the war brought about a massive reduction in birth rates: they were divided by 2.



**Fig. 5: Reductions in births in France during the First World War.** During the 5 years of World War I France experienced a reduction in births of up to 50%. The two years after the end of the war were marked by a weak and short-lived babyboom; in 1920 the birth rate did no longer exceed its pre-war level. In contrast, the end of World War II was marked by a strong and lasting babyboom. So far, we do not really understand the reason of this difference. Sources: *Annuaire Statistique de la France 1966, Résumé Rétrospectif*.

A natural question is whether the pyramid also allows us to identify the disappearance of the more than one million soldiers who died on the battle fields. If we look at the step corresponding to an age of 40 (that is to say 20 in 1916) we see a reduction of 14% in the size of the male step. There is no such reduction on the female side. However, this reduction is much less visible than the fall in birth numbers. Not only is it much smaller but it can be identified with certainty only because it did not affect the women.

Incidentally, one can also see on this pyramid the effect of the war of 1870-1871 between France and Prussia allied to Austria. It appears as a reduction of 17% for the step corresponding to age 64 ( $1936 - 64 = 1872$ ). In this case the deaths which occurred during the war are completely invisible because they affected people who are 84 year old in 1936.

**United States** The Civil War brought about a substantial reduction in birth rates especially on the Confederation side. This makes sense because in contrast to Connecticut and Massachusetts all the four Confederate states considered in Fig. 6 were directly confronted to military occupation by Union troops.

In contrast, neither World War I nor World War II seems to have led to a reduction in US birth rates. How can one understand this? For World War I, the explanation is probably that US troops played a role only in the last months of the war. During World War II some 12 million Americans (10% of the population) served in the armed forces. Thus, the lack of any reduction in birth rate may seem more surprising. One possible explanation is the following. During the Great Depression there was a marked reduction in birth rates but in 1940 with the beginning of the war came a great wave of prosperity. The two effects probably cancelled one another.

### Are birth rates sensitive to food shortages?

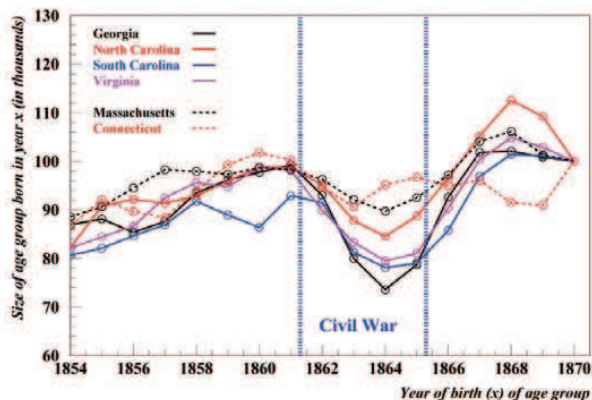
Reductions in birth rates occur not only during wars but also as a result of other kinds of hardships. For instance one may wonder what is the impact of food shortages. Nowadays food shortages are rare in developed countries but they were fairly common in former centuries. In other words, in order to observe the effects of food shortages it is a good idea to use data from former centuries.

**France between 1800 and 1850** This was done by the present author in a study (Roehner 1990) about France in the first half of the 19th century. It was shown that in this time there was a significant correlation coefficient ( $r = -0.6$ ) between the price of wheat and the number of births. Naturally a high price of food meant scarcity and shortage for the poorest people. However, these reductions in birth rates were too small (compared to the noise) to be visible on the population pyramid of 1851. The same study also shows that for these relatively mild food scarcities there was no significant correlation between wheat prices and mortality.

In other words, birth numbers are a much more sensitive indicator of food shortages than death numbers. Thereafter we will refer to this result as the “birth-hardship criterion”.

However, one must recognize that in some cases the effect on births is surprisingly small. This is what we discuss now.

