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Was seventeenth-century British political arithmetic a precursor of nineteenth-century economic science?

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The 19th-century English economist W.S.Jevons revisited the work of Gregory King. A seventeenth-century follower of Sir Francis Bacon, King had described in a brief empirical observation how price correlated with supply. The history of seventeenth-century commercial mathematics, this essay suggests, provides essential background for understanding the empirical observation which Jevons received from King. The 17th century was the pivot time during which new techniques appeared in higher mathematics, calculus and mathematical probability among them. Higher mathematics incorporated innovations which had previously appeared in commercial mathematics, Arabic numerals, pen and paper calculations, new notations, etc. At the same time, ancient Greek higher mathematics continued for a while, and Gregory King also borrowed some calculations from James Ussher who used ancient Greek higher mathematics. King learned Bacon's empirical method from John Graunt and Sir William Petty, and all three represented a stage of political arithmetic which was midway between Bacon's simple empiricism on the one hand and later mathematical probability and random sampling on the other hand. In this midway stage, statesmen made policy while taking care to obtain data from professional advisors whom they employed. The advisors based their advice at first on a combination of observation, skill, and intuition, but then later they added commercial arithmetic.

Keywords: *commercial mathematics; shop arithmetic; political arithmetic; mathematical probability; James Ussher; Sir William Petty; John Graunt; Gregory King; William Stanley Jevons; Ancient Greek Higher Mathematics*

JEL codes: *B11; B12*

Была ли британская политическая арифметика XVII века предшественницей экономической науки XIX века?

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Английский экономист XIX века У.С. Джевонс вновь обратился к трудам Грегори Кинга. Будучи последователем Френсиса Бэкона, живший в XVII веке Кинг в сжатом обзоре эмпирических данных описал взаимосвязь цены и предложения. Согласно автору статьи, история коммерческой математики XVII века предоставляет контекст, необходимый для понимания эмпирических наблюдений, которые Джевонс почерпнул у Кинга. XVII век – ключевой момент в развитии новых методов высшей математики, включая математический анализ и математическую теорию вероятностей. Высшая математика восприняла инновации, возникшие ранее в рамках коммерческой математики: арабские числа, методы устного счета, новые системы нотации. Древнегреческая высшая математика также продолжала оказывать влияние. Так, Грегори Кинг позаимствовал у Джеймса Ашера некоторые расчеты, сделанные с использованием древнегреческой высшей математики. Кинг унаследовал эмпирический метод Бэкона от Джона Гранта и Уильяма Петти. В истории развития политической арифметики эти три автора ознаменовали промежуточный этап между простым эмпиризмом Бэкона, с одной стороны, и позднейшей математической теорией вероятности и случайного отбора, с другой. В те времена власти, принимая политические решения, основывались на данных, предоставляемых специально нанятыми профессиональными советниками. Советники же сначала давали свои рекомендации на основе наблюдения, навыка и интуиции, а затем к этому набору добавилась коммерческая арифметика.

Ключевые слова: *коммерческая математика; вычислительная арифметика; политическая арифметика; математическая теория вероятностей; Джеймс Ашер; Уильям Петти; Джон Граунт; Грегори Кинг; Уильям Стенли Джевонс; древнегреческая высшая математика*

Introduction

Commercial arithmetic was anciently conducted on an abacus, and it comprised addition, subtraction, multiplication, and division. English-speaking people called commercial arithmetic by another name in the seventeenth century. They called it "shop arithmetic", and we will adopt their phrase here from now on. Commercial arithmetic and shop arithmetic were the same thing by different names. We begin with a discussion of ancient Greek mathematics.

Ancient Greek mathematics

Nicomachus of Gerasa was a Roman who lived during the first century in what is now Jordan. A Pythagorean of whom we have better knowledge than we do of Pythagoras, Nicomachus authored a book on arithmetic, and we have the book. It remains a core text in the history of mathematics. The book merged the Pythagorean tradition of mathematics with Plato's ideas of the forms to make a compelling early version of pure mathematics. Written after Plato, and showing clear influence from Plato, Nicomachus' book was nevertheless an excellent source for us to study Plato's own sources. Plato was an intermediary between Pre-Socratic mathematicians (Pythagoras and Thales) and early Neoplatonism as exemplified by Nicomachus. Nicomachus gave us a clear account of this Pre-Socratic mathematics (Nicomachus of Gerasa et al., 1926).

Let us also take examples of the other type of ancient Greek mathematics, shop arithmetic. Greeks borrowed it from Egypt and also from Babylon. Merchants often used an abacus for their commercial calculations which comprised addition, subtraction, multiplication, and division. An abacus was a wooden frame with wires on which were beads. You moved the beads to perform a calculation. Sometimes people used a tabletop on which they marked squares as one does on a chessboard now. The person doing the calculations moved counters on the tabletop – something like pieces in a game of checkers. The tables stood in markets and other public places. When a trader went out of business, the table would be broken, hence the English word "bankrupt". Skilled people could calculate very quickly on an abacus. Note that the abacus recorded only the ending sum or the result of a calculation, not its intermediate stages. Nor could the abacus easily deal with fractions. These were important points as we will see later.

Note also that shop arithmetic took influence from the practical needs of those societies in which it arose. Take the question of base numbers. We use ten as our base number, but we also use one and zero as base numbers for computers so our choice of a base number system reflects its practical application in the real world. It was so in the past. Babylonians used twelve sixty as their base numbers. It was a good system for merchants, and English coins from Anglo Saxon times until 1971 had twelve pennies to the shilling and twenty shillings to the pound sterling. Their number system survives even now the standard measure in the English-speaking world for roses, eggs, and in the dozen inches which constitute the foot (a unit of length equal to about one third of a meter). Thirteen of course is an unlucky number in English-speaking countries so people there never buy thirteen roses. Russian florists by contrast will sell a bouquet of twelve roses only for a funeral. The Russian convention for flowers otherwise is thirteen called in English "a baker's dozen". The conventional basis of these things is shown clearly by the fact that these different people use different base numbers.

Greeks often prized geometry over shop arithmetic. They sometimes boasted that they had developed geometry exclusively from Greek sources. They denied that they borrowed anything important in it from other civilizations. The ancient historian Diogenes Laertius even said in the prologue to his Lives of the Philosophers that the Greeks invented everything in philosophy, even human knowledge of the gods (Diogenes Laërtius, 1883).

As the late Plato scholar Ian Mueller rightly said, Plato, while brilliant, was also sometimes hasty, careless, and imprecise with his mathematics (Mueller, 2005).

Plato was especially imprecise with his shop arithmetic, and that was because he hurried through it too quickly. He wanted to get to his geometric forms. Why was geometry more important to Plato than shop arithmetic? Geometry and all mathematics were tools, not ends in themselves. He used them as the models for his notions of moral philosophy. Mathematics was Plato's path to his theory of right action. In *The Seventh Epistle*, Plato gave us a summary of his teaching about the use of the forms to establish a theory of right action. Here is what he said about the forms.

> "For everything that exists there are three instruments by which the knowledge of it is necessarily imparted; fourth, there is the knowledge itself, and, as fifth, we must count the thing itself which is known and truly exists. The first is the name, the, second the definition, the third. the image, and the fourth the knowledge. If you wish to learn what I mean, take these in the case of one instance, and so understand them in the case of all. A circle is a thing spoken of, and its name is that very word which we have just uttered. The second thing belonging to it is its definition, made up names and verbal forms. For that which has the name "round," "annular," or, "circle," might be defined as that which has the distance from its circumference to its centre everywhere equal. Third, comes that which is drawn and rubbed out again, or turned on a lathe and broken up-none of which things can happen to the circle itself-to which the other things, mentioned have reference; for it is something of a different

> order from them. Fourth, comes knowledge, intelligence and right opinion about these things. Under this one head we must group everything which has its existence, not in words nor in bodily shapes, but in souls-from which it is dear that it is something different from the nature of the circle itself and from the three things mentioned before. Of these things intelligence comes closest in kinship and likeness to the fifth, and the others are farther distant." (Harward, 1932: 136)

In *The Seventh Epistle* also, Plato gave us a synopsis concerning morality or right action. Note in this example how Plato used geometry. Mathematics led Plato to moral truth, not the other way around. Mathematics was a beginning and a middle in philosophy, but it was not the desired end result. Here is what he said.

> "And we should in very truth always believe those ancient and sacred teachings, which declare that the soul is immortal, that it has judges, and suffers the greatest penalties when it has been separated from the body. Therefore also we should consider it a lesser evil to suffer great wrongs and outrages than to do them. The covetous man, impoverished as he is in the soul, turns a deaf ear to this teaching; or if he hears it, he laughs it to scorn with fancied superiority, and shamelessly snatches for himself from every source whatever his bestial fancy supposes will provide for him the means of eating or drinking or glutting himself with that slavish and gross pleasure which is falsely called after the goddess of love. He is blind and cannot see in those acts of plunder which are accompanied by impiety what heinous guilt is attached to each wrongful deed, and that the offender must drag with him the burden of this impiety while he moves about on earth, and when he has traveled beneath the earth on a journey which has every circumstance of shame and misery." (Harward, 1932: 128)

Ratios fascinated the Greeks. One of the chief ratios in this regard was the Golden Mean, a ratio such that the longer section of a length is to the whole as the shorter section is to the longer section. This ratio was said to resemble a harmony in music, and, like music, the ratio was thought to provoke good and pleasing emotions. The Parthenon exhibited many examples of this ratio. The Greeks therefore asked important philosophical questions when they did their higher mathematics. The Golden Mean provoked much discussion of number theory since the ratio (1 to approximately 1.6) could not be expressed in a whole number (Lehman and Weinman, 2018).

When we get to James Ussher and others later, please remember that Plato used higher mathematics as a pathway to knowledge about morality or right action. That was typical of Greek higher mathematics. It was about the good, the beautiful, the true. Commercial arithmetic dealt by contrast with number, weight, or measure.

Scholarly bibliography about seventeenth-century British political arithmetic

Lawyers say that experts never agree. Scholarship about political arithmetic confirms that maxim. Historian Julian Hoppit showed the broad range of scholarly opinion on political arithmetic, and more scholarship has appeared since he published his article in 1996. Although it would be helpful if he were to give us an updated review of this bibliography, his article is still a good place to begin study of the topic. We will argue later that the history of mathematics provided an answer to one of the questions which he asked but left unanswered (Hoppit, 1996).

We will mention here only a few other key materials. Let us name them. This list is chronological.

Karl Marx was the author of Capital. During long sessions at the British Library, he read most seventeenth-century books of British political economy closely. Marx argued that Sir William Petty wrote the best of them. Marx credited Petty with combing two key notions – the concentration of capital and the division of labor – out of which combination Adam Smith and others eventually developed of scientific economics. The judgments which Marx made of Petty and Smith left a deep impression on subsequent economic theory.

The twentieth-century English historian Peter Laslett argued by extension that Gregory King anticipated the key techniques of twentieth century economic analysis (Laslett, 1973).

An historian in Canada, Ted McCormick, wrote more recently that political arithmetic was "the gathering, interpretation, and dissemination of quantitative demographic information for various political, economic, scientific, and scholarly purposes" (McCormick, 2014: 239) McCormick extended the purview of political arithmetic to include a wide range of primary materials. He included Irish and Carribean documents in the canon of political arithmetic, and he would make other additions as well, looking for instance at the influence of alchemy. Ted McCormick's definition of political arithmetic was correct, but he confined it to the eighteenth century, and we must take into account the fact that changes occurred in the meaning of the phrase "political arithmetic" before the eighteenth century (McCormick, 2006; 2014).

John Graunt was a seventeenth-century draper or haberdasher who is usually said to have invented statistical science and demography, and Gregory King was a seventeenth-century English herald, land-surveyor, and statistician who is known now for two things. The first was King's Law or the King-Davenant Law. It was this Law which Jevons revisited, and it correlated supply with price. Second was King's Natural and Political Observations and Conclusions, an estimate of English national wealth and population which King compiled in 1696, working with data for 1688.

Petty, Graunt, and King combined Bacon's empiricism with shop arithmetic. Petty threw numbers around without concern for accuracy, but Graunt and King did their best to be accurate. Graunt and King were skilled craftsmen who were content with professional guesses and who used shop arithmetic to analyze their samples. They gave their conclusions to persons of high rank who made policy – to the great and good men who were of her majesty's council as Gregory King once said to John Chamberlayne. He and King were both in the circle of Robert Harley, speaker of the house of commons (Taylor, 1996; 2005).

The chain of influence leading from Francis Bacon to W.S. Jevons

We seek the connection between seventeenth-century political arithmetic and nineteenth-century economic science. We argue that the history of mathematics provides essential background for William Petty, John Graunt, and Gregory King who mixed Bacon's empiricism with shop arithmetic. If we now move forward briefly to William Stanley Jevons, we can see how Bacon's empiricism evolved through Petty, Graunt, and King to Jevons.

Jevons was part of what economists call the marginalist revolution. He sought a general mathematical principle for economics. He held that value and price were subjective constructions. Jevons achieved his marginalist insight independently although similar notions were simultaneously developed by other famous economists such as Carl Menger and Léon Walras.

Jevons turned to the seventeenth-century work of Gregory King. This was in 1863. Jevons wanted to predict the subsequent fall in the price of gold given a prior increase in the overall available supply of gold (Roncaglia, 2017: 144; Jevons, 1865; Jevons, 1871; Jevons, 1866; Jevons, 1863; Project Gutenberg, 2012).

Thomas Hobbes was key to the use of Sir Francis Bacon's empiricism by Sir William Petty. Hobbes lived from 1588 until 1679, and he was in his youth a pageboy to Bacon when the latter was an old man. Because Hobbes lived so long, he was able to champion and spread Bacon's empiricist philosophy during much of the seventeenth century. Hobbes influenced Petty who influenced John Graunt who influenced Gregory King (Taylor, 2019).

Petty was at first only a brilliant, poor, unscrupulous boy who ran away to sea. When he was taken prisoner by the French, Petty turned his coat. He said to them that he was a Roman Catholic, persuading Jesuits to pity him and educate him, which they did. No doubt they regretted it later. Petty left a long string of such regretful people behind him during his career. Returning to England, he resumed his English (and Protestant) allegiance and identity. While King Charles I was losing the civil war in England, Hobbes and Petty were royalists. They then fled to Paris where they lived together in poverty. They were in a bare room with but a single book in it. That unhappy time, no doubt, was the key formative experience for both of them, and eventually it forced them apart. They went separate ways. Each of them returned to England although that country was then still under the protectorate of Oliver Cromwell. Hobbes remained true to his royalist principles and friends while Petty turned his coat again, becoming a servant of Cromwell, accompanying Cromwell to Ireland, and plundering Ireland. Petty entered Ireland poor, and he left Ireland with immense wealth. Immense. Petty came to Ireland as a doctor in Cromwell's army, and Petty left Ireland as a politician, a writer, and a nascent statistician. Moreover, he later became a nobleman and the founder of a great noble house (Petty, 1899).

Petty linked Bacon to John Graunt. Graunt sought to lay aside abstract notions and to compute only number, weight, and measure. He therefore used only shop arithmetic, he said. He also followed Bacon explicitly with regard to notions of social rank or status. Graunt was of too humble a social rank or social station to solicit the attention of great persons so he asked help from Sir William Petty, and the resulting book was for a long time said to have been written by Petty although Graunt was the real author. Gregory King followed Graunt in many details, and King may have thought he was following Petty (Graunt, 1973).

Petty and Graunt linked Bacon to Gregory King who lived from 1648 until 1712. King was an engraver, a herald, and he was a surveyor as his father had been before him. Gregory King was a brilliant schoolboy, but his father decided not to send him to university. Instead, the father apprenticed Gregory to Sir William Dugdale of the College of Arms. That was a wise choice. The College of Arms was part of the royal household. There, King became a skilled courtier with a knack for pleasing those in high office. He rose far. When Dugdale died, King was at a loss for a new patron, for instance. He therefore prepared the document for which he is best known now. It was an estimate of the wealth and population of England in 1688. King modeled his document on the prior work of John Graunt. King showed his document around, and it attracted the attention of Robert Harley who gave King employment as his adviser. Harley was speaker of the house of commons and eventually one of Queen Anne's principal secretaries of state. King lived in comfort and security for the rest of his life, and Harley sent King questions to which King responded. We have one such exchange, a letter from King about Queen Anne's Bounty. Second, economists now associate King's name with the Law of King or Law of Demand. (King's colleague Charles Davenant published the law, and some people called it the King-Davenant Law. King himself published several lavish books on heraldry but almost nothing of his quantitative research.) The Law showed how the price of wheat rose when a harvest fell below expectations. The price rose in accord with the following table.

