By the Numbers:
Understanding the World in Early Modern England

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Abstract

The ways English men and women apprehended numbers underwent a transformation during the last half of the sixteenth century and first decades of the seventeenth century. This dissertation analyzes the changes in how people encountered, perceived, and subsequently employed numbers in their day-to-day lives. It also argues that a quantitative worldview coexisted with Christianity and was supported by the belief that God used numbers to create the world.

At the beginning of the sixteenth century, most English men and women expressed numerical concepts through a combination of performative and object-based symbolic systems, such as tally sticks and counting boards. Those who used written systems relied primarily on number words and Roman numerals. During the late sixteenth century, the advent of vernacular arithmetic textbooks combined with rising literacy rates to encourage the adoption of a single symbolic system: Arabic numerals. Unlike other number systems, Arabic numerals combined two different functions: permanent recording and calculation. Over the course of the seventeenth century, Arabic numerals became the dominant form of English numeracy, subordinating arithmetic to the previously separate skill of writing.

During the same period, English men and women increasingly used numbers to interpret the world around them. Mathematical texts and teachers stressed the utility of numbers, often bolstering their claims by citing a Biblical verse describing God's creation of the world in number, weight, and measure. Seventeenth-century almanacs reveal popular uncertainty about a chronologically fractured world and people's use of numbers

to situate their lives with respect to both the past and present. At the same time, anxieties over the unknowable future led people to employ numbers in an increasingly probabilistic fashion to predict chance events and future risks. Fears of the plague, in particular, led to the collection of demographic data that formed the basis of political arithmetic in which the population itself became subject to numerical analysis.

By examining a diverse array of sources, this dissertation establishes the social pervasiveness of numbers and their power to shape modes of thought in early modern England. It also demonstrates the historiographical importance of numeracy by evaluating patterns of symbolic change within the context of changing social and educational practices, and by placing numbers in conversation with broader developments in English intellectual, political, and cultural histories.

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Abbreviations

APS	American Philosophical Society
BL	British Library
Bodl.	Bodleian Library
CUL	Cambridge University Library
ESTC	*English Short Title Catalogue*
HEH	Huntington Library
KJV	King James Version of the Bible
LMA	London Metropolitan Archives
ODNB	*Oxford Dictionary of National Biography*
OED	*Oxford English Dictionary*
SHL	Senate House Library
TNA	The National Archives of the UK
UIUC	University of Illinois, Urbana-Champaign
WL	Wellcome Library

Style, Dating, Money, and References

Early modern punctuation, capitalization, italics, and spelling have been retained with the exception of abbreviations, which have been expanded to their modern equivalents by the insertion of the missing letters in italics.

Unless otherwise noted, dates are given in the Julian/Old Style calendar that was used in England until 1752. With respect to the date of the new year, consistency is maintained with the original source. Although the new year officially began on Lady Day, March 25, most almanacs and printed books preferred January 1.

Pre-decimal English money contained 12 pence (*d.*) to the shilling, and 20 shillings (*s.*) to the pound (*li.* or £).

When possible, references have been made to modern or printed versions of manuscript material to facilitate ease of access. Signatures have been used only when printed page numbers are mistaken or not available.

Chapter One

"Number, Weight and Measure"
Numeracy in Early Modern England

In an almanac written for the year 1659, George Wharton mentioned a Biblical passage that would have been familiar to early modern "well-wishers," "lovers," and "students" of mathematics: "For indeed all things were made by *God*, in *Number, Weight* and *Measure*."[1] One of Wharton's readers found this passage so interesting that he underlined it.[2] The implications of this simple statement were enormous. If numbers were indeed the building blocks of God's Creation, then everything in the world could be understood through the use of numbers, particularly the concrete numerical exercises of weighing and measuring. Furthermore, a knowledge of numbers would be not only sufficient, but also necessary, for those who wished to study any aspect of God's inherently numerical Creation.[3] This Biblical passage was not a common subject for Sunday sermons and the Book of Wisdom in which it can be found is technically part of the Apocrypha. Despite this, Wisdom 11:21 – God's creation of the world by number, weight, and measure – formed a rallying cry for mathematicians who wished to

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[1] George Wharton, *Calendarium Ecclesiasticum: or, A New Almanack After the Old Fashion* (London: J. Grismond, 1659), C5r. The group of men to whom I will refer by the catch-all title of "mathematicians" gave themselves a variety of titles, including well-wishers, lovers, students and practitioners of mathematics. Those who authored almanacs, in particular, tended to style themselves as "*Philomathematicus.*" While a detailed analysis of these titles might be a worthwhile endeavor, it is beyond the scope of this work.

[2] HEH, 479104, f. C5r. The almanac contains significant underlining in addition to this particular passage. While it impossible to know for certain who underlined the passage, it was most likely done by Henry Oxinden of Barham, who also left extensive manuscript comments throughout the monthly pages of the almanac. For more on Henry Oxinden, see Dorothy Gardiner, ed., *The Oxinden letters, 1607-1642; being the correspondence of Henry Oxinden of Barham and his circle* (London: Constable, 1933) and *The Oxinden and Peyton Letters, 1642-1670. Being the correspondence of Henry Oxinden of Barham, Sir Thomas Peyton of Knowlton* (London: Sheldon Press, 1937).

[3] Variations on this concept, sans the Christian God, date back to at least the ancient Greeks. Plato's *Timaeus* describes a creator-god who uses geometry to impose order on the fabric of the world. John Fauvel and Jeremy Gray, eds. *The History of Mathematics: A Reader* (New York: Palgrave MacMillan, 1987), 76-9.

encourage the wider study of mathematics among the general population of early modern England.[4]

One of the earliest of these English mathematicians was Robert Recorde, whose 1543 book, *The Ground of Artes*, was reprinted throughout the sixteenth and seventeenth centuries and became a byword for vernacular arithmetic textbooks.[5] Recorde considered numbers to be the foundation, or ground, of all human arts and sciences.[6] As a consequence, he argued that numbers were indispensible to every aspect of early modern society: "no man can do any thing alone, & moch lesse talke or bargayne with other, but he shall styll haue to do with numbre."[7] Recorde expected some of his claims to be self-evident to his readers. For example, clerks, auditors, geometricians, and astronomers – "whose offices without Arithmetike is nothing" – must understand numbers as a matter of course. However, Recorde also argued that those who wished to study a wider variety of subjects – including law, grammar, and philosophy – would find themselves sorely lacking if they did not also possess some knowledge of numbers. Most importantly, for England as a whole, a knowledge of number was essential for the "gouernaunce of co*m*myn weales in tyme of peace: and in dewe prouision and order of armes in tyme of

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[4] Variously Wisdom 11:20. The passage to which Wharton refers, as translated in the King James Version of the Bible, reads: "but thou hast ordered all things in measure and number and weight."

[5] Recorde's arithmetic textbook was supplanted in the late seventeenth century by Edward Cocker's arithmetic textbook, which included fractions and the newly invented decimal arithmetic. Cocker's arithmetic maintained its dominance throughout the eighteenth century, only to disappear in turn by the beginning of the nineteenth century.

[6] While "science" is arguably an anachronistic term when understood in the modern sense, it also appears frequently in early modern mathematical writings. I follow the usage pioneered by Deborah Harkness, who argues the Elizabethan definition of a science is "both a study of the natural world and a manipulation of the natural world for productive and profitable ends." Deborah Harkness, *The Jewel House: Elizabethan London and the Scientific Revolution* (New Haven: Yale University Press, 2007), xv.

[7] Robert Recorde, *The Ground of Artes Teachyng the Worke and Practise of Arithmetike* (London: R. Wolfe, 1543), A1v-A2r.

warre."[8] In short, "[w]herfore as without nomberynge a man can do almost nothynge, so with the helpe of it, you maye attayne to all thyng."[9]

Recorde thus conceived of a world that was inherently quantifiable, in which numbers and mathematics could be applied to every aspect of the world to help accomplish any conceivable goal. He wanted the mathematical arts and sciences to be not just the domain of an elite body of professionals – clerks, auditors, geometricians, and astronomers – but also available to all men and women, no matter their station in life. As such, he formed part of a vanguard of mathematicians who advocated for the wider study of mathematics and transformed English numerical practices during the late sixteenth and early seventeenth centuries.

This transformation in numerical practices was threefold. First, it was a transformation in symbolic systems – the culturally agreed upon symbols and syntax used to represent numbers. Second, it was a transformation in mathematical education, enabled by increasing literacy rates and the printing revolution. And third, it was a transformation in technologies of knowledge, specifically the way the people of early modern England conceived of and used numbers in their daily lives. By the turn of the eighteenth century, theirs was still a world made by God, but it was also a world made – and made understandable – by number, weight, and measure.

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[8] Recorde, *The Ground of Artes,* A4v.

[9] Recorde, *The Ground of Artes*, A2v.

Defining Early Modern Numeracy

The foundation of mathematical knowledge, and thus something that will figure prominently in this dissertation, is numeracy. But what, exactly, does it mean to be numerate in any period, much less the early modern one? This question is particularly problematic because the noun *numeracy* and its associated adjective form *numerate* are very recent additions to the English language.[10] The *Oxford English Dictionary* attributes the first use of both words to a report written by the English Ministry of Education in 1959 and even fifty years later they still have the character of neologisms and awkward cognates of *literacy* and *literate*. While *numeracy* is therefore an anachronistic term, it remains analytically useful in drawing comparisons with other technologies of knowledge, particularly literacy, a term that only emerged during the mid-fifteenth century. Furthermore, the lack of the specific term *numeracy* did not prevent early modern authors from expressing an interest in the human ability to perform basic counting, arithmetic, and geometry, or – as Recorde formulates it – to "number."

The *OED* defines literacy as "the quality or state of being literate; knowledge of letters; condition in respect to education, *esp*. the ability to read and write," therefore various forms of literacy can be judged by the demonstrated ability to read and/or write.[11]

[10] Another definition of the adjective "numerate" – meaning "counted" – dates to at least the end of fifteenth century. As a verb – meaning "to count" – the word dates to the mid-seventeenth century. *OED*, s.vv. "numerate, *adj*,[1]" "numerate, *v*." This is consistent with significant and growing interest in counting and quantification of objects during the early modern period.

[11] *OED*, s.v. "literacy." For comparison, the definition of *literate* as an adjective is "acquainted with letters or literature; educated, instructed, learned" or, in noun form, "one who can read and write. Opposed to *illiterate*." *OED*, s.v. "literate, *a.* and *n*." For an extended discussion of the various types of early modern literacy, see Keith Thomas, "The Meaning of Literacy in Early Modern England," in *The Written Word: Literacy in Transition, Wolfson College Lectures 1985,* edited by Gerd Baumann, (Oxford: Clarendon Press, 1986): 97-131.

In a not-quite-parallel formulation, numeracy has been defined as "the quality or state of being numerate; ability with or knowledge of numbers."[12] Unlike the definition of literacy, the definition of numeracy does not reference any markers or behaviors by which such knowledge can be judged, and its vague reference to "knowledge of numbers" could be interpreted as anything from the ability to subitize to the mastery of Euclid's *Elements of Geometry*.[13] As we shall see, there was an astonishing range of such markers during the early modern period. The definition of *numeracy*'s associated adjective, *numerate*, may provide a further clue, asserting that a numerate person is "competent in the basic principles of mathematics, esp. arithmetic; able to understand and work with numbers."[14] However this still fails to define the basic principles of mathematics, or what parts of arithmetic must be included in those basic principles.

This very ambiguity works to the historian's advantage, providing the flexibility to define "knowledge of number" from within the context of a culturally specific time and place. While numbers themselves may transcend cultural boundaries, the knowledge of number required to be considered "numerate" varies greatly from culture to culture. Therefore, to construct an early modern English definition of numeracy, we need first to consider what contemporaries had to say about the subject of numbers.

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[12] *OED*, s.v. "numeracy."

[13] Subitizing is the ability to recognize, at a glance, the number of objects in a small group. The upper limit on the group size is generally three, four or five. This ability has been shown to be present in human infants as something inborn, rather than something learned. Laboratory testing has also shown that some animals can subitize, including great apes, parrots, ravens and rats. Brian Butterworth, *What Counts: How Every Brain is Hardwired for Math* (New York: The Free Press, 1999). Stanislas Dehaene, *The Number Sense: How the Mind Creates Mathematics* (New York: Oxford University Press, 1997).

[14] *OED*, s.v. "numerate, *adj*^{2}."

Many early modern authors were keenly interested in man's abilities with respect to numbers.[15] Mathematicians such as Recorde believed that a knowledge of numbers was one of the fundamental distinctions between man and beast:

> in no*m*ber was there neuer beaste found so co*n*nyng, y[t] coulde know or discerne one thynge from many, as by dayly experyence you maye well co*n*syder, when a bytche hath many whelpes... take fro*m* them all theyr yonge, sauyng onely one, & you shall perceyue playnly y[t] they mysse none... but take awaye that one that is lefte, and then wyll they crye and complayne: and restore to them y[t] one, then are they pleased agayne.[16]

John Bulwer, a medical practitioner interested in deafness and sign language, similarly argued in his *Chirologia* that "man [is] a naturall Arithmetician, and the only creature that could reckon and understand the mistique laws of numbers." This uniqueness was not an accident, but rather the foundation for man's dominance over all the rest of God's Creation: "that divine Philosopher doth draw the line of mans understanding from this computing faculty of his soule, affirming that therefore he excells all creatures in wisdome, because he can account."[17]

Furthermore, a man's reason actually depended on his ability to use numbers. Bulwer went on to "account such for idiots and halfe-sould men who cannot tell to the

[15] While early modern authors almost always used the term "man" as opposed to "human," I have found no evidence that they believed women incapable of performing the same mathematical feats as men. Surviving account-books and almanacs demonstrate that at least some women performed bookkeeping for their households. In 1686 the Royal Society in Dublin examined the case of an eleven-year-old girl who "understands all Arithmetick, and Algebra, Trigonometrie, and the use of the Globes," and determined that there was nothing "extraordinary in her natare to Mathematick: but doe impute all to her timely earlie education." Bodl., MS Aubrey 10, ff. 10r, 29v. For more on early modern education and gender, see Chapter Four.

[16] Recorde, *The Ground of Artes*, _6r. This is not true for all animals, as some possess the ability to subitize. See Butterworth, *What Counts*, 129-144.

[17] John Bulwer, *Chirologia, or, The naturall language of the hand composed of the speaking motions, and discoursing gestures thereof: whereunto is added Chironomia, or, The art of manuall rhetoricke.* (London: Thomas Harper, 1644), 185.

native number of their *Fingers*."[18] Judge and legal writer Sir Anthony Fitzherbert also defined the inability to comprehend numbers as a standard by which escheators and sheriffs could determine natural idiocy.

> He who shall be said to be a Sot and Idiot from his birth, is such a person, who cannot accompt or number twenty pence... so as it may appear, that he hath no understanding of reason what shall be for his profit, or what for his loss: But if he have such understanding, that he know and understand his letters, and to read by teaching or information of another man, then it seemeth he is not a Sot, nor a natural Idiot.[19]

Thus Fitzherbert made a crucial distinction between the ability to read and the ability to count. Literacy was a learned skill, something that could only be acquired through the assistance of some teacher. Literacy could then constitute sufficient proof of mental competency, as only a man of intelligence could acquire that skill. By contrast, the ability to count was something that every reasonable man should possess. An inability to count constituted sufficient proof of mental incompetency, as opposed to mere lack of education. A man who could not count to twenty must be an "Idiot from his birth" and naturally deficit in some mental facility common to the rest of mankind.[20]

Recorde, Bulwer, and Fitzherbert all made several basic assumptions about the nature of man's knowledge of number that are worth examining in detail before attempting to construct an early modern definition of numeracy. First, they took for granted that there exist spoken number words with which every English speaker should be familiar. Modern neuropsychology has shown the so-called "mathematical module" in

[18] Bulwer, *Chirologia*, 185.

[19] Anthony Fitz-herbert, *The New Natura Brevium, Of the most Reverend Judge Mr. Anthony Fitz-Herbert* (London: W. Lee, M. Walbank, D. Pakeman, and G. Bedett, 1652), 583. This work was first printed in Latin circa 1534 and went through almost two dozen reprints in the sixteenth and seventeenth centuries.

[20] For a modern analysis of inborn human abilities with respect to numbers, see neuropsychologist Brian Butterworth's *What Counts: How Every Brain is Hardwired for Math* (New York: The Free Press, 1999).

the brain is actually distinct from language facilities. The early modern link between the mental concept of numbers and number words is thus cultural, rather than biological. However, despite the theoretical potential for number concepts without number words, all known languages have at least a few number words and most, like English, have an extensive and comprehensive number vocabulary.[21]

Second, these authors all assumed that number words are distinct from all other words in the English language. Someone learning English would not be able to repurpose an existing word for counting, but rather must learn the number words separately.[22] Thus learning a number word in English requires the learner not just to memorize the word and its pronunciation, but also to recognize the existence of an abstract quantity indicated by that word.[23] This is not true of every language. The Foi, Oksapmin, Imbonggu, Kewa, Daribi, and Paiela – all of Papua New Guinea – count using body-part names, while the Iqwaye count using a combination of number words and body-part names.[24] Closer to home, Bulwer's sign language in the *Chirologia* does not

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[21] The closest thing to a counterexample can be found in the Aranda, a desert people in Australia, who have number words only for *one*, *two*, and *three*. For larger numbers they have a word meaning *this many, as many as indicated*, which is accompanied by drawing the appropriate number of lines in the sand. Butterworth, *What Counts*, 50, 154-5.

[22] English does have words with both numerical and non-numerical meanings. For example, *gross* can mean the quantity *one hundred and forty four* – that is, twelve twelves, an important number in base twelve systems of arithmetic. The word *gross* also has a host of associated definitions, including large, easy to understand, and the entirety of some group. An even greater range of definitions can be found for *brace*, which can describe a piece of armor, part of a bridge, or a type of fastening device but is also used to mean *two* of something. However none of these words are in the main counting sequence; we say, "one, two, three," not "one, brace, three." *OED*, s.v.v. "gross, a. and n.[4]" "brace, n.[2]"

[23] Paul Sillitoe, ed. *Local Science vs. Global Science: Approaches to Indigenous Knowledge in International Development* (New York: Berghahn Books, 2007), 265. Calvin C. Clawson, *The Mathematical Traveler: Exploring the Grand History of Numbers* (New York: Plenum Press, 1994), 28.

[24] Butterworth, *What Counts*, 52. Sillitoe, *Local Science*, 263-4.

have separate number gestures, instead creating a one-to-one correspondence between numbers and the letters of the alphabet.[25]

The assumptions Recorde, Bulwer, and Fitzherbert made differed in one regard: the extent of man's natural ability to string together number words in a given sequence. Recorde only explicitly referenced the ability to differentiate one and more-than-one, though he strongly implied the ability to count an unspecified number of objects. This demonstrated an understanding of the associated quantities by creating a one-to-one relationship between number words and physical objects.[26] Bulwer similarly required an accused idiot to count, but only to ten, the number of a man's fingers, arguing that "*Fingers* by an ordinance of nature, and the unrepealable statute of the great Arithmetician, were appointed to serve for casting counters" for mankind.[27]

In contrast, Fitzherbert picked twenty as the smallest number to which his alleged idiot must be able to count. Assuming we restrict ourselves to the natural or "counting" numbers, one through nineteen form the complete set of lexical (one through ten) and irregularly formed (eleven through nineteen) number words in English. Beginning with twenty, the rest of the English number words are syntactical, formed by a regular combination of a power of ten and a number less than ten – e.g, twenty-one is two-ten and one; fifty-seven is five-ten and seven; eighty is eight-ten and an implied zero. The syntax grows more complicated by the addition of hundreds, thousands, tens of

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[25] Bulwer, *Chirologia*, 188-9.

[26] For modern English speakers, children as young as three-and-a-half are generally able to recognize the last word in a counting sequence as the number of objects that have been counted. Between the ages of four and six, children begin to understand the irrelevance of order in counting a collection, as well as learn to ignore perceptual clues such as object spacing while counting a collection of objects. Butterworth estimates that a little over 3% of children in any given population will be born with dyscalculia, "a severe inner inability to deal with numbers normally." He compares dyscalculia to dyslexia, both of which may be at least partially compensated for. Butterworth, *What Counts*, 110-5, 250.

[27] Bulwer, *Chirologia*, 185.

thousands, etc. but the numbers remain syntactical in nature.[28] Thus Fitzherbert required his accused idiot to demonstrate a facility with all the non-syntactical numbers, but left unspecified whether mastering the syntax of larger numbers requires an equivalent intellect to mastering the symbols and syntax of written language.

The ability to learn English number words, with their implicit addition and syntax, was thus considered inherent in every mentally competent human being and something every child in England should learn without much, if any, deliberate instruction.[29] If this is used as the marker for an early modern "knowledge of number," then the population of England was almost universally numerate. However, the English number words were only one way of symbolizing numbers and such a definition excludes the other early modern symbolic systems. It will therefore be more analytically useful to consider the knowledge of English number words as a lower bound for a range of learned numerical skills whose acquisition might indicate a "knowledge of number." In particular, these skills include other methods of enumeration and calculation that had to be learned separately from the English language, through formal or informal training in the symbolic system peculiar to each method.[30]

One way to accommodate this multiplicity of systems would be to define early modern English numeracy as knowledge of a symbolic system for representing and manipulating numbers that is distinct from the English number words. However this definition creates new analytic issues by lumping together a wide variety of symbolic

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[28] James R. Hurford, *Language and Number: The Emergence of a Cognitive System* (New York: Basil Blackwell Inc, 1987).

[29] Modern English-speaking children also develop these initial number skills before they begin school, without much in the way of instruction from their parents. Butterworth, *What Counts*, 288. Dehaene, *The Number Sense,* 119-124.

[30] Some of these symbolic systems enabled calculation, while others were geared towards enumeration only – a point which will be discussed at length in Chapter Three.

systems and obscuring the very real differences between them. Some symbolic systems were performative, such as hand gestures. They required no physical aids but were also inextricably bound up in the present and incapable of being used to communicate over physical or chronological distances. Other symbolic systems were based on the manipulation of objects, like tally sticks. The materiality of these objects also created the possibility of an object also being invested with a host of both numerical and non-numerical information. Still others were written, like Roman numerals. Mastery of these systems required access to a specific set of tools as well as prerequisite skills associated with literacy. Furthermore, it would be ahistorical to privilege any one symbolic system over the rest, as there was no dominant system during the early modern era and several of these systems were, in practice, codependent with other systems.[31]

It will therefore be most useful to treat each symbolic system as its own type of numeracy – e.g. hand gesture numeracy, tally stick numeracy, etc. – and to recognize the existence of early modern English *numeracies*, plural, within the overarching formula of early modern English numeracy, singular. This multiplicity gives us the freedom to analyze the differences between various "knowledges of number" and the ways in which these differences shape how people chose to use each symbolic system. As will be argued in the next chapter, such choices were not neutral decisions but rather had a profound influence on what, and how, information could be conveyed. This formulation also highlights one of the most important consequences of learning any symbolic number

[31] Tally sticks, for example, remained in use throughout the entire early modern period, but were primarily confined to use in the court of the Exchequer. Counting boards and Roman numerals began as the dominant calculating and enumerating symbolic systems, respectively, but by the beginning of the eighteenth century these had given way to Arabic numerals in most – but not all – circumstances.

system: the ability to transcode, or translate, between abstract ideas, words, and numerical symbols.

Culture, Mathematics, and the Scientific Revolution

This dissertation is, at heart, a work of cultural history. It explores the place of mathematical knowledge in the culture of early modern England, where culture is taken in an anthropological sense to mean "a system of shared meanings, attitudes and values, and the symbolic forms (performances, artifacts) in which they are expressed or embodied."[32] This is not the culture of early modern mathematicians, whose knowledge of numbers exceeded that of ordinary men and woman, and thus cannot be considered representative. Instead, it is the culture of the general English population – what might be termed popular culture in its pluralistic, rather than binary, sense.

The concept of a popular culture originated with the work of Peter Burke in the late 1970s. While he initially defined *popular culture* in a purely negative fashion – "unofficial culture, the culture of the non-elite, the 'subordinate classes'"[33] – he later refined his definition to correspond with the little tradition model of social anthropologist Robert Redfield. According to Redfield, there are two cultural traditions, a great and a little. The great tradition encompasses everything taught in centers of learning such as schools and temples, while the little tradition is everything else. In the case of early modern Europe, the little tradition is generally considered to include folksongs, folktales, devotional images, mystery places, broadsides, and chapbooks. While the culture of the

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[32] Peter Burke, *Popular Culture in Early Modern Europe* (New York: New York Press, 1978), xi.

[33] Burke, *Popular Culture*, xi.

common people corresponded to the little tradition, the elites participated in both the great and the little tradition.[34] In this slightly altered binary formulation, popular culture might still be called the culture of the non-elites, but the elites were not barred from participating in it, particularly during their childhood before they completed their education.

In either formulation, access to education creates the boundary between popular and elite. During the early modern period, this access was predicated upon the skill of literacy – no student could attend the great universities, inns of court, or even grammar schools without the ability to read. Even the less-formal acquisition of knowledge through the new and proliferating medium of printed books seemed to require at least rudimentary literary skills. Literacy was thus reframed to be not just *a* technology of knowledge, but *the* technology of knowledge, whose acquisition or lack thereof could serve as a de facto boundary between the early modern popular and elite. Questions about the extent and spread of literacy thus took on new prominence as historians such as David Cressy and Jonathan Barry sought to map the boundary between the oral culture of the illiterate populace and the literate culture of the elites, and tried to analyze how it changed over time.[35]

However the stark binaries of oral versus literate and popular versus elite were swiftly undermined by the work of other historians. In his seminal article, "The Meaning

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[34] Burke, *Popular Culture*, 24-8.

[35] Cressy argued that overall male literacy rose from 10% in 1500 to 30% by 1600 and 50% by 1700, with female literacy rates persistently lagging 10-20% behind male literacy. Broken down by social rank, Cressy found almost universal literacy among the elites, increasing literacy levels among tradesmen and craftsmen, and persistent illiteracy among husbandmen and the poor. David Cressy, *Literacy and the Social Order: Reading and Writing in Tudor and Stuart England* (Cambridge: Cambridge University Press, 1980), 142-56, 177. Jonathan Barry's study of Bristol put the rate of adult male literacy in the city at 65% by the 1660s. Jonathan Barry, "Popular Culture in Seventeenth-Century Bristol," in *Popular Culture in Seventeenth-Century England*, edited by Barry Reay (London: Croom Helm, 1985): 62.

of Literacy in Early Modern England," Keith Thomas demonstrated that there actually existed varying degrees of literacy, including the different abilities to read printed black letter fonts, printed roman fonts, and scribal hands. Furthermore, early modern definitions of literacy did not always refer to the ability to read English. Rather, literacy was also defined with respect to the ability to read Latin and Greek, languages that were acquired through the English grammar schools.[36] Thomas also clarified the early modern distinction between the related, but separate, skills of reading and writing. This distinction is particularly crucial given that a common method for estimating literacy rates is signature-counting, which measures the signer's ability to write rather than read. These skills were taught consecutively, rather than concurrently, creating a situation in which a significant percentage of students might drop out of petty schools after learning to read but before learning to write.[37] Thus, while signature-counting can provide illuminating information about trends in writing ability, it is less useful as a method to determine who could – or could not – access knowledge conveyed by the written word.[38]

Other historians studied the movement of ideas between oral and written media, and argued that even complete illiteracy did not form an impenetrable barrier to the acquisition of knowledge in the sixteenth and seventeenth century. In his literacy study,

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[36] "'The word illiterate in its common acceptation,' declared Lord Chesterfield in 1748, 'means a man who is ignorant of those two languages [Latin and Greek]." By this definition of literacy most twenty-first century college students are illiterate. Thomas, "The Meaning of Literacy," 101.

[37] This was especially likely to be true for poorer boys, as reading was taught at a young age whereas writing was taught to boys who were old enough to earn a meaningful wage. Margaret Spufford, *Small Books and Pleasant Histories: Popular Fiction and Its Readership in Seventeenth Century England* (Athens, GA: University of Georgia Press, 1981), 27.

[38] Even historians who rely on signature-counting note have noted its problematic nature. Burke claimed that the two skills were correlated and reading skills closely paralleled writing skills. Burke, *Popular Culture,* 251. Cressy conceded that signature-counting probably underestimated the "number able to read with hesitation" or only enough to claim benefit of clergy, but argued that signature-counting "indicates with some accuracy the number who were functionally literate by the standards of the seventeenth century." Cressy, *Literacy*, 17, 55.

Cressy noted the interdependence of print and orality, pointing out that "every [illiterate] villager had in his parish clergyman as well as in his literate neighbors a bridge to events and ideas beyond his immediate horizon."[39] Margaret Spufford argued that cheap print and oral transmission were inextricably intertwined, with the demand for familiar tales in print shaping printed material, and the printed material itself shaping and influencing the oral tradition in a synthetic fashion.[40] Steven Pincus explained London coffeehouses were locations designed to support both oral and literate communication. People "could gather news or political gossip and criticize or celebrate the actions of the government" as well as "read the most recent newspaper, newsletter, pamphlet, or manuscript poetry collections."[41] Most recently, Adam Fox studied proverbial wisdom, historical stories, libels, and rumors, and concluded that "the written word tended to augment the spoken, reinventing it and making it anew, propagating its concerns, heightening its exposure, and ensuring its continued vitality, albeit sometimes in different forms."[42]

While the written word was thus a restrictable technology of knowledge, the information conveyed by the written word was socially pervasive, freely passing back and forth between the written and the oral. Indeed, the very act of reading often involved oral communication – reading out loud – as opposed to the silent, solitary reading most common in the twenty-first century.[43] Literacy might still determine access to elite educational institutions like universities, while the dual growth of both literacy and

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[39] Cressy, *Literacy*, 14.

[40] Spufford, *Small Books*, 227.

[41] Steve Pincus, "'Coffee Politicians Does Create': Coffeehouses and Restoration Political Culture," *The Journal of Modern History* 67, no. 4 (Dec. 1995), 822, 833.

[42] Adam Fox, *Oral and Literate Culture in England 1500-1700* (Oxford: Clarendon, 2000), 5.

[43] Bernard Capp, "Popular Literature," in *Popular Culture in Seventeenth-Century England,* edited by Barry Reay (London: Croom Helm, 1985), 202-3.

printing formed the basis for a new, literate and elite culture, but the literate was still inextricably intertwined with an older, oral culture.

Where, then, does this leave the idea of popular culture? Tessa Watt, in her study of popular piety, criticized Burke's original, binary formulations of popular culture and argued that "we must think of popular culture as a 'total, unified culture.'"[44] She moved away from discussions of elites, education, and literacy, and instead defined popular culture as "'shared values', 'widespread attitudes' or 'commonplace mentalities.'" Significantly, Watt pointed out that this culture was "not a homogeneous, articulated set of doctrines, but a mosaic made up of changing and often contradictory fragments."[45] Using this formulation, we can escape binaries and study the pluralism that existed within the overarching structure of a popular culture – a culture that consists of those practices, views, and experiences shared by and available to the majority of the population.

Commonplace knowledge of and shared attitudes towards numbers existed within this framework. Such knowledge was extensive. As argued above, a rudimentary understanding of numbers is actually inborn in humans and early modern authors expected all mentally competent men and women to naturally acquire the ability to count as part of learning the English language. The multiplicity of early modern numeracies further supported the universality of numbers, as there was no dominant form of numeracy. Transcoding between symbolic systems was a matter of course and a lack of knowledge of any particular symbolic system did not imply a lack of numerical knowledge in general. This multiplicity of systems combined to create a unified culture of numeracy. While some of these systems were written, and thus required at least a

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[44] Tessa Watt, *Cheap Print and Popular Piety* (New York: Cambridge University Press, 1991), 2.

[45] Watt, *Cheap Print*, 3.

passing acquaintance with the same physical tools as literacy – pens and pencils, paper and parchment – the performative and object-based systems were not dependent upon any prerequisite skills.[46] Unlike literacy, which was a restrictable technology of knowledge with high entry costs, knowledge of numbers was both socially pervasive and an integral part of English popular culture.

While this dissertation is formulated in terms of cultural history, its subject matter – numbers and mathematics – is also intrinsically bound up in another historiographical tradition, that of the history of science. In particular, mathematics and mathematical modes of thinking were central to the original conception of the early modern scientific revolution. In the middle of the twentieth century, historians of science such as Alexander Koyré, Herbert Butterfield, and Rupert Hall argued for the existence of a radical break between medieval and modern science – a scientific revolution.[47] This break was characterized by a change in ways of thinking about and understanding the world, a change that was most evident in the mathematization of natural philosophy.

Not all historians of science concurred that there was a historical moment that could be called a scientific revolution. A minority instead followed in the tradition of Pierre Duhem, stressing the continuities between medieval and early modern science.[48] Other historians encountered difficulties with the idea of *a* scientific revolution when they moved beyond the physical sciences of astronomy, physics, and mathematics.

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[46] For more on the various types of early modern numeracies, see Chapter Two.

[47] Alexander Koyré, *From the Closed World to the Infinite Universe* (Baltimore: Johns Hopkins Press, 1957); Herbert Butterfield, *The Origins of Modern Science, 1300-1800* (New York: Macmillan Co., 1951); A. Rupert Hall, *The Scientific Revolution, 1500-1800: The Formation of the Modern Scientific Attitude* (New York: Longmans, Green and Company, 1954).

[48] Pierre Duhem, *Le Système Du Monde: Histoire Des Doctrines Cosmologiques de Platon à Copernic* (Paris: A. Hermann, 1913). A.C. Crombie, *Robert Grosseteste and the Origins of Experimental Science, 1100-1700* (Oxford: Clarendon Press, 1953).

Chemistry and the life-sciences cannot easily be reconciled to the original, mathematically-driven narrative of change, and arguments for the existence of a "delayed," eighteenth-century chemical revolution undermined the scientific revolution's original formulation as a discrete historical event. Some historians even began to doubt that there was an early modern practice that could be called science in the first place.[49] As a consequence, a more multiplistic and nuanced view of science – and any potential revolution of such science – began to emerge. Early modern science was not a singular entity but rather "a diverse array of cultural practices aimed at understanding, explaining, and controlling the natural world, each with different characteristics and each experiencing different modes of change."[50]

In part, this multiplistic view of the scientific revolution also stemmed from new historical approaches arising from within the history of science community. From the 1950s through the 1980s, the history of science community was split over the importance of "internal" versus "external" factors in the development of scientific ideas. The "internalist" historians traditionally focused on tracing the intellectual lineage of people and ideas that are significant to present-day science. Their studies had a *telos* and can be generally characterized as a search to understand the origins of modern science.[51] In contrast, "externalist" historians sought to explore factors "external" to science, something which was often conflated with "social" factors – i.e. factors pertaining to

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[49] For an excellent discussion of the definition of early modern "science," see Deborah Harkness, *The Jewel House,* xv-xviii.

[50] Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996), 3.

[51] Such present-oriented, teleological studies have acquired a negative reputation, particularly in the field of early modern English history where they have been decried as "Whiggish" narratives, that is, having a Whig political agenda. However this is a legitimate historical approach within the history of science, so long as such studies are understood and acknowledged to be limited in scope, and do not claim to be representing widespread historical practices.

society as a whole.[52] While most historians soon embraced "eclecticism" – the combination of both internal and external factors to whatever degree the historian desired – the debate did lead to a re-evaluation and expansion of the disciplinary boundaries of the history of science. Historians such as Mario Biagioli began to historicize science by embedding scientists and their ideas into historical cultures.[53] Part of understanding scientists in their cultural contexts included studying their well-known successes alongside their lesser-known activities to help construct a more rounded view of historical scientific practices.[54] This interest also extended to the study of historical figures and ideas that failed to be included in the canon of scientific "ancestors," as well as more general studies of scientific culture.[55]

This last approach most closely approximates the goals of this dissertation: to analyze numerical and mathematical practices in sixteenth- and seventeenth-century English popular culture. These practices were multiplistic and existed in a dynamic equilibrium, which gradually shifted over the course of the late sixteenth- and seventeenth-century. These changes encouraged the people of early modern England to adopt new, mathematical ways of interpreting the world around them. But this was not a

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[52] For more on the externalist-internalist debate, see Steven Shapin, "Discipline and Bounding: The History and Sociology of Science as Seen through the Externalism-Internalism Debate," *History of Science* 30 (1992): 333-69.

[53] Mario Biagioli, *Galileo Courtier* (Chicago: University of Chicago Press, 1993).

[54] See, for example, Betty Jo Teeter Dobbs, *The Janus Face of Genius: the Role of Alchemy in Newton's Thought* (Cambridge: Cambridge University Press, 1991) and Lawrence Principe, *The Aspiring Adept: Robert Boyle and his Alchemical Quest* (Princeton: Princeton University Press, 1998).

[55] See for example Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1994); Mary Poovey, *A History of the Modern Fact: Problems of Knowledge in the Sciences of Wealth and Society* (Chicago: University of Chicago Press, 1998); and Barbara Shapiro, *A Culture of Fact: England, 1550-1720* (Ithaca: Cornell University Press, 2000).

transformation in the natural philosophy practiced by scientists. It was a transformation in the everyday knowledge of ordinary English men and women.

Methods and Structure

In keeping with this dissertation's cultural history approach toward numbers, my methodology includes both textual analysis and techniques derived from material culture studies. I have analyzed a wide range of sources, from manuscripts and printed books to carved sticks and stones. All of these sources can be generally categorized as artifacts – physical objects or, more simply, *things*. By acknowledging the materiality of the written word, and treating writings as both texts and artifacts, the historian can apply the methods of material culture to provide greater depth and understanding to textual analysis. Conversely, bridging the divide between textual and material enables the historian to read artifacts as texts that speak to the culture that created them.

Academics come to material culture studies from a wide variety of fields – from archeology and anthropology to art history and cultural history. As a consequence, within material culture studies itself there are a similarly wide variety of methods for studying historical artifacts. Bernard Herman, in his *Stolen House*, divides these methods into two broad categories: object-centered and object-driven. Methods in the first category "utilize material and documentary evidence to explain the meaning of the object in and of itself." Methods in the latter category "take the evidence and questions generated by material culture and extend them into a broader inquiry aimed at the interpretation of society and culture."[56] In other words, they see artifacts "as evidence of other complex social relationships" and seek to reconstruct those relationships through the process of thick description popularized by anthropologist Clifford Geertz.[57]

Alternatively, historian Giorgio Riello constructs a tripartite division of material culture methods: history *from* things, history *of* things, and history *and* things. History *from* things is roughly analogous to Herman's object-driven category. It tends to appeal most to historians and treats artifacts as primary sources, "raw materials for the discipline of history and the interpretation of the past."[58] However, Riello argues, the majority of material culture studies focus instead on something akin to Herman's object-centered category: the history *of* things, in which the object itself is the subject of study and not a source used to illuminate some other subject. One example of this approach can be found in the history of consumption, which focuses on the "very material objects that were produced, bought and consumed to satisfy people's physical, but also relational, psychological and moral needs."[59] If history *from* things gives primacy to historical narrative, while history *of* things gives primacy to artifacts, then history *and* things seeks to give equal weight to both.[60] Riello argues that the juxtaposition of narrative and artifacts can be particularly useful for overcoming the positivist biases in historical

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[56] Bernard L. Herman, *The Stolen House* (Charlottesville: University of Virginia Press, 1992), 11.

[57] Herman, *The Stolen House*, 4, 7. For more on "thick description," see Clifford Geertz, *Interpretation of Cultures: Selected Essays* (New York: Basic Books, 1973).

[58] Giorgio Riello, "Things that Shape History: Material Culture and Historical Narratives," in *History and Material Culture: A Student's Guide to Approaching Alternative Sources*, edited by Karen Harvey, (New York: Routledge, Taylor & Francis Group, 2009), 25.

[59] Riello, "Things that Shape History," 32.

[60] Riello's case study for illustrating the method of history *and* things is an image of an "Aerial Steam Carriage," which was designed in the 1840s, during the Industrial Revolution, but never became a working prototype. Riello, "Things that Shape History," 41.

research, enabling the historian to "recast" traditional narratives by using negative artifact evidence to illuminate the holes in historical narratives.[61]

As a whole, this dissertation most closely adheres to history *from* things, or an object-driven model. I examine objects such as jetons and tally sticks in order to discover what they can tell us about the state of English numerical practices and how these objects' material characteristics either assisted or impeded their common historical uses. In doing so, I pay particular attention to material characteristics that were not intrinsically bound up in conveying numerical information – what I will refer to as "extranumerary" characteristics.

I also examine books and broadsides as artifacts, looking at material properties such as page size, cover choices, sale price, marginalia, and changes between editions.[62] Because of the persistence of physical objects over time, I can trace the history of

[61] A more mathematical example of negative evidence may be found in a 1700 edition of *Cocker's Arithmetick*, in which an annotator copied several passages:

"What has become of Cocker's Arithmetic? It is not in the British Museum, and with the exception of a mutilated copy of the thirty-seventh edition (1720) we never found it in London, either in a shop or on a stall."

Companion to British Almanac 1836.

"Cocker's Arithmetic has now become almost extinct."

The Parthenon.

"Query – what has become of Cocker's Arithmetick?"

Mirror

These passages lament the loss of a physical object – old editions of a popular arithmetic textbook. In doing so, they draw attention to negative evidence, that is, books that did not survive the passage of time. SHL, [DeM] L.1 [Cocker] SSR.1700, 3r.

[62] For more on the history of the physical book in early modern England, see Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago: University of Chicago Press, 1998). For recent scholarship on marginalia and the use of specific books, see William Sherman, *Used Books: Marking Readers in Renaissance England* (Philadelphia: University of Pennsylvania Press, 2008) and Owen Gingerich, *The Book Nobody Read: Chasing the Revolutions of Nicolaus Copernicus* (New York: Walker & Company, 2004).

individual books over decades or even centuries of use.[63] For the most part, I use these artifacts to answer questions about early modern culture – particularly questions related to reader access to and interaction with printed books, and what that reveals about their own understandings of numbers and mathematics – rather than questions relating to the history of the book, per se.

Structurally, this dissertation is divided into two parts. The first part, consisting of Chapters Two through Four, focuses explicitly on symbolic and education changes related to early modern numeracy, while the remaining chapters focus on the use of numbers to understand the world. Of the chapters in the first part, Chapters Two and Three, in particular, utilize methods of material culture studies that are more in line with Riello's hybrid of history *and* things. They focus on the materiality of early modern numeracies and analyze the meaning of mathematical artifacts both as material objects and as evidence of cultural practices. These chapters also examine the increasingly widespread adoption of Arabic numerals – which is often portrayed as a straightforward example of inevitable mathematical "progress" – by situating them in their historical context: that of multiplistic early modern numeracies.

Chapter Two examines the universality, multiplicity, and materiality of early modern numeracies, with particular attention paid to Arabic numerals. I argue that number symbols were not disembodied signifiers of quantity, but rather material artifacts that functioned as signifiers. These artifacts functioned differently, according to their

[63] While this dissertation limits itself to discussing the sixteenth- through eighteenth-century use of these books, I would be remiss in not pointing out that their history continues into the present. Consider, for example, a 16th-century copy of Robert Recorde's *Whetstone of Witte* that resides in the Senate House Library at the University of London. This book was collected in the nineteenth century by Augustus DeMorgan, one of the earliest historians of arithmetic, and subsequently shredded in the World War Two bombing of London. Ironically, it is still possible to see DeMorgan's January 1863 annotation declaring, "This copy is perfect." SHL, [DeM] L.2 [Record] SSR, f. 4r.

respective material forms. Only numerical information could be transcoded between symbolic systems. As a consequence, the decision to use a symbolic system in any particular situation was predicated upon the extranumerary characteristics associated with the material form of each system.

Chapter Three further explores the relationship between the material form and preferred functions of each symbolic system. I argue that the extranumerary characteristic of *permanence* informed decisions to trust a system and use a system for recording or calculation. Early modern men and women ascribed greater trustworthiness to symbolic systems that were not easily altered, and used those systems in situations where they wished to record numerical information. They reserved systems that were easily altered for calculating, which was considered a separate mathematical operation. Unlike other systems, Arabic numerals had the potential to unify the functions of recording and calculation, by yoking both to the skill of writing. However, perceptions of permanence and trustworthiness were still key factors in early modern people's decisions whether or not to use Arabic numerals.

Just as there were multiple symbolic systems in early modern England, there were multiple ways to acquire a knowledge of these symbolic systems. Chapter Four investigates the changing ways in which an early modern student could learn the various "mathematical arts and sciences," particularly arithmetic based on the Arabic numeral symbolic system. I argue that the sixteenth-century rise of the printing press facilitated the production of arithmetical textbooks, which helped popularize Arabic numeral arithmetic and encouraged the growing association of mathematics with writing. Close ties existed between textbook authors and schoolteachers, who together advocated for the utility of mathematical learning, for both intuitive and non-intuitive practical purposes.

Chapter Four also serves as a bridge to the second part of this dissertation, which examines the changing ways seventeenth-century men and women used numbers to understand the world. Chapters Five through Seven focus on three specific uses of numbers as case studies for the larger changes happening in English popular culture. In particular, I argue that their world grew increasingly mathematical in nature, while numbers became a valid tool for analyzing abstract phenomena such as time and chance, or even the English population itself.

In Chapter Five, I argue that early modern people used numbers in an attempt to locate the events of their lives chronologically, with respect to the past and present. Time was already highly quantified in the sixteenth century; chronological units were the first place where most early modern people chose to utilize Arabic numerals. However, I argue that partial calendar reform, the rise of the yearly almanac, and the geographical relativity of global time, all contributed to an increasing awareness of time as a numerical construct. By the mid-eighteenth century, this awareness facilitated the uncontentious adoption of the Gregorian calendar.

In Chapter Six, I explore early modern conceptions of chance and its relationship to God's providence, in order to argue that early modern people used numbers in an attempt to cope with the uncertainties of the future. I demonstrate that gambling was a socially pervasive activity in the sixteenth and seventeenth century, enjoyed by men, women, and children from all stations of life. I argue that the late sixteenth century saw the gradual adoption of a mathematized concept of gambling odds. This new idea of odds was subsequently applied to other areas of uncertainty and used as a numerical method for predicting future events. During the seventeenth century plague epidemics, numbers were used to predict and avert risk, and by the late seventeenth century, quantified risk and risk aversion strategies led to the widespread creation of insurance companies. While the mathematization of chance implied a quantifiable world based on natural laws, these conceptions of chance coexisted with, rather than replaced, providential understandings of chance and the future.

In Chapter Seven, I shift focus to look at how changes in mathematical knowledge affected the traditional government practices such as taxation and censuses – colloquially known as "numbering" the people. Over the course of the seventeenth century, people increasingly analyzed demographic data collected from a variety of government sources to support a wide range of arguments, transforming censuses from a tool of government policymaking to a more general method for using numbers to understand the English population. Lastly, I draw over-arching conclusions about the general growth of mathematized ways of thinking about the world and how they came to exist side-by-side with earlier worldviews.

Conclusions

Although terms such as *numeracy* and *numerate* are anachronistic with respect to the sixteenth and seventeenth centuries, the people of early modern England had an active interest in both numbers and what constituted a "knowledge of numbers." There existed a host of early modern symbolic systems for representing numbers, ranging from performative to object-based to literate, and knowledge of any one of these systems could constitute a knowledge of numbers. In part because of the multiplistic nature of early modern numeracy, numbers were a socially pervasive technology of knowledge, available to any mentally competent English man or woman. Numbers – and mathematics in general – thus constituted an integral part of the everyday fabric of early modern life.

Commonplace numerical knowledge and practices also underwent a transformation during the early modern period. The middle of the sixteenth century saw the invention of a new genre of printed books – the vernacular arithmetic textbook – that did much to popularize the Arabic numeral symbolic system in the late sixteenth and early seventeenth centuries. These changes encouraged new ways of experiencing the natural world, as ordinary English men and women began to consider numbers as a tool for interpreting the world around them. Over the course of the late sixteenth and seventeenth centuries, numbers were transformed from the tools of clerks and geometricians to the building blocks of God's Creation and the foundation of ordinary men and women's efforts to understand their world.

Chapter Two

"The Dyuers Wittes of Man"[1]
The Multiplicity and Materiality of Numbers

In 1607, an entry in the Earl of Northumberland's accounts notes that 20s was paid out "to one that taught the accountant, Mr. Fotherley, the art of arithmetic."[2] At first glance, this entry appears nonsensical. As an accountant, Mr. Fotherley must have already been using at least the first two parts of arithmetic – numeration and addition – to keep the earl's account books.[3] The multiplicity of early modern numeracies stands at the root of this terminological confusion. Given that Mr. Fotherley was keeping written account books for an earl, he must have already been familiar with several different symbolic systems – particularly those used by the Exchequer and local merchants. This entry thus references the hiring of a tutor, not to teach the accountant the basic arithmetical operations necessary for his job, but rather to teach the accountant a new symbolic system of numbers, in addition to the systems with which he was already familiar. Given that this occurred at the turn of the seventeenth century, the tutor was most likely instructing him in the still relatively new Arabic numeral arithmetic.[4]

Early modern English men and women utilized a wide range of symbolic systems for arithmetic, including but by no means limited to the written systems of accountants

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[1] Robert Recorde, *The Ground of Artes Teachyng the Worke and Practise of Arithmetike* (London: R. Wolfe, 1543), T2r.

[2] *Historical MSS Commission Reports*, vi. 229" as cited in Keith Thomas, "Numeracy in Early Modern England: The Prothero Lecture, Read 2 July 1986," in *Transactions of the Royal Historical Society*, 5th Series, no. 37 (London: The Royal Historical Society, 1987), 120.

[3] Early modern English arithmetic textbooks and mathematical tutors' advertisements divided the subject of arithmetic into parts, the first five of which were numeration, addition, subtraction, multiplication and division. For more on this, see Chapter Four.

[4] More recently these numbers have also been called "Hindu-Arabic numerals", to reflect their transmission from India, through the Arabic world, then to the Latin west. To maintain terminological continuity with my sources, I will use the older name of "Arabic numerals."

such as Mr. Fotherley. In his 1543 arithmetic textbook, Robert Recorde covers three systems in detail, then informs his readers that he cannot possibly teach them every system they might encounter. They must learn other systems by observing "the workying of eche sorte: for the dyuers wittes of men haue inuented dyuers and sundry wayes almost vnnumerable."[5] Given this variety of systems, Recorde saw no reason why those with little other learning – particularly "them that can not write and rede"[6] – shouldn't be able to acquire knowledge of a symbolic system and use arithmetic in their day-to-day lives. Two of the three systems taught in his book required no literacy at all and could easily be passed on from Recorde's literate reader to any number of less literate men, women or children.[7] While different systems catered to those with varying levels of literacy, taken together they served the entire population of early modern England.

As mentioned briefly in the previous chapter, one of the most important consequences of learning multiple symbolic systems is the strengthening of the ability to transcode – that is, translate back and forth between the abstract idea of a specific number, its associated number word, and the various symbols used to represent that number. Humans naturally transcode when they associate number words with abstract concepts of number, and learning multiple symbolic systems further develops that ability

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[5] Recorde, *The Ground of Artes*, T2r. Over 100 structurally distinct symbolic systems are known to have been used between 3500 BC and the present day. Many of these systems coexisted in time and space; the historical peak of system diversity occurred around the turn of the sixteenth century. Stephen Chrisomalis, *Numerical Notation: A Comparative History* (Cambridge: Cambridge University Press, 2010), 425.

[6] Recorde, *The Ground of Artes*, Q2v.

[7] For example, a merchant or tradesman passing on knowledge to an apprentice or other children. As reading, writing and arithmetic were not yet seen as intertwined, there would not necessarily be a reason to wait until a child had mastered writing to start the child on arithmetic.

by associating even more symbols with each number.[8] These symbols are not only quantitative signifiers but also *artifacts* that signify quantity. In early modern England, the material characteristics of these artifacts helped shape the situations in which they were deployed, however material characteristics could not be transcoded alongside abstract quantitative ideas. Transcoding thus enabled the coexistence of multiple symbolic systems, but allowed only a limited amount of strictly quantitative data to be transferred from one system to another.

The main symbolic systems employed during the sixteenth and seventeenth centuries can be roughly divided into three categories based on their most prominent material characteristics: performative, object-based, and written. Performative systems were the only systems that did not require the assistance of physical objects and thus could be employed under any circumstances. Object-based systems involved the alteration or manipulation of physical objects, which were invested with numerical meaning that persisted across time and space. Written systems also involved the assistance of physical objects – such as pen, ink, and parchment – but only as a means to convey numerical symbols, not as symbols themselves. These categories are analytically useful, however it is important to recognize that most systems had multiple characteristics: jeton calculations were performed, tallies often contained a written element, and both Roman and Arabic numerals were engraved on material objects. The boundaries between these categories should therefore be considered fluid rather than hard-and-fast divisions.

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[8] Because of linguistic differences, transcoding does vary from culture to culture, even when transcoding the same symbolic system. For example, an English-speaker would transcode the Roman numeral *ix* to *nine* whereas a Spanish-speaker would transcode *ix* to *nueve*.

While there existed a working balance among the multiple symbolic systems in early modern England, that balance shifted over the course of the late sixteenth and seventeenth centuries. As the population of England became increasingly literate, they also began to abandon performative and object-based symbolic systems in favor of written symbolic systems, particularly Arabic numerals. This transition was by no means straightforward, nor was it universal. The material characteristics of performative and object-based symbolic systems enabled them to remain attractive alternatives to Arabic numerals in the eighteenth century. However, by 1700, Arabic numerals had emerged as the most dominant symbolic systems in England and the new, literate standard by which numeracy might be measured.

Words and Gestures: Performative Symbolic Systems

The most universal symbolic systems in early modern England were spoken words and gestures, as they enabled people to perform enumerations and calculations without any physical aids other than their bodies. Oral numeration formed the basis of early modern numeracy and was something that all mentally competent human beings were supposed to acquire along with language. Arithmetical operations could then be performed mentally or using gestures – most commonly counting on fingers – for physical assistance. There was no stigma attached to the use of gestural arithmetic and some arithmeticians taught students to perform the relatively complicated operations of multiplication and division on their fingers. However this widespread acceptance applied only to calculation with gestures. The related practice of enumeration with gestures was not widely practiced in early modern England and was seen as a method of secretive, rather than universal, communication.

English number words formed both a universal and a necessary part of everyday speech. Robert Recorde began his arithmetic textbook, *The Ground of Artes*, with a discussion between a master and scholar that mocked the concept of speech without numbers. When the scholar complained about having to learn arithmetic, the master challenged him: "Yf nombre were so vyle a thynge, as thou dyddest esteme it, then nede it not to be vsed so moch in mens co*m*munycation. Exclude nombre and answere me to this question: Howe many yeares olde arte thou?" The scholar was only able to respond with the inarticulate sound, "Mum." The master continued to harry the scholar with unanswerable questions, "How many dayes in a weke? How many wekes in a yere? What landes hath thy father? How many men doth he kepe? How longe is it syth you came from hym to me?" He mocked the scholar's continued inability to provide a numberless answer: "So that yf nobmre wante, you answere all by mu*m*mes." Finally the scholar stopped playing by the rules and responded to a question about the distance to London with the nonsensical statement: "A poke full of plumbes." The master's point was made.[9]

Oral numeration thus served as a basis for English arithmetical knowledge. The numerical information from other symbolic systems could always be transcoded to and communicated through spoken words. Thomas Hobbes even argued that non-verbal symbolic systems were useless without this verbal reference base. Words registered human thoughts and "without words, there is no possibility of reckoning of Numbers."[10]

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[9] Recorde, *The Ground of Artes*, A2r-v.

[10] Thomas Hobbes, *Leviathan, or, The matter, forme, and power of a common wealth, ecclesiasticall and civil* (London: Andrew Crooke, 1651), 14. Some modern linguists, such as Heike Wiese, similarly argue that the concept of numbers evolved from human language: number words "do not refer to numbers, they

Educators such as grammar school master John Brinsley encouraged this codependence by requiring students to practice transcoding between oral numeration and other numerical systems. Brinsley had his scholars recite numbers "backwards and forwards, so that your scholler be able to know each of them, to call them, or name them right, and to finde them out, as the child should finde any letter which he is to learne: in a word to tell what any of these numbers stand for, or how to set downe any of them."[11]

While addition and subtraction can also be performed orally, through the process of counting-on, this does not appear to be a common early modern practice. Instead, John Hall of Richmond described children learning to add small numbers as a combination of oral and mental processes. "We finde children, one with another, making it one of the first tryals of their abilities to pose each other in mental addition of numbers," for example "having the question asked them how many two and three do make, or the like" small numbers. The child so questioned would respond by "calling into memory the figure of any three and two things so and so posited; and so, by comparing them do know what they amount unto." When children were unable to rise to the challenge, they generally resorted to a physical aid rather than counting orally to discover the answer: "they help themselves in their numeration by an outward figure, as by counting on their fingers, or the like."[12]

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serve as numbers." Heike Wiese, *Numbers, Language, and the Human Mind* (Cambridge: Cambridge University Press, 2003), 5.

[11] John Brinsley, *Lvdvs Literarivs: or, the Grammar Schoole; shewing how to proceede from the first entrance into learning, to the highest perfection required in the Grammar Schooles* (London: Felix Kyngston, 1627), 26.

[12] John Hall, *Of government and obedience as they stand directed and determined by Scripture and reason* (London: T. Newcomb, 1654), 265-6.

When mental manipulation of numbers becomes too difficult, humans naturally transition to using body parts as an aid to counting and calculation.[13] In early modern England, the body parts in question tended to be limited to hands and fingers – those being parts usually left unobscured by clothing.[14] Physician John Bulwer argued that humans finger-count by God's express design:

> we must not account as an accident, but a thing propagated from the fountaine of nature, since it is ever done and that by all Nations. For the *Fingers* by an ordinance of nature, and the unrepealable statute of the great Arithmetician, were appointed to serve for casting counters, as quicke and native digits, alwaies ready at *Hand* to assist us in our computations.[15]

Hobbes saw the origin of base five and ten arithmetical systems in finger-counting:

> there was a time when those names of number were not in use; and men were fayn to apply their fingers of one or both hands, to those things they desired to keep account of; and that thence it proceeded, that now our numerall words are but ten, in any Nation, and in some but five, and then they begin again.[16]

There were, however, variations on this method of assigning numbers to fingers. Thomas Randolph, in his poem *Vpon the losse of his little finger*, whimsically likened the

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[13] Modern children appear to pick up this behavior spontaneously, though no studies have been conducted to confirm that they reinvent finger-counting as opposed to modeling behavior they see in older children or adults. Brian Butterworth, *What Counts: How Every Brain is Hardwired for Math* (New York: The Free Press, 1999), 211.

[14] Other systems are possible. For example, the natives of the Torres straights use fingers, arms, torso, legs and toes in a specific order to denote numbers up to 33. Stanislas Dehaene, *The Number Sense: How the Mind Creates Mathematics* (New York: Oxford University Press, 1997), 93. Georges Ifrah*, From One to Zero: A Universal History of Numbers,* trans. Lowell Bair (New York: Penguin Books, 1985), 11.

[15] John Bulwer, *Chirologia, or, The naturall language of the hand composed of the speaking motions, and discoursing gestures thereof: whereunto is added Chironomia, or, The art of manuall rhetoricke.* (London: Thomas Harper, 1644), 185.

[16] Hobbes, *Leviathan*, 14. Similar theories had been advanced since the ancient Greeks; see, for example, Herodotus and Aristotle. John Fauvel and Jeremy Gray, eds. *The History of Mathematics: A Reader* (New York: Palgrave MacMillan, 1987), 2. An overwhelming majority of historical symbolic systems are base 10, and it is probable that finger-counting is the ultimate origin of this similarity. However, in all known cases of independently invented symbolic systems, the system has the same base as the number words in the inventors' native language, making language an important intermediary factor between finger-counting and the creation of a symbolic system of numbers. Chrisomalis, *Numerical Notation*, 379.

narrator's remaining fingers to the nine digits of Arabic numeral arithmetic and joked that the lost finger "did only for a Cipher stand."[17] More seriously, a system of astronomical calculations first laid out by the Venerable Bede calculated solar and lunar cycles by counting a combination of fingers and finger joints.[18]

Anecdotal evidence suggests finger-counting was considered a simple yet powerful aid to calculation, and one which could be unashamedly used by people with any level of arithmetical knowledge. Mary Astell indicated to her readers that they should mock the ignorance of her "city-critick" character by describing him as someone who aspired to arithmetical learning but was unable to perform such a simple operation as finger-counting: he "mistakes frequently in the tale of his Fingers."[19] Frenchman Pierre de La Primaudaye described how men calculated the value of estates by finger-counting, arguing that it was short-sighted and foolish for men to "marrie by the report of their fingers, counting vpon them how much their wiues bring to them by mariage."[20] Even the educated arithmetician could use finger-counting as a study aid. One of Margaret Cavendish's narrators encounters an educated man "counting on his Fingers, and looking in his Book; by which he saw he was studying Arithmetick."[21] For Cavendish, finger-

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[17] Thomas Randolph, *Poems with the Muses looking-glasse* (Oxford: Leonard Lichfield, 1638), 41.

[18] The twenty-eight years of the solar cycle were counted using the fourteen joints on each hand. The nineteen years of the lunar cycle were counted by using the fourteen joints and five fingertips on one hand. Ifrah, *From One to Zero*, 62-3.

[19] Mary Astell, *An Essay In Defence of the Female Sex. In which are inserted the CHARACTERS OF A Pedant, A Squire, A Beau, A Vertuoso, A Poetaster, A City-Critick, &c.* (London: A. Roper, E. Wilkinson and R. Clavel, 1696), 120.

[20] Pierre de La Primaudaye, *The French Academie Fully discoursed and finished in foure bookes.* (London: Thomas Adams, 1618), 203.

[21] Margaret Cavendish, *Natures picture drawn by fancies pencil to the life* (London: A. Maxwell, 1671), 166.

counting was thus a marker of the arithmetical student, not an indication of inferior skill or learning.

Scottish arithmetician and minister George Brown even considered "how to add, subtract, multiply, and divid by the figners [sic]" to be preliminary knowledge for those wishing to learn the relatively advanced art of decimal arithmetic. He gave no explanation for adding numbers less than six, which he considered intuitive, and his method for adding numbers greater than five was almost as simple. Given two numbers, "you may make the one on the left, the other on the right Hand, accompting the shut hand five; and if you open one Finger 6, two 7, three 8, and four 9." The sum was thus ten plus the sum of the open fingers. His method for multiplication of numbers over five was slightly more complicated, occasionally requiring the multiplier to carry a one from the units place to the tens place. "The sum of the open Fingers, on both hands, yields the Tens, and the product of the shut Fingers yields the Unites of the Product demanded; thus 7x8=56."[22]

While finger-counting systems were often deployed as aids for mental calculation, gestural systems intended for visual enumeration were less common. The most famous of these latter systems was reproduced in the Venerable Bede's *De computo vel loquela digitorum* and was probably brought to England by the Romans; for the numbers one through fifteen, there exist Roman counters with Bede's gestural numbers on one side and the corresponding Roman numerals on the other.[23] Luca Pacioli included a markedly similar gestural system in his 1494 *Summa de Arithmetica*, which was probably a

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[22] George Brown, *A Compendious, but a Compleat System Of Decimal Arithmetick, Containing more Exact Rules for ordering Infinities, than any hitherto extant.* (Edinburgh: George Brown, 1701), 3-4.

[23] Karl Menninger, *Number Words and Number Symbols: A Cultural History of Numbers*, trans. Paul Bronner (Cambridge, Massachusetts: MIT Press, 1969), 211. Stephen Chrisomalis, "The Cognitive and

Gestural Enumeration from the 1543 Edition of Recorde's The Ground of Artes.[24]

descendent of the original Roman system. This same system was reproduced in Robert Recorde's *The Ground of Artes* in its first edition in 1543, and reprinted in subsequent editions through the 1590s.

However, despite its longevity, this gestural system never appears to have been in general use during the early modern period. Recorde extolled "the arte of nombryne on

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Culture Foundations of Numbers," in *The Oxford Handbook of the History of Mathematics*, edited by Eleanor Robson and Jacqueline Stedall (Oxford: Oxford University Press, 2009), 505.

[24] Recorde, *The Ground of Artes*, T3r.

the hand, with diuers gestures of the fyngers, expressynge any summe conceaued in the mynde" but admitted that "[t]his feate hath ben vsed aboue 2000 yeares at the leaste, and yet was it neuer como*n*ly knowen, especyally in Englysshe it was neuer taughte yet." Still, Recorde believed this gestural system was "ryghte worthy to be well marked" and suggested its "straungenes and secretnes" could make it useful for facilitating secret and silent communication.[25] His book's later editors were not impressed by a system that was only useful as a curiosity or a code and dropped the section from all seventeenth-century editions to make room for other, more widely marketable content.

While the commercially-inclined editors of *The Ground of Artes* failed to find gestural systems useful, sporadic interest in such systems persisted through the seventeenth century. In the 1640s, John Bulwer published three separate editions of his *Chirologia: or The naturall language of the hand*. He argued that

> to begin with the first finger of the left hand, and to tell on to the last finger of the right, is the naturall and simple way of *numbring* & *computation*: for, all men use to count forwards till they come to that number of their *Fingers*, and being come to that number, prompted as it were by nature to returne at this bound[26]

after which point they start over again. Bulwer expanded on this natural communication by hands, creating a system of alphabetical gestures and numbering the gestures to make them interchangeably alphabetical and numerical. However, like Recorde, this gestural system of letters and numbers was "so ordered to serve for privy cyphers for any secret intimation," rather than designed to facilitate universal communication in the same manner as other symbolic systems of numbers.[27]

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[25] Recorde, *The Ground of Artes*, T2r.

[26] Bulwer, *Chirologia,* 184.

[27] Bulwer, *Chirologia*, 187.

Performative symbolic systems such as oral enumeration and gestural arithmetic thus formed a natural method of communication, universal to English-speaking humans. Spoken number words were a part of everyday communication, while gestures provided a simple yet powerful aid for reckoning. Ironically, the potential universality of gestural systems was inverted by early modern authors such as Recorde and Bulwer, who stressed the importance and utility of gestural enumeration for secret communication. Whether their gestural systems ever functioned as such is doubtful – a code whose key has been printed and published repeatedly is less than secure. However, the impulse to transform universal numerical concepts and a universally accessible physical medium into a secret code persisted throughout the seventeenth century.

Tally Sticks and Jetons: Object-Based Symbolic Systems

While oral and gestural systems were the most universal symbolic systems in early modern England, systems based upon the manipulation of physical objects were almost as widespread. It was only a short conceptual step from fingers to external objects that, like fingers, were a manipulatable substitute for the objects to be counted. Virtually any collection of objects could serve as an aid to counting, particularly objects small enough to carry.[28] Such systems often had a written or performative component, though this was secondary to their primary characteristic: the alteration or manipulation of a specific type of physical object that could be simultaneously invested with numerical and non-numerical meanings. While many of Recorde's "dyuers and sundry wayes" of

[28] These objects could even be found, rather than purpose-made. For example, the exciseman John Cannon had a grandfather who used beans to keep his accounts and the servants of George Purefoy used twigs to reckon up how many people had been given charity. Thomas, "Numeracy," 119.

enumeration and arithmetic were probably based on a wide variety of objects, the two most prominent object-based systems during the early modern period employed tally sticks and jetons.

Use of wooden tally sticks in England dates back to the Anglo-Saxons.[29] While tally sticks varied widely in size, each was a wooden stick – often hazelwood – with a series of notched marks cut into the sides.[30] Shopkeepers used notched tally sticks to calculate their accounts, while shepherds them to keep track of their flocks.[31] For credit and debt transactions, these sticks could also be split in half, with each party keeping one half to prevent the possibility of fraud. When the two parties reconvened to settle the debt, the two halves of the tally stick were compared and only if they matched each other was the debt considered paid and the account balanced. These split tally sticks were famously used by the Royal Exchequer to keep track of its financial transactions from the twelfth through the beginning of the nineteenth century.[32] Exchequer tally sticks were so ubiquitous that many people adopted the Exchequer cutting and labeling customs – which remained fixed for over seven centuries – in their private tally sticks.[33] These

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[29] Menninger, *Number Words*, 228. The British Museum has several examples of older tallies, Roman in origin, which were made of bronze and bone/ivory and were simple number sticks as opposed to split tallies. See for example Item Registration numbers 1868,0520.39 ; 1873,0820.646 ; 1814,0704.1081 ; 1772,0311.8 ; 1814,0704.1080 ; 1859,0301.51

[30] The *Dialogus de Saccario* explains the proper "length of a tally is from the tip of the index finger to the tip of the thumb extended," yet some surviving examples held by the Bank of England are eight and a half feet long. Hilary Jenkinson, "Exchequer Tallies," in *Archaeologia or, Miscellaneous tracts relating to antiquity*, 2nd ser., 62 (1911): 373. Hilary Jenkinson, "Medieval Tallies, Public and Private," in *Selected Writings of Sir Hilary Jenkinson* (Gloucester, England: Alan Sutton Publishing Limited, 1980), 63.

[31] Adam Fox, *Oral and Literate Culture in England 1500-1700* (Oxford: Clarendon Press, 2000), 21.

[32] The use of tally sticks was finally abolished by the early nineteenth century. The 1834 fire that burned down the palace of Westminster was a result of the decision to burn the old tally-sticks still stored there.

[33] This was most likely to occur when private individuals had pre-existing experience with Exchequer tallies. Jenkinson, "Exchequer Tallies," 377-9.

Fifteenth-Century Exchequer Tally Sticks from the London Science Museum

customs included a distinct notch type and location for each monetary unit, or large multiple of a monetary unit, resulting in a versatile object that could function simultaneously in all three numerical bases of the English monetary system: base 10, base 12, and base 20.[34]

Object-based symbolic systems, like tally sticks, have traditionally been viewed as the province of the illiterate. During the sixteenth and seventeenth centuries, literacy rates increased enough that by 1714 the author of *The Gentleman Accomptant* could denigrate tally sticks as being "of ordinary Use in keeping Accompts with illiterate People, and serves well enough for meer Tale."[35] However, this ignores the fact that Exchequer tally sticks always contained a written component, indicating the names of the parties originally involved in the transaction. For example, one such tally stick in the possession of the British Museum was made out for the sum of 6s 8d and is inscribed in Latin: *a Waltero de Everley de fine pro lud's*.[36] Consequently, this tally stick could only

[34] Jenkinson, "Exchequer Tallies," 373

[35] Thomas, "Numeracy," 119.

[36] British Museum Registration number: CIB.50150

be completely interpreted by a person who not only had the ability to read, but also had the ability to recognize at least a few words of Latin.

Although it would be possible to transcode the numerical information contained on tally sticks while ignoring the Latin inscription, the names written onto Exchequer tally sticks were a vital component of the tally stick as a physical object. During the late medieval and early modern period, the written component of tally sticks enabled them to begin functioning as bills of exchange. This was particularly useful for the Exchequer, which could make payments with previously received tally sticks in lieu of coin – compensating for potential coin shortages while also conveniently transferring the responsibility for collecting its debts to its own creditors. Conversely, this also enabled the Exchequer to spend income well in advance of its collection, cutting tally sticks on future revenues and spending them at the fraction of their eventual expected value.[37] Individuals could also use private tally sticks as transferable bills of credit, though the value of such tally sticks varied depending on the credit of the original debtor, as Samuel Pepys found out to his chagrin when "upon his tally [I] could not get any money in Lombardstreet, through the disrepute which he suffers."[38]

Private tally sticks may have catered more to the completely illiterate than Exchequer tally sticks, however the former do not survive in large enough numbers to draw broad conclusions about their use. What few examples survive indicate that private tally sticks could vary widely in notational conventions – particularly when used to tally non-monetary objects such as trees or sheep – to the point where sometimes only the

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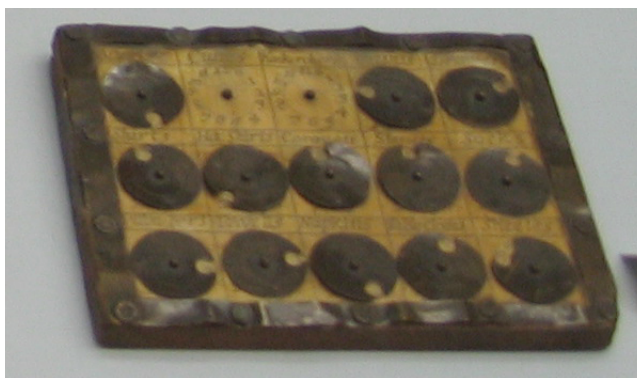
[37] Many of Samuel Pepys' diary entries on tally sticks involved this sort of trading on future income. See, for example, Samuel Pepys, *The Diary of Samuel Pepys*, ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1972), 6:133, 157, 163-4, 7: 170, 407.

[38] Pepys, *Diary*, 6:70.



Seventeenth-Century Baker's Tallies & Laundry Tally from the London Science Museum

original parties involved could read them.[39] For example, the 1680s baker's tallies, shown above, are markedly different in form from Exchequer tallies, while still utilizing notches in combination with the written word. By contrast, the laundry tally pictured below it is even more of a departure from Exchequer standards. It is not a stick at all, but

[39] Hilary Jenkinson, "An Original Exchequer Account of 1304 with private tallies attached," in *Proceedings of the Society of Antiquaries of London, 27th November 1913 to 25th June 1914, Second Series, Vol. XXVI* by Society of Antiquaries of London (Oxford: Horace Hart, 1914), 40.

a brass construction with spinning wheels that could be rotated to convey numerical information about clothing instead of money. Like other tallies, this laundry tally also has a written component: words that label the type of clothing counted by each circle, as well as numbers written in Arabic numerals. While it is possible that an illiterate person could have used the laundry tally by memorizing the positions of the various circles, its construction clearly indicates that it was built for the use of a literate person.

It is therefore likely that the early modern appeal of tally sticks was a product of their material characteristics – including security against fraud, versatility, and transferability – more than their ease of use for the illiterate.[40] Certainly, many literate people continued to employ tally sticks at the turn of the eighteenth century, when rising literacy rates would have curtailed the use of a system whose appeal was solely towards the illiterate. The Bank of England made extensive use of tally sticks in their first decades of existence, while the Exchequer continued to use tally sticks for another hundred years.[41] Only after 1783, when the Exchequer introduced indented cheque receipts whose cut-edges were clearly modeled after the split in tally sticks, were tally sticks finally phased out of service.[42]

Besides tally sticks, the other widespread object-based symbolic system in early modern England relied on sets of metal discs called counters or jetons, which were

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[40] Jenkinson, "Exchequer Tallies," 368. For more on tally sticks as guarantors, as well as records, of numerical information, see Chapter Three.

[41] Within the first week of its operation, the Bank of England accepted deposits of tally sticks worth over £112,000, and much of its early banking activities involved tally sticks. R.D. Richards, *The Early History of Banking in England* (London: P.S. King & Son, Ltd., 1929), 154.

[42] Tally sticks were technically abolished in the same act that introduced the cheque receipts, however the implementation of the act was officially delayed until the two incumbent chamberlains left office, which only occurred in 1826. Jenkinson, "Exchequer Tallies," 368-9.

generally used for calculation more than simple enumeration.[43] Jetons tended to be round and thinner than most coins. They generally came in sets – or casts – of a hundred, but a set could be as small as thirty. They varied in size, as there was no incentive for standardization, but they were almost universally cut in low relief to enable the user to manipulate, stack, and sweep jetons on the flat surface of a counting board.[44] In the fifteenth and early sixteenth century, most jetons were minted in Tournay, France, but by the middle of the sixteenth century, Nuremberg had become the new center of jeton production. Cheaper jetons would be made of latten, brass, copper, bronze and lead, while more expensive jetons would be made of silver or gold. Thousands of jetons survive today, though the metallic value of silver and gold jetons was high enough that many were probably melted down and recast.[45]

Jetons were often, but not always, used in tandem with a counting board or reckoning table, such as the one pictured below. Together, they formed a type of abacus along similar lines to ancient Greek and Roman pebble abacuses.[46] The Exchequer derived its name from the checked cloth it used as a counting board: "a black cloth marked with parallel lines at equal distances… In the spaces between the lines the

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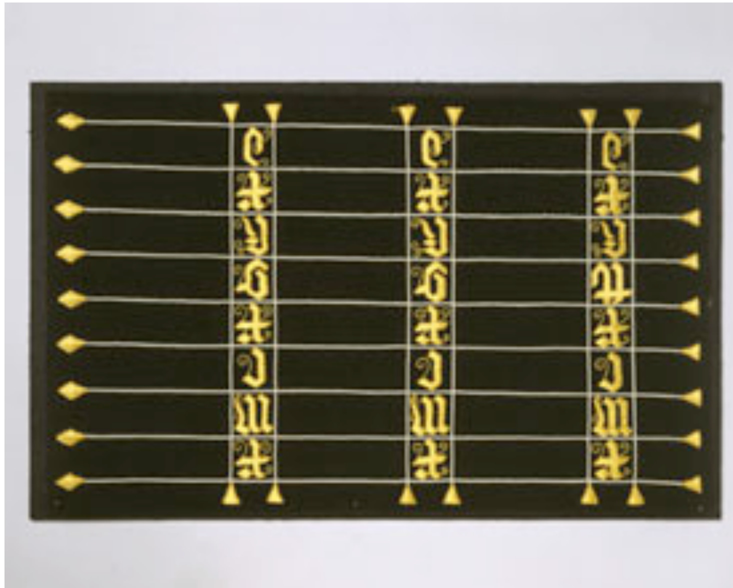
[43] This latter term came from the French *jeter*, "to push," referencing the action of pushing jetons around a counting board. This term gradually fell out of use after the loss of the French provinces, however I use the older term to maintain continuity with secondary sources and avoid terminological confusion regarding permutations of the verb "to count". Francis Pierrepont Barnard, *The Casting-Counter and the Counting-Board: A Chapter in the History of Numismatics and Early Arithmetic* (Oxford: Clarendon Press, 1916), 26-7.

[44] Barnard, *Casting-Counter*, 32-33.

[45] Barnard, *Casting-Counter*, 7. At the time of writing, his personal collection ran to 7,000 jetons and he surveyed approximately five times that number.

[46] Chrisomalis, "Foundations of Numbers," 504.



Replica Bavarian Counting Board and Nuremberg Jetons
from the London Science Museum

counters were placed according to the rules."[47] Counting boards were often cloths, or wooden tables with painted or chalked lines, rather than a "board" as the name implies. For example, a 1596 inventory of the Earl of Huntington's goods included "One Compter Clothe" and together with another cloth was valued at xij d.[48] Frequent use would require the replacement of cloths and repainting of lines, as evidenced by the new cloths "to cover the chequer" purchased for the Reading town hall in 1521, 1522 and 1523.[49] Only a handful of these cloths survive, but references to jetons and counting boards can be found in many early modern inventories and wills.[50] Purses of jetons also appear in the records as a standard New Year's gift, one particularly lavish example of which can be seen when a Mr. Surton presented Queen Mary with a pair of counting-tables, three boxes for jetons, and forty jetons.[51]

While Recorde's primary purpose in *The Ground of Artes* was to teach Arabic numeral arithmetic, he and his subsequent editors deemed his "second dialogue" on the use of counting boards important enough to be included in every edition except the final one, in 1699.[52] This system was useful for those who could not read and write, however it was also important “for the[ym] that can do bothe, but have not at some tymes their

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[47] Menninger, *Number Words*, 347.

[48] HEH, MS HA Inventories Box 1, Folder 1, f. 13.

[49] Barnard, *Casting-Counter*, 245.

[50] For an extensive listing of early modern wills and inventories referencing either jetons or counting boards, see Barnard, *Casting-Counter*, 243-252.

[51] Menninger, *Number Words,* 334, 378. The was especially the custom in France, where the king gave gifts of jetons to his officials and received jetons in return.

[52] The penultimate edition of *The Ground of Artes* was 1668. The 1699 edition was a temporal outlier and markedly different from earlier editions; it represents a last-ditch effort to resurrect the title and make it relevant in an arithmetic textbook market that had moved on to other standards such as *Cocker's Arithmetic*.

penne or tables ready with them."[53] Recorde clearly believed that those who learned the new Arabic numerals might find themselves in situations where they would need to know how to use the older system of counting boards. Since jetons were often employed in conjunction with other symbolic systems – particularly tally sticks and Roman numerals, but also Arabic numerals – to be ignorant of the use of jetons and counting boards would put one at a marked disadvantage in business transactions.[54]

The frontispiece of the 1543 edition of Recorde's *The Ground of Artes* is particularly interesting for its visual depiction of the counting board being used in tandem with Arabic numeral arithmetic.[55] Four men crowd around a counting table and at least three of them are directly involved in the calculations. The one on the left manipulates jetons over the lines of a counting board that have either been temporarily chalked or permanently inscribed onto the table. Given the sword at his hip, he is probably of relatively significant social status and it is highly likely that he would be literate. His use of jetons and a counting board is therefore a deliberate choice, rather than a reflection of his inability to write. Two men on the right stand over an Arabic numeral division problem that appears to be worked out directly on the table – possibly writing with chalk, but no slate – while the man at the back writes down the results of all their calculations on a piece of paper using Arabic numerals.[56] The image hints at Recorde's personal

[53] Recorde, *The Ground of Artes*, M6v. The tables refer to multiplication tables, such as the table provided in Recorde's *The Ground of Artes*, F7r. Recorde did not expect his readers to have memorized their one through ten times tables.

[54] For more on the relationship between jetons, counting boards and Roman numerals, see Chapter Three.

[55] A similar image is reproduced in the 1558 edition of *The Ground of Artes* but without the writing on the wall under the shelf. A different image, in the 1615 edition, shows two men and a boy calculating with jetons alone. See page 133.

[56] The Arabic numerals on the right side of the table are struck-through as part of division calculations.

Woodcut from the Title Page of the 1543 Robert Recorde's The Ground of Artes[57]

preference for Arabic numerals both by the sole counting board user's spatial isolation and by the use of Arabic numerals for the date on the wall – the year of the book's publication, 1543.[58] However, his calculators' use of two different systems also indicates

[57] Recorde, *The Ground of Artes*, A1r.

[58] The VDMIE is most likely an abbreviation for *Verbum Domini Manet in Eternum* – the Word of the Lord shall remain forever. This was a slogan used by German Reformers in the 1520s. John M. Todd, *Luther: A Life* (London: Hamish Hamilton Ltd., 1982), 282.

that both had an important place in the realm of financial transactions and carries with it the implication that one system might be used to double-check calculations in the other.

Recorde's frontispiece also illustrates the way in which calculations done with jetons lent themselves well to outside observations. This performative aspect of jetons, combined with their ability to take imprints in the same fashion as coins and medals, resulted in a form of conspicuous numeration.[59] In the sixteenth and early seventeenth centuries, those with the financial means to do so acquired jetons engraved with images and written legends designed to convey information about the jetons' owner. These images and legends would then be prominently displayed to onlookers through every act of calculation.

Some of the earliest jetons spoke only to their owners' skill with the physical act of calculation. A silver jeton struck around the turn of the fifteenth century proclaimed its purpose and encouraged its users with the legend GETES SEUREMENT GETES ET LE COMPTE TROUVERES – cast up correctly, cast up, and you will find the amount. Yet while the act of calculating with jetons could be observed and understood by the illiterate, this message would only be available to someone able to read French. Observers who could only understand the images were instead regaled with information about the owners' political allegiance, with the field of fleurs-de-lis and the three lions passant guardant – the arms of France and England, respectively – on each side.[60] A

[59] The unscrupulous used jetons as a coinage substitute, as can be seen in both legal records and contemporary literature. As a character in *Crafy Conueyaunce* states, "A foole beleeveth every thing; That copper is gold, and a counter an angell." A similar passage can be found in *Leviathan*: "Words are wise men's counters, they do but reckon by them: but they are the mony of fooles." Barnard, *Casting-Counter*, 78-9.

[60] Edward Hawkins, compiler, Augustus W. Franks and Herbert A. Brueber, eds. *Medallic Illustrations of the History of Great Britain and Ireland to the Death of George II* (London: Spink & Son Ltd, 1969), 1:7. This jeton is labeled as counter 6 and was lost in 1844.

similar counter from 1557 also reassures the Latin-reading observer with the legend QVI BIEN GECTERA SON COPTE TROVE – he who casts up correctly will find his account – while its images instead showed the busts of Philip II and Mary I on one side, and the arms of Spain and France on the other.[61]

During the religiously and politically tumultuous sixteenth century, many jetons were commissioned to testify publicly to their owners' loyalties. Jetons belonging to Sir Nicholas Throckmorton, the English ambassador in Paris from 1559 to 1564, bear his personal crest and arms but also express his sympathy and friendship for Mary, Queen of Scots.[62] Dozens of late sixteenth-century jeton sets express support for the United Provinces and commemorate Spanish defeats. At least five surviving sets specifically reference the defeat of the Spanish Armada, and bear legends such as VENIT IVIT FVIT – it came, it went, it was.[63] Jetons bearing the image of the current monarch were perennial favorites. A silver jeton from 1547 reflects the coronation of Edward VI, proclaiming him king of England, France and Ireland, while a series of jetons from the late 1550s bear images of Philip and Mary I, with their arms on the obverse.[64] Nicholas Hilliard, engraver to Elizabeth I and James VI/I, issued counter sets with images of members of the royal family, "for reckoning and for play," and obtained a presumably lucrative twelve-year monopoly over such images beginning in 1617.[65]

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[61] Hawkins, *Medallic Illustrations,* 1:85.

[62] Hawkins, *Medallic Illustrations*, 1:101.

[63] Hawkins, *Medallic Illustrations*, 1:133, 146-7, 153, 160-2. See especially counter 113 on p. 146.

[64] Hawkins, *Medallic Illustrations*, 1:55, 85.

[65] Jetons often served a secondary purpose as instruments of gaming. Elizabethan sources talk of children playing with points, pins, cherry-stones, and jetons, all of which served the dual function of game tokens and a currency substitute to determine winners and losers. Nicholas Orme, *Medieval Children* (New Haven: Yale University Press, 2001), 177-8. Hawkins, *Medallic Illustrations*, 1:375-6.

Jetons also served as status symbols, particularly for men who held a public office in which they might be expected to perform calculations as part of their positions. During the reign of Philip and Mary, a set of counters was struck with the legend declaring they would be used at the Chamber of Accounts at Lille, while thirty years later Sir Thomas Heneage struck himself a set of personalized counters while he held the office of Treasurer at War.[66] Thomas Sackville had jetons struck in 1602, declaring him Baron of Buckhurst and Treasurer of England, both positions that he had held for years under Elizabeth and again under James I.[67] While the date casts some doubt as to whether Sackville had his jetons cast before or after the death of Elizabeth, Sir Robert Cecil also had jetons struck and dated 1602, which proclaimed him Principal Secretary to the King – not Queen – and Master of the Court of Wards.[68] Later seventeenth-century examples include Bishop Juxon's jetons, which celebrated his consecration as Bishop of London and subsequent position as Lord High Treasurer, and Sir Robert Pye's jetons, declaring him Auditor of the Receipts of the Exchequer of His Majesty the King.[69]

Other people commissioned counters for their own private use in accounting, proclaiming their personal titles rather than their public positions. Robert Dudley, Earl of Leicester, had counters stamped with his motto on both sides – DROET ET LOYALL – while a 1635 inventory by Lettice, Countess of Leicester, notes: "Item, castinge counters

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[66] The Lille counters read GECT DE LA CHAMBR DES COPT A LILLE – counter of the Chamber of Accounts at Lille. Hawkins, *Medallic Illustrations*, 1:85, 151.

[67] They bear the legend T SACKVIL B D BVCH ANG THES Eq^{r} AVRA and the old style date 1602. According to the old style Julian calendar, where the new year began on March 25, Elizabeth I died on the last day of the year 1602. Whether or not the date was accurate, the jetons must have been ordered before March of 1603/4, when Sackville was created Earl of Dorset. Hawkins, *Medallic Illustrations*, 1:188.

[68] They were most likely cast before Cecil was made Baron Cecil of Essendon, on May 13, 1603. Hawkins, *Medallic Illustrations*, 1:189.

[69] Juxon's counters bear the legend GVIL LOND EPVS ET ANGLIAE THESAVR while Pye's bear the legend ROBERTVS PYE MILES AUDIT RECEPT SCACARII D^{NI} R^{IS}. Hawkins, *Medallic Illustrations*, 1:279 and 286.

of silver one and forty."[70] A flurry of new, personalized jetons were struck during the celebrations that marked the death of Elizabeth and the accession of James I. In addition to those mentioned above, Thomas Cecil, Sir Edward Coke and Sergeant Hele all had jetons cast in 1602/3.[71] Robert Cecil also had new jetons cast in 1602/3, 1606 and 1608, to celebrate his various new honors and titles under James I.[72]

The use of personalized jetons – either in association with public offices or as a private declaration of social status – flourished until the civil wars in the middle of the seventeenth century. After the Restoration, a new generation of nobles and public office-holders continued to strike medals with their mottos and images, but no longer showed an interest in commissioning their own, personalized jetons. It is probable that most had transitioned from using jetons to using written Arabic numerals by this time. While there was still some post-Restoration demand for jetons – and *Recorde's Arithmetic* continued to reproduce its section on jetons through 1668 – surviving jetons from the late seventeenth century contained only generically marketable images of the reigning monarch and other members of the royal family. Jetons were produced throughout the eighteenth century, however the quality of their workmanship declined and, increasingly, they appear to have been used less for their original purpose of calculating financial transactions and more as tokens for scoring children's games.[73]

Object-based symbolic systems thus combined a mixture of written and performative characteristics with the alteration or manipulation of physical objects.

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[70] Hawkins, *Medallic Illustrations*, 1:152.

[71] Hawkins, *Medallic Illustrations*, 1:189-91.

[72] Hawkins, *Medallic Illustrations*, 1:189 and 196-7.

[73] Hawkins, *Medallic Illustrations*, 2:413-15, 464, 483. Many so-called "Queen Anne's farthings" are in fact counters produced over the course of her reign. See, for example, counter 282 on p. 415.

These systems were diverse in form, ranging from the standardized cutting conventions of Exchequer tally sticks to personalized jetons to idiosyncratic private tallies whose meanings were known only to their original owners. However their primary characteristic was their reliance on a set of physical objects, which could be invested with both numerical and non-numerical meaning. Only the former could be transcoded into another symbolic system. The latter was inextricably bound to the material characteristics of the physical objects. In the case of tally sticks, their ability to function as both a guarantor of debts and a bill of exchange ensured their continual use until a structurally similar, paper-based bill of exchange was developed to take its place at the end of the eighteenth century. By contrast, jetons' secondary function as political statements and status symbols was not useful enough to prevent their post-Restoration decline in favor of the new, pen-and-paper methods of arithmetic based on written Arabic numerals.

Roman and Arabic Numerals: Written Symbolic Systems

While many early modern symbolic systems had a written component, only three systems required the user to possess the same tools and skills as literacy. The simplest system involved writing out number words using the same alphabetic symbols as any other English word. The other two systems involved special symbols to indicate numbers. The older of the two was the additive system of Roman numerals, which was adopted throughout Europe during the period of the Roman Empire and remained the primary written symbolic system of medieval England.[74] During the sixteenth and seventeenth centuries, however, Roman numerals were gradually replaced in most contexts by the newer, positional system of Arabic numerals, which was transmitted from India through Muslim Iberia to Christian Europe. The widespread adoption of Arabic numerals in England would have particular importance for numeracy and arithmetic, as it also encouraged the population to adopt new calculation methods based on Arabic numerals.

As discussed above, number words formed an essential part of the English language and were learned alongside other English words. Written English number words thus required the same skills as writing any other English word: knowledge of the Latin alphabetic symbols and the ability to use the tools of literacy such as pen and paper. Such written number words were cumbersome in length, but did not require the literate user to memorize any new symbols or syntactical rules for constructing numbers. This system thus formed a subcomponent of, and was taught in conjunction with, the ability to read and write in English. Written number words became increasingly familiar to the English population as literacy rates rose throughout the sixteenth and seventeenth century. They were, however, confined to the literate section of the English population, and could not be taught independently like Roman and Arabic numerals.

Roman numerals were a simple and intuitive symbolic system that could be easily taught, so long as the student already knew the words for numbers up to a thousand and had a basic grasp of mental addition and subtraction. There were only seven symbols to

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[74] At 2400 years old, Roman numerals are one of the longest-lived symbolic systems; the only older system still in use are the Greek alphabetic numerals. Two other systems were used over a longer period of time – the Egyptian hieroglyphic and hieratic systems – however both went extinct before the early modern period. Chrisomalis, *Numerical Notation*, 416.

memorize, all of which had analogs in the English alphabet, and the system's additive structure required little explanation. Brinsley spent a mere two paragraphs on this lesson, explaining to his readers that I stood for one, V for five, X for ten, L for fifty, C for a hundred, D for five hundred and M for a thousand.[75] As for how these letters were to be used, he noted

> any number set after a greater, or after the same nu*m*ber, doth adde so many mo [sic], as the value of that later number is. As, I. set after X. thus, XI. doth make eleuen. XV. fifteen. XX. twentie. But being set before, they doe take away so many as they are: as I. before X thus, IX. nine.... And thus much shortly for numbring by letters.[76]

However, despite the additive construction of Roman numerals, they in no other way facilitated arithmetical calculations. Those who wished to sum multiple numbers, multiply, divide, or extract roots had to resort to another symbolic system – generally jetons and a counting board – before they could perform their calculations and only then return to pen and paper to record the results in Roman numerals. Thus Roman numerals encouraged transcoding among multiple symbolic systems and worked well in conjunction with symbolic systems based upon the manipulation of physical objects.

Arabic numerals were newcomers in comparison to Roman numerals, but by the sixteenth century they also had a relatively long history in England. Arabic numerals first entered Europe through Muslim Iberia and were introduced to Christian Italy in the late tenth century. Their earliest appearance in England dates to 1130, when Adelard of

[75] When the i was employed in a terminal position, early modern writers would sometimes convert it to a j, to indicate the end of the number and prevent anyone from altering it by adding another i. Thus xii would become xij, so that someone could not easily forge it into an xiii or xiiii.

[76] Brinsley, *Lvdvs Literarivs,* 25-6.

Bath translated al-Khwarizmi's treatise on Arabic numeral arithmetic into Latin.[77] Around the same time, one of Adelard's students – known only as "H. Ocreatus" – attempted to merge the Roman numerals I through IX with Arabic numerals' positionality and zero to create a hybrid that combined the traits of both systems. Positions were separated with dots, a feature that would later be resurrected – or reinvented – to separate different denominations of currency.[78] However, despite this early introduction, neither Arabic numerals nor Ocreatus's hybrid system gained much initial traction among the existing symbolic systems. Adelard himself continued to use Roman numerals and although Arabic numerals appeared in fourteenth-century mathematical manuscripts – including astronomical tables, nativity calendars, and psalter calendars[79] – it would be another four centuries before vernacular, printed arithmetic textbooks made information on Arabic numeral arithmetic widely available to the general population.[80]

When people did begin to adopt Arabic numerals, they did so in a piecemeal fashion that was consistent with multiplistic numeracy – picking and choosing the contexts where Arabic numerals would be most helpful, rather than completely replacing one or more of the existing systems. There is a clear pattern of Arabic numerals initially being adopted for use in a single context – specifically, to record the year of the incarnation.[81] During the late sixteenth and seventeenth centuries, people subsequently

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[77] Peter Wardley and Pauline White, "The Arithmeticke Project: A Collaborative Research Study of the Diffusion of Hindu-Arabic Numerals," *Family & Community History* 6 (May 2003), 7. Chrisomalis, *Numerical Notation,* 223.

[78] Chrisomalis, *Numerical Notation,* 120.

[79] By the fifteenth century, Arabic numerals also began to be used for pagination and chapter numbers in such manuscripts. G.F. Hill, *The Development of Arabic Numerals In Europe: Exhibited in 64 Tables* (Oxford: Clarendon Press, 1915), 34-5, 54-61.

[80] For more on vernacular arithmetic textbooks, see Chapter Four.

[81] In early modern England, there were two main methods for denoting the year. The regnal year began on the day of the current monarch's coronation and numbered the years that monarch had reigned. The year of

broadened their Arabic numeral use to include an increasing number of diverse contexts. While there was considerable variation in the timing of individuals' first use of Arabic numerals, there was a fairly consistent pattern in the order of contexts where these numerals appeared: first in the year of the incarnation in engravings and written documents, followed by other aspects of dating, quantities and monetary values, and only lastly the summation of accounts.

One of the first places where people chose to employ Arabic numerals was for the year of the incarnation, particularly in engravings. An astrolabe at the British Museum unmistakably bears the year '1326' and, in the year 1424, the seal of Fountains Abbey was found to bear the Arabic numerals '1410'.[82] Later in the fifteenth century, people began to used Arabic numbers to record the year of the incarnation on wooden gates and doors, stone walls and pavement, and decorative shields. A stone from the London Bridge, discovered in 1758, was inscribed with the date '1509' in Arabic numerals. By the turn of the sixteenth century, Arabic numerals could also be occasionally found recording the year of the incarnation on material objects such as jetons, tabernacles, wood-cuts, roof beams, tombs, brasses, bells, cups, and windows.[83]

Over the course of the sixteenth century, English men and women also began to use Arabic numerals for the year of the incarnation in their written accounts and letters,

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the incarnation, or *anno domini*, began on March 25th and numbered the years since the birth of Christ. By the seventeenth century, it became common to unofficially start the year on January 1st and thus the year might be expressed 1678/9 to indicate the months between the unofficial and official start dates for the year 1679. Almanac writers often included other methods, such as numbering the years since the creation of the world or historical events such as the English Reformation or the Restoration of Charles II. See Chapter Five for more on early modern time-keeping and calendar systems.

[82] Although the British Museum holds an earlier astrolabe, it can only be tentatively dated to 1260. Furthermore, while the 1260 astrolabe could be of Islamic origin, the *anno domini* year inscribed on the 1326 astrolabe indicates it was made for a Christian. A 1342 astrolabe contains a Latin inscription as well as an *anno domini* date. Hill, *Development*, 61.

[83] Barnard, *Casting-Counter*, 53-4. Hill, *Development,* 34-5 and 54-61.

however they retained Roman numerals as the primary method for recording quantities, monetary costs, and most aspects of dates, including the regnal year.[84] The only occurrence of Arabic numerals in the churchwardens' accounts of St. Michael, Spurriergate, York, between 1518 and 1548, were two years of the incarnation – the first in 1547,[85] the second in 1548.[86] Four Peterborough churchwardens recorded their receipts in Roman numerals, over the period of the "feast of S. Mychell in Anno 1554 vntill the Feast of S. michell in Anno 1557."[87] William Chancy, who kept the accounts of Robert Dudley, calculated Dudley's "1559 Forin Expenses and rewards."[88] In the parish of Prestbury, the register book listed Arabic numeral years beginning in 1560, but did not use Arabic numerals for any other purpose until 1611-2.[89] From 1600 to 1611, Thomas Hassall, the vicar of the parish of Amwell, consistently recorded baptisms, weddings and funerals with the year in Arabic numerals and the day of the month in Roman numerals.[90] As late as 1627-8, the churchwarden Nicholas Goore in Walton-on-

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[84] The exception to this trend is the merchants and tradesmen who had greater contacts with continental merchants – particularly Italians, who were some of the earliest adopters of Arabic numerals – and hence greater exposure to Arabic numerals than the rest of the country's population. John Isham, for example, probably learned Arabic numerals while apprenticed in Antwerp. Esther M.E. Ramsay, ed, *John Isham, mercer and merchant adventurer : two account books of a London merchant in the reign of Elizabeth I,* (Gateshead, Co. Durham : Northamptonshire Record Society, 1962).

[85] In the first instance, the date "anno 154" is crossed out and replaced by "and dew in anno 1547" however this appears to be a case of the writer forgetting to insert words, not confusion about the numbers themselves. C.C. Webb, ed., *The Churchwardens' accounts of St Michael, Spurriergate, York, 1518-1548,* ([York]: University of York, Borthwick Institute of Historical Research, 1997), 2:327.

[86] Webb, *St Michael, Spurriergate*, 2:328.

[87] William Mellows, ed., *Peterborough local administration; parochial government before the reformation. Churchwardens' accounts, 1467-1573, with supplementary documents, 1107-1488*, Publications of the Northamptonshire Record Society 9 (Kettering: Northamptonshire Record Society, 1939), 164.

[88] Simon Adams, ed., *Household accounts and disbursement books of Robert Dudley, Earl of Leicester, 1558-1561, 1584-1586* (London: Cambridge University Press, 1995), 103.

[89] James Croston, ed., *The register book of christenings, weddings, and burials, within the parish of Prestbury, in the county of Chester, 1560-1636,* ([Manchester]: Record Society of Lancashire and Cheshire, 1881), 188.

[90] Stephen G. Doree, ed., *The Parish Register and Tithing Book of Thomas Hassall of Amwell*, ([Ware, Hertfordshire]: Hertfordshire Record Society, 1989).

the-Hill, Lancashire, used Arabic numerals for the year and Roman numerals in all the remaining quantities, save one.[91]

It is most likely that these early modern writers were taking advantage of the inherently shorter length of the year of the incarnation, as recorded in Arabic numerals.[92] Whereas in Arabic numerals, the year can be recorded as “anno 1581,”[93] in Roman numerals the date would be “the yere of owr Lord M^{1} CCCCC xxv^{ti}”[94] or “Anno Domini millesimo CCCC^{o} lxxix^{o}”[95] or even “the yere off owr Lord a thowsand fyve hundreth xxxviijth.”[96] Even a mixture of Roman and Arabic numerals could shorten the recorded year, such as the Spelsbury, Oxfordshire, churchwardens’ account entry of “anno M quingentesimo 24.”[97] This shortening would be particularly useful when a number was being carved or engraved onto a physical object. The year of the object's creation, as measured from the incarnation, was the most usual number to carve on an object. However, the shortening effect of Arabic numerals would also have been useful for saving space on a piece of still-expensive paper, thus encouraging the use of Arabic numerals for the year of the incarnation more generally.

Given the advantages of a shorter number, it is perhaps surprising that Arabic numerals did not also make an early appearance in other large numbers. Arguably, the

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[91] Esther M.E. Ramsay, ed., *The churchwardens' accounts of Walton-on-the-Hill, Lancashire 1627-1667,* ([Liverpool]: The Record Society of Lancashire and Cheshire, 2005), 4.

[92] Arabic numerals do not always produce a shorter number than Roman numerals – compare 1000 with M, for example – however only a few numbers between 1400 and 1700 would have been shorter in their Roman numeral equivalents and many would have been significantly longer.

[93] Robert Tittler, ed., *Accounts of the Roberts Family of Boarzell, Sussex: c1568-1582*, Sussex Records Series, 71 (Lewes, England: Sussex Record Society, [1977]), 55.

[94] Webb, *St Michael, Spurriergate,* 1:64.

[95] Mellows, *Churchwardens*, 28

[96] Webb, *St Michael, Spurriergate*, 1:190.

[97] F.W. Weaver and G.N. Clark, eds., *Churchwardens' Accounts of Marston, Spelsbury, Pyrton*, Oxfordshire Records Series, 6 (Oxford: Oxford University Press, 1925), 38.

place-based nature of Arabic numerals might make them difficult to master – particularly for those people unfamiliar with the place-based counting board system – and thus discourage more widespread use. In *The Ground of Artes*, Recorde spent fifteen pages on the concept of "Nvmeration" and all but one of these pages were concerned with explaining the concept of place. Recorde even included a table to illustrate this discussion. This restricted usage could therefore reflect an incomplete understanding of how the numerals worked. However, even those writers who limited themselves to using Arabic numerals for the year of the incarnation had to be able to update the number at the end of each year. Furthermore, such writers used Arabic numerals to refer to past years, as well as the present year. Accounts continuously made reference to the previous year, such as the Stratford-upon-Avon chamberlains' accounts that refer in 1584 to "the yere of our lord god 1583."[98] Others referred to even more distant years, such as Thomas Hassall's memory of "my first comminge to Amwell, which was in the yeare 1599"[99] and his summary of "the circuit and bounds of the parish of Amwell Magna begune 1601 and finished the 10th of May 1613."[100] It is therefore likely that understanding place was not a significant barrier to the use of Arabic numerals.

Although early modern English men and women initially saw no need to use Arabic numerals for recording anything other than the year of the incarnation, they eventually began to extend their use of Arabic numerals to all aspects of recording dates. Particularly in the latter half of the sixteenth century, there appears to be a trend in individual accounts of Arabic numeral days of the month beginning to appear beside

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[98] Richard Savage and Edgar L. Fripp, eds, *Minutes and accounts of the corporation of Stratford-upon-Avon and other records, 1553-1620,* (Oxford: Dugdale Society, 1921), 3:146.

[99] Doree, *Thomas Hassall*, 179.

[100] Doree, *Thomas Hassall*, 193.

Arabic numeral years. Some writers were inconsistent in their practices, such as John Bekynsaw, who wrote to Lady Lisle on the "13" and "19 off July 1538,"[101] followed by a letter on "the xvjth day of August 1538."[102] Other letters written to Lord Lisle, the King's Deputy of Calais, were more consistent in their use of Arabic numerals to date their letters "the 19th day of November, 1533"[103] and "Anno 1533. the 25. day of November."[104] More idiosyncratically, Sir Henry Savile employed Roman numerals for the day and Arabic numerals for the regnal year when he wrote to William Plumpton on "the xxviij of November, anno 1544, 36 H.8."[105] Henry Higford, the clerk of the corporation of Stratford-Upon-Avon in the late 1560s, consistently recorded the year of the incarnation in Arabic numerals, while varying between Arabic and Roman numerals for the day of the month.[106] The gentleman farmer James Bankes began his memoranda book on the "Eyght daye of October in the xxviii yeare of quene Elezabeath" but only three folios later gave the date as "the 8the daye of Julye 1598."[107] In many places, this transition extended into the seventeenth century. Parish registers of Prestbury recorded christenings performed on "29th Marcij" and "vj^{to} Aprilis" in 1623, while the

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[101] Muriel St. Clare Byrne, ed., *The Lisle Letters* (Chicago: University of Chicago Press, 1981), 4:514.

[102] Byrne, *Lisle Letters*, 4:515. Lady Lisle also received letters with Arabic numeral dates from the Frenchwoman Mary Uvedale on "1535 the 22 day off noue*m*ber" and her French-educated daughter, Katherine, on "the 17th Daye of February." Ibid., 4:191, 298. Therefore women might also be familiar with Arabic numerals, although men were far more likely than women to be reading and writing. Keith Thomas, "The Meaning of Literacy in Early Modern England," in *The Written Word: Literacy in Transition, Wolfson College Lectures 1985,* edited by Gerd Baumann, (Oxford: Clarendon Press, 1986): 117.

[103] Byrne, *Lisle Letters*, 1:616.

[104] Byrne, *Lisle Letters*, 1:630.

[105] Joan W. Kirby, *The Plumpton letters and papers,* (New York: Cambridge University Press, 1996), 220.

[106] Savage and Fripp, *Stratford-upon-Avon*, 2:2-39.

[107] Joyce Bankes and Eric Kerridge, eds., *The Early Records of the Bankes Family at Winstanley*, Remains, Historical and Literary, connected with the Palatine counties of Lancaster and Chester, 3d ser., 21 ([Manchester]: Chetham Society, 1973), 13-5.

Peterborough feoffees used a mixture of Arabic and Roman numerals throughout the 1610s and 1620s, except for the years, which were consistently the year of the incarnation in Arabic numerals.[108]

Account-keepers also began to use Arabic numerals to record quantities and prices, as well as dates. The Peterborough churchwardens' accounts also list payment for, among other things, "37 povnd of Salder," "14 stone lead," "2 antiphoners bynding, and "4 yardes of haircloth to the high alter" in 1554-7.[109] In his parish register Thomas Hassall of Amwell used Roman numerals for the days of the month until 1611, and used a mixture of Roman and Arabic numerals until 1636. As early as 1603, however, he noted the total dead in his parish in Arabic numerals:

Buried in all this yeare 41
of the plage 19 [110]

A 1615 list of Adventurers for Virginia in the first Wycombe ledger book list investments of "10s.," "5s.," "40s.," "13s. 4d.," and "20s."[111] The churchwarden Nicholas Goore noted that he had "paid the glazier for worke done at the church/for Fourteen Foote of new glass at 6*d*/the foote" in 1627-8.[112]

As account-keepers began to employ the Arabic numerals in a wider variety of places, their overall use of numbers remained multiplistic. They used the Arabic and

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[108] William Mellows, ed., *Peterborough local administration; parochial government from the Reformation to the Revolution, 1541-1689. Minutes and accounts of the feoffees and governors of the city lands with supplementary documents,* Publications of the Northamptonshire Record Society 10 (Kettering: Northamptonshire Record Society, 1937), 1-82.

[109] Mellows, *Churchwardens*, 166.

[110] Doree, *Thomas Hassall*, 81. For more on the quantification of plague deaths, see Chapter Six.

[111] R.W. Greaves, ed., *The First Ledger Book of High Wycombe*, Buckinghamshire Record Society Publications, 11 (Hertfordshire: The Broadwater Press, 1947), 110.

[112] Ramsay, *Walton-on-the-Hill*, 4.

Roman numeral systems side-by-side and interchangeably.[113] The church records of St. Andrew Hubbard include a 1534 will in which the hatmaker William Harber bequeathed "in 5 Friday every 5d. sterling to v poor, needy persons in the honour and worship of the v wounds of Our Lord Jesus Christ."[114] The Prescot churchwardens accounts record a payment for "8 ashlers" immediately before a payment for "ij daies worke in layinge the ashlers."[115] In his will, John Done of Utkingtone, Edsbury, "Cheeff forester and M[aste]r of her Ma[jesties] game of the forest of Delamare" died on "xxiijth of March, 1600" and left behind "John Done, soone and heir; Thomas, 2d soone; James, 3rd soone; Saveag, 4th soone" along with four similarly listed daughters.[116] The Peterborough Feoffees' accounts note "all soe xxs. of the same Some is in like Mannour to bee oute being parte of the 60*li*. of Mrs. Swinscotes gift."[117] Fluent use of multiple symbolic systems even occasionally manifested itself in quantities that can best be described as "mixed," in that they use both Arabic and Roman numerals in the same number. This sometimes occurred in years such as "anno M quingentesimo 24" or "Mij. 63"[118] or monetary values, such as

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[113] This undifferentiated use of both symbolic systems also extends to the use of number words side-by-side and interchangeably with Roman and Arabic numerals. For example: Sir Edward Don paid "to T. Portter for one narow yerde of frysceade from Jankelyne xiii^{d}". Ralph A. Griffiths, ed., *The Household Book (1510-1551) of Sir Edward Don: An Anglo-Welsh Knight and his Circle*, (Bedford: Buckinghamshire Record Society, 2004), 353. The St. Michael Spurriergate accounts list payments "to twoo underclarkes, iiij^{d}." Webb, *St Michael, Spurriergate*, 2:223.

[114] Thus on each of the first five Fridays following his death, 5d. was to be given to five of the parish poor. Clive Burgess, ed., *The church records of St Andrew Hubbard, Eastcheap, c1450-c1570,* ([London]: London Record Society, 1999), 266.

[115] F. Bailey, ed., *The churchwardens' accounts of Prescot, Lancashire, 1523-1607,* (Preston: Record Society of Lancashire and Cheshire, 1953), 133.

[116] John Paul Ryland, *Cheshire and Lancashire Funeral Certificates, 1600 to 1678,* Record Society of Lancashire and Cheshire, 6 (London: Record Society of Lancashire and Cheshire, 1882), 71.

[117] Mellows, *Feoffees*, 111.

[118] Weaver and Clark, *Marston, Spelsbury, Pyrton*, 38. Robert Steele, *The Earliest Arithmetics in English* (London: Oxford University Press, 1922), xvii.

"xxvii*s* 8*d*" and "ii*s* 6*d*."[119] When recording quantities or prices, however, the different symbolic systems were more commonly used in separate numbers, though they might be employed in the same sentence or entry. Mixed numbers were never used frequently enough to create a hybrid system and ceased to appear in records after about 1650.[120]

Only around the turn of the seventeenth century did people begin to use Arabic numerals for the final type of numbers that appeared in their accounts: valuation columns and sums. Peter Wardley and Pauline White's collaborative study of probate inventories specifically focused on this context as an indicator of "complete" mastery of Arabic numerals, "ignoring numbers in the text, dates and quantities of objects" where Arabic numerals were already in use.[121] While the way they framed their questions ignores the multiplistic nature of early modern numeracy, their study did yield interesting data about the use of Arabic numerals in accounting. They found that most people in their sample adopted Arabic numerals for use in valuation columns between 1590 and 1650, with the main transition period beginning in the 1620s and 1630s and continuing through to 1650.[122] The Norfolk probate inventories showed some of the earliest uses of Arabic numeral sums, in 1584, while most of the places surveyed had earliest adoption dates between 1607 and 1612. However, this was by no means a universal trend. Roman numerals remained the dominant written system for sums in Bermondsey and Rotherhithe

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[119] Anthony Palmer, ed., *Tudor Churchwardens' Accounts*, Hertfordshire Record Society, 1 ([Ware, Hertfordshire]: Hertfordshire Record Society, 1985), 41, 177.

[120] Chrisomalis, *Numerical Notation*, 122.

[121] They did, however, note "a significant tension" between recording numerical information and calculation, and briefly mentioned "the likelihood of binumeracy on the part of some" account keepers who used both Roman and Arabic numerals in their accounts. Wardley and White, "The Arithmeticke Project," 8, 13. For more on the conceptual distinction between recording and calculation, see Chapter Three.

[122] This corresponds well with Wardley's earlier research on Bristol and West Cornwall, where he found a slightly earlier adoption period of 1570 to 1630. Wardley and White, "The Arithmeticke Project," 6.

until the end of the seventeenth century, while individuals continued to use Roman numerals alongside Arabic numerals in most of the other areas surveyed.[123]

Unlike Roman numerals, the positional nature of Arabic numerals lent itself well to calculation with pen and paper. Vernacular arithmetic textbooks, such as Recorde's *The Ground of Artes*, proliferated during the late sixteenth and seventeenth centuries and provided instruction on Arabic numeral arithmetic to an increasingly literate English population. The growing popularity of Arabic numeral arithmetic was reflected in the changing terminology used to distinguish it from other forms of arithmetic. From the thirteenth century, Arabic numeral arithmetic had been known as *algorism*, after al-Khwarizmi. By 1530, it was also known as *cyphering*, to reflect its positional dependence on the concept of the cypher, or zero.[124] John Palsgrave included both words in his 1530 French-English dictionary, translating sample phrases such as "I Cyfer[,] I acompt or reken by algorism," "I can cyfer well ynough," "I Reken[,] I counte by cyfers of agrym," and "I shall reken it syxe tymes by aulgorisme or you can caste it ones by counters."[125] However by the latter half of the seventeenth century, terms intended to distinguish arithmetic by Arabic numerals from arithmetic by counters began to drop out of use. They were replaced by the term *vulgar arithmetic*, intended to distinguish arithmetic in whole numbers from other common types of arithmetic, including fractional, decimal, and logarithmical arithmetic.[126] By 1701, the term *arithmetic* itself

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[123] Surveyed areas included Northumberland and Newcastle; South Westmorland; Dronfield, Derbyshire; Yoxall, Staffordshire; Norfolk; Warminister, Wiltshire; Bermondsey and Rotherhith; and Maidstone, Loose, and Aldington, Kent. Wardley and White, "The Arithmeticke Project," 9-10.

[124] *OED*, s.v.v. "algorism, *n*." "cipher*, v.*"

[125] John Palsgrave, *Lesclarcissement de la Langue Francoyse* (London: Richard Pynson and Iohan Haukyns, 1530), 188r, 336v.

[126] *OED*, s.v. "vulgar, *adj.*"

had become so synonymous with Arabic numeral arithmetic that John Arbuthnot could declare it "would go near to ruine the Trade of the Nation, were the easy practice of *Arithmetick* abolished: for example, were the Merchants and Tradesmen oblig'd to make use of no other than the *Roman* way of notation by Letters" in conjunction with jetons, tally sticks or other non-literate numerical systems.[127]

Of the written systems common during the sixteenth and seventeenth century, both number words and Roman numerals encouraged their use in conjunction with other symbolic systems. The material characteristics of each system – namely their verbal and additive structures – did not lend themselves well to calculation, which was more easily performed via jetons and a counting board. At the beginning of the sixteenth century, Arabic numerals were also one symbolic system among many, used primarily to shorten the lengthy year of the incarnation. However over the course of the next two centuries, English men and women began to employ Arabic numerals in increasingly diverse contexts, including Arabic numeral arithmetic. At the end of the seventeenth century, Arabic numerals were still one symbolic system among many, however they had also become the most dominant symbolic system in England and the standard by which eighteenth-century numeracy would be judged.[128]

[127] Arbuthnot also disparages nations that had not adopted Arabic numerals: "the Nations, that want it, are altogether barbarous, as some *Americans*, who can hardly reckon above twenty." John Arbuthnot. *An essay on the usefulness of mathematical learning, in a letter from a gentleman in the city to his friend in Oxford.* (Oxford, 1701), 27.

[128] For more on eighteenth century popular numeracy, see Benjamin Wardhaugh, *Poor Robin's Prophecies: A Curious Almanac, and the Everyday Mathematics of Georgian Britain* (Oxford: Oxford University Press, 2012).

Conclusions

Early modern English men and women employed a variety of symbolic systems to convey numerical information, transcoding freely among performative, object-based and written systems. Oral systems were the most universal and served as a basis for acquiring a familiarity with other symbolic systems. Finger-counting was a widespread aid to mental arithmetic, but other gestural systems were considered curiosities and were promoted as methods for secret communication. More common were object-based systems such as tally sticks and jetons. These objects could be invested with both numerical and non-numerical information, however only the former could be transcoded into other symbolic systems. Both performative and object-based systems were employable by those with varying degrees of literacy and thus were institutionalized for use in government courts such as the Exchequer.

Number words and Roman numerals were the dominant written symbols at the beginning of the early modern period and were employed in conjunction with jetons and counting boards. Over the course of the sixteenth century, people adopted Arabic numerals in a context-specific fashion consistent with multiplistic numeracy. This began with dates and gradually expanded to include quantities and sums during the first half of the seventeenth century. After the Restoration, the population increasingly abandoned Roman numerals, jetons, and counting boards for Arabic numerals and written arithmetic, a process that will be further examined in the next chapter. While there were still multiple symbolic systems in the eighteenth century, knowledge of Arabic numerals had become the standard by which to judge English numeracy.

Chapter Three

"Finding Out False Reckonings"
Trust and the Function of Numbers

In 1635, Gervase Markham published a treatise on husbandry and farm management in which he argued a servant's trustworthiness was far more important than his or her skill with letters. However the more Markham discussed his servants' learning, the more he shifted his discussion of trust into terms of accounting and numbers, conflating numeracy with literacy as he argued:

> there is more trust in an honest scoure chaulkt on a Trencher, then in a cunning written scrowle, how well so ever painted on the best Parchment.... I had rather be my Mans *Amanuensis* to register his Truthes, then a Witnesse of his Learning in finding out false Reckonings. And there is more Benefit in simple and single Numeration in Chaulke, then in double Multiplication, though in never so faire an hand written.[1]

He was not completely opposed to writing – in particular, he argued "as touching the Master of the Family himselfe, learning can be no Burthern" – however he refused to put too much stock in it either, as writing could easily be "falsified and corrupted" while a servant's integrity "if it be sound will hardly be shaken."[2]

Markham not only made trust judgments based on the actions of his servants, he extended those judgments to cover the symbolic systems with which those servants conveyed information to him. Chalked scores were "honest" – a straightforward and a trustworthy symbolic system which was not prone to error. By contrast, he denigrated written symbolic systems as "cunning" – playing off the word's dual definition of both

[1] Gervase Markham, *The English Husbandman, drawn into two Bookes, and each Booke into two Parts* (London: William Sheares, 1635), 8-9.

[2] Markham, *The English Husbandman*, 8-9.

being learned and covertly deceitful – and argued this deceitfulness was an attribute that writing retained regardless of whether or not it was presented in an aesthetically pleasing manner.[3] However his examples suggest he was less mistrustful of writing in general and more wary of a new type of written calculations – "false reckoning" and "double Multiplication" in writing with Arabic numerals.

There are several historians whose epistemological work on truth and facts has led them to examine the role of trust in the creation of knowledge, particularly in the context of early modern England. Steven Shapin argued that to understand the nature of knowledge one must explore the culturally specific manifestations of a moral bond – trust – which enables a person to accept others' truth-judgments without proof. Any knowledge that is received, rather than personally experienced, requires the intermediation of another person and the construction of a trust bond between two or more people.[4] Consequently, "our knowledge of what the world is like draws on knowledge about other people – what they are like as sources of testimony, whether and in what circumstances they may be trusted."[5] With respect to the creation of seventeenth-century English scientific knowledge, Shapin argued that trust originated in "the purposeful relocation of the conventions, codes, and values of gentlemanly conversation into the domain of natural philosophy."[6] Barbara Shapiro vehemently disagreed with Shapin on this final point, arguing that "skill and experience played a greater role in the creation of the model of the scientific investigator than birth" and gentlemanly culture in

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[3] *OED,* s.v. "cunning, *adj*."

[4] Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1995), 7.

[5] Shapin, *A Social History of Truth*, xxv-xxvi.

[6] This is often referred to as Shapin's "Gentleman Thesis." Shapin, *A Social History of Truth*, xvii.

early modern England.[7] More generally, the origins of the modern "fact" lay not in the royal court but in the law court, where jurors determined the truthfulness of witnesses from all levels of society, not just those of gentle birth. In the courtroom – and later, as adopted for travel writing, newspapers, and science – all that was needed to establish truth were "credible and uninterested witnesses," regardless of social status, "attesting any fact under the solemnities and obligations of religion, and the dangers and penalties of perjury."[8]

Mary Poovey similarly located the basis of early modern truth judgments in credibility and disinterest, however she attributed these characteristics not to individuals or a group of people but rather to objects: double-entry bookkeeping and numbers. It was the formal system of double-entry bookkeeping, rather than the merchants using the system, which was invested with "an aura of credibility."[9] Poovey argued that numbers came "to seem preinterpretive or even somehow noninterpretive" during the eighteenth century, despite being a "knowledge system that privileges quantity over quality and equivalence over difference."[10] In Poovey's formulation, human actors still played a role in the use of double-entry bookkeeping and numbers, but one half of the trust bond could also shift to reside in a material object rather than another person.

During the early modern period, trust bonds could thus be formed either with other people or with material objects. In the first case, trust judgments were based on the

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[7] Barbara Shapiro, *A Culture of Fact: England, 1550-1720* (Ithaca: Cornell University Press, 2000), 165. Shapiro also addresses the early modern "fact" in her 1983 book *Probability and Certainty in Seventeenth-Century England: A Study of the Relationships Between Natural Science, Religion, History, Law, and Literature* (Princeton: Princeton University Press, 1983).

[8] Shapiro, *A Culture of Fact*, 31.

[9] Mary Poovey, *A History of the Modern Fact: Problems of Knowledge in the Sciences of Wealth and Society* (Chicago: University of Chicago Press, 1998), xvii.

[10] Poovey, *Modern Fact*, xii, 4.

person's character; in the second, trust judgments were similarly based on the object's material characteristics. As argued in Chapter Two, the various symbolic systems' extranumerary characteristics – which could not be transcoded between systems – differentiated the systems from one another and informed people's decisions about what system to use for what purpose. In the same fashion, extranumerary characteristics also formed the basis for trust judgments and influenced people's decisions about whether or not to trust a symbolic system to perform a specific function.

Two extranumerary characteristics that were particularly important in this regard were the opposing characteristics of *permanence* and *manipulability*. People who sought to record numerical information ascribed greater trustworthiness to systems with more permanent and less manipulable symbols. They even developed strategies to further decrease the manipulability of such symbols, thus increasing the trustworthiness of the system for conveying numerical information across time and space. By contrast, people who performed numerical calculations required less permanent, more manipulable symbols. The very act of calculating transformed two or more numbers into a single, numerical answer. The functions of recording and calculation were thus both conceptually and practically distinct, with competing needs with respect to permanence and manipulability.

This distinction is vital for understanding when and why early modern men and women chose to use – or not to use – the Arabic numeral system to convey numerical information. Retrospectively, it is easy to assume that as soon as the barrier of illiteracy could be overcome, "the western world would at once adopt the new numerals... which were so much superior to anything that had been in use in Christian Europe."[11] Indeed, one could wonder at the "stubborn resistance to the new numerals"[12] and denigrate those "few reckoners who went on using the old, obsolete methods."[13] But from an early modern viewpoint, Arabic numerals were not the most trustworthy of recording systems. Instead, their main allure came from one key feature that gave them the potential to operate differently from other symbolic systems; they enabled the unification of permanent recording and calculation. Early modern men and women could, and did, use Arabic numerals for solely one function or the other. However the potential for increased efficiency encouraged people to adopt the unification of both functions, even in the face of Arabic numerals' other limitations. During the last decades of the sixteenth century and the first half of the seventeenth century, Arabic numerals' enhanced functionality increasingly – but not universally – trumped the security of other symbolic systems.

Permanence and Trustworthy Records

The trustworthiness of a system could be judged by its ability to create a permanent record that persisted across space and time, particularly one resistant to later

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[11] Eugene Smith and Louis Charles Karpinksi, *The Hindu-Arabic Numerals* (Boston: Ginn and Company Publishers, 1911), 132.

[12] Karl Menninger points to the existence of a viable alternative in the counting board, and the confusion arising from an explicit zero, as the main "intellectual obstacle" to the widespread adoption of Arabic numerals. Karl Menninger, *Number Words and Number Symbols: A Cultural History of Numbers,* trans. Paul Bronner (Cambridge, Mass.: M.I.T. Press, [1969]), 422.

[13] Oddly, Georges Ifrah places the "decisive change" to Arabic numeral calculations in what he calls the "third phase of the Middle Ages." This seems to fall, chronologically, somewhere between the twelfth and fourteenth centuries. He admits that "a few reckoners" – which, even in the fourteenth century, would still include the majority of the English population – continued to use counting boards "for many generations," but does not attempt to follow up on that observation. Georges Ifrah, *From One to Zero: A Universal History of Numbers*, trans. Lowell Bair (New York: Viking Penguin Inc., 1985), 481.

alteration.[14] Of the seven most common early modern symbolic systems for representing numerical concepts, four were suitable for creating a permanent record. The performative systems – spoken words and gestures – were necessarily ephemeral because they existed only for the length of time necessary to perform a certain action. The system of jetons and counting boards lasted longer, but was ill-suited for creating permanent records because jetons were designed to be easily moved around a board and could not be fixed into a specific, unalterable location. The remaining systems – tally sticks, written English number words, Roman numerals, and Arabic numerals – created permanent records with varying degrees of resistance to later alteration. The two main ways the integrity of these systems could be compromised were the addition of new symbols and the alteration of existing symbols. The men and women of early modern England took these weaknesses into account when choosing how to use each symbolic system, employing strategies to minimize the risk of alterations and increase the trustworthiness of their numbers.

Of all the early modern symbolic systems, the split tally stick was considered the most secure and trustworthy, as it was specifically designed to create a permanent record and prevent later alteration of that record. The shape and grain of each stick was unique and the security of its notches was ensured by splitting the stick into two unequal parts. The smaller part – the foil – was given to the creditor and the larger part – the stock – was given to the debtor.[15] Any attempt to alter or add to the notches on either part would be

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[14] Not all alterations were made with malicious intent, however systems which allowed such alterations were more vulnerable to fraud.

[15] In the case of the Exchequer, the Exchequer would keep the foil and the stock went with the payer, to be returned to the Exchequer when the account was finally paid up. It is for this reason – the stocks often not coming back to be tied with the foils in the Exchequer archives – that most of the tallies which survived the Parliament fire are stocks. Intriguingly, the opposite pattern seems to hold for private tallies, for which

immediately apparent when the two were brought back together to check the account. When one late medieval creditor added 60*s*. to the notches on his Exchequer tally stick, his deceit was promptly discovered and he was sentenced to a year and a day in prison. [16] The tally stick thus had a built-in fraud detector and there appears to have been little to no early modern concern about attempts to counterfeit tallies.

Because of this tamper-resistance, tallies were considered trustworthy enough to function as a viable substitute for money in the form of specie.[17] During the early modern period, the Exchequer both received and disbursed funds through the use of tally sticks. Instead of keeping specie on hand, the Exchequer would cut a tally stick then give the foil to the debtor and the stock to their own creditor. For example, one fifteenth-century tally stick was entered into the Receipt Roll as follows: on July 11th, it was recorded as received "Sussex. De Johanne Perpount et Johanne Yerman collectoribus custumarum et subsidorum domini Regis in portu ville Cicestrie vij libras de eisdem custumis et subsidiis." A marginal note was later added, "pro domino de Bourchier per restitutionem vnius tallie videlicet xvij^{0} die Februarii anno xxiij^{o} Regis nunc leuate per manus Ricardi Wode."[18] This tally stick thus recorded a £7 debt owed by the king's

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more foils than stocks survive. Hilary Jenkinson, "Exchequer Tallies" in *Archaeologia or, Miscellaneous tracts relating to antiquity*, 2nd ser., 62, (London: Society of Antiquaries of London, 1911), 374, 379. Hilary Jenkinson, "Medieval Tallies, Public and Private" in *Selected writings of Sir Hilary Jenkinson* (Gloucester, England: Alan Sutton Publishing Limited, 1980), 49.

[16] Jenkinson, "Exchequer Tallies," 374.

[17] Samuel Pepys, in his diary, fretted equally over being robbed of tally sticks and being robbed of specie. When he evacuated during the Great Fire of London, the survival of his tally sticks was one of his main concerns: he "got my bags of gold into my office ready to carry away, and my chief papers of accounts also there, and my tallies into a box by themselfs." Samuel Pepys, *The Diary of Samuel Pepys*, ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1970-1983), 7:272.

[18] As translated by Hilary Jenkinson, this reads: "Sussex. From John Perpount and John Yerman, collectors of the king's customs and subsidies in the port of the town of Chichester, £7 of the said custom and subsidies. for Lord Bourchier by return of one tally, to wit one levied on the 17th day of February in the 23rd year of the present king, by the hand of Richard Wode." Hilary Jenkinson, "Exchequer Tallies," 370-1.

customs and subsidy officers in Chichester, which remained uncollected seven months later when it was reassigned to cover a debt to Henry Bourchier. By this means, the Exchequer could avoid both collecting its own debts – that duty falling to whatever creditor they had given the stock – and disbursing its own money.

Tally sticks proved so trustworthy as a symbolic system and so successful as a specie substitute that, during the seventeenth century, the Exchequer began issuing tallies for debts that had not yet come due. During his tenure as Treasurer of the Tangiers committee, Samuel Pepys was often concerned with obtaining permission to strike tallies upon future revenues. These tallies were given to various goldsmiths to secure an advance on the Excise Tax and thus to provide operating funds for the Tangiers committee.[19] After the Restoration, creditors were also authorized to charge interest on tallies, in essence, transforming tallies into a loan at interest rates of 10% per annum.[20] Pepys complained bitterly about losing so much money to interest, writing in his diary about being unable to find a

> way of shortening the time which our tallies take up before they become payable – which is now full two years – which is 20 per cent of all the King's money for interest – and the great disservice of his Majesty otherwise.[21]

Pepys was not the only one who lost part of the value of his tally sticks to interest and fees. Seventeenth-century goldsmiths, who were primarily responsible for exchanging tally sticks for gold, systematically "discounted" tally sticks. The holder of a tally stick

[19] See for example, Pepys, *Diary*, 6:106, 133, 157, and 162-4.

[20] R. D. Richards, *The Early History of Banking in England* (London: P.S. King & Son, Ltd, 1929), 59.

[21] Pepys, *Diary*, 7:407

would often only get sixty, fifty, or even forty percent of the money owed by the Exchequer.[22]

Tally sticks were thus an extremely trustworthy system for conveying numerical information; indeed, the only problem with their use as a specie substitute lay in the fact their monetary value depended upon both their unimpeachable trustworthiness as a symbolic system as well as the more problematic personal credit of their issuer. As Pepys discovered when he unwisely accepted a tally stick from an acquaintance: "upon his tally could not get any money in Lombardstreete, through the disrepute which he suffers."[23] No one doubted the veracity of Pepys's tally stick, only the ability of its issuer to make good upon his debt. Similar cracks began to appear in the Exchequer tally stick system when Charles II suspended Exchequer payments in 1672 – essentially declaring their tally sticks void – and caused a short-term panic among tally stick holders.[24] However over the successive decades, people continued to trust government tallies enough that the Bank of England accepted tallies for deposit starting in their first week of operation.[25] Only after the 1783 introduction of indented cheque receipts, whose cut-edged design mimicked the tally stick split, were tally sticks finally phased out of government service.[26]

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[22] There was even an established market for the buying and selling of government debt through tallies and other bills, a proto-stock market run by "stock jobbers" and "tally jobbers." Jenkinson, "Exchequer Tallies," 371. Richards, *Banking*, 205-6, 230.

[23] Pepys, *Diary*, 6:70.

[24] Charles II did not resume regular payment of interest on tally sticks and other government loans until 1677. Richards, *Banking,* 231. Jenkinson, "Exchequer Tallies," 371.

[25] Five tallies, valued at 112,000 *li*., were in the Bank's possession by its fifth day of operation. Richards, *Banking*, 154.

[26] Tally sticks were technically abolished in the same act that introduced the cheque receipts, however the implementation of the act was officially delayed until the two incumbent chamberlains left office, which only occurred in 1826. Jenkinson, "Exchequer Tallies," 368-9.

Of the three written systems, only writing out the English number words came close to matching the inherent permanence and ascribed trustworthiness of tally sticks. The alteration of a few letters within a word could not easily or invisibly change the meaning of the word itself. While extra words could be added to a number – forming and lengthening compound number words such as forty three or two hundred forty three – this required large amounts of extra space to write the new words. Such alteration could easily be prevented by embedding the number in a line of text. Thus the expansiveness of written number words was both a strength and a weakness, preventing the alteration of numbers while requiring significantly more space than the other written symbolic systems, particularly for large quantities.

Roman numerals were also a relatively difficult symbolic system to alter, though they were not as inherently secure as tally sticks and number words. The I, V, X, C, and M were distinctly different symbols and could not be easily exchanged for one another without leaving visible proof on the page. The only place the Roman numeral system was vulnerable to tampering was at the beginning and end of each written number. For instance, the number 'XVII' could be transformed into 'XXVII' or 'CXVII' by the addition of a larger numeral at beginning of the number. Similarly though less dramatically – and thus less likely to be noticed – the number could become 'XVIII' or even 'XVIIII' by the addition of another I at the end of the number.[27]

When Roman numerals were used within a line of written text, they were generally safe from this type of tampering. As with number words, adding a numeral would lengthen the number, crowd the text immediately before or after, and be noticeable

[27] While many early modern accounts did use the subtraction-based 'IV' to indicate the number four, others used 'IIII' to indicate the same thing. The use of one or the other seems to have been a matter of personal preference, as opposed to "correct" or "incorrect" standardized usage.

at a glance. However, as shown in the images below, most early modern accounts were set up in two columns, with the left column containing the description of an expense in textual form and the right column containing only the cost to be recorded, and possibly summed. The free-floating numbers of the right-hand valuation column were particularly vulnerable to tampering by the addition of extra numerals.

The three main strategies for minimizing this risk involved spatially isolating the otherwise free-floating numbers; this could be done via placement, the addition of non-numeric symbols, or the modification of the existing symbol set. Placement generally entailed left-justification of numbers, which made it impossible to add extra symbols to the left end of the number without destroying the clean vertical line of the number column.[28] Horizontal and vertical lines, along with brackets, could also be used to spatially locate the beginning of numbers in the same fashion. The addition of non-numeric symbols generally involved periods or colons placed before and after numbers, to isolate the number from any attempted addition, or the use of denomination symbols such as £, *s*, and *d* to the immediate right of the number. Lastly, the symbol J could be substituted for the terminal I in a number – i.e. 'XVIJ' instead of 'XVII' – and thus prevent the subsequent addition of more I's.[29] Most account keepers did not rely on a single strategy, but mixed and matched among them. The account pictured below, for example, used a combination of left-justification, horizontal lines and brackets, periods, denomination symbols, and terminal Js to constrain the otherwise free-floating Roman numerals.

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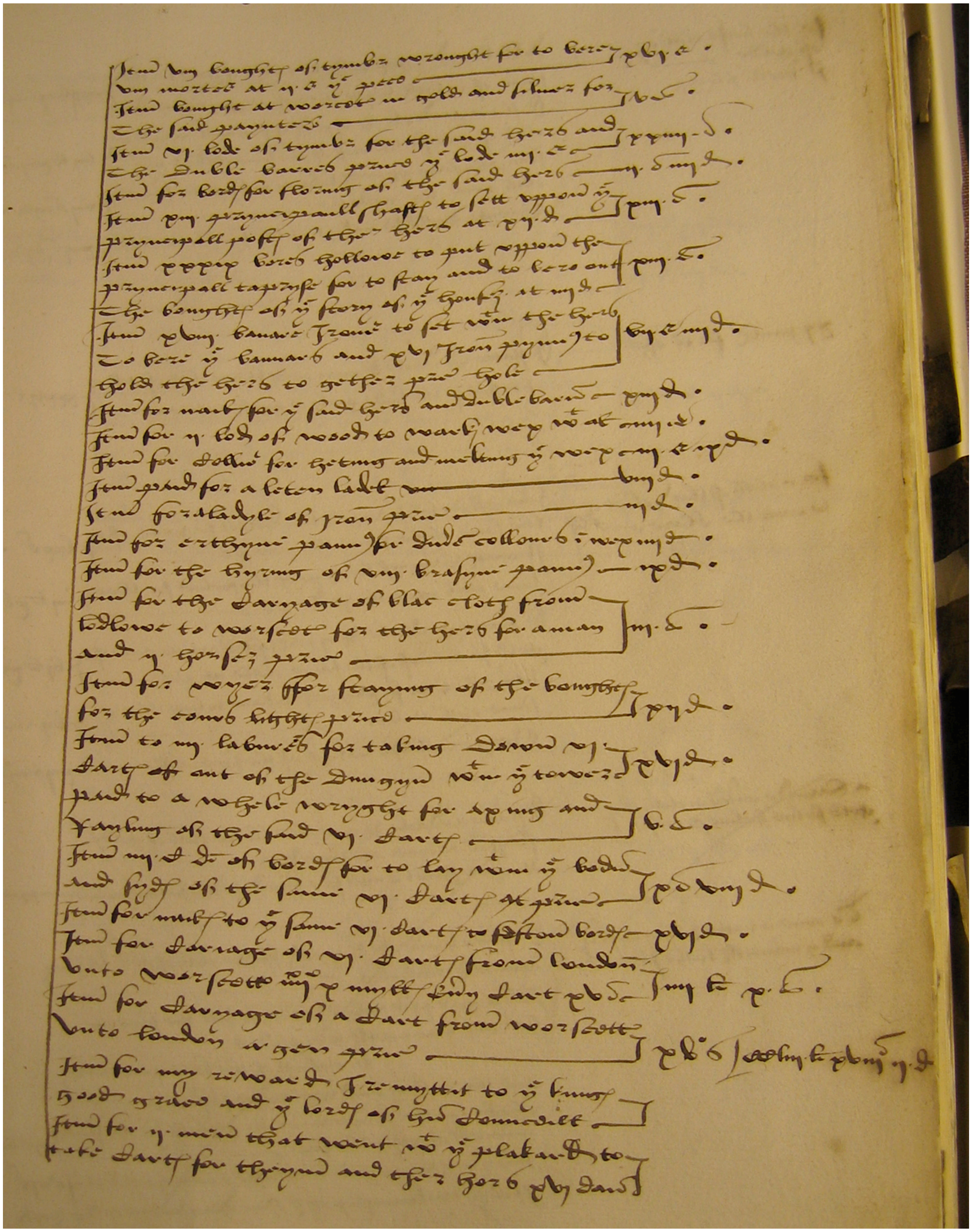
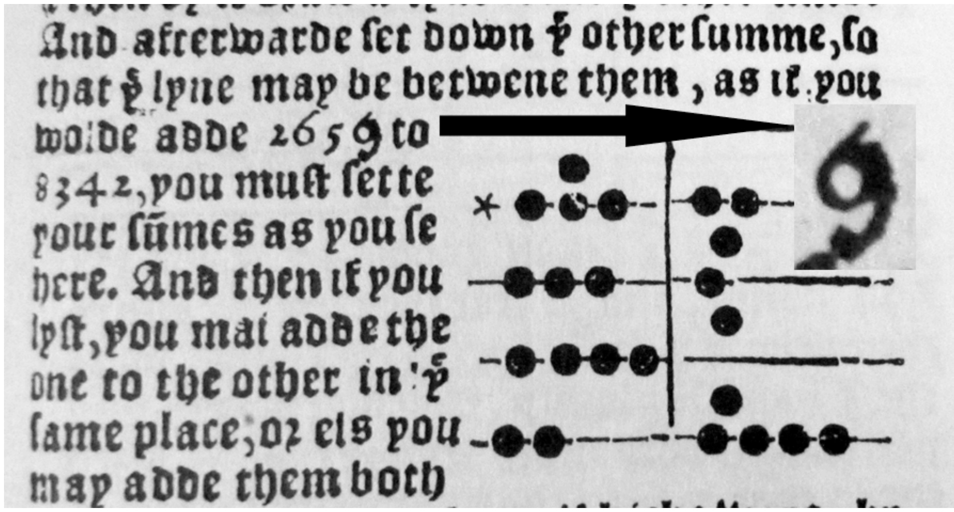
[28] Not all accounts were left-justified. Some were right-justified, although this did not provide the same protection against tampering with the left end of the numeral, e.g. altering 7 to 17 or V to XV.

[29] The terminal J probably originated in southern Italy around the year 900, though a few classical texts use an upside-down J in a similar fashion. Stephen Chrisomalis, *Numerical Notation: A Comparative History* (Cambridge: Cambridge University Press, 2010), 119.



Roman Numeral Account[30]

[30] Prince Arthur's funeral expenses, from the Lord Chamberlain's accounts of special events. TNA, LC2/1, f. 20r.



Correct Alteration of Arabic Numerals from Recorde's The Ground of Artes[31]

Of all the potentially permanent systems, Arabic numerals were the most vulnerable to tampering. The place-value system allowed a person to add any of the ten Arabic numerals to the end of a number, and all but the zero to the beginning of a number, providing a greater range of possible alterations. However most of the strategies that people used to minimize risk for Roman numerals could also be used with Arabic numerals. Placement and the addition of non-numeric symbols did not rely on any particular characteristic of Roman numerals. Only the practice of using a terminal J was not directly translatable to Arabic numerals.

More problematically, Arabic numerals were the only written system where the symbols themselves were easy to alter. The Arabic numeral '1' could be invisibly transformed into a '4' or a '7,' and could be transformed into most of the other numerals

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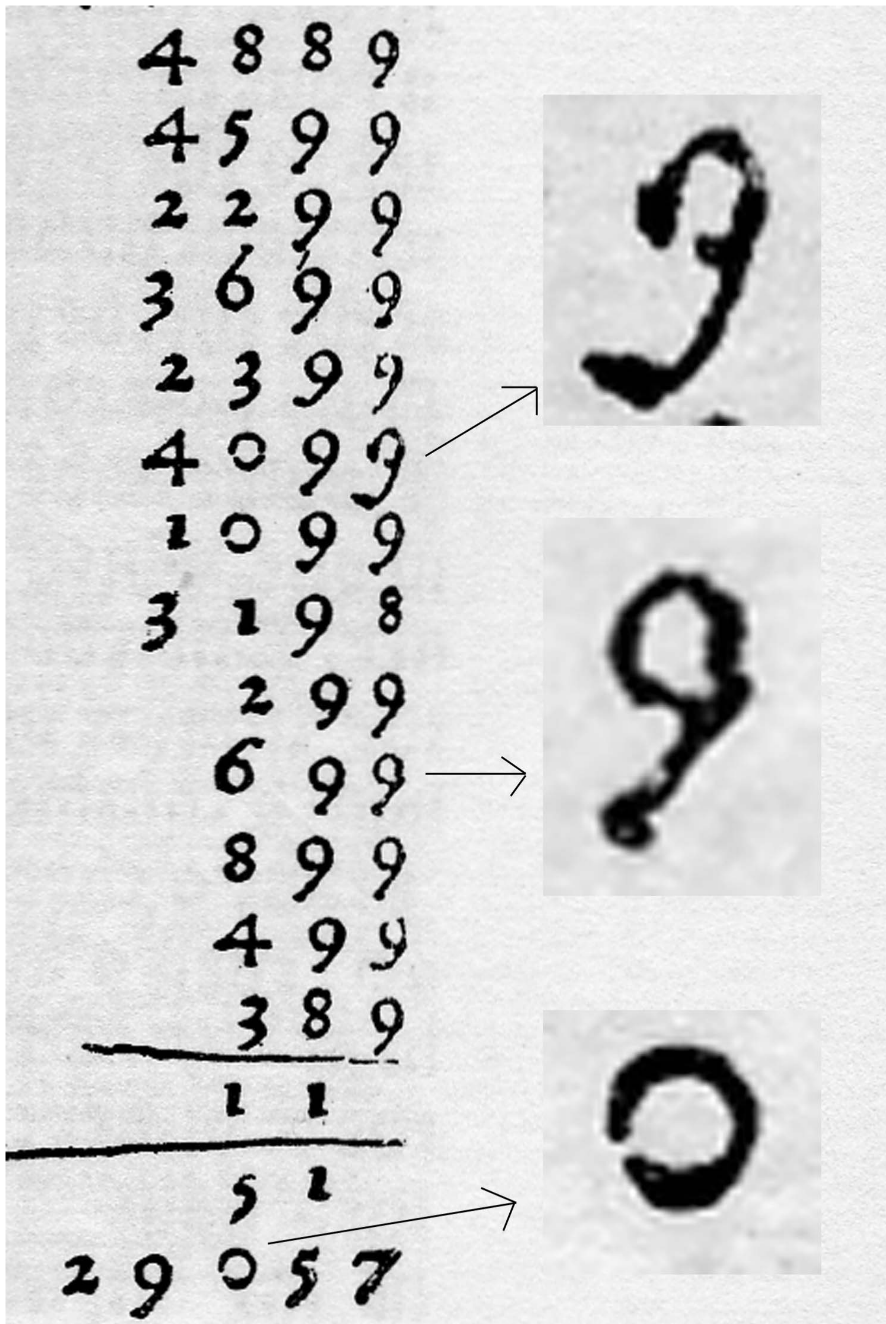
[31] Robert Recorde, *The Grounde of Artes Teachyng the Worke and Practise of Arithmetike* (London: Reynold Wolff, 1542; Amsterdam: Theatrum Orbis Terrarum Ltd., 1969), M8r. It is unclear precisely when this change was made, but it is a handwritten change made after the 1542 printing and preserved in the facsimile.

with only a little more effort. Similarly, ‘0,’ ‘6,’ and ‘9’ could be interchanged.[32] Depending on the neatness and style of a person's handwriting, other numerals could also be changed. Even in printed texts, Arabic numerals could be altered with varying degrees of success. In the image above, a copy of Robert Recorde’s *The Ground of Artes* has a ‘6’ that has been altered to a ‘9’ – because it is printed, the rising line of the original numeral can still be seen. By comparing the numbers written in Arabic numerals with their counterparts, as laid out with jetons, it becomes clear that the numeral actually should have been a '9' and that the anonymous writer was simply correcting the printed text. The image below shows another problem – in which a '0' was altered to a '9' – where the change is more difficult to detect. The altered '9' is distinctive from the other '9's in two different ways. Although each '9' has a different tail, the altered '9' has a suspicious splotch at the bottom of its tail. Furthermore, the circle of the '9' has a break in the same place as the '0's, as opposed to the generally complete circles of the rest of the '9's. The numbers, as currently written, add to 29066; using the originally printed number, 4090 instead of 4099, yields the correct sum of 29057. Other editions all have the numeral in question printed as a '0'.

Given this greater vulnerability to tampering, early adopters of the Arabic numeral system often preferred to retain more trustworthy English number words and Roman numerals for sections of their accounts that were at higher risk of tampering. As argued in Chapter Two, the common pattern for the adoption of Arabic numerals shows the initial use of Arabic numerals for the year of the incarnation. This date was relatively

[32] This claim is also made by Patricia Cline Cohen in *A Calculating People: The Spread of Numeracy in Early America,* (Chicago: The University of Chicago Press, 1982), 19. The changes did not even have to be deliberate – sloppily written ‘6’s or ‘0’s can easily be mistaken for one another.



Incorrect Alteration of Arabic Numerals from Recorde's The Ground of Artes[33]

[33] The alteration was probably an attempt to "correct" the problem, however it was correct as originally written and the alteration results in a sum that is 9 more than the given answer. Ironically, Recorde uses this sum to demonstrate how to check sums for correctness. His method – which involves calculating the numbers modulo 9 (i.e., the remainder when the number is divided by 9) and then summing – is incapable of detecting any error which involves a multiple of 9. Recorde, *The Grounde of Artes*, C8v.

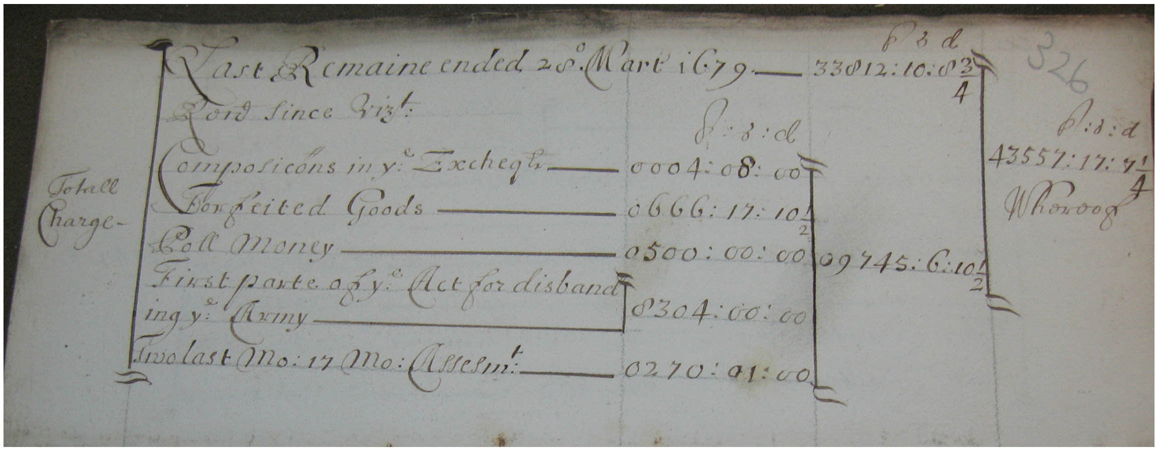
safe from alteration, as it would be clearly evident if someone added another numeral to the beginning or end of the year, and the date itself was generally clear from context.[34] Arabic numerals subsequently began to be used for all aspects of date-keeping and for numbers protected within lines of text, such as in the left-hand column of account books. However, many people – such as the Elizabethan merchant John Isham or the Caroline bailiff of Peterborough – preferred to retain Roman numerals for the free-floating numbers in the right-hand column of account books, even after Arabic numerals had become their system of choice for all other numbers.[35] As an advisor to the Cannock ironworks explained in 1590, other things might be written with Arabic numerals, but "Prises, for to avoide mistaking, are better written in letters."[36]

When Arabic numerals were employed to record the price of an item in the right-hand column of an account, the numbers tended to be spatially isolated into three separate columns – one each for pounds, shillings, and pence. Each price would then be recorded with six or more digits, even when such length was unnecessary. For example, as seen below, 4*li* 8*s* was recorded as 0004: 08: 00. The additional zeros prevented minor alterations to entries that might transform a single penny into 10 or 11 pence. However this did nothing to prevent alteration of the numerals themselves – the

[34] Even when discussing, for example, anno 492, there would be a clear contextual difference between 492 and 1492. Altering 1492 to 11492 or 14921 would result in a number which was clearly incorrect.

[35] Esther Ramsay, *John Isham, mercer and merchant adventurer: two account books of a London merchant in the reign of Elizabeth I* (Gateshead, Co. Durham: Northamptonshire Record Society, 1962). William Mellows, ed., *Peterborough local administration: parochial government from the Reformation to the Revolution, 1541-1689. Minutes and accounts of the feoffees and governors of the city lands with supplementary documents*. Publications of the Northamptonshire Record Society 10 (Kettering: Northamptonshire Record Society, 1937), 78.

[36] Keith Thomas, "Numeracy in Early Modern England: The Prothero Lecture, Read 2 July 1986," in *Transactions of the Royal Historical Society*, 5th Series, no. 37 (London: The Royal Historical Society, 1987), 121.



Arabic Numeral Account[37]

example above has at least three altered numerals. The alteration of numerals remained the greatest vulnerability of and barrier to trust for Arabic numerals.

Arabic numerals were thus the least trustworthy of the four early modern symbolic systems that could create a permanent record. The form of the numerals themselves, combined with the place-based value system, did not lend itself well to inalterably recording numbers. Even early adopters of the Arabic numeral system often retained Roman numerals for their most sensitive numerical data – monetary costs. For more important and extensive monetary transactions, the Exchequer chose to continue using tally sticks instead of switching to a completely written system that might be less bulky and easier to store; the trustworthiness of the tally stick form still trumped the possible advantages of moving to a different system.

Given this weakness in the Arabic numeral system, it should not be surprising that early modern English men and women were not particularly eager to give up Roman for

[37] From Miscellaneous Exchequer accounts. Notice an entry for 00*s* has been altered to 08*s* and an entry for 10*s* has been altered to 01*s*. The '5' in the entry for 0500*li* has also probably been altered from an unknown numeral. TNA, SP46/157, f. 326r

Arabic numerals. Markham was not the only person to prefer another symbolic system over the "cunning scrowle" of Arabic numerals. However for some, the disadvantages of Arabic numerals as a system for permanently recording information were outweighed by the advantages and flexibility of Arabic numerals used in calculation.

Manipulability and Calculation

In describing his ideal servant, Markham both made judgments about the trustworthiness of different symbolic systems and also expressed a desire for his servants to limit themselves to recording numerical data, rather than calculating with it. As he explained to his readers, "there is more Benefit in simple and single Numeration in Chaulke, then in double Multiplication."[38] This highlights an important conceptual distinction in early modern numeracies – the difference between recording and calculation. Most early modern symbolic systems lent themselves more readily to one or the other, depending on their degree of permanence or openness to manipulation, which reinforced this conceptual distinction. Of the available systems, only Arabic numerals had the potential to readily unite both recording and calculation.

Mathematicians divided arithmetic into several "parts," the first of which was always numeration or knowledge of the number symbols themselves. Subsequent parts of arithmetic – addition, subtraction, multiplication, division, and then various rules of three – all involved calculation and were conceptually distinct skills from numeration. For example, the seventeenth-century grammar school master John Brinsley only

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[38] Markham, *The English Husbandman,* 9.

expected students to learn numeration or "the perfect knowledge of these numbers." He required his students "to tell what any of these numbers stand for, or how to set downe any of them" and was content if his students could use a book's index, number pages correctly, and find the chapter and verse named in a church sermon.[39] For those students who wished to learn the separate skill of calculation, he recommended they acquire a copy of an arithmetic textbook such as "*Records* Arithmetique, or other like Authors, and set them to the Cyphering schoole."[40]

Technically, the skill of numeration and the subsequent act of being able to record numbers via symbols have a built-in series of implicit calculations: specifically, adding one to a given quantity. Sir Anthony Fitzherbert's accused idiot, by counting to twenty, was implicitly recognizing that one plus one is two, two plus one is three, and so on. To count beyond twenty requires either a massive memorization effort or, because of the syntactical nature of English number words, the ability to add a number less than ten to a power of ten – twenty-one is twenty plus one, forty seven is forty plus seven, and so on. Counting can even be used for general addition, through the practice known as "counting on" – e.g. adding five and three by counting to five, then counting on three more numbers: six, seven, eight.[41] However this inherent additivity within the natural numbers did not – and could not – enable more complex calculations.[42]

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[39] John Brinsley, *Lvdvs Literarivs: or, the Grammar Schoole: shewing how to proceede from the first entrance into learning, to the highest perfection required in the Grammar Schooles* (London: Felix Kyngston, 1627), 25-6.

[40] In this context, Brinsley is using the word "cyphering" to indicate calculations performed by Arabic numerals, not calculating in general. Brinsley, *Lvdvs Literarivs*, 26. For more on arithmetic textbooks and arithmetic education, see Chapter Four.

[41] Brian Butterworth, *What Counts: How Every Brain is Hardwired for Math* (New York: The Free Press, 1999), 253.

[42] The natural numbers are also known as the counting numbers. They begin with 1, 2, 3 and continue indefinitely through the positive integers.

Aside from conceptual differences, the distinction between recording and calculation was largely practical. Creating a permanent record requires fixing a numerical symbol so that it cannot be easily altered. By contrast, the numerical symbols used for calculation need to be manipulable, as the entire purpose of a calculation is to transform two or more numbers into a single number – the result. There is thus an inherent tension between recording and calculation, with their conflicting needs for permanence versus manipulability. As a result, different symbolic systems tended to be more suitable for one function over the other, depending on their extranumerary characteristics.

While performative systems were too ephemeral to create a permanent record, they could be used for calculation. Spoken number words technically supported addition and subtraction, through the practice of counting on, and fingers were widely recognized as a useful aid in calculation; George Brown's finger-counting system included instructions on how to perform addition, subtraction, multiplication, and division on one's fingers.[43] Object-based systems were also more suited to calculation than recording, but of the written systems only Arabic numerals could be used in calculation.[44] During the early modern period, the three main systems employed for calculations – non-split tally sticks, jetons, and Arabic numerals – fell into these last two categories.

Although the split tally stick of the early modern era was most associated with creating permanent records, the tally stick actually began as a calculating aid. In its original form, the tally stick was simply a stick with marks on its length, used by

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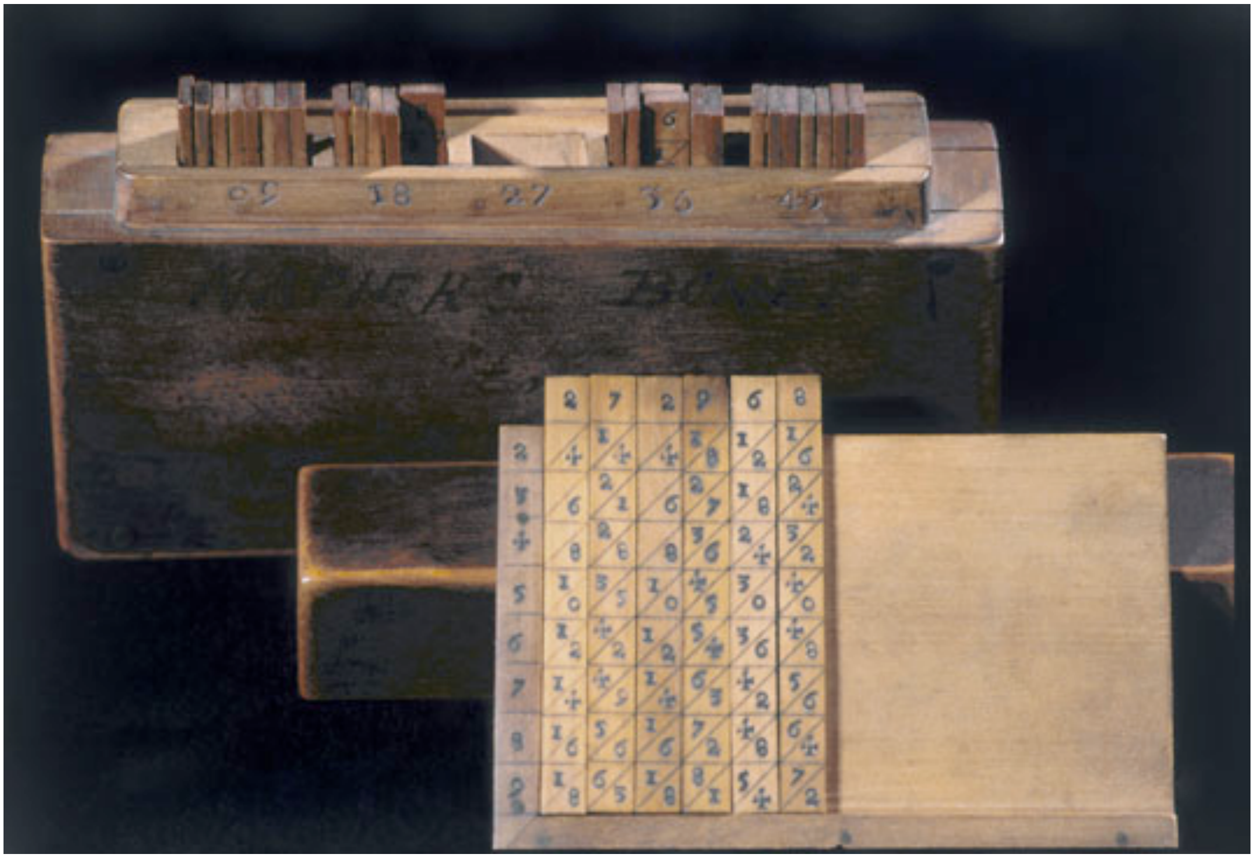
[43] George Brown, *A Compendious, but a Compleat System Of Decimal Arithmetick. Containing more Exact Rules for ordering Infinities, than any hitherto extant* (Edinburgh: George Brown, 1701), 3-4.

[44] Techniques for performing calculations via Roman numerals have been invented, but were never widely used. Chrisomalis, *Numerical Notation*, 115-6.



Set of Napier's Bones and Carrying Case from the Science Museum of London

shopkeepers to keep track of quantities during mental calculations. Eventually, they were pressed into service for keeping records of transactions instead and, with the invention of the split tally stick, became firmly associated with permanently recording information as opposed to as a calculation.[45] However the simple, non-split tally stick remained a useful calculating tool. Napier's bones, or calculating rods, are essentially tally sticks marked with numbers in a specific pattern which enable the user to reduce the complicated operations of multiplication and division to simple addition and subtraction.

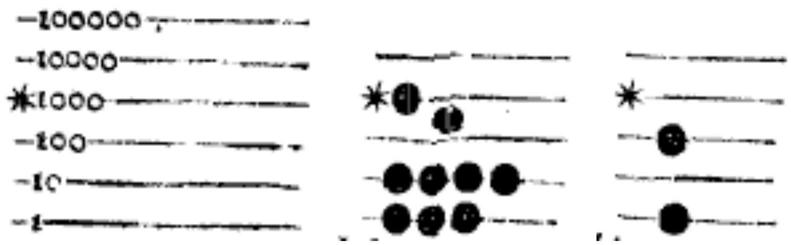
[45] For simple tally sticks, see for example several Roman tally sticks in the British Museum, registration numbers: 1868,0520.39; 1859,0301.51; 1856,1226.1494; 1772,0311.9; 1814,0704.1081; 1814,0704.1082; etc.

In the sixteenth and early seventeenth centuries, by far the most prevalent system for calculations was the combination of jetons and counting board, which was used in tandem with another system for permanently recording the results of each calculation. Jetons had numerous advantages as a calculating system. They were concrete, easily manipulable objects, which made addition and subtraction particularly intuitive. They could also be visually followed by someone other than the calculator, making it possible for a small group of people to watch and comment on the calculations as they occurred. This was especially helpful in matters of credit and debit, when several parties needed to agree that calculations had been done correctly.[46]

Significantly, jetons on a counting board also possessed the two most highly touted features of the Arabic numeral system: place-value notation and – albeit implicitly – the zero.[47] As read from the bottom up, the horizontal lines on the counting board signified the ones, tens, hundreds, thousands, and so on. In the middle example below, the three counters placed on the bottom line indicate the number three; the four counters placed on the second line indicate the number forty; and the single counter placed on the fourth line indicates the number one thousand. A counter placed between two lines – such as the counter between the hundreds and thousands line – indicates five of the line below, i.e. five hundred. This combination of base five and base ten characteristics was particularly convenient when paired with Roman numerals, which had separate symbols

[46] See, for example, the calculations being performed in the image on page 49.

[47] Historians exploring why Arabic numerals became the dominant symbolic system, worldwide, generally explain it by referencing both place-value notation and the explicit expression of zero. For example, Georges Ifrah writes: "In conjunction with the place-value principle, discovery of the zero marks the decisive stage in a process of development without which we cannot imagine the progress of modern mathematics, science, and technology. The zero freed human intelligence from the counting board that had held it prisoner for thousands of years, eliminated all ambiguity in the written expression of numbers, revolutionized the art of reckoning, and made it accessible to everyone." Ifrah, *From One to Zero*, 433.



The Places On A Counting Board, 1543, and 101 expressed in counters[48]

for five, fifty and five hundred. Overall, then, the counters took their value from their places on the counting board and the full number reads, in Roman and Arabic numerals, MDXXXIII or 1543.

Because of the structure of the counting board, this system also has an implicit zero – namely any line or space with no jetons placed upon it. For example, two jetons placed on the ones line and hundreds line indicate the quantities of one hundred, zero tens, and a single one. This in no way requires a person using a counting board to have an explicit concept of zero as a number because the zero is indicated by simply leaving a place empty and ignoring it, rather than by a specific action or symbol. However, an empty place on the counting board is functionally – if not necessarily conceptually – equivalent to the '0' in Arabic numerals.

Jetons and the counting board did have some minor disadvantages as a calculating system. First and foremost was speed. Calculations could be slow, particularly in comparison with similar systems, such as the Chinese abacus, or the use of Arabic numerals. As schoolmaster John Palsgrave wrote in his dictionary: "I shall reken it syxe

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[48] The star on the 1000 line was intended to keep students from losing track of which line belonged to which power of ten. Recorde, *The Grounde of Artes*, 117r-v, 119v.

times by aulgorisme or you can caste it one by counters."[49] This relative slowness was due partly to the length of time required to lay out the jetons, as well as the time required to move jetons back and forth across what could be a rather large board.

More importantly, each step of a calculation completely and irrevocably erased the previous step in the same calculation. There was no way to discover, after the fact, where an error occurred in a multi-step calculation. Nor was there a way to recover the previous step if the calculator noticed an error in the middle of a calculation. In both instances, the calculator had no choice but to start the calculation over again at the beginning. It is here where the practical difference between recording and calculating is most apparent – the very act of calculation literally erased the information recorded by the jetons in the previous step.

Of all the symbolic systems used in early modern England, only Arabic numerals had the potential to unite the two distinct functions of permanent recording and calculation. Like counting boards, Arabic numerals combined place-value notation with the – in this case explicit – concept of zero. The place-value-based methods of calculation employed with counting boards could therefore be adopted for use with the symbols of the Arabic numeral system. However, at the same time, the written characteristics of Arabic numerals led to the creation of a permanent record of both the answer and the calculations that led to that answer. Arabic numerals were thus capable of supporting both functions, albeit imperfectly; the competing needs of these functions, with respect to permanence, were the source of the Arabic numeral system's primary weakness both as a system for creating permanent records – its symbols' vulnerability to

[49] Cited in Thomas, "Numeracy," 106-7.

alteration – and as a system for calculation – its need for copious amounts of scratch paper to support the act of calculation.[50]

However during the early modern period, recording and calculation remained conceptually distinct functions, which complicates any attempt to examine the adoption of Arabic numerals for calculation rather than recording. The presence of Arabic numerals in a document does not necessarily mean they were also used for calculations. In some cases, explicit evidence of Arabic numeral calculations survives in the form of scratch work written in the margins of accounts, almanacs, and other papers. This is particularly common in early modern arithmetic textbooks geared towards the teaching of Arabic numeral arithmetic.[51] In cases where there is no explicit evidence, the existence of Arabic numeral calculations done on separate piece of scratch paper – which either did not survive or was separated from the pages bearing the calculations' results – can still be deduced through examining variations in the general Arabic numeral adoption patterns.

As argued above, there exists a pattern in the early modern adoption of Arabic numerals, which was primarily driven by the needs of permanent recording and perceptions of the system's trustworthiness. First, Arabic numerals turned up in dates – generally the year, followed by the day. Second, they appeared in quantities and prices safely sandwiched in the lines of text that form the left-hand column of accounts. Only lastly were Arabic numerals used for the free-floating prices in accounts' and inventories' right-hand valuation column, along with the *summa totalis* or "sum total" of that column. This last number is particularly significant, as the sum total is the clearest intersection of

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[50] This was especially problematic before the invention of paper mills and has often been cited as one of the factors delaying the widespread adoption of Arabic numerals. Calvin C. Clawson, *The Mathematical Traveler: Exploring the Grand History of Numbers* (New York: Plenum Press, 1994), 130; Menninger, *Number Words*, 224.

[51] For an analysis of marginalia and scratch work in early modern arithmetic textbooks, see Appendix A.

recording with calculation, being the sum of the numbers recorded in the column above. It is in the sum total where the majority of pattern variations occur.

For example, the accounts of the Roberts family of Sussex contains a folio that was used as a scratch sheet to calculate a sum using Arabic numerals, indicating the scribe's familiarity with Arabic numeral calculations.[52] However at the same time, the scribe used Roman numerals to record almost all the numerical information in his account book, with the exception of the year of the incarnation and – surprisingly – the sum total of the account columns. The scribe was thus familiar with Arabic numerals for calculation, while retaining Roman numerals for almost all aspects of recording. Nor was this anomalous use of Arabic numerals for sum totals an isolated example; the churchwardens of Ashwell, Knebworth, and Prescot parishes, also used Arabic numerals to record the sum total of Roman numeral columns. John Isham, a London merchant and member of the Mercers' Company, and his clerks similarly used Roman numerals to denote values in their right-hand columns, then employed Arabic numerals for the sum total.[53]

This suggests that, despite the general use of Roman numerals for permanently recording most numbers, these account keepers were using Arabic numerals and Arabic numeral arithmetic to perform calculations. If account-keepers used scratch paper to do their Arabic numeral calculations, then the otherwise anomalous use of Arabic numerals for a sum total indicates that the sum was calculated with Arabic numerals and not

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[52] Robert Tittler, ed., *Accounts of the Roberts Family of Boarzell, Sussex: c1568-1582*, Sussex Records Series 71 (Lewes, England: Sussex Record Society, 1977), 59. In the original document, it is labeled as folio 26v.

[53] Anthony Palmer, ed., *Tudor Churchwardens' Accounts*, Hertfordshire Record Society, 1 (Ware, Hertfordshire: Hertfordshire Record Society, 1985), 16, 25-6, 79-84. F. A. Bailey, ed., *The Churchwardens' Accounts of Prescot, Lancashire 1523-1607.* (Preston: Record Society of Lancashire and Cheshire, 1953), 135. Ramsay, *Isham*, cxi.

translated back into Roman numerals afterwards. While leaving the sum total in Arabic numerals theoretically left the number open to alteration, the item costs could always be recalculated to check the accuracy of a disputed sum. By a similar logic, on the rarer occasions when costs were recorded in Arabic numerals and sum totals were recorded in Roman numerals, counting boards were probably used to obtain the sum. While the sum theoretically could have been written in Arabic numerals, the lines and spaces of the counting board coincided more closely with Roman numerals. Thus it would have been both easier and more secure to record the final results into Roman, rather than Arabic, numerals.

In instances where only Roman numerals or only Arabic numerals appear, the continuing distinction between recording and calculating makes it difficult to determine with any degree of certainty what method was most likely used to calculate the sums. Account-keepers who did not use Arabic numerals for any recording purposes, including the year of the incarnation, were probably unfamiliar with Arabic numeral calculations. After the introduction of Arabic numerals to other parts of the account, it is possible that account-keepers used Arabic numerals for calculation and then translated their results back into Roman numerals for recording accuracy. Similarly, it is also possible that an account-keeper using only Arabic numerals might have mastered their use for recording but not calculation, and thus retained the use of a counting board for calculations only. Over the course of the seventeenth century, however, it is increasingly likely that the use of Arabic numerals for all aspects of recording went hand-in-hand with the use of Arabic numerals for calculations.

These variations in patterns of number use for the valuation column and sum totals formed the core of Peter Wardley and Pauline White's Arithmeticke Project, a collaborative project sponsored by the Family and Community Historical Research Society, which examined Arabic numeral use in 2422 probate inventories spread across seven counties. They divided their inventories into eight different "classes," with five covering the majority of situations. The inventories' valuation columns and sum totals were recorded, respectively, using Roman numerals and Roman numerals (class one); Roman numerals and Arabic numerals (class two); Arabic numerals and Arabic numerals (class three); Arabic numerals and Roman numerals (class four); and a varying mixture of Roman numerals and Arabic numerals (class five).[54] Their data supported the conclusion that the critical period of transition from Roman to Arabic numerals occurred in the decades between 1590 and 1650, with each parish having around a twenty-to-thirty year period where the majority of the transition was concentrated.[55]

Significantly, in four out of the five areas where Wardley and White had complete data, their probate inventory scribes began recording sum totals in Arabic numerals several years before they adopted Arabic numerals for recording prices in the valuation columns. In the remaining area – which consisted of three parishes in Kent – the use of Roman numerals with Arabic numeral sums was preceded, three years earlier, by a single inventory that used Arabic numerals with a Roman numeral sum.[56] This suggests that scribes generally adopted Arabic numerals for the function of calculation prior to

[54] The remaining categories were English number words/text (class six); "rough listings unable to be shoe-horned into 1-6 above" (class seven); and other (class eight). Peter Wardley and Pauline White, "The Arithmeticke Project: A Collaborative Research Study of the Diffusion of Hindu-Arabic Numerals," *Family & Community History* 6 (May 2003), 8.

[55] Wardley and White, "The Arithmeticke Project," 9.

[56] Wardley and White, "The Arithmeticke Project," 10. More extensive data and reports from The Arithmeticke Project are available online at: http://www.rw007a7896.pwp.blueyonder.co.uk/

employing them for all aspects of creating a permanent record. Only after adopting Arabic numerals as a system for calculation did scribes choose to adopt a single system for all aspects of recording as well as calculation.

The mixing and matching of seventeenth-century systems appears to have slightly baffled Wardley and White, who note the "significant tension" between recording and calculation, while at the same time apologizing for the scribe in their earliest example of a class three inventory as follows: "his command of the new system is almost complete, though Roman numerals creep in to the quantity descriptions." The idea that using Roman numerals might be a conscious choice, rather than a deficit in learning, is mentioned later, but only briefly.[57] However, in the context of multiplistic numeracy, it seems clear that these patterns of number use and Arabic numeral adoption resulted from both the practical need for trustworthy records as well as the continuing conceptual distinctions between recording and calculation.

The conceptual distinction between recording and calculation was thus reinforced by the conflicting, practical requirements of each function with respect to permanence and manipulability. Most symbolic systems had extranumerary characteristics that predisposed them towards either permanence and recording or manipulability and calculation. Only Arabic numerals were equally suited – or rather, equally not too ill-suited – for both functions, combining the relative permanence of writing with the manipulable place-value notation and zero of the counting board. Its strength as a system lay in combining the characteristics of two preexisting systems that had previously existed in symbiosis with one another.

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[57] Wardley and White, "The Arithmeticke Project," 10, 13.

Conclusions

Early modern men and women considered the extranumerary characteristics of symbolic systems when making decisions about whether or not to trust a system to perform either of the conceptually distinct functions of recording and calculation. In particular, they looked at the permanence of a system's symbols when choosing a system for recording, and developed strategies to increase symbols' resistance to after-the-fact alterations. At the same time, they looked for the opposing characteristic of manipulability when choosing a system that would facilitate calculations. Because recording and calculation remained conceptually distinct, people could employ different systems for each function, choosing the system that was best suited to the task at hand.

As a consequence, Arabic numerals were neither immediately nor universally believed to be a significant improvement over other early modern symbolic systems. While they shortened long numbers, Arabic numerals were also more open to alteration and manipulation that other common recording systems. For cases where the trustworthiness of recorded data was paramount – such as in the extensive dealings of the English Exchequer – tamper-proof tally sticks continued to be used throughout the eighteenth century. Even those who preferred to maintain written accounts tended to trust Roman, instead of Arabic, numerals for accuracy in recording the numbers in their valuation columns.

However, the easily-manipulated Arabic numerals did gain significant popularity as a calculating system during the late sixteenth and early seventeenth centuries, providing a viable alternative to the prevailing system of jetons and counting boards. The adoption of Arabic numerals for calculation was enabled, and encouraged, by changes in mathematical education practices that will be discussed in Chapter Four. For those who used Arabic numerals for calculation, the system's ability to combine calculations with the creation of a permanent record encouraged the further adoption of Arabic numerals for all aspects of recording. For those who chose to employ Arabic numerals for both recording and calculation, the advantages of the system's versatility outweighed the potential security risk.

Chapter Four

"Of Number's Use, The Endless Might"[1]
Textbooks and Mathematical Education

In early 1642, eighteen-year-old Adam Martindale became a schoolteacher in the town of Rainford. While there, he began writing an arithmetic textbook that was subsequently lost during his brief stint with the Parliamentary army at Liverpool. The only remnant of his manuscript is a brief description in his autobiography:

> a booke of Arithmetick for whole numbers and fractions in the old method of Record, Hill, Baker, &c. (for then I knew nothing of Decimals, Logarithms or Algebra) but somewhat more contracted by with an appendix of mine owne invention touching extracting the rootes of fractions.[2]

Martindale spent the next twenty years as a minister before returning to the study of mathematics, publishing two yearly almanacs and a book on surveying. An advertisement in the back of his 1682 Country Survey Book declared his willingness to board students during the winter and spring, and listed the mathematical skills he was able to teach. This included both the arithmetic in whole numbers and fractions that he had taught in his youth, as well as new subjects like balancing accounts, decimals, logarithms, mathematical instruments, and algebra. He could also provide instruction in other "parts of the *Mathematicks*" which built upon the basic arithmetical skills but took a purely practical bent: the doctrines of plain and spherical triangles, measuring land and

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[1] This is the first line of a longer poem by John Dee. Robert Recorde, *Record's Arithmetick, or, the Ground of Art*, ed. by John Dee, John Mellis, and Robert Hartwell (London: James Flesher, 1654), A1v.

[2] BL, MS Additional 4239, f. 18r. Martindale was not the only one to begin writing an arithmetic textbook, but never make it to publication. For example, BL, MS Additional 4473, ff. 24-27, contains the partially completed textbook of "William Senior professior of the Mathematiques 1641" who taught mathematics out of his house.

solid bodies, gauging casks, the use of globes, principles of astronomy and navigation, and the art of dialing by logarithms, scales, and geometrical projection.[3]

While Martindale is remembered more as a nonconformist minister than a "friend to mathematical learning," his career exemplified many of the kinds of mathematical instruction that were available in the late sixteenth and seventeenth centuries. Martindale was a product of a grammar school education and also taught at a grammar school early in his career. He later created his own mathematical academy that – according to John Aubrey – was the only place in England a boy could learn Latin and mathematics together.[4] He also ventured into the world of mathematical publication through his first, abortive attempt at an arithmetic textbook and his later mathematical work on surveying. This, along with his almanacs, provided the opportunity for him to share his mathematical knowledge more widely, as well as advertise his willingness to teach in person.

Mathematics education underwent important changes during the early modern period. Vernacular arithmetic textbooks were introduced in the mid-sixteenth century, and the increasing connection of arithmetic and writing manifested in the rise of special writing cum arithmetic schools. By the seventeenth century, arithmetic instruction could be acquired within most common educational trajectories, though such instruction only tended to be taken advantage of by boys who either intended to become tradesmen or were self-motivated by a fascination with numbers. Educators and mathematicians thus advocated for the recognition of the practical utility of mathematics, taking particular

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[3] Adam Martindale, *The Countrey-Survey-Book: or Land-Meters Vade Mecum*, (London: A.G. and J.P., 1682), M3r.

[4] Aubrey also praised Martindale's teaching methods, noting that "all his scholars are good Surveyors; they take a great delight in it: and on playdayes make it their pastime." Bodl, MS Aubrey 10, f. 8r.

notice of the ways that mathematical learning could advance the interests of the English state. By the end of the seventeenth century, this encouraged an increasing awareness of arithmetic as being more than just for merchants and shopkeepers – numbers could be used in anyone's daily life.

Textbooks and Tutors

Vernacular arithmetic textbooks were a vital source of mathematical instruction in the late sixteenth and seventeenth centuries. Their use was facilitated by the printing press, which made it possible to disseminate texts cheaply and widely, and by increasing literacy rates throughout the sixteenth and seventeenth century. These textbooks were written by professional mathematics tutors, who drew upon their practical teaching experiences to formulate arithmetical concepts in a manner that would be both comprehensible and appealing to potential students. Both authors and editors used textbooks as a vehicle for promoting their mathematical schools and attracting students to learn advanced mathematics in practical subjects.[5] During the seventeenth century, changes in both methods of instruction reflected the expanding content of an arithmetical education and the increasing connection between the skills of calculating and writing.

Printed books were increasingly available throughout the early modern period. Nearly one hundred thousand different titles survive from the sixteenth and seventeenth

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[5] Alternatively, some seventeenth-century mathematicians advertised through almanacs – for example Daniel Browne, Thomas Bretnor, Henry Coley, Peter Parker, and John Taylor. Arithmetic textbooks and almanacs were useful enough places to advertise that even non-authors placed advertisements for students. James Atkinson announced his ability to teach writing, arithmetic, merchants accounts, geometry, algebra, trigonometry, astronomy, navigation, gunnery, fortification, and the use of mathematical instruments, in *Cocker's Decimal Arithmetick*. Edward Cocker, *Cocker's Decimal Arithmetick* (London: Tho. Passinger, 1685), A8v. For more on almanacs, see Chapter Five.

centuries, with annual publication going from forty-six titles in 1500, to 259 titles in 1600, to 577 titles in 1640.[6] Most of the printing industry was concentrated in London, the home of the Stationers' Company and the center of English book production. London booksellers abounded and carried large inventories of diverse titles. In the 1660s, George Thomason stocked 14,942 pamphlets and 7,216 newspapers, while Charles Tias had over 90,000 octavo and quarto books in his shop, house, and warehouse.[7] There was a considerable trade in books outside of London, as well. In 1585, Roger Ward of Shrewsbury had an inventory of 2,500 books, including 546 different titles, while in 1644 John Awdley of Hull had 832 different titles for sale.[8] Peddlers also carried smaller stocks of printed broadsides and books with them to sell at inns throughout the kingdom.[9]

While it is impossible to determine exact literacy rates, there was a general upward trend in literacy during the sixteenth and seventeenth centuries. David Cressy used signature counting – a method which conflates the abilities of reading and writing – to estimate overall male literacy rates of 10% in 1500, rising to 30% by 1600 and reaching 50% by 1700. Cressy's female literacy rates persistently lagged 10-20% behind their male counterparts' rates.[10] Urban areas tended to be more literate than rural areas, with London and Bristol both having perhaps as high as 65% literacy in the mid-

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[6] Keith Thomas, "The Meaning of Literacy in Early Modern England," in *The Written Word: Literacy in Transition, Wolfson College Lectures 1985*, ed. by Gerd Baumann (Oxford: Clarendon Press, 1986), 99. Adam Fox, *Oral and Literate Culture in England, 1500-1700* (Oxford: Clarendon Press, 2000), 14.

[7] Fox, *Oral and Literate Culture*, 16. Margaret Spufford, *Small Books and Pleasant Histories: Popular Fiction and Its Readership in Seventeenth Century England* (London: Methuen, 1981), 101.

[8] Thomas, "The Meaning of Literacy," 112. Fox, *Oral and Literate Culture*, 15.

[9] Tessa Watt, *Cheap Print and Popular Piety, 1550-1640* (Cambridge: Cambridge University press, 1991), 6. Spufford, *Small Books,* 66.

[10] David Cressy*, Literacy and the Social Order: Reading and Writing in Tudor and Stuart England* (Cambridge: Cambridge University Press, 1980), 142-56.

seventeenth century.[11] The major problem with signature counting as a method for estimating literacy is that reading and writing were taught sequentially, rather than concurrently, during the early modern period. Thus these numbers must significantly underestimate the number of people who had the ability to read, particularly those who had the ability to read printed black letter – the "type for the common people," which was given to convicted criminals attempting to claim benefit of clergy – as opposed to roman type or various styles of handwriting.[12] Overall, however, it seems clear that the number of people able to read printed books rose considerably over the course of the early modern period.

The increasing availability of printed books – and the increasing percentage of the population able to read them – enabled the production of nearly 300 titles relating to arithmetic education in the early modern period.[13] Only a few arithmetic textbooks were printed during the first three quarters of the sixteenth century, but their rate of production began to increase in the 1570s and continued growing throughout the seventeenth century. These textbooks were usually printed in the more portable and affordable octavo or duodecimo formats, with seventeenth-century prices ranging from two to four shillings – though previously used textbooks sold for as little as sixpence.[14] Successful titles were reprinted whenever the previous edition sold out, as Thomas Rooks – the stationer who reprinted *Hodder's Arithmetick* – proudly explained in 1667:

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[11] Jonathan Barry, "Popular Culture in Seventeenth-Century Bristol," in *Popular Culture in Seventeenth-Century England*, ed. by Barry Reay (London: Croom and Helm, 1985), 62. Fox, *Oral and Literate Culture*, 18.

[12] For more on the multiplicity of early modern literacies, see Thomas, "The Meaning of Literacy," 99.

[13] See the *ESTC*.

[14] Surviving arