FROM JOHN GRAUNT TO ADOLPHE QUETELET: ON THE ORIGINS OF DEMOGRAPHY

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Abstract

John Graunt (1620-1674) and Adolphe Quetelet (1796-1874) were two important personalities, who contributed to the origins of demography. As they both developed statistical techniques for the analysis of demographic data, they are important also from the point of view of history of statistics. The contributions of both Graunt and Quetelet especially to the development of mortality tables and models are recalled in this paper. Already from the 17th century, the available mortality tables were exploited for computing life annuities. Also the contribution of selected personalities inspired by Graunt are recalled here; the work of Christian Huygens, Jacob Bernoulli, or Abraham de Moivre is discussed to document that the historical development of statistics and probability theory was connected with the development of demography.

Key words: history of demography, history of statistics, probability theory, moral statistics, mortality tables

JEL Code: J19, Z13, N33

Introduction

This paper is aimed to recall two personalities considered as the founders of demography, who have both have a significant anniversary in 2024. These are John Graunt (1620-1674) with the anniversary of 350 years from his death and Adolphe Quetelet (1796-1874) with the anniversary of 150 years from his death. A literature research of their contribution to demograhy reveals that they both were interested in serving the society and the whole humankind. Apart from developing new demographic methodology, they both contributed to the origins of statistics. However, while Quetelet is widely acknowledged as a person with a strong influence on the development of modern statistics (Tafreshi, 2022), Graunt remains to be much neglected from this perspective, although he greatly influenced the origin of census techniques and independently on this also the very origins of probability calculus (Qian, 2020).

Section 1 recalls the empiricism as the philosophy influencing the origins of modern experimental science. Section 2 is devoted to John Graunt. The origins of probability theory with a focus on the influence of John Graunt are discussed in Section 3. Abraham de Moivre, who became influential with his analysis of mortality data as well, is recalled in Section 4. The contribution of Adolphe Quetelet to demography and statistics is discussed in Section 5.

1 The philosophy of empiricism

The scientific spirit in England of the 16th century demanded to create and develop a new experimental science based on measured data. It was the philosophy of empiricism that served as the theoretical foundation for the origin of demography and at the same time statistics. Francis Bacon (1561-1626) was an eminent philosopher, politician, and scientist, the founder of empiricism, who heavily contributed to the methodology of modern science. He promoted a new scientific method based on repeatedly performed experiments with measurable results and formulated methodical principles of performing scientific experiments.

Francis Bacon considered experiments, denoted literally as *experiments of light*, as an irreplaceable source of new discoveries with a potential to be transferred to new situation by induction (inductive reasoning). Bacon demanded to investigate new areas and to serve a useful purpose, benefit and liberation of the humankind. The knowledge is for Bacon the most important prerequisity of the good, allowing the humanity to find its place in the cosmic order. This vision of experimental science was critically oriented against rationalism or against science, which both were based purely on deduction at that time. Empiricism overcame the ideas of Aristotle, who acknowledged only pure theory and only discoveries obtained by abstract thinking (Young, 2017). A leading philosopher and exponent of empiricism after Bacon was Thomas Hobbes (1588-1679), who also had a heavy influence on John Graunt, especially with his political and social opinions (Connor, 2022).

2 John Graunt

John Graunt (1620-1674) was a self-educated English haberdasher and tradesman, who became an influential man in London through his work devoted to mortality tables. His family background was studied in details in Connor (2022). He was well acquainted with books by Francis Bacon so that he was, just like his whole generation, under a strong influence of Baconian empiricism.

Graunt's statistical approach to mortality data is important in the history of statistics (Connor, 2022). He started to perform his computations only with a small dataset coming from a single parish in London and only later was able to obtain more represtantive data for the whole London. Particularly, he analyzed data from the available Bills of Mortality, which were basically lists of dead people from the whole London (Harkness, 2020). The available data had the form of percentages of survivors and were accompanied also by the causes of deaths. Graunt focused on distinguishing between deaths from chronic diseases and acute diseases in his analysis. On a statistical level, he studied the causes of death for individual diseases and made specific analysis for the mortality in infancy and childhood (Qian et al., 2020). He developed a statistical apparatus for the construction of first mortality tables, however without using any probability thinking (Qian et al., 2020). In 1661, Graunt had a public presentation of his results in London, which was the historically first demographic presentation in the world. There, he explained the results and also the principles of his analysis of mortality data. In 1662, he Graunt published his analysis of mortality tables in his influential book *Natural and Political Observations Made Upon the Bills of Mortality*.

After the publication of the book in 1662, Graunt continued with other important demographic work focused on various population statistics for London. For this purpose, Graunt formulated the first modern census techniques and is considered to be their founder. The number of inhabitants of London, which was unknown at that time, was estimated by Graunt to be 384 000 in 1661. He replaced guesswork with estimates of population sizes and obtained the first accurate estimate of the ratio of the number of men and the number of women (Connor, 2022). Graunt quantified migration trends from villages to cities, quantified infant mortality, and founded the field of statistics of births, marriages, and deaths (Harkness, 2020). He also compared data about London with data obtained in some English villages.

Graunt's methods for studying the progress of an epidemic made him to be also the first epidemiologist in the world. He applied his methods during the Great Plague of London, which occurred to represent a devastating epidemic in 1665, in which up to one fifth of the London population died. During the plague epidemic, the available weekly tables of deaths aroused his curiosity and he computed the excess deaths. He also distinguished between dying of a certain disease and dying with the disease; in our opinion, such approach would be very useful (but remained neglected) during the COVID-19 pandemic. Graunt's fight against diseases by means of numbers, which appears in the title of the paper by Harkness (2020), represents the aim of current medical informatics (Kalina, 2022).

Graunt was a friend of William Petty (1623-1687), who was an influential economist with an interest in census techniques. Petty was the main protagonist of political arithmetic, which represented a science devoted to the economic and demographic statistics (Taylor, 2023). Petty also attempted to prepare and collect relevant demographic and economic data across the Kingdom of England. Graunt became the only tradesman in the Royal Society. Graunt closely collaborated with Petty and as a consequence, the authorship of Graunt's work was questioned for a long time. Graunt is now undoubtedly acknowledged as the author of his works also because Graunt's statistical approach apparently required much patience and care. These were not characteristic for Petty, who used computing averages as the only statistical approach in his writings (Qian et al., 2020).

Graunt performed his demographic research with the aims to use science for the service to the humankind in a Baconian spirit (and in the spirit of the Royal Society), and to support the research of his friend Petty. Graunt did not use the demographic models to make more profit in his own business so that he bankrupted and soon after that died in poverty already at the age of 53. The moral flavour of his statistical work was discussed in Harkness (2020). It is known that Graunt devoted much time to his religious practices and it was his zealotism that has driven his effort to use statistics to fight against social pathologies (Connor, 2022). Graunt was declared a predecessor of *moral statistics* in England. He believed that his work on mortality of infants actively contributed to decreasing this mortality. An original result of Graunt was his pointing out that syphilis (French pox) is spread mainly by prostitution; he namely discovered from the statistical data that syphilis as a death cause is the major problem particularly in parishes with prostitution (Harkness, 2020).

3 Origins of probability theory

The aim of this section is to discuss the origins of probability theory as being influenced by the work of John Graunt. Probability theory (or probability calculus) started by the correspondence between Pierre de Fermat (1607-1665) and Blaise Pascal (1623-1662); it was in 1654 when they laid the mathematical foundations of the discipline. While Fermat lived in Toulouse and Pascal in Paris, they had to rely on correspondence, which formed the genesis of actuarial thinking in mortality rates and continues to be intrepreted as a living teaching resource until the current era (Goswami et al., 2019). John Graunt studied their correspondence as a witness of the dawn of probability theory (Connor, 2022) and was directly influenced by it. Fermat and Pascal attempted to answer the question raised by the French gambler Chevalier de Méré (1607-

1684) related to the so-called problem of division of stakes (Devlin, 2010). The problem was how to fairly divide the stake when a hazard game is unfinished. Pascal's probability computations can be interpreted as more influential than his construction of a calculator *la Pascaline,* which is perceived as a predecessor of a modern computer.

Christian Huygens (1629-1695), a Dutch polymath, is known to have read Graunt's book already in 1662, when he was interested in studying life expectancy (Connor, 2022). Huygens wrote the historically first work devoted to probability calculus. This treatise *De ratiociniis in ludo aleae* (in English *On the Value of Chances in Games of Fortune*) was published already in 1657 as asupplement of a book *Exercitationum mathematicarum* published by Frans van Schooten, who was a professor of Huygens. Huygens was impressed by Graunt's book, which he apparently appreciated, and linked Graunt's ideas to the new probability theory.

Probabilistic thinking was used for solving statistical tasks also already during Graunt's life. Johan de Witt (1625-1672), a Dutch politician with a profound knowledge of mathematics, namely utilized Graunt's tables in his treatise *The Worth of Life Annuities Compared to Redemption Bonds* published in 1671. He studied life annuities and was the first to combine Graunt's statistical apparatus with probabilistic thinking. He was also the first to use probability calculus in economic tasks related to his political interests, when he served as the prime minister of the United Provinces of the Netherlands.

Jacob Bernoulli (1655-1705), who further developed probability calculus, is considered to be the founder of probability theory as a self-standing scientific discipline especially thank to his masterly book *Ars conjectandi*, which was published after the death of the author by his nephew Nicolaus Bernoulli (1687-1759). The English title (*The Art of Conjecturing*) evokes that Bernoulli perceived probability calculus as the task to compute (or in fact assign) a certain probability to different random phenomena. The book *Ars conjectandi* is inspired by Huygens and is largely devoted to combinators or zero-one trials, i.e. Bernoulli trials with only two possible outcomes. This book was published in 1713 and became very influential with a direct influence e.g. on Abraham de Moivre (Schneider, 2006).

4 Abraham de Moivre

After Graunt's death, mortality tables were constructed by a number of thinkers including the prominent English astronomer Edmund Halley (1656–1742). He published his estimates of mortality in 1693. Although he was bound to analyze data with a low reliability, he was still able to use his influence to promote the idea that mortality data should contain more accurate information. The focus on more reliable data also influenced Abraham de Moivre, who studied mortality tables on a higher level (Goswami et al., 2019).

Abraham de Moivre (1667-1754) was a versatile mathematician living the majority of his life in London. His interest in mathematical foundations of hazard games (probabilistic aspects of gambling) led him to a great contribution to probability theory and combinatorics. Moivre was able to perceive statistical estimation as an inverse probabilistic problem, which is based on estimating probabilities of a given random event based on data observed in reality. In 1718, Moivre published his book *Doctrine of Chances*, which contains an overview of his knowledge (as the title suggests) on probability theory and represents the historically first textbook on probability theory.

Only after publishing his textbook in 1718, Moivre started to use probability theory in the evaluation of demographic data. Moivre was a friend of Halley and he became interested in annuities through this friendship. Halley had data about the demographic structure of the population of the city of Breslau (now Wrocław in Poland). Moivre improved mortality tables previously analyzed by Graunt and used them to evaluate mortality in London. One of Moivre's aims was applying probability calculus in the analysis of mortality data, particularly to the preparation and creation of mortality tables or computation of death rates. Moivre's book *Annuities upon Lives* from 1725 was devoted to computations of insurance premiums for life insurance. Moivre constructed mortality probabilistic models based on particular probabilistic distributions (Bellhouse, 2011). He relied on the assumption that the occurrence of deaths is uniformly distributed over the interval until the high age; such assumption is commonly denoted as de Moivre's law of mortality. He studied age-specific mortality rates and found the mortality rate to be normally distrubuted over the age of an individual person. In this context, he formulated the Stirling's formula for the approximation of factorials. This analysis of demographic data yielded important results for commercial applications of annuities. It namely allowed straightforward annuity evaluations using Moivre's tables and saved much work compared to previous approaches for annuity pricing. The law of mortality formulated by Moivre is until now acknowledged as a suitable survival model applicable for the computation of annuities.

5 Adolphe Quetelet

Adolphe Quetelet (1796-1874) was a Belgian polymath, who contributed to the development of demography and at the same time statistics. Quetelet was active in compilation of mortality tables. He used the term *moral statistics* previously used by French and German statisticians and is now considered to be the main personality in the whole *moral statistics* movement, especially because of focus on data about crime or the number of suicide deaths (Tafreshi, 2022). Quetelet studied mortality in connection with insurance and published mortality data for Brussels for groups of individuals according to their gender and age. He was also interested in infant mortality and distinguished between natural deaths and deaths from accidents.