Table

Correlation between supply and price

Defect in supply of wheat		Above the common rate
1 tenth	raises the price	3 tenths
2 tenths	raises the price	8 tenths
3 tenths	raises the price	16 tenths
4 tenths	raises the price	28 tenths
5 tenths	raises the price	45 tenths

Source: Davenant, 1771: 224. On the attribution to King, see Evans, 1967 and Kim, 1995

This all had an enormous impact on Jevons and subsequent economists. You may think that this table is very spare and simple for all the furor which surrounds it in later economic literature.

The purpose of this present part of the paper is to show that King followed rules for political arithmetic. Bacon and Petty set down the rules for him. By those rules, King was to supply data, and King was not to presume to make state policy himself. Writing an entry for Springer about Sir William Petty, the world-famous historian Phyllis Deane stated the situation very clearly: "Most of Petty's pamphlets on economic questions were circulated privately and published posthumously, for the second half of the 17^{th} century was an age in which giving politicoeconomic advice to governments was a perilous occupation" (Deane, 2008: 459).

Gregory King was not a man for peril. He knew how to make a snug place for himself by pleasing those in high office. By not publishing them himself, and by giving his Natural and Political Observations privately to Harley, King followed the rules of Bacon's empiricism and the rules of political arithmetic. As for the table about demand and price, we may presume that King had given the table first of all to Harley who approved its publication by Davenant who was one of Harley's publicists.

Laslett reprinted King's working manuscripts in this volume (King, 1973). Sir Winston Churchill, a man of the house of commons himself, wrote the best historical account of Harley (Churchill, 2014).

Graunt did not seek divine truth in his study of plague and death. He studied only number, weight, and measure, and he relied only on sense experiences, not on mental abstractions. Gregory King did the same. Population, wealth, and change over time, but no divine truth. Both Graunt and King supplemented skilled guess work with shop antithetic. Let us turn to that point now.

Seventeenth-century Shop Arithmetic

We will use *The Ambassadors*, a painting by Hans Holbein the younger, to carry on our discussion. A sixteenth-century German and Swiss immigrant to England, Holbein became court painter to King Henry VIII. If you are lucky, you have seen some of his paintings in person. *The Ambassadors* is at the National Gallery in London. You can also see it reproduced in books or on the Internet. The painting is exceptionally large, however. Life size. It is a striking object, a thing of power, an impression you may not grasp fully if you see it only on the Internet or in a book (Buck, 1999: 99).

Among other items depicted in Holbein's *The Ambassadors*, we see a printed and bound handbook *Arithmetic for Merchants*. The ambassadors had many items lying behind them in this great painting. This book was one. It was a real book one of many such which were published at that time. You can track them down and read them even today. This one was in German so the ambassadors, who of course were French, may not have brought the book with them. If Holbein read it and owned it himself, it may have been ready to hand among his possessions when he painted the picture. We can imagine where he got it. German merchants had their own quarter in London. They called it the steelyard, and Holbein was often a visitor there. His studio was nearby, and he came to the merchants speaking his own native German to them, painting their portraits, and admiring their successes. In one regard, *The Ambassadors* resembled Holbein's portraits of merchants, he also depicting many artistic, mathematical, and technical items in the background of these paintings of merchants. The background items in *The Ambassadors* were symbolic of human art and knowledge, especially natural philosophy, and science. Among the items in pride of place was this then-new book of shop arithmetic. This book's presence in the painting proved that shop arithmetic played a key role in daily life among persons of high status[1].

Why did high-ranking people use shop arithmetic? Most persons of high rank owned land. They were therefore accustomed to receive reports concerning their landed properties, reports which stewards and managers prepared for them. These reports contained money accounts so they were in the form of shop arithmetic.

When you look at Holbein's painting, you should remember that ambassadors and other men of high station would have regarded Holbein as far inferior to themselves in social status. He was a mere craftsman, an artisan. Men of high rank similarly felt themselves vastly superior to merchants and to medical doctors. That was so even if those merchants and doctors had become rich.

There was one more mark of this clear distinction. Language was important. One of the ambassadors was a French bishop. Educated persons were taught to read Latin which was the universal language of learning in Europe. Craftspeople seldom knew Latin, and merchants sent their sons to special schools where they studied shop arithmetic and modern languages. The schools had schoolbooks for students to read in their own vernacular languages. Perhaps Arithmetic for Merchants was used as a schoolbook for young German students at such a merchants' school in the steelyard. Herman Melville the America author said that a whale ship was his Yale College, a whale ship was his

[1] The digital copy of the book is accessible from MDZ (Münchener Digitalisierungszentrum) site: Eyn Newe unnd wolgegründte underweysung aller Kauffmanß-Rechnung in dreyen büchern, mit schönen Regeln un[d] fragstucken begriffen ... [Ingolstadt]: [Apianus], [1527]. https://mdz-nbn-resolving.de/details:bsb11110160 (accessed: December 21, 2022)

Harvard. Merchant schools were the Oxford and the Cambridge where merchants taught their special knowledge to their young people. Shop arithmetic was the mystery, the skill, of merchants, and social superiority was the basis for Sir Francis Bacon's clear distinction between the statesman who made policy and the expert craftsman who collected data.

