



Coupling between death spikes and birth troughs. Part 1: Evidence

Peter Richmond^a, Bertrand M. Roehner^{b,*}

^a School of Physics, Trinity College Dublin, Ireland

^b Institute for Theoretical and High Energy Physics (LPTHE), University Pierre and Marie Curie, Paris, France

HIGHLIGHTS

- Sudden death spikes are followed 9 months later by birth troughs.
- Six case-studies ranging from 1860 to 2011 provide closer insight.
- A crucial parameter is the number of collateral sufferers

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ABSTRACT

In the wake of the influenza pandemic of 1889–1890 Jacques Bertillon, a pioneer of medical statistics, noticed that after the massive death spike there was a dip in birth numbers around 9 months later which was significantly larger than that which could be explained by the population change as a result of excess deaths. In addition it can be noticed that this dip was followed by a birth rebound a few months later. However having made this observation, Bertillon did not explore it further. Since that time the phenomenon was not revisited in spite of the fact that in the meanwhile there have been several new cases of massive death spikes. The aim here is to analyze these new cases to get a better understanding of this death–birth coupling phenomenon. The largest death spikes occurred in the wake of more recent influenza pandemics in 1918 and 1920, others were triggered by the 1923 earthquakes in Tokyo and the Twin Tower attack on September 11, 2001. We shall see that the first of these events indeed produced an extra dip in births whereas the 9/11 event did not. This disparity highlights the pivotal role of collateral sufferers. In the last section it is shown how the present coupling leads to predictions; it can explain in a unified way effects which so far have been studied separately, as for instance the impact on birth rates of heat waves. Thus, it appears that behind the apparent randomness of birth rate fluctuations there are in fact hidden explanatory factors.

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1. Introduction

This paper is about a remarkable case of birth and death fluctuations which, apart from its own interest, may give new insight in the more general problem of vital rate fluctuations. We begin with the following observation.

* Corresponding author.

E-mail addresses: roehner@lpthe.jussieu.fr (P. Richmond), roehner@lpthe.jussieu.fr (B.M. Roehner).

1.1. Two alternative views of birth fluctuations

The number of births in a given time interval θ can be written: $b(t) = \lambda(t)P(t)$ where $\lambda(t)$ is the crude death rate at time t and $P(t)$ the size of the population.¹ Depending on whether θ is one day, one week, one month or one year, λ will be the daily, weekly, monthly or annual rate.

We can immediately distinguish two cases:

(1) The rate is fixed $\lambda(t) = \lambda$. In this case the changes of $b(t)$ reflect the changes of the population.

(2) The population is constant $P(t) = P$. In this case the fluctuations of $b(t)$ reflect the fluctuations of the birth rate $\lambda(t)$.

Conceptually, there is a great difference between these cases. For in the first there is nothing to explain whereas the second case raises many questions. What we mean by “nothing to explain” is that, as the population increases or decreases regularly the only question that one may possibly raise is why the birth rate is set at its given value λ .

However, fluctuations of the rate raise numerous questions in the sense that $\lambda(t)$ reflects the behavior of individuals and the conditions under which they live. In other words, for any major change in $\lambda(t)$ one is prompted to ask to what change in real life it is tied.

A quick comparison of the orders of magnitude of the two types of fluctuations can be made as follows.

- In the early 20th century European populations were increasing at an annual rate of around 1%. Under the assumption of a constant λ birth numbers will see the same annual change. Thus, for *monthly* changes the rate will be 12 times smaller, i.e. around 0.1%.

- In contrast, the monthly birth rate fluctuations of actual observed monthly birth numbers were about 4%.² This is 40 times larger than the fluctuations under constant birth rate.

However remarkable, the case considered in this paper is possibly just one of several similar processes leading to predictable birth rate changes. The topic of short-term fluctuations has so far attracted much less attention than the study of medium- or long-term changes. For instance the demographic transition in developed countries was brought about by changes of vital rates over a time interval of several decades.

The present study shares several important features with the research field that is concerned with the fluctuations of sex ratio at birth, see [1,2].

- Both researches rely crucially on comparative analysis, either in space across different countries or in time over past centuries.

- Both investigations focus on short-term effects, for instance the changes that occur in the months following an epidemic or a war, see [3] and [4].

- The respective key-variables, monthly birth rates on one hand and sex ratio fluctuations on the other, can be used as markers, in other words as measurement devices which give insight into abnormal situations. For instance, James [5] documents how offspring sex ratios can reveal endocrine disruptions; similarly mortality sex ratios can be used to explore anomalies of the immune system, see [6] and [7].

1.2. Are there “hidden variables”?

In any country the time series of monthly births display substantial fluctuations. There is usually a seasonal pattern which is country dependent; in addition for the same month (say October) in different years there are annual fluctuations of about the same magnitude. It is customary to say that these are random fluctuations but are they really random? In this respect one can observe that by saying that a phenomenon is random one gives up *ipso facto* all attempts to understand it. It is probably for this kind of reason that Albert Einstein supported the “hidden variable” interpretation of quantum physics. In 1935, i.e. some 10 years after quantum mechanics was introduced, Einstein et al. [8] suggested that the wave function description of quantum objects was incomplete in the sense that it did not include some hidden parameters.

1.3. The Bertillon discovery

In 1892 Jacques Bertillon, a pioneer of medical statistics and one of the designers of the “International Classification of Diseases”, published an analysis of the influenza pandemic of November 1889–February 1890 in which he showed that approximately 9 months after the climax of the epidemic a temporary birth rate trough (of an amplitude of about 20%) was observed in all countries where the pandemic has had a substantial impact, particularly Austria, France, Germany or Italy. While writing his paper Bertillon did not know that some 28 years later there would be a massive influenza pandemic through which his discovery could be tested. We will show below that it was indeed confirmed in all countries where the pandemic has had an impact. Apparently, there has been no further studies of this phenomenon ever since. Actually, even in Bertillon’s paper the effect is discussed fairly briefly. In particular its mechanism remains to be uncovered. This is the purpose of the present paper.

While in 1889–1890 and 1918–1919 the effect can be detected very clearly, is it not natural to assume that it exists also in less spectacular cases. This raises the following question. In most countries the death rate presents a winter peak in January

¹ The difference between θ and t is that θ is a time interval, whereas t is a specific time.

² The 4% estimate is for normal conditions; exceptional birth dips and rebounds can be much larger, for instance $\pm 30\%$ in the case of Fig. 1b.

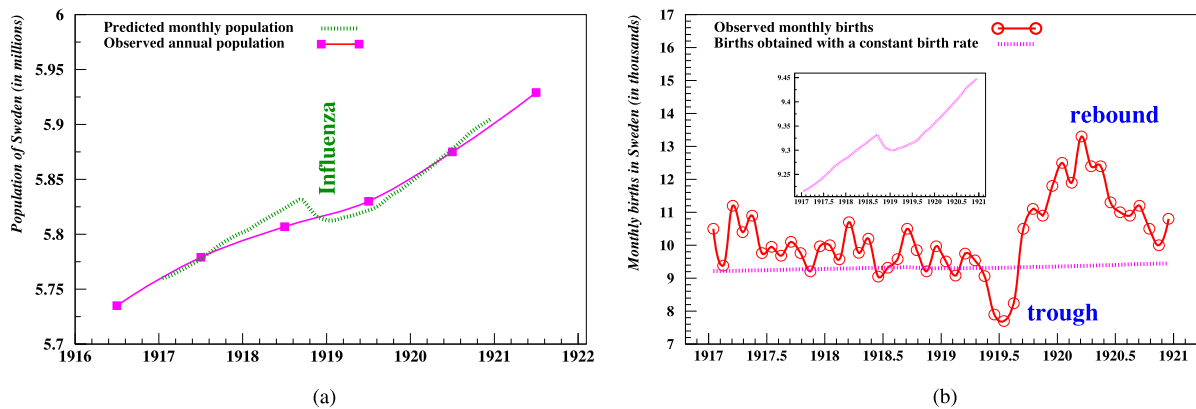


Fig. 1. Comparison of the births produced through population changes under constant birth rate on the one hand and observed monthly fluctuations of birth numbers on the other hand. The data are for Sweden. Fig. 1a shows that the population changes based on the summation of monthly births and deaths approximates correctly the observed annual population changes. The curve of birth numbers based on a constant birth rate is naturally parallel to the population curve; it is displayed in the inset graph of Fig. 1b; the variation interval of births numbers (as shown on the vertical axis of the inset) is (9.20, 9.45). These variations are much smaller than the actual fluctuations of birth numbers; as a result the broken line of predicted birth numbers looks almost completely flat when displayed on the same graph as the actual births fluctuations.

Source: Bunle [11].

or February. According to the Bertillon coupling one would expect a trough of births 9 months later that is to say in October or November. Is this indeed the case? If not, in what respect do exceptional death surges differ from regular winter surges? This point will be discussed in the second one of the two papers devoted to this question.³

In an attempt to get a clearer idea of the mechanism of the coupling effect the present paper will address the following questions.

(1) First, we will review and expand the analysis presented in [10]. The question which comes immediately to mind is whether the same effect can be observed in other pandemics.

(2) If the answer to the previous question is affirmative it raises another interrogation, namely is this effect restricted to pandemics or does it also exist for other large-scale mortality shocks, for instance famines, earthquakes and so on. Wars should not be included in our study for in this case the separation between husbands and wives interferes with the coupling that we wish to observe.

(4) A possible mechanism that one can imagine is through a transient impact on marriages. If the marriage rate is reduced during the time of the epidemic, one would indeed expect a reduction in birth numbers some 9 months later. Such an explanation can easily be tested provided one can find *monthly* marriage data (see below).

2. What is the *direct* incidence on births of mortality spikes?

Before starting this investigation we need to answer an obvious objection which can be stated as follows.

Is it not natural that following a reduction in population one sees a fall in the number of births? After this fall the birth numbers will go up again as the population resumes its ascending movement.

Qualitatively the argument seems satisfactory. If correct, the effect would become trivial. However, in what follows we show that quantitatively the argument is not correct for it explains less than one tenth of the observed birth changes.

Before coming to more elaborate arguments one can make a simple remark. What we see after 9 months is a fairly narrow dip. On the contrary, a fall in population would produce a permanent reduction, in other words not a dip but a Heaviside step. It is true that because of the upward trend due to the overall population growth after a while the births would resume their ascending progression, however the resulting shape would be a broad trough rather than a narrow dip; this difference can be seen clearly in Fig. 1a versus 1b.

We present the reasoning in two forms. While straightforward, the first is perhaps not very transparent; the second is more theoretical but intuitively clearer.

2.1. Prediction of birth numbers under the assumption of a constant birth rate

The first argument is very simple.

³ In this respect see also [9].

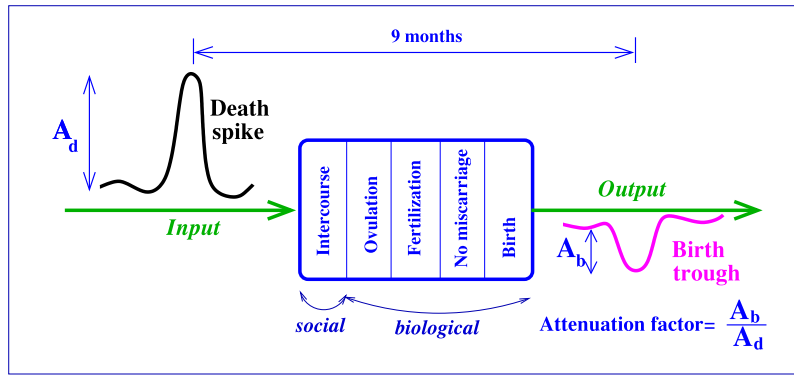


Fig. 2a. Representation of the Bertillon coupling effect in the form of an input/output system. If one interprets the death spike as an impulse function, the birth trough can be seen as the impulse response of the system. An important point is that, as explained in the text, the loss of lives during the death spike cannot by itself account for the observed birth trough. Its direct effect is at least 10 times too small which means that there must also be an indirect effect; it is the purpose of the paper to identify it more closely.

The statistical records provide monthly birth and death numbers, $b_e(t)$ and $d_e(t)$. Thus, starting from a known population at initial time t_0 we can forecast the population $P_f(t)$ in all subsequent months simply by summing up the monthly population increases $b_e(t) - d_e(t)$. It can be checked (Fig. 4a) that $P_f(t)$ is indeed consistent with the observed population evolution $P_e(t)$ (which amounts to say that in this time interval emigration and immigration do not play a great role). Then, under the assumption of a constant birth rate λ the predicted monthly birth numbers will be: $b_f(t) = \lambda P_f(t)$. When these numbers are compared with the observed monthly birth numbers $b_e(t)$ one sees a huge difference in the magnitude of the fluctuations (Fig. 1b). To double check that there is no flaw in the data on which the graph is based consider the start and end points. According to Flora et al. [12, p.73]:

- In 1917 when the mid-year population was 5779 thousands a (constant) annual birth rate of 20 per thousand gives 115,580 births for the year, i.e. an average of 9631 births per month.
- In 1920 when the mid-year population has increased to 5875 the same birth rate gives 117,500 births, i.e. an average of 9791 per month. This represents a total predicted birth number increase of 1.67% whereas the observed monthly birth numbers show fluctuations of the order of 30%.

2.2. Implication of a constant birth rate for the fluctuations of birth numbers due to population changes

The following statement (explained in Appendix A) summarizes the situation.

Proposition Under the assumption of a constant monthly birth rate λ the fall in births resulting from a monthly death excess e is given by: $\Delta b = \lambda e$; for European countries in the early 20th century $\lambda \simeq 2\%/12$ which leads to: $\Delta b \simeq e/600$.

The proposition has a fairly clear intuitive interpretation. To make things simple let us assume that the death-excess variable e takes place in one month, as is for instance the case for earthquakes. In a virtual world where everybody conceives once every month, for each missing person there would be a missing baby 9 months later. Under this assumption the birth trough would be of same magnitude as the death spike. However we know that actually the probability to conceive in a given month is $\lambda/12 = 0.0017$ where λ is the annual birth rate. In other words in 10,000 persons only 17 may conceive in the relevant month. Thus, this direct effect contributes very little to the birth trough.