Quetelet worked as a professor of astronomy and mathematics at the Royal Military Academy in Brussels. He was an expert both in physics and mathematics and was well known of fascinating discoveries in physics of the 19th century. He strived for exploiting probability calculus in the analysis of large-scale data in physics and also in other fields than physics, such as in sociology, demography, criminalistics etc. Thus he found a new field, which was at that time denoted as social physics or social mechanics. Quetelet became the main exponent of the new field and thus became a predecessor of current sociology. He was using physical methods to the science of man (Pavlík, 2009). These physical methods naturally include probability and statistics, which both were heavily associated with the analysis of physical measurements.

Quetelet was also involved in the economic statistics. In this context, the aim was focused on collecting facts, which described the human activities in the country or the state of the society and its development. Such collecting data included also comparing corresponding facts acquired in different countries. As the president of the Belgian Statistical Office and at the same time a gifted organizer, Quetelet actively contributed to the development of the official state statistics. Particularly, he introduced regular censuses every ten years starting from 1846 and developed modern questionnaries for the purpose. At the same time he was the main initiator and organizer of international cooperation of statisticians. The official state statistics was subsequently organized also in other countries following Quetelet's model implemented in Brussels. Quetelet enjoyed evaluating various indicators of social phenomena aggregated over the whole Belgium. He also constructed tables of the counts of mental diseases for various countries (Caponi, 2013).

Quetelet was the first who applied the normal distribution to measurements related to humans, and in a more general sense he was the first who applied the normal distribution to different phenomena than measurement errors. He interpreted the normal distribution, which was at the time denoted as the law of errors of (Gaussian) curve of errors, as a universal principle. He used theological arguments for using the normal distribution for analyzing groups of individuals . Such considerations always assumed a homogeneous population and Quetelet compared an individual with the average. Instead of measurement errors considered by Carl

Friedrich Gauss (1777-1855), the uncertainty in Quetelet's data comes from indvidual variability. Quetelet's anthropometric measurements were performed on random samples from the entire population. The averaged values of the measured dimensions thus expressed the averaged characteristics of the appearance of a typical representative of the population (Tafreshi, 2022).

This led Quetelet to introduce the concept of an average human. According to his main work *Sur l'homme et le développement de ses facultés, ou Essai de physique sociale* from 1835, the average human (who remains only fictituous) has the very ideal properties in all possible aspects. Quetelet's interpretation is different from that of Gauss, who considered all his measurements to be approximations (estimates) of a constant. Gauss measured objectively existing physical variables and the measurement would find the constant precisely in the ideal situation without measurement errors. Moreover, the variability of physical measurements is much smaller compared to anthropometric measurements. Quetelet was aware that for this reason he needs to perform a much larger number of measurements (Jahoda, 2015); this understanding was the reason for his interest in population data.

Conclusions

The ideas of Francis Bacon and the philosophy of empiricism founded by him directly influenced the development of both demography and statistics. Also the Bacon's focus on useful science, which pervaded the work of John Graunt, seems very inspiring nowadays. As another perpetual accent, let us recall the desire for a higher quality of demographic data as expressed by Graunt, Halley, or Moivre.

The moral dimension of the demographic work deserves to be recalled for both Graunt and Quetelet. The pioneering ideas of both of them stemmed from their religious visions and the origins of statistics were thus related to new concepts in theology. This was pointed out in a profound synthetic paper by Pavlík (2009), who discussed the history of statistics to be linked hand in hand with a progress in the field of methodology of science. Demography and statistics are largely interconnected and this paper documents that the connection has existed already since the very origins of demography. The traditional methods proposed by Moivre (such as his mortality law based on his linear survival function) and Quetelet remain to be used until now for mortality modeling, although more flexible tools allow to obtain more accurate predictions; this is true e.g. for models proposed by Benjamin Gompertz (including the Gompertz curve) in the 19th century (Tai and Noymer, 2018).

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