Social status shaped the concept which people had of probability. It was the reason for John Graunt's giving William Petty's name as the author of Graunt's book. The word "probability" may have had an origin in courts of law where testimony by persons of high rank was thought to be more worthy of credit or belief than the testimony of persons of lower rank. The testimony of persons of high status was said to be more probable. Some people tried to qualify the degree of probability which courts should accord based on high social status (Daston, 1988).

Although Bacon retained a lot from Aristotle, Bacon also proclaimed the twin aims of moving away from Aristotle, first, and, second, moving toward a new empirical investigation of nature. He urges his followers to avoid abstract concepts when studying nature. The followers later combined Bacon's empiricism and sampling with simple shop arithmetic, and sampling-plus-shop-arithmetic is the stage we are discussing in this portion of our essay (Butterfield, 1957: 115).

We spoke earlier about good guessing. We will now follow the seventeenth-century transition of the word "stochastic" from a first to a second meaning. The word "stochastic" in the early seventeenth century denoted skill. At that time, "stochastic" meant your ability to aim a weapon so that you hit your target with your arrow or your bullet for instance. The word also named a property or characteristic which some lucky people sometimes had. They were able to guess correctly, and if you had lots of unanalyzed data then guessing well was a valuable aptitude or knack. You must remember this when you think of Gregory King's table, the one which Jevons borrowed. King was a skilled guesser. The table was a guide to good guessing.

Later, the word "stochastic" evolved to accommodate new techniques in mathematical probability. Let us consider it as an example of the absorption into higher mathematics of prior changes in shop arithmetic. If we count the legal background, the evolution of mathematical probability began well before the seventeenth century, continued in the eighteenth century, and then bloomed in the nineteenth century and later. The word "stochastic" eventually named properties or behaviors which were recurring in observed data. These recurring properties or behaviors could be analyzed statistically but their appearance could not be predicted precisely.

Bacon and Political Arithmetic

Sir Francis Bacon suggested the institutionalization of empiricism in his book New Atlantis. Bacon's opinion was the origin of what (only later) came to be called political arithmetic. He imagined a government-funded research institute, Solomon's House. Government should organize and fund a large-scale attempt to improve human life through the empirical study of nature, he said. Prior suggestions for institutional research involved only the recovery of ancient learning. Researchers at Solomon's House therefore – in Bacon's imagination – would accumulate new data about the natural world, and Bacon said such empirical research would lead to valuable improvements in the conditions of human life.

Political arithmetic was like the Holbein painting. You may prefer nineteenth-century photography, but do not obscure for yourself the beauty of the painting and the skill of the artist. You may prefer Jevons to Graunt and King, but they were skillful craftsmen, and they deserve your praise and your appreciation, too.

As for political arithmetic, the thing itself was implicit in New Atlantis, but the name "political arithmetic" was not yet invented for it. Bacon and his immediate followers distinguished between policy on the one hand and discourse about data on the other hand. Remember that courts of law gave more heed to persons of high status than to those of low status. Bacon was a lawyer who made a similar distinction between those craftsmen who compiled data and those few men and women who ruled and who therefore had the power to make public policy. Those few who ruled should be informed, and they should employ scholars to inform them, and the informed making of public policy was their duty. Bacon described it clearly although he did not use the phrase "political arithmetic". The name came only later, political arithmetic. Scholars were craftspeople who compiled data, mind, and they did not themselves make policy.

This emphasis on social status makes more sense if you imagine or reconstruct the role of social status in spoken conversations from the past. History is the study of written records, and historians may lay too much emphasis on written texts. The great did not write in the past, they talked. They did not read silently to themselves much either. At most, they dictated or they had people read to them. If a nobleman and a workman spoke within a group context, imagine how much deference the workman would show to the nobleman.

Shop arithmetic transformed

During the Renaissance, merchants began to transform shop arithmetic. Let us trace this process. Important influences came to European shop arithmetic from the Islamic world. The ancient Greeks distinguished arithmetic sharply from higher mathematics, and this often meant in practice that many educated people in medieval Europe sharply separated arithmetic from geometry. When European merchants visited Muslim countries, however, they found that mathematicians there blurred the separation between arithmetic and geometry. Muslim mathematicians taught European visitors an algebra that blurred the distinction between arithmetic and geometry, for instance. The English name "algebra" reflected this Arabic origin. Writing as follows, John F. Barrett of the University of Southampton gave the history of algebra.

> "The word derives from the Arabic "al-jabr" which occurred in the title of a book of the Arabic mathematician al-Khwarizmi (fl. 813-850) who taught at the University of Cordoba. His book was translated into Latin in 1145 by Robert of Chester from where the form "algebra" originated. The word had the meaning of restoration and this meaning survived in Spanish as "algebrista", a bone-setter (e.g. in Don Quixote, part 2, chap.15 where the Don goes to an algebrister after falling from his horse)." (Barrett, 2016)

Although algebra itself was very old, and although some of its principles were known and used both in arithmetic and geometry by people in ancient Mesopotamia and Egypt, the Welsh physician Robert Recorde first brought algebra to widespread attention in the British Isles. He did so during the middle years of the sixteenth century. He also introduced the equal sign, =, and popularized the use of the plus sign, + (Merzbach and Boyer, 2011: 262).

Fibonacci numbers were like algebra in some regards. First, they also blurred the distinction between shop arithmetic and higher mathematics. Second, they were also borrowed from India through the Islamic world when in 1202 they became known in Europe through Leonardo of Pisa, later known as Fibonacci.

Most importantly, Renaissance merchants changed European mathematics by borrowing a system of numerals from India. Fibonacci numbers helped to spread knowledge of this system of notations. English-speaking people often called them "Arabic" numerals because Europe received this Indian invention through the Muslim world. Mathematicians in ancient Egypt and Mesopotamia had long been in close contact with India. Someone of genius had already added the zero. We do not know exactly when that happened or who was responsible, but something like the zero was already in use both in ancient Mesopotamia and then later in Egypt during Ptolemaic or Hellenistic times. Higher mathematics borrowed this system of Arabic numerals.

By the end of the seventeenth century, logarithms further transformed shop arithmetic, leading first to the production of printed tables to enable calculations and finally to the invention of the slide rule. These items were especially valuable for mariners who added them to their twelfth-century invention the magnetic compass. The slide rule was just as valuable on land for the practice of shop arithmetic.

The slide rule accustomed people to accept quick but not entirely precise calculations. This tolerance for approximation was already standard usage in shop arithmetic, and it became an important precedent for calculus.

Nevertheless, merchants often retained the ancient practice of writing down for their masters only the final tally. They would then offer the written intermediate stages of their calculations as appendices to their reports. This practice was widespread in Italy by the fourteenth century. Manuals appeared about bookkeeping similar to those which taught people how to do shop arithmetic.

Petty praised numbers and scattered numbers about in his writing, doing so however without much caring whether he got his sums right. We may suspect that Bacon was equally careless with numbers himself. It was the mathematical equivalence to illiteracy. If you are an English-speaking person traveling in Japan, it is all familiar to you because you see there many examples of writing in which people use the Roman alphabet without care for the meaning of what they write. They write something which they think looks stylish and which purports to be in the English language and which pleases Japanese people but which does not make any sense in English. Petty's arithmetic was like that. At first glance, it looked like it might be calculation, but it was not. It was stochastic in the earliest sense of the word. Petty guessed, and he may have been unskilled in mathematics, but he was a good guesser. He had the knack. However, he also had the knack of pleasing people by saying what they wanted to hear. He said that England was bigger than France, for instance. Then he dressed up his work with numbers as though he had done mathematical calculations when he really wrote only mathematical gibberish.

Graunt had the same skill as a guesser, but he was an ordinary merchant, an honest man, and a good and worthy calculator. He got the sums right. Petty may have been a genius, but he was not ordinary, and he was not honest.

Eventually a brilliant new combination of shop arithmetic and higher mathematics did emerge. This was at the turn of the eighteenth century. This new combination used innovations from shop arithmetic. It borrowed Arabic numerals, algebra, and other innovations. It displayed the intermediate stages of a calculation as practitioners of shop arithmetic began doing when they used pen and paper or chalk and board. The new combination did not disdain to answer the question, how many? It had another thing borrowed from shop arithmetic. The new combination was more secular than Greek higher mathematics. The full flowering of that new combination came at the beginning of the eighteenth century when Leibniz in Germany published the calculus. He and Sir Isaac Newton quarreled bitterly about which of them was the first to discover it.

Here are other aspects of shop arithmetic which made their way into higher mathematics. As we said, shop arithmetic was already secular. Merchants did not aim at divine truth.

Shop arithmetic allowed approximations. Shop arithmetic took influence from land surveying, for one thing. Approximations were commonplace in surveying. For another thing, merchants allowed merely practical and imprecise solutions to tricky mathematical problems. Merchants usually got their sums right, but they were also content with an approximate answer to a problem when no precise answer was available and when the approximate answer was sufficient for some practical purpose. For instance, take squaring the circle. This was an intractable puzzle in theory yet merchants required a practical solution because they often had to compare the volumes of different containers. Each box or barrel in those days was made by hand so like the coins each one differed slightly from all the others. If you wanted to calculate the volume of a box as compared to the volume of a barrel, you had to know how to square a circle, approximately. They learned how to do the approximation.

Sir Isaac Newton relied in his calculus upon that same kind of approximation. There was therefore a direct resemblance between calculus and shop arithmetic. Bishop George Berkeley objected to the calculus because it relied on approximation. He said that approximation in higher mathematics raised huge metaphysical questions, and he said that Newton brushed these questions aside (Berkeley, 1754).

In sum, secular, practical, and newly equipped with Arabic numerals, algebra, new symbols such as plus and minus signs, other innovations, and the zero, the new higher mathematics became a powerful tool. It had changed the ancient system to allow the writing down of the intermediate stages of a calculation because calculators could now observe the intermediate stages, something which could not be done when a calculation was done on an abacus. That was the importance of Recorde's invention of the plus and the equal signs. They made writing down calculations easy, and writing down calculations had already led practitioners of shop arithmetic to practical and valuable inventions including double-entry bookkeeping.

Furthermore, as we have already seen, people worked out social rules for dealing with shop arithmetic. Persons of the highest rank patronized shop arithmetic, and their patronage consisted of having persons of lower rank do calculations which persons of high rank used for the making of policy.

Shop arithmetic sometimes mixed with Greek higher mathematics in the seventeenth century

Let us remember why some people still valued the knowledge of divine things which Greek higher mathematics was said to reveal. When you look closely at the Holbein painting The Ambassadors you see why.

Death and resurrection. First you see a skull. It can be seen clearly only from an angle, however. You can either see the skull whole and the rest of the painting in distortion, or you can see the painting whole and the skull in distortion. The skull was a reminder of death. Second, you see a crucifix on the top left margin of the painting. Status and political power afforded no protection against death, but the cross did. Death was weird and distorted from the perspective of ordinary life, and ordinary life was weird and distorted when seen "under the aspect of eternity", as the poet Edmund Spenser said to Sir Walter Raleigh.

Here is an example, and a very moving example, of seventeenth-century Irish usage of Greek higher mathematics to obtain knowledge of divine things. We will use this information presently in our further discussion of Gregory King.

James Ussher was the Anglican archbishop of Armagh, and therefore a man of remarkably high rank. He lived through the Wars of the Three Kingdoms – wars which a changed fashion now forbids us to call by the old name, the English Civil War. These wars included the trial and killing of King Charles I and the rise of Oliver Cromwell. Ireland then had a Protestant Church of Ireland established and imposed by the authorities in London even though most Irish people were Roman Catholic. Ireland was a tinder box which caught fire and burned down during the wars. Cromwell reduced it to ruins. Fleeing an Ireland in flames, Ussher went to Oxford University in England and there devoted himself to quiet scholarship.

As war made this scar across the British Isles, Ussher made a leap of faith like that which is sometimes taken by great artists. If you know the music of the Austrian composer Joseph Haydn then you can see a similar leap and a similar steadfast faith. Listen to The Mass in Time of War, 1796. What a great piece of music! A loyal subject of the Habsburg emperor in Vienna and a devoted Roman Catholic, Haydn wrote this sacred music when Austria was struggling against the French Revolution. French troops brought with them the apocalypse, a turning away from God and native land, Haydn thought. He wrote on the musical score or manuscript of the mass, Praise be to God! The French Revolution was a harbinger of the last judgment, Haydn thought. He depicted the apocalypse with drum rolls. Ussher remembered the prophecy in Saint Matthew's gospel, "ye shall hear of wars and rumors of wars: see that ye be not troubled: for all these things must come to pass, but the end is not yet". Ussher never doubted that prophecy, not for a moment. Instead, seeking after divine knowledge and praising God, James Ussher saw in his own day the fulfillment of this prophecy.

Ussher calculated the date of God's creation of the world. Ussher said that event occurred in the late afternoon on 22 October in 4004 BC. To calculate the date, he did immense labor both on the progression of the equinoxes and on the comparison of disparate data in ancient Jewish calendars and other calendars. A lunar calendar was difficult to reconcile with a solar calendar, but Ussher thought that he must reconcile those calendars in order to predict the second coming of Christ.

This scholarship was immense, truly prodigious, and it earned Ussher both fame and infamy. He was famous in the seventeenth century. The French writer Voltaire devoted a whole chapter of his Letters Concerning the English Nation to a discussion of Sir Isaac Newton's historical chronology. (Newton's was a revision of Ussher's.) Voltaire included a discussion of the procession of the equinoxes which was the key point of Ussher's calculation (Voltaire, 1773).

Ussher's fame continues to the present day in some contemporary American circles. Oxford University Press published the Scofield Reference Bible at the beginning of the twentieth century, and it has been what people call a rainmaker for the press. They sold many millions of copies of the book, and they have it still in print. Borrowing his narrative history wholesale from Ussher, Scofield complied this borrowed material into a commentary which he placed in the margins alongside the text of the King James Version. Those who believed in a "young earth" accepted this bible history with its set of dates, 4004 BC and all, and many of those same people also rejected the evolutionary theories of English biologist Charles Darwin. The viewpoint is commonplace in America today as the continued sales of the Scofield Reference Bible testify.

Of course, his popularity with readers of the Scofield Reference Bible earned Ussher only infamy from mainstream academic scholars today.

Gregory King's use of Ussher's chronology

Gregory King made extensive use of Ussher's chronology. King used it to calculate the rate of population increase for England from ancient times to the present day and then into the future. He did this calculation while he prepared the document which he entitled Natural and Political Observations, a title which paid homage to John Graunt. King did not publish much himself although Charles Davenant did publish a few of King's data. Davenant was of a higher rank and salary than Gregory King, but Davenant was also, like King, a trusted servant of Robert Harley. Gregory King hardly mentioned Ussher's chronology in "Natural and Political Observations", the document he gave to Harley. King cited Ussher only in the working papers from which he took this finished product. This procedure was in accord with Bacon's principles of political arithmetic. King was only an advisor. He presented to Harley formal final tallies which King made using the convention of shop arithmetic. King used his own observations although he may also have had official data because he had a brother at the Excise Office. Gregory King also gave credence to the bare and unadorned testimony of holy scripture. That was where Ussher came in. King did not borrow Ussher's dates about the beginning or end of the world. King borrowed only dates which enabled him to establish a rate of population increase from a single couple of man and wife and a small number of couples.

Citing holy scripture, Gregory King followed the methods of his late teacher and mentor Sir William Dugdale, a noted antiquary. Dugdale credited holy scripture when it presented plain fact which needed neither supplement nor supposition. King therefore took from Ussher's chronology only what King thought were simple facts which were based on the plain authority of scripture. Clear as a bell. Not open to dispute or analysis.

We see here the status of political arithmetic at the end of the seventeenth century. Political arithmetic was an outgrowth of Bacon's empiricism. Graunt and king were secular, expert, free of scholastic or medieval dependence on theological interpretation. Nevertheless, they respected the Bible. Their empiricism was also free of Aristotle's view of nature. Graunt and King furthermore combined empiricism with an honest effort to calculate correct sums. On the other hand, Graunt and King still relied to a large extent on skilled guesswork. They did not seek out or use new techniques of higher matematics. For instance, they selected their samples based on intuition and experience and not yet by random methods. On the other hand, King used some material from Ussher which itself reflected Greek higher mathematics with its ancient desire for knowledge of divine things.

Miscellaneous remarks in closing

In his review of scholarly literature on political arithmetic, Julian Hoppit asked why eighteenth-century mathematics in Britain fell behind mathematics in the continent of Europe. Here are two suggestions.

First, we should remember the famous thesis of sociologist Robert Merton, an expert on this very topic. As Merton pointed out, and as we all know, the seventeenth-century Church of England split between radical Calvinist Protestants who then called themselves "the Godly" (and whom their Elizabethan opponents named in ridicule as Puritans) and less-radical Protestants who were then called Arminians. That name came from the Dutch theologian Jacobus Arminius (1560–1609). The split between these two groups in the Church of England was a root cause of the civil war which broke out in the country as a whole. The Godly controlled the house of commons, and King Charles I, who favored the Arminians, controlled the church hierarchy. The king appointed bishops and therefore the old joke was that a church-goer came out of a parish church on Sunday and shook the pastor's hand. Tell me, said the church-goer, what do the Arminians hold? Why, sir, they hold all the best church appointments in England, replied the clergyman. The Arminians also controlled all the best schools in England, and they did not favor innovation. They stuck with Aristotle and the old curriculum. They thus did not encourage innovation in mathematics. Merton also surveyed all the practicing mathematicians whom he could discover in seventeenth-century England, and he found that almost all of them had some connection to radical Protestantism. Radical Protestants ran their own schools. Rich members of this group sent their sons for education to the Netherlands where radical Protestants controlled education and where the study of mathematics in school was encouraged. After the murder of King Charles I, the radical Protestants gained full control in England, and they abolished the Church of England, leaving schools free to teach mathematics. When King Charles II came to the throne in 1660, however, the Church of England regained control of education, and innovation in mathematics was again discouraged.

This was Merton's account of the discrepancy which Professor Hoppit observed between English mathematics in the seventeenth century and European mathematics in the eighteenth century. Merton was a brilliant man, and this book was brilliant (Merton, 2001).

Second, Sir Isaac Newton was a genius, but he was also a bitter and vindictive opponent of colleagues whom he disliked. He reviled G.W. Leibniz, and thereafter the German philosopher's reputation never recovered in the English-speaking world. That was both an injustice for Leibniz and a misfortune for English-speaking mathematics. Voltaire recognized the injustice. Let us recognize the loss. Leibniz made many mathematical techniques which were as important as calculus, Voltaire said. Voltaire for instance recognized that the Bernoulli brothers in Switzerland had combined with Leibniz – not Newton – to create mathematical probability. It should not surprise us at all that a flock of great mathematicians added to the fame of England in the seventeenth century while Thomas Bayes and George Boole were the only two brilliant English students of mathematical probability in the succeeding age, and the first was a radical Protestant minister while the second was unschooled and self-taught. On the other hand, this English-speaking injustice was convenient to Arminians. While the whole European world continued its contribution to higher mathematics, the injustice obscured that European achievement for the eighteenth-century English-speaking world while they sept their Arminian sleep of the just. The shade into which Newton cast upon Leibniz obscured for English speakers even the reputations of Pascal and Descartes (Bardi, 2009).

Here are four more stray considerations.

Reading the vast scholarly material on political arithmetic is time-consuming. Certain basic texts in mathematic remain essential, nevertheless. Plato, Nicomachus, Ussher, Graunt, and King all remain essential.

Based on the above-mentioned point, we must commend Ted McCormick for drawing our attention to the influence which Sir William Petty took from alchemy. However, we must also remember that alchemists mixed alchemy with Greek higher mathematics. We should not separate alchemy from Greek higher mathematics ourselves.

Take John Dee as an example. The twentieth-century historian Frances Yates said he practiced Christian Cabalism. Dee was an alchemist, an astrologer, and a practitioner of Neoplatonic Greek philosophy while at the same time he was at the forefront of mathematics and published a Euclidian text on geometry. Dee devoted his whole life to mathematics, astrology, and alchemy and he tried to discover and decipher angels' language. Although he died in poverty in 1608, he had high patrons during his lifetime. When Dee visited Paris, he turned down a position at the university there, and he came back to England. Under Queen Mary I he was imprisoned as a conjuror, but Queen Elizabeth I released him and consulted him about the date of her coloration, and he thereafter became her court magician. Dee was an English patriot who used his knowledge of geometry to improve maritime navigation. He also assisted his queen by suggesting that her navigators seek an empire for England beyond the Atlantic Ocean. He was in the circle of the poet Sir Philip Sidney, a royal favorite, and Dee's career languished after Sidney's untimely death. Dee influenced the poet Edmund Spenser who was also in Sidney's circle and whom Queen Elizabeth favored, granting him a pension. It is proper and fitting that some of the most exciting and readable books on Dee are either fictional or else controversial among recent scholars. Dee was almost certainly William Shakespeare's model for Prospero in *The Tempest*. That play may be the best introduction to this extraordinary man, and many other books are also a lot of fun to read (Dee, 2004; Hooper, 2011; Yates, 1983).

In addition, if we read Dee and Ussher, we can see why Sir Isaac Newton regarded higher mathematics, as both Dee and Ussher had done, as a gateway to divine knowledge. Newton saw his work on optics as a tool to understand what sense experience revealed about the phenomena of light. As he said in his Optics, the ancients understood much about mechanics, but they imputed the causes of material motion to spirits indwelling in matter or to occult forces, Newton followed Bacon's new empiricist approach to the study of nature, but Newton did not abandon the two older approaches, Greek higher mathematics and shop arithmetic. Newton worked with Ussher's predictions of the second coming of Christ, and Newton devoted forty years to alchemy. He finally was master of the mint and therefore a user of shop arithmetic.

Conclusion

Let's face it. W.S. Jevons failed to find a mathematical principle which underlies economics and which guides us to accurate predictions about prices. Therefore, we must ask, what went wrong? That is the question for another essay.

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