3. From conception to birth

3.1. The role of collateral sufferers

The birth rate reduction can be attributed to one of the factors mentioned in Fig. 2a. The objective of the present paper is to see more clearly which one of these factors plays a leading role. What real-life mechanisms can one think of that may explain the temporary birth rate fall?

In Fig. 2a there is a distinction between social and biological factors. It is by comparing different case studies that we came to the conclusion that social factors play a key-role. How?

As famine and influenza have biological effects, at first sight the resulting birth reduction might also be attributed to such effects. On the contrary, birth reductions after earthquakes can hardly be accounted for by biological factors. For that reason the case of the Tokyo earthquake of 1923 played a key role in our understanding. It convinced us that the suffering of the many people who are affected but do not die was of central importance.

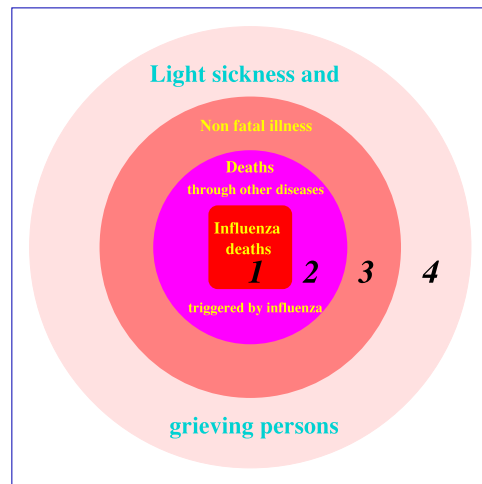


Fig. 2b. The impact of a shock ranges from fatalities to minor afflictions. The figure was drawn for the case of an influenza outbreak but the same argument applies also to other kinds of shocks. Thus, for an earthquake some persons are killed, others only injured and still others are unharmed but have their house destroyed.

In examining successive case-studies it will also be seen that the magnitude of the birth reduction is compatible with the existence of a group of people that we call *collateral sufferers*. This term refers to persons who are affected by the event under consideration (whether epidemic, disease or anything else) but do not die. In order to generate the observed birth dips the size of this group must be several times larger than the number of fatalities.

This is illustrated in Fig. 2b. In Sweden although there were only 43,000 excess deaths in 1918, it is estimated that about one third of the population, that is to say almost 2 millions (50 times more than those who died), was affected by the disease. Naturally, this fraction is difficult to define precisely because there is a continuum between the persons who were not affected at all and those who experienced very mild forms of the disease.

The two following points need to be emphasized.

- Among the persons affected by the disease (or even in the whole population), there may have been a more restrained sexual behavior for instance by fear of a possible contagion. This may have produced a reduction in the number of conceptions.

- Among the persons mildly affected by the disease there may have been biological effects leading to less fecundation or early miscarriages in the 2 or 3 first months of pregnancy. The fact that in what follows we will observe the Bertillon birth effect not only for diseases but also for earthquakes may seem to speak against such biological effects. However, one cannot exclude possible psychosomatic effects resulting from a stressful situation. An example is the so-called famine amenorrhea [13–16].

3.2. Impact of induced delivery

Finally it should be mentioned that the birth phase represented in Fig. 2a comprises in fact two cases: natural birth and medically assisted birth through caesarean or induced delivery. Such medical interventions are much more frequent on ordinary working days than on holidays. For that reason, there is a drastic reduction in daily birth numbers on Saturdays, Sundays and on holidays. For instance in the United States; 1 January, 4 July, Labor Day, Thanksgiving, 24–25 December are marked by a reduction of about 30%. This effect is of great importance when one uses daily data; at the level of monthly data the effect is “diluted” because the deliveries are simply postponed by a few days, thus the total monthly figure should not be affected.

3.3. Marriage date does not play a great role

At first sight one might think that birth dates may be critically affected by marriage dates. However, in the discussion of Appendix B it is shown that this effect is fairly weak. One reason for that is because only first born children are concerned. Thus, in the 19th or early 20th century when having four or five children was common, only a small fraction of the births were affected.

3.4. Length of time between sexual intercourse and birth

It is currently said that, as indicated in Fig. 2a, pregnancy lasts 9 months which corresponds to $9 \times 365/12 = 274$ average days. However this statement raises two questions.

(1) For this 9-month estimate what starting point is considered?

(2) What is the dispersion of pregnancy around its average? This question is of importance because it affects the width of the birth trough.

These questions are discussed in Appendix C; it appears that the average time interval between sexual intercourse and birth can be taken equal to:

$$267 \pm \sigma \text{ days, where } \sigma = 9 \text{ days.}$$

The fact that the standard deviation is of the order of a few days shows that the dispersion of the births (that is to say the width of the dip) will be mostly due to the dispersion of the conceptions. Even for a sharply defined event such as an earthquake, the behavior of collateral sufferers may be modified for several weeks. Actually, it is through the width of the dip that we can know how the survivors reacted to the shock in terms of intercourse frequency.

4. Case-study 1: The Great Famine in Finland (1868)

4.1. How did it happen?

In Finland the Spring of 1867 was unusually cold; in May 1867 the average temperature was only 1.8 °C, which is some 8 degrees below the long-term average. This made it very difficult to grow spring cereals or potatoes. Then, in autumn the winter started early and was also colder than average. At the end of 1867 and early 1868 relief grains were imported thanks to a loan of the Rothschild Bank in Frankfurt, however, as often in such cases, the inadequacy of the transportation network hampered delivery.⁴ In 1867 the death rate was 38 per thousand, already 35% above average; then in 1868 it climbed to 78 per thousand. Just as an element of comparison, it can be mentioned that this rate was 2.8 times higher than the rate of 28 per thousand reached during the famine of 1961 in China. In the breakdown of the deaths according to their causes only 2350 famine deaths were recorded whereas 27,215 deaths were attributed to tuberculosis, dysentery, smallpox and whooping cough. An additional 59,717 were attributed to “various fevers” [17, p. 416–417]. These numbers illustrate the zones of Fig. 2b; food scarcity was the triggering factor but it killed very few people directly.

With respect to a population of 1.7 million, the excess-deaths of 80,000 correspond to a rate of 47 per thousand.

4.2. Test of the Bertillon birth effect

Of the mortality cases that we are going to examine, this one is the most massive. Thus, one expects the Bertillon birth effect to be clearly visible and indeed it is. For the respective peaks the birth–death ratio is approximately $40\%/500\% = 0.08$. In other words, if one considers the mortality increase as the signal and the change in births as the response of the system we have here an output signal which is about 1/10 of the input signal.

Incidentally, it can be noted that these data were available in Bertillon’s time but he did not use them.

5. Case-study 2: The influenza pandemic of 1889–1890

5.1. Circumstances

The pandemic of December 1889–January 1890 is described in [10]. In Paris the first cases occurred in the week of 17 November 1889. On the basis of death certificates in Paris influenza was given as the direct cause of death for only 250 persons. However, during the time of the epidemic there were about 5000 more deaths than in the corresponding period of the previous years. Thus, zone 2 of Fig. 2b was 20 larger than zone 1. With the population of Paris numbering about 3 million, one gets a fatality rate of 1.6 per thousand.

Whether the epidemic can be called a pandemic is a matter of definition. It is true that there was a death spike in many places (Saint Petersburg, Berlin, Vienna, Paris, London, New York) but with the exception of Paris and London, in all other places it was not more severe than the common annual winter death spike.