**The case of Henan in 1938 and 1944** It is well known that in the 1930s there were a number of serious food shortages in several provinces of China. One of the most severe occurred in Henan in June 1938 after the levees of the Yellow River were blown up by Kuomintang troops in a desperate attempt to stop the Japanese Army. We are told that almost one million people died through the flood and ensuing food shortage and that 12 million were made homeless



**Fig. 6: Reduction in birth rates during the Civil War in the United States.** Solid lines correspond to Confederation states whereas broken lines correspond to Union states. The war was marked by falls in births of up to 30% in the Confederation and of the order of 10% in the Union. This suggests that, as expected, Confederate states suffered much more than Union states. It can be noted that no records of birth statistics are available in this period. These states became so-called registration states only in the 1910s. In other words, the only way to explore this demographic aspect of the Civil War is to use population pyramids. Sources: *IPUMS USA (University of Minnesota)*.

(see <http://mygeologypage.ucdavis.edu>). In 1943 there was another flood in Henan during which (according to the same website) “3 million of people starved to death”. If one estimates the population of Henan in the 1940s to be of the order of 30 millions<sup>5)</sup>, 3 million deaths represent 10% of the population. Yet, the birth rate as reflected in the population pyramid of Henan, shows only a modest fall of 22% between 1941 and 1944. Between 1937 and 1939 the reduction was even smaller, only 18%. One must keep in mind the possibility that the figures of one and three millions of deaths are perhaps over-estimates.

Below we take the problem by the other end in the sense that we consider episodes that are marked by large birth reductions. The problem then is to understand what kinds of hardship were responsible.

**The birth reduction of 1961 in Chinese provinces** A clear case of birth reduction is provided by the Chinese province of Sichuan in south-west China. The population pyramid of this province shows that between 1958 and 1961 the number of births fell by 63%. In other provinces birth numbers fell also but less. For instance, in the cities of Beijing and Shanghai the reduction was only 30%. The reduction was even smaller in the Northern provinces of Heilongjiang, Jilin and Inner Mongolia (20%). The province where the

reduction was the smallest was Tibet (5%)<sup>6)</sup>. For all provinces together the average reduction was about 40%. This is of the same magnitude than the reduction in France during World War I.

What were the factors behind these reductions? René Dumont, a French expert in agricultural economics who traveled extensively throughout China in these years, cites mainly three factors. (i) Food shortage due to bad weather combined with the fact that many peasants were employed far away from their village in the amelioration of irrigation systems and could not take part in the harvests<sup>7)</sup>. (ii) As the men were often sent to other places for work on dams, canals or dykes, family life was disrupted. Moreover these rapid changes generated a reaction of social resistance and the resulting conflicts added to the hardship of families (Dumont 1964 p. 387). (iii) Finally, there was already an attempt at some limited forms of birth control. Early marriage was discouraged and late marriage encouraged; economic advantages for children were restricted after the third child (Dumont 1964, p. 396).

A confirmation of the role played by the disruption of family life comes from the fact that birth reductions were twice as high in regions such as Henan and Sichuan (where hydraulic systems are of key importance) as in the northern provinces.

To the three factors listed by Dumont one can add a fourth that he does not mention but which appears fairly clearly by examining the population pyramids. After the end of the civil war in 1950 there was a babyboom in many Chinese provinces. Such episodes usually last only a few years. It seems that this boom came to an end toward 1957-1958 which means that, together with the other factors, this contributed to the birth reduction. Incidentally, after 1963 there was a second babyboom which lasted some 12-13 years.

<sup>5)</sup> This rough estimate results from the population of Henan in 2010 divided by the growth factor of the total Chinese population which is about 3).

<sup>6)</sup> The population pyramid of Tibet is one of the smoothest and most regular of all provinces. It has no visible indentation and moreover the male/female ratio does not show any systematic deviation from 1, a feature which is in marked contrast with many other provinces.

<sup>7)</sup> Dumont writes the following: “Between 1955 and 1964 I observed the most extraordinary transformation of the agricultural landscape. When one flies over China from Hanoi to Beijing one sees that the regions to the south of the Yangtze are now covered with canals, levees and dikes where only water reservoirs had existed previously.” (Dumont 1964, p. 393, my translation)



Before we leave this topic a last remark is in order. There has been an ongoing debate about the amount of excess deaths during the years 1958-1961. Unfortunately, at this point we have no way to make reliable estimates based on population pyramids<sup>8)</sup>. This is an ongoing work however and we hope that in the future it will be possible to solve this question.

### Another cause of birth reduction

Just to show that the factors mentioned previously are not the only causes of sudden reductions in birth numbers we describe here a very different cause. In Fig. 4 there are two events labelled “Fire Horse” which are marked by sudden, short-lived birth reductions. These events occurred in 1906 and 1966 respectively. The expression “Fire Horse” refers to the Chinese calendar. This calendar comprises 12 different animals such as “Horse” and 5 different symbols such as “Fire”. This means that a specific animal together with a specific symbol will occur every  $12 \times 5 = 60$  years. In Japan there is a strong belief<sup>9)</sup> that a daughter born in a Fire Horse year will bring ill-being and suffering to her family. As a result some 10% of the couples preferred to postpone a possible birth to a later year. The fact that this reduction occurred twice and exactly in the expected years suggests that this explanation is indeed the right one.

Previously we mentioned factors which affect people in their material living conditions. The Fire Horse events show that social beliefs can have an equally strong impact on births.

### Simple versus difficult cases

In the previous section we have seen that abrupt changes in birth numbers sharply affect the shape of population pyramids. Why is this so? The reason is very simple. For any age-group the birth year represents a single year. So any short-lived event which affects births will leave its mark on only one or two steps of a pyramid. On the contrary, an event such as an earthquake or a disease will affect all ages and reduce many steps of a pyramid. As a result, it will be difficult to distinguish this effect from a multi-year trend in birth rate.

In addition the effect of special events on birth rates can lead to reductions as large as 50%. On the contrary, even major wars hardly ever kill more than 10% of an age group. For instance, over one million French soldiers were killed on the battle fields of World War I but these deaths were distributed over several age groups with the result that in each age-group the reduction did not exceed 15%.

In short, any event that (i) is concentrated in time (ii) affects only one or two age-groups and (iii) affects them strongly (effect larger than 10%) will be easy to analyze through population pyramids. On the contrary, episodes which last several years and affect a whole population from young to elderly will have only a “diluted” impact on age-groups and therefore will be hard to detect and even more difficult to analyze.

## Population pyramids of North and South Korea

In the previous sections we have shown two things: (i) That population pyramids can be used to estimate birth rates. (ii) That a dip in birth rate provides a signature of hardship whether due to war or to other factors. In the present section we wish to apply these clues to a specific case, namely a comparison between the population pyramids of North and South Korea (Fig. 7).

### Similarities

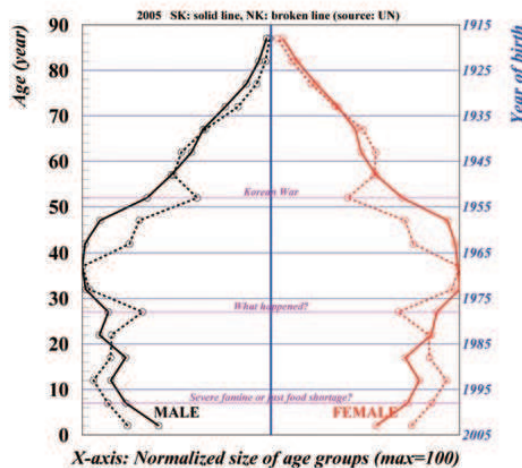
First of all, by comparing the broad shapes of the two pyramids we see that they look fairly similar. From top to bottom (that is to say from 1915 to 2005) one can mention the following features.

- For women of old age (over 65) the slopes are almost the same which points to similar conditions in caring for the elderly. The case of men seems different but this comes from a depletion of these age groups before World War II (as will be seen below).
- In contrast to the case of European countries or Japan there was no babyboom in North and South Korea after the end of World War II<sup>10)</sup>.
- In both countries a babyboom started at the end of the Korean War and lasted until 1970.
- Both pyramids show a narrow base which indicates a reduction in birth rates after 1975.

<sup>8)</sup> In the next section we explain why this is a more difficult problem.

<sup>9)</sup> Although the same calendar is used there is no similar belief in China.

<sup>10)</sup> A babyboom can be defined by the fact that in the years after the war the birth rate is higher than it had been before the war. France provides a spectacular illustration. Between 1946 and 1969 the birth rate was on average 50% higher than between 1930-1939. In Japan birth rates in 1947-1950 were 25% higher than before the war but after 1950 they quickly came back to their pre-war level. Fig. 7 suggests that there was a small increase in births in South Korea between 1945 and 1950 but the real babyboom came after 1953.



**Fig. 7: Comparison of the population pyramids of South and North Korea.** The comparison raises the question of what caused the dip of 1978. Two factors seem to have played a role: (i) The fact that the reduced age groups of the Korean War reached marriage age (ii) The birth-control program launched by the North Korean government possibly following the example of the one-child policy which was introduced in China around this year. Sources: *United Nations: World Population Prospects, 2008 revision.*

## Differences

One can note the following differences.

- From the 1965 pyramid it can be seen that for North Korean people born between 1900 and 1935 the ratio male/female is much lower than for South Korean people. It becomes as low as 0.6 whereas in South Korea it is almost 1. At this point we have no explanation.
- Whereas the Korean War did not much affect the birth rate in South Korea it strongly affected the birth rate in North Korea.
- The North Korean pyramid shows a substantial indentation around 1978. For South Korea there is also a reduction but it is more a trend than a sudden event. This indentation can be explained by two factors. (i) It occurs some 25 years after the Korean War which means that the reduced age groups due to the war will have fewer children than the normal corresponding age groups in South Korea. However, because of the dispersion in the age at marriage this effect should be less abrupt than in 1953 which means that there was probably a second factor. Indeed, in these years (and probably following the example of China) the North Korean government started a policy of birth control. More details can be found in the article “Changes in population of North Korea”.

## Was there a severe famine in North Korea?

Although this point does not originate from a comparison of the two pyramids one can hardly avoid this question because it has generated a vivid debate in recent years and even up to now. On the one hand, there are some Western experts who claim that around 1998 there was a severe famine in North Korea which caused between 600,000 and 4 millions deaths. On the other hand one has the thesis that there was indeed a food shortage but no real famine with many deaths. What is the truth?

We said that it is not the examination of the pyramid which raises this question. Indeed, the pyramid show nothing special in 1998. According to our previous hardship criterion a famine should have produced a marked indentation, at least of same magnitude as the one in 1978. But nothing of the sort can be observed.

As a matter of fact, if one believes that the population data transmitted to the United Nations by the North Korean government are basically correct, the famine thesis does not hold. This follows not only from the population pyramid but also, more simply, from the examination of the total population. During the 1990s and 2000s in normal years the natural population increase (due to the difference between birth and death rates) was about  $15 - 7 = 8$  per thousand. With a population of about 20 millions one gets an annual surplus of 160,000. Now, even if one takes the lowest famine death toll estimate, namely 600,000, and if one assumes that this toll was spread over 3 years, one gets an annual population change of  $160,000 - 600,000/3 = -40,000$  which means that the population should have been decreasing over 3 years. This is in contradiction with the data about the North Korean population<sup>11</sup>. The curve which shows the evolution of the population between 1961 and 2003 does not reveal any annual fall.

In short, the two claims are incompatible. One of them must be wrong. Because it would lead us too far away from the main topic of this article we will not here try to discuss the validity of the two theses. More details can be found in the longer version of the paper which is available on the author’s homepage. In particular, it will be seen that the internal documents of two organizations which should be well informed on this matter, namely the US State Department and the United Nations Food and Agriculture Organization, hardly ever mention a famine in North Korea. They mention a chronic food shortage but they do not mention

<sup>11</sup> See for instance on Wikipedia the file Korea-North-demography.png

people starving to death. Beyond this debate, what is perhaps the most important point from a scientific perspective is to realize that the thesis of a famine which caused 2 million deaths is not as well established as the broad coverage it has received in western media would lead us to think<sup>12)</sup>.

## Conclusion and perspectives

In this article we tried to convince the reader that population pyramids are an effective tool for exploring the demographic facet of social phenomena. As the purpose of the paper is to provide an overall introduction it focused on basic principles and some illustrations. Many questions still need to be investigated more closely. For instance in the case of a war what is the key-factor? Is it the death of soldiers, the occupation of parts of the country by foreign troops, the destruction of cities by air raids or some other factor?

### As in physics one can study each factor separately

In contrast to many other questions in the social sciences for which we cannot set up many experiments, here we can. We are in the same position as the astrophysicists mentioned at the beginning of the paper. We have enough cases at our disposal to isolate one factor after another. For instance, if we wish to study the effect of air raids, we can investigate the cases of Germany or Japan in 1945, of North Korea in the Korean War, of North Vietnam in the Vietnam War, of Iraq in the First and Second Gulf Wars. Similarly, for occupation cases there are many specific episodes.

In fact, we are even in a better position than astrophysicists because we can first test our methodologies on known cases. An example will explain what we mean. By using the population pyramids of Japan for the years 1898, 1903 and 1908 it is possible to estimate the number of excess deaths due to the Russo-Japanese War of 1905. This provides a useful test of the methodology because it is possible to compare such excess-deaths to what historians tell us about the toll of the war.

<sup>12)</sup> An example chosen at random among many similar sentences reads as follows. “The exodus of North Koreans to Jilin and Liaoning Provinces [North of China] began in earnest in the waves of famine that struck North Korea in the mid-1990’s, killing as many as two million people” (New York Times 24 March 2005). It can be noted that the 2 million death toll is presented here as a fact not an estimate or a conjecture. Incidentally, there was also an exodus of Polish people to the UK, Ireland and Iceland in the 2000s without any famine in Poland; they were just seeking better wages.

## Research agenda

This example suggests a 4-step research agenda.

(i) First one develops a new measurement method (ii) Then one tests it on several “known” cases. (iii) If the death estimates provided by the method agree with those given by some reliable sources, the method will be validated. (iv) Once validated, it can be used to explore cases for which there are no reliable data or for which there are conflicting data.

## How to find new measurement methods?

For discovering new measurement methods (the first step in our previous agenda) the strategy that we suggest is inspired from what physicists do. To make this point clearer it may be useful to recall a well-known example.

- Light rays usually move along straight lines. This is what can be called the basic rule.
- However, in some cases they do not move along straight lines. This signals that some “special event” is taking place. For instance, the basic rule will not hold in a substance whose index of refraction is not uniform or in the strong gravitational field that exists in the vicinity of the Sun. In such cases the trajectory of the light-ray is bent.
- By measuring the angle of deviation of the light-rays, it is possible to get information about the “special events”. Thus, in the two previous cases one can determine the gradient of the refraction index or the strength of the gravitational field.

Similarly, our strategy will comprise the following steps.

- First, one must analyze the process of aging and discover some “basic rule”. As an example of such a rule, one can mention Gompertz’ law which says that after the age of 40 the probability of death doubles every 8 years.
- When population pyramids show a deviation away from the basic rule this tells us that a special event has occurred.
- By comparing actual data to what the rule would lead us to expect, one can determine the characteristics of the “special event”.

## Appendix A. Sources for census data

In order to build population pyramids by single year of age for the different provinces of a country, one needs census data about age and place of residence. Moreover, one would like to find such statistics for as many countries and as many dates as possible. Where can one find such information? There are several possible sources. Thanks to the Internet all of them are fairly easily available.

## National statistical organizations

For census data the primary sources are the statistical agencies of each country. Although more and more countries publish their statistical yearbook in bilingual form (national language + English) the more detailed statistical data that we need are usually not published in bilingual form. In other words to get access to such Japanese data (for instance) one needs some knowledge of the Japanese language.

Fortunately, there are some websites which provide the information that we need for many countries. In what follows we restrict ourselves to such sources which are freely available on the Internet<sup>13)</sup>.

## The IPUMS websites

IPUMS is an acronym which means “Integrated Public Use Microdata Series”. The word “microdata” means that this website provides individual census data for representative samples (usually 1% samples) of the whole population of a country. There are two IPUMS websites: “IPUMS USA” gives data for American censuses from 1850 to 2000. “IPUMS International” covers several countries<sup>14)</sup>. Through these data bases one can build population pyramids at regional level (provinces for China, canton for Switzerland, and so on).

## UN database of populations by single years of age.

The United Nation provides population data by sex and single year of age for almost all countries and at various dates. These data can be used very easily to build population pyramids at country level.

## UN database of populations by 5-year age groups (1950-2010)

The Population Division of the United Nations periodically publishes a dataset entitled: “World Population Prospects”. The 2008 Revision was released on 1 September 2010. Among other things, this database gives the population of all countries by sex and 5-year age groups.

<sup>13)</sup> We do not give the addresses of the websites because usually Internet addresses have only a short life-time. However, all these websites can be easily located through their titles with the help of a search engine.

<sup>14)</sup> E.g. Argentina, Brazil, Chile, China, Egypt, France, India, Iraq, Kenya, Mexico, Pakistan, Palestine, Philippines, Puerto Rico, South Africa, Spain, Switzerland, Thailand, United Kingdom, Venezuela, Vietnam. It can be noted that some important countries are missing, e.g. Germany, Indonesia, Japan, Korea, Russia. Except for a few cases the dates are posterior to 1970.

It should be noted that, strictly speaking these data are not census data. This is clear from the fact that the tables are given for the same years (1950, 1955, 1960, 1965, ...) in each country whereas actual censuses take place in different years depending on the country. In other words, the data given in this database are estimates computed by the Population Division.

There are two sections about “Sources” and “Assumptions” in which official sources are listed. However, this list mentions only the most recent censuses. For instance in the case of Korea (North and South) no indication is given about the sources which were used for the estimates of 1950 and 1955. Moreover, the “Assumptions” section does not say precisely how the interpolations (or extrapolations) have been performed. The assertion which is made that “population data from all sources were evaluated for completeness, accuracy and consistency, and adjusted as necessary” actually means that one must trust the experts who produced the estimates. We do not intend to say that the estimates are not good but rather that one cannot know how good they are.

In addition to the previous multi-national websites one can also mention a very convenient website which gives historical data for Japan.

## Historical Statistics of Japan

The statistical series on the website “Historical Statistics of Japan” are published by the Japanese Ministry of Internal Affairs and Communication. The population data give the distribution by single years of age for all censuses held in Japan between 1884 and 2000.

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# Status and perspective of numerical relativity

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In dynamical phenomena in strong gravitational field such as formation of a black hole in stellar core collapse and merger of black holes and neutron stars, general relativity plays a crucial role. The basic equation in general relativity is Einstein's equation, which is highly nonlinear equation. To theoretically understand general relativistic phenomena, we have to solve Einstein's equation. Because of its nonlinearity, it is impossible to solve this equation analytically for general dynamical problems (except for highly idealized problems possessing high spatial symmetries). Numerical simulation is the unique approach for solutions of such interesting phenomena in nature. Numerical relativity is the field which pursues numerical solution of Einstein's equation using supercomputers. In the last two decades, importance of numerical relativity has been increased in theoretical physics, and as the demand for it increased, the community of numerical relativity has achieved great progress. The purpose of this article is to review the progress achieved in the last decade and the resulting current status of numerical relativity.



There are currently at least three important roles in numerical relativity. First, numerical relativity is an invaluable tool for predicting gravitational waveforms from the gravitational-wave sources for kilo-meter size laser-interferometric gravitational-wave detectors such as LIGO [1], VIRGO [2], and LCGT [3]. To detect gravitational waves and to extract physical information from the detected signal, it is necessary to prepare a theoretical template for data analysis [4]. To derive such a template for highly nonlinear phenomena such as merger of compact binaries composed of black holes and neutron stars, numerical relativity is obviously the unique approach. Second, numerical relativity is an important tool for theoretically studying general relativistic astrophysical phenomena such as supernova stellar core collapse and formation of central engine of gamma-ray bursts. For these phenomena, compact objects (black hole and/or neutron star) are believed to be accompanied, and thus, a highly dense state is realized. Then, it is quite difficult to directly observe such a dense region, in which key information is hidden. A well-known example is supernova stellar core collapse. To clarify the mechanism of supernova explosion, it is necessary to clarify the physical state of the central region around the collapsing core which is composed of a protoneutron star and infalling material. However, this task is impossible by electromagnetic wave observations. Even if observations by neutrinos and gravitational waves become possible in the future, the information obtained is restricted. For understanding such phenomena, numerical-relativity simulation plays a crucial role. Third, numerical relativity can play an important role for clarifying the nature of gener-

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