Of the 38 pages of Bertillon’s report, only two are devoted to the effect on birth numbers 9 months later. From the weekly data that he gives for Berlin and Paris (as well as some other European capitals) one can draw the following observations.

- In Berlin the peak of the epidemic occurred in the last week of December 1889 whereas the lowest point of the trough of birth numbers (with respect to the same weeks of the previous 4 years) occurred in the 38th week of 1890.

⁴ In Sweden where there was a similar yet less serious situation [18]. According to contemporary newspaper sources, it seems that a large part of the relief ended in the pockets of officials instead of reaching those really in need (see the Wikipedia article entitled “Famine of 1866–68”).

Finland: famine, 1868

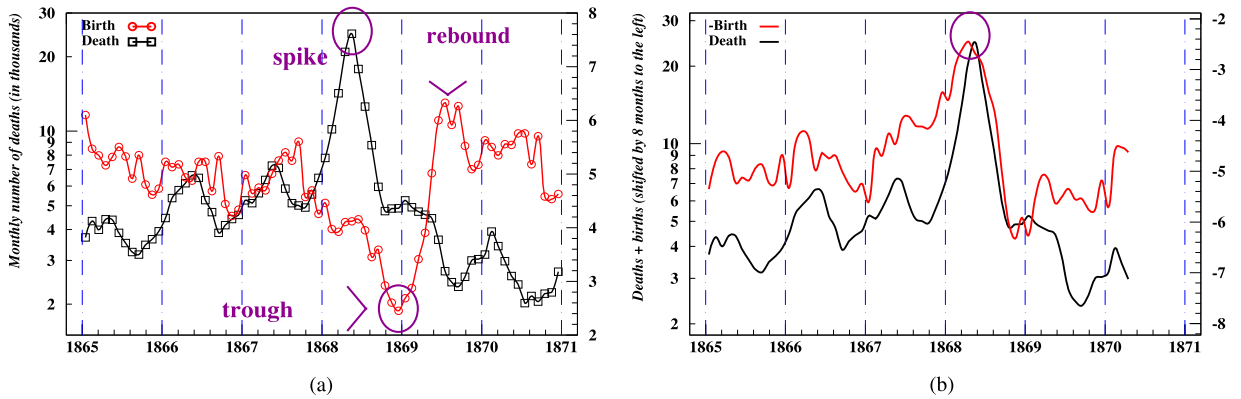


Fig. 3. Deaths and births in Finland during the famine of 1867–1868. Fig. 3a shows the two curves in normal graphical representation; the death scale is on the left and the birth scale on the right (both are expressed in thousands). In Fig. 3b the birth curve was shifted 8 months to the left and turned upside down (by turning to negative numbers). As a result this new series represents the conceptions (at this point we do not know why the time lag is rather 8 months instead of 9 months). The Bertillon birth effect is clearly visible in the fact that the maximum of the deaths coincides with a minimum of the conceptions. In Fig. 3b the correlation of the two series is 0.76. A correction was performed on the monthly data so as to give all months the same length of $365/12 = 30.42$ days. All monthly data used in the rest of the paper were corrected in this way before being used. Source: Finland [17].

France: influenza, 1889

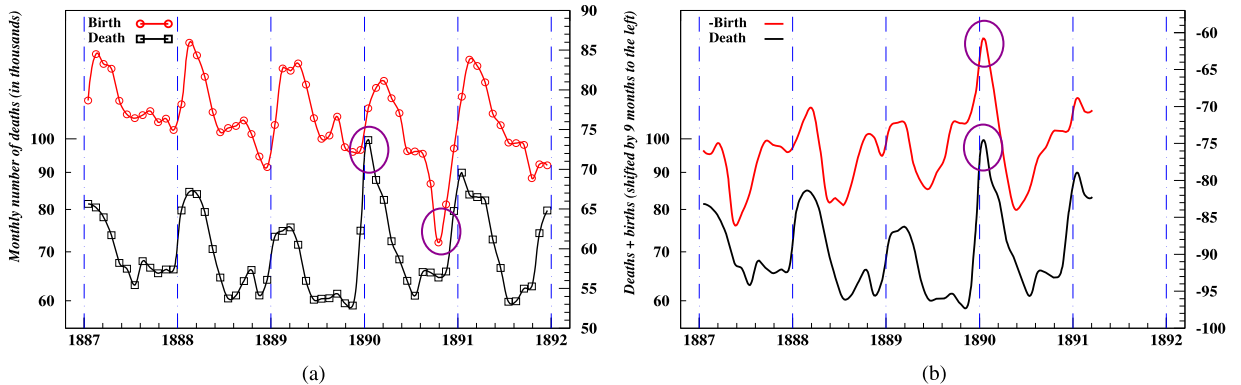


Fig. 4. Deaths and births in France during the influenza epidemic of 1889–1890. In Fig. 4a the death scale is on the left and the birth scale on the right (both are expressed in thousands). In Fig. 4b the birth curve was shifted 9 months to the left and turned upside down. The Bertillon birth effect is again clearly visible, this time with the expected time lag of 9 months. In Fig. 4b the correlation of the two series is 0.63. Source: Statistique de la France, Nouvelle série. Statistique annuelle, various years.

- In Paris the peak of the epidemic occurred in the first week of January 1890 whereas the lowest point in the trough of birth numbers occurred in the 41st week of 1890.

In both cases the time lag is close to the 39 weeks of a normal pregnancy.

Although Bertillon examines the timing with great accuracy he does not discuss the question of the amplitude of the troughs. In particular, he does not show that the troughs cannot be explained solely by the deaths due to the epidemic. That is of course a key point which is why in the previous section we discussed it with great care.

5.2. Test of the Bertillon birth effect

Although the death toll was much smaller than in the case of Finland, the Bertillon birth effect appears fairly clearly. What makes the observation more convincing is of course the fact that the trough can be identified not just in a single city (where it might occur almost by chance) but simultaneously in several cities having non-identical seasonal birth fluctuations. In addition to Paris and Berlin (see Fig. 5), Bertillon gives also evidence for Barcelona, Rome and Vienna. In Barcelona and Vienna the lowest point of the birth trough occurred in September 1890 whereas in Rome it occurred in the 3rd week of October 1890.

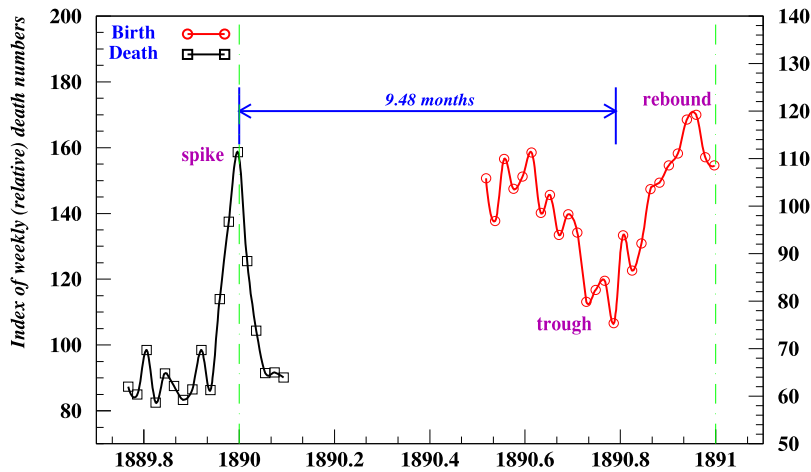


Fig. 5. Deaths and births in Berlin during the influenza epidemic of 1889–1890, weekly data. The death scale is on the left and the birth scale on the right; the indexes are ratios of the weeks of 1889–1890 to the average of the same weeks in the 4 previous years. These weekly data provide a more accurate estimate of the death–birth time lag than the monthly data used in other graphs.

Source: Bertillon [10], Statistique Générale de la France [19, p. 513].

Twenty eight years after the pandemic of 1889–1890 there was the great influenza pandemic of 1918. The death–birth coupling can be observed in all countries where this disease had a substantial impact.⁵ However, we will not examine these cases here because they will be studied closely in the second one of this series of two papers.

6. Case-study 3: The Kanto earthquake of 1923 in Japan

The particular interest of this case comes from the fact that it was neither due to famine nor to a disease. Although called the “Great Kanto Earthquake” in Japan, it concerned in fact mainly two of the 7 prefectures which constitute the Kanto Region, namely Tokyo and Kanagawa (i.e. Yokohama just south of Tokyo). Some 84% of the fatalities were concentrated in these two prefectures.

6.1. Circumstances

The number of fatalities can be estimated by subtracting the average death numbers of 1922 and 1924 from the death number of 1923,⁶ i.e. (in thousands): $1332 - 1270 = 62$ [11, p. 441]. For the whole of Japan the death rate was 1.1 per thousand, in Tokyo it was 8.0 per thousand and in Yokohama it was 13 per thousand. The earthquake was accompanied by a tsunami with a wave up to 13 meter high and, especially in Tokyo, by fire tornadoes.

6.2. Evidence

The birth trough is of smaller amplitude than in previous cases and in fact there are two circumstances which play a crucial role in its identification.

(1) Although the seasonal births have wide fluctuations (in fact much larger than in other countries) their annual repetitions are very regular.

(2) As one knows exactly where the trough is expected even a small signal can be identified.

A purely statistical analysis that would fail to take into account these circumstances would result in overestimating the size of the confidence interval. Incidentally, if monthly data were available at prefecture level one could get a better accuracy.

⁵ It can be observed that in the southern hemisphere (Australia, Chile) it had a different timing than in the northern hemisphere: instead of October 1918 it peaked in April 1919. The reason of this lag remains an open question.

⁶ According to the Wikipedia article entitled “1923 Great Kanto Earthquake” there were between 105,000 and 143,000 deaths; this estimate appears to be highly exaggerated.

Japan: Kanto earthquake, 1923

r=0.58

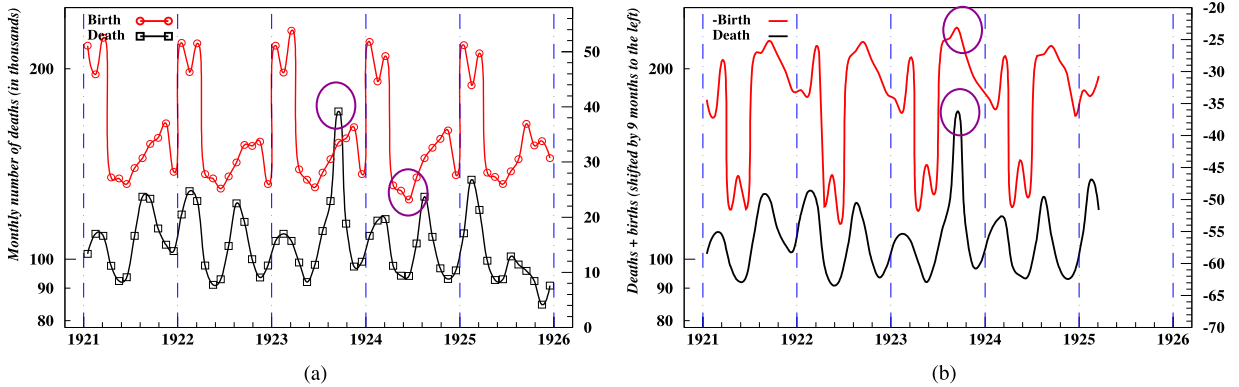


Fig. 6. Deaths and births in Japan as a result of the Kanto earthquake. In Fig. 6a the death scale is on the left and the birth scale on the right. In Fig. 6b the birth curve was shifted 9 months to the left and turned upside down. It is the fact that the seasonal birth fluctuations repeat themselves with great regularity that makes the Bertillon effect detectable. As the earthquake concerned only the Kanto region one would expect a greater birth effect in the Tokyo and Kanagawa prefectures.

Source: Deaths: Bunle [11], p. 441; birth rates: Ministry of Health, Labor and Welfare on the “Portal site of Official Statistics of Japan”.

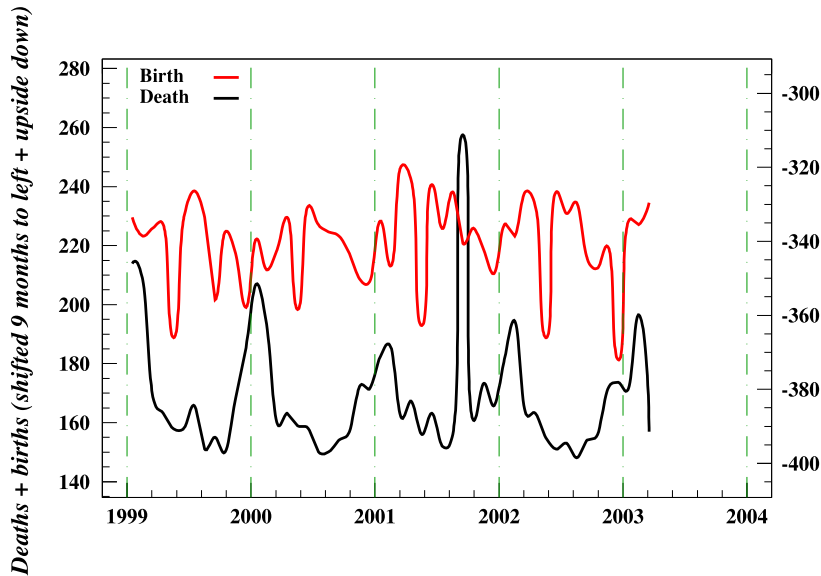


Fig. 7. Monthly death and birth numbers in New York City, 1999–2003. After the birth series has been shifted 9 months to the left and reversed one would expect to see a peak in September 2001 but there is none.

Source: Summary of vital statistics. The city of New York. Separate volumes for the years from 1999 to 2003 (available on Internet).

7. Case-study 4. The shock of 9/11 in New York City (2001)

7.1. Circumstances

Two airliners belonging respectively to United Airlines and American Airlines were crashed into the North and South towers of the World Trade Center complex in New York City.⁷

Within about two hours both buildings collapsed. There were some 3000 fatalities including some 400 firefighters and police officers. With respect to the 8 million population of New York city this corresponds to a rate of 0.37 per thousand.

⁷ There have been many odd stories and speculations about this attack. However, there is one well documented, indisputable and nevertheless not often mentioned aspect which is the huge amount of put options bought in the days preceding the attack. For stock owners, put options provide a protection against the fall of a stock price because it gives them the right to sell their stock at a predetermined price which may be much higher than the current price. Moreover, because the price of a put option increases when the price of the stock declines, speculators can make a profit by selling their put options. More details can be found on the following webpage: <http://911research.wtc7.netsept11/stockputs.html>.

7.2. Evidence

Fig. 7 is remarkable because it shows that 9/11 did not produce any birth trough whatsoever. It shows that the death–birth coupling is by no means commonplace.

Here the zones 1 and 2 of Fig. 2b can be merged into one which corresponds to the total death toll. Zone 3 would correspond to persons (some 6000) injured but not killed. Zone 4 can be seen as comprising the families and close relatives of the persons killed or injured. Based on the average size of US households which is of the order of 2.6, one gets for zone 4 a total number of: $2.6 \times 9000 = 23,400$. Of this number only the fraction in the age interval 20–35 would contribute to the birth trough. Based on the US population pyramid this fraction is of the order of 15%.

For the pandemics considered so far, it is almost impossible to estimate the size of zone 4. However, for an earthquake one can posit that zone 4 corresponds to the persons whose houses have been destroyed or damaged.

8. Case-study 5. SARS outbreak in Hong Kong (spring 2003)

The outbreak of SARS (Severe Acute Respiratory Syndrome) in Hong Kong is interesting for two reasons.

(1) The number of deaths was small, namely only 300. With respect to the 6.7 million population of Hong Kong this represents a rate of only 0.045 per thousand. Actually the death spike of January–April 2003 was lower than the annual winter death spikes of 2004 and 2005.

(2) In 2002, 2004 and 2005 the conception curves (that is to say the shifted but not reversed birth curve) has a peak in January and a trough in mid-August. Yet, in 2003 there is a deep trough in late March that is to say in coincidence with the height of the outbreak as defined by the histogram of new cases which shows a sharp peak in the fortnight 22 March–5 April.

8.1. Circumstances surrounding the death spike

It is not only the number of deaths which was small but also the number of cases, namely 1730 (i.e. 260 per million population). Worldwide it was the same picture; there were only some 700 deaths compared with the 500,000 who died from influenza in the same year. Nonetheless, the city took drastic measures.

- Primary and secondary schools were shut for a month beginning in late March.
- Various public places were closed.
- Financial companies asked their employees not to come to their office and work from home.
- A whole residential complex called Amoy Gardens was put under an emergency quarantine. The residents were sent to a vacancy center and the building was closed. Altogether in this complex 329 people were infected and 42 died.
- Unlike the influenza pandemic of 1918, SARS was particularly severe for elderly people. None of the infected females under 30 died whereas among males older than 70 the death rate was 75%. Thus, although healthcare workers accounted for 23% of all infected persons [20, p. 14] only few died.

8.2. Statistical evidence

Despite the small death toll, the death effect of the SARS epidemic can be identified fairly clearly because it occurs two months later than the standard winter death outbreaks (Fig. 8). The conception effect can also be identified clearly the trough occurs of shifted births occurs in March rather than in August.

9. Case-study 6. Earthquake of March 2011 in Japan

9.1. Circumstances

The epicenter of the earthquake was under sea near the city of Sendai which is 300 km north-east of Tokyo. The death toll (including the missing) was about 18,400 and a further 6000 were injured. Moreover some 400,000 buildings collapsed or half-collapsed.⁸ In other words we can take $H = 400,000$ as an estimate of the number of people who were *directly* affected. We will see below that under appropriate assumptions one can use this estimate to derive the expected birth number reduction.

9.2. Statistical evidence

The conception trough of March 2011 due to the earthquake appears fairly clearly because it is distinct from the seasonal troughs seen in other years (see Fig. 9).

⁸ The source is a report of the Japanese police published on 10 March 2015 and described in the Wikipedia article entitled “2011 Tohoku earthquake and tsunami” (the Tohoku region is the northern part of the main island of Japan).

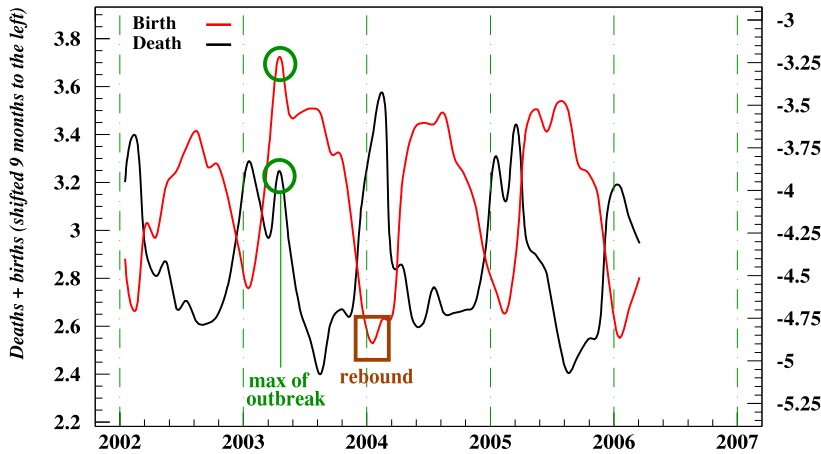


Fig. 8. Death spike and birth trough in Hong Kong as a result of the SARS epidemic of March–May 2003. Despite the small magnitude of the death spike, the trough of the births is clearly identifiable. However, unlike most other previous cases, the correlation between the two curves is negative (equal -0.53) instead of being positive. We have here an interesting case where the seasonal winter death spikes, despite being higher than the SARS spring spike, do not give rise to any birth trough.
 Source: United Nations Statistics Division, Demographic Statistics: Deaths by month of death + Births by month of birth (available on Internet).

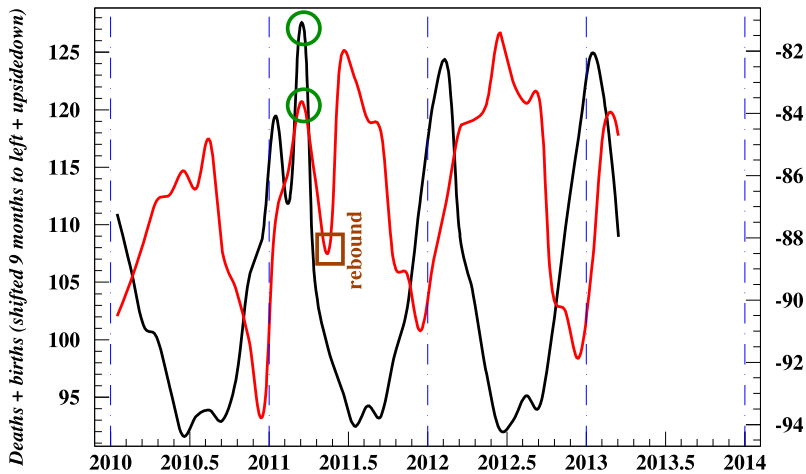


Fig. 9. Death spike and birth trough in Japan as a result of the earthquake of 11 March 2011. Although the conception trough of March 2011 is not the lowest it is clearly distinct from the seasonal troughs which occur in May–July; the same observation applies to the rebound.
 Source: United Nations Statistics Division, Demographic Statistics: Deaths by month of death + Births by month of birth (available on Internet).

In 2011 the Japanese crude birth rate was $\lambda = 8.3$ per 1000 population. Let us assume that for the 400,000 persons directly affected their conception rate in March 2011 was reduced to zero. Thus, nine months later the birth rate of this group of persons would also be zero. With respect to a normal year this would result in a reduction of $400,000 \times 0.8/1000 = 3200$ births. Is this number compatible with what is observed?

In December 2011 there were $b_0 = 83,600$ births, in December 2010 and December 2012 there were $b_{-1} = 88,100$, $b_1 = 84,400$ respectively. Thus the reduction is: $b_0 - (b_{-1} + b_1)/2 = 2650$ which is of an order of magnitude compatible with the expected estimate of 3200.

In all epidemics and disasters, apart from the fatalities, there is a group of persons which is *directly* affected. For an influenza epidemic this would include the persons who fell seriously ill but did not die. For an attack like 9/11 it would be the family members of those who died or were injured.

Naturally, the previous dichotomous picture is a simplification. Actually, there is a gradual transition from those highly affected to those lightly affected. Under such an assumption the reduction ΔB in the number of conceptions would be written:

$$\Delta B = \int_0^\lambda (\lambda - x) h(x) dx \tag{1}$$

Table 1

Excess death rates in previous case-studies.

Area Year	Finland 1868	Tokyo 1923	Massachusetts 1918	Paris 1889	New York 2001	Hong Kong 2003
Death rate (per 1000 population)	47	8.0	6.4	1.6	0.37	0.045
Death–birth coupling	yes	yes	yes	yes	no	yes

Notes: The excess death rates d_e are defined in the following way: $d_e = \text{Excess deaths with respect to normal years divided by the population}$. For instance, in the case of Finland there were 80,000 excess deaths for a population of 1.7 million which gives $d_e = 80/1.7 = 47.0$. The cases are ranked by decreasing death rate. While episodes involving diseases extend to the whole country, episodes involving localized incidents (e.g. terrorist attacks or earthquakes) extend to areas whose definition is somewhat arbitrary. For instance, whereas the attack of 9/11 concerned a very small area we computed the death rate with respect to New York City but other possible areas would have been Manhattan or New York State.

Here λ is the “normal” conception rate, x is the zone-dependent conception rate and $h(x)dx$ is the number of persons having a conception rate comprised between x and $x + dx$. The dichotomous argument which gives $\Delta B = \lambda H$ would correspond to: $h(x) = 2H\delta(x)$ where $\delta(x)$ denotes the Dirac delta distribution and H the total number of people affected.

The function $h(x)$ describes the severity of the shock among the surviving population. If $h(x)$ is concentrated in a narrow interval $(\lambda - \epsilon, \lambda)$ it means that the surviving population is not much affected. On the contrary, a function $h(x)$ concentrated in a narrow interval $(0, \epsilon)$ means a severe incidence among those affected (their reproduction rate falls from λ to almost zero).

In the next section we discuss shortly how information about the function $h(x)$ can be derived from observation.

10. Comparison

10.1. Overview of excess-death rates

Table 1 summarizes the death rates of the various case studies considered above.

10.2. How to get information about $h(x)$ from observation

The function $h(x)$ describes the incidence of the death spike in terms of suppressed conceptions and suppressed births. How can one derive information about it from observation? One can offer the following suggestions.

- First, is suppressed conceptions identical to suppressed births? Not necessarily. There can be a biological regulation which leads to early elimination of embryos which are not in good shape because they were generated in conditions of illness, scarcity or famine. This is a medical question for which one should be able to find reliable information in the medical literature.

- The fraction of the population directly affected by the mortality spike comprises the following subgroups.

- (i) persons killed (K)

- (ii) persons injured or who were seriously ill (H_2)

- (iii) persons whose living conditions were affected in a major way, for instance because they lost a family member (H_{3a}) or because their home was destroyed (H_{3b}).

So far, we have focused on death spikes. However, according to the view outlined above there could also be cases displaying birth troughs without any (or at least very few) fatalities but instead a substantial number of persons who become ill, injured or were otherwise severely affected.

As possible example we investigated West Nile fever in the United States. This disease which is due to a virus carried by mosquitoes peaks in August–September which would give a birth trough in May. However, we could not identify any significant birth trough even in the states most affected, e.g. Texas in 2012. The number of incapacitated persons may be too low.

10.3. Why is there no birth trough in the case of 9/11?

There is no birth trough following 9/11 but there is one in the Hong Kong SARS epidemic whose death rate is about 10 times smaller. This seems fairly puzzling but the two events were of very different kinds. Whereas 9/11 was a one-day event, the SARS epidemic lasted a few months and, especially during early times, the spread of the disease as well as its severity (in terms of number of deaths per cases) were a matter of uncertainty and concern. Thus, even persons who did not become ill were affected.

11. Conclusion and predictions

We have shown that sudden death spikes are almost always followed 9 months later by a birth trough. We have also seen that the spike of 9/11 did not lead to the expected birth reduction. This observation is particularly intriguing when compared with the SARS outbreak in Hong Kong in which there were less deaths than in 9/11 and which was nonetheless followed by a birth dip. Although a tentative explanation was proposed it is clear that in order to get a better understanding it would be useful to examine other cases in which a death spike is *not* followed by a birth dip.

For that purpose the normal procedure is to propose predictions in the hope that for some of them the expected dip will not materialize. This strategy is very much in line with what was done in the development of physics. Every time an expectation happened to be contradicted by observation, this was an opportunity for new progress. A well-known case was the non-observation of the aether by Michelson and Morley which led to the theory of relativity.

There are two possible kinds of predictions.

- The first kind consists in what we may call standard predictions; they are instances very similar to those already analyzed but less well known because of smaller amplitude. The predictions of birth troughs in the Netherlands in 1920–1922 and in Chile in 1923 are of this kind. Both graphs are shown in Appendix E which is included in the arXiv version of this paper. Although in the case of Chile we do not yet know the reason of the death spike of July–August 1923, the birth trough could indeed be observed in the month in which it was expected.

- In the second kind of predictions one deliberately considers a cause of death that has not yet been tested. One case of that kind are deaths due to heat waves. For instance in France in August 2003 a heat wave caused 13,700 excess deaths. This was a fairly exceptional case. Most other heat waves caused only of the order of one or a few thousands excess deaths. In contrast with diseases, for heat waves there is no contagion effect; in contrast with earthquakes there are no collateral destructions. However, in contrast with 9/11, all persons (at least those who do not have air conditioning) are directly affected to some degree.

Are there birth dips in the wake of heat waves? Because of the fairly low amplitude of most death spikes the identification of the troughs turns out to be more difficult but they are nevertheless present [21,22].

Acknowledgments

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Appendix A. Population fluctuations vs. birth fluctuations

In this appendix we examine the implication of a constant birth rate on population and birth changes.

The monthly birth rate is defined as: $\lambda = b(t)/P(t)$ where $b(t)$ is the number of births in month t . Now let us apply changes Δb and ΔP to the numerator and denominator respectively. How these changes must be connected if λ is to remain constant is shown by the following calculation.

$$\lambda = \frac{b(t) + \Delta b}{P(t) + \Delta P} = \frac{b(t)}{P(t)} \frac{1 + \Delta b/b(t)}{1 + \Delta P/P(t)}$$

$$\lambda \sim \frac{b(t)}{P(t)} \left[1 + \frac{\Delta b}{b(t)} - \frac{\Delta P}{P(t)} \right], \quad \lambda \text{ constant} \implies \Delta b = \left[\frac{b(t)}{P(t)} \right] \Delta P$$

In the case of a death spike the population change will be given by the excess-death number $\Delta P = -[d(t) - b(t)] = -e$ (for the sake of simplicity we ignore the 9-month time-lag between conception and birth). This leads to the proposition given in the text.

As a case in point in order to illustrate the previous argument with real data we consider again Sweden during the influenza epidemic of 1918.

A.1. Example of Sweden in October 1918

It is by purpose that we selected a country which did not take part in the First World War so as to avoid any interference. The data are taken from [11, p. 313, 438] and [12, p. 73]. In early 1918 the Swedish population numbered 5.8 millions; on average its annual birth and death rates were 2.0% and 1.3% respectively.

Whereas in “normal” years (e.g. in the adjacent years 1917, 1919) there were 5862 October deaths, in October 1918 there were 17,278 deaths which represents an excess-death number of 11,416. With a constant monthly birth rate of $2/12 = 0.16\%$ these excess deaths would result in a birth deficit of $11,416 \times 0.16/100 = 18$. Let us compare this number with the births actually observed in July 1919.

Whereas in “normal” years there were on average 10,618 July births, in July 1919 there were only 7703 which represents a birth deficit of 2465. This is 136 times more than the 18 expected under the assumption of a constant birth rate.

In other words, the birth number reduction cannot simply be a “mechanical” consequence of the death spike. It can only be explained by a drastic reduction in the birth rate.

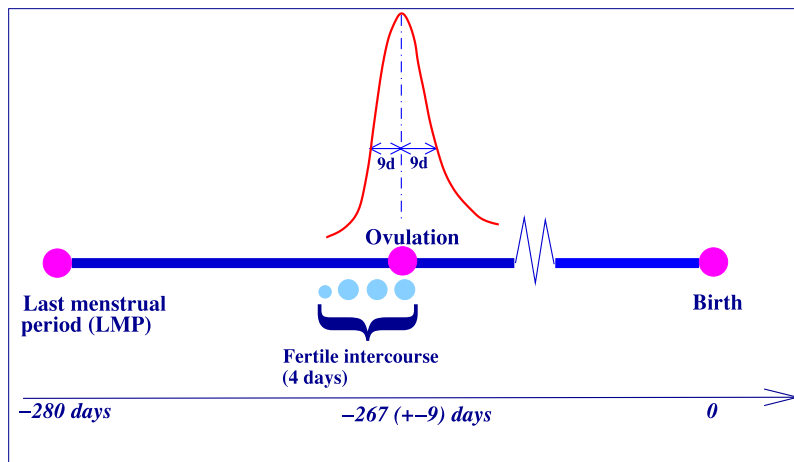


Fig. C.1. Average time interval between intercourse conducive to conception and birth. The familiar estimate of 9 (mean) months corresponds to an interval of 274 days, that is to say one week longer than the (more accurate) estimate given in the figure. The standard 280 day figure refers to the time interval between the last menstrual period and birth; it overestimates the time between sexual intercourse and birth by two weeks. The 9 day dispersion of ovulation refers to its standard deviation.

Source: Wilcox et al. [23,24], Bhat and Kushtagi [25].

Appendix B. Incidence of marriage postponement

An explanation based on the number of marriages may be considered but in fact it can be quickly discarded. One may say that during the time of the epidemic people postponed planned marriages. As in Sweden in any normal month there were about 4000 marriages a drastic reduction could in principle account nine months later for a fall in births of the same magnitude, that is to say of the size actually observed. However, it appears that in most countries there was only a slight reduction in the number of marriages or even none at all. Thus, in Sweden in October 1918, at the height of the influenza epidemic, there were 4323 marriages compared to an average of 4255 in the same month of October 1915, 1916, 1917.

Even when there is a fall in marriages it has not necessarily an impact on the number of births 9 months later. An illustration is provided by New York City in September 2001. As a result of the World Trade Center attack the number of marriages fell from 6753 in August 2001 to 2616 in September. However the correlation between the time series of monthly percentage variations of marriages and conceptions over the 60 months from 1999 to 2003 is as low as 0.025 (which, for a confidence level of 0.95, is not a significant correlation). The corresponding linear regression reads: $\Delta b/b = 0.003(\Delta m/m) + 0.11$ which shows that the observed fall of 61% of marriages will translate in a fall of less than 1% for the births.

In short, in some cases where there is both a substantial reduction in the number of marriages (which is rare) and a significant marriage–birth correlation, this factor may contribute but it cannot be the root factor that we are looking for.

Appendix C. Length of time between conception and birth

The standard length of pregnancy, namely 40 weeks (280 days) is counted from the woman's last period, not the date of conception which generally occurs two weeks later. For the present study we rather need the time D between the sexual intercourse which led to the conception and birth. The conception results from the encounter between a spermatozoon and an ovum (also called ovule or egg cell). Ovulation means that the egg is released from the ovary into the Fallopian tube; it remains there in good shape for only one day which means that conception and ovulation must take place almost on the same day. In contrast the spermatozoa can stay alive in the Fallopian tube for 3 days with similar conception probabilities during those 3 days.⁹ Once fertilized, the egg starts its journey down the Fallopian tube and into the uterus where it will get implanted (see Fig. C.1).

The key-question then is: when does ovulation occur? It is often said that it occurs at day 14 in the menstrual cycle. In fact, this depends upon the length of the menstrual cycle [24]. When the length of the cycle is 28 days, ovulation occurs on average at day 12. When the cycle lasts more than 30 days, the ovulation takes place on day 14. The global average for all cycles is 14 days. Coupled with the standard estimate of 280 days starting from the beginning of the cycle one gets: $280 - 14 = 266$ days following ovulation. With respect to intercourse one gets time intervals of $D = 266, 267, 268$ days with same probability for

⁹ Actually they can remain alive for about 6 days but the probability of conception during these three extra days is only one third of the conception probability during the first 3 days [23].

each duration, which gives an average of $D = 267$. The distribution of the fertility window is approximately Gaussian¹⁰ with a standard deviation of 9 days. In summary:

$$D = 267 \pm \sigma, \quad \sigma = 9 \text{ days.}$$

This estimate is confirmed by the following result based on a sample of 125 pregnancies in which “the median time from ovulation to birth was 268 days” [26].

Remark. In the previous results ovulation time was determined by urinary hormone measurements or estimated through ultrasound observation performed later on in the pregnancy. Needless to say each of these methods involve some uncertainty. It might seem that medically assisted conception would afford a direct and henceforth more accurate method. The difficulty here is that such pregnancies are known to lead to an inflated proportion of preterm deliveries.

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¹⁰ Actually with 80% of the cases within $\pm\sigma$ (instead of 60% for a Gaussian) the distribution is somewhat more narrow than a Gaussian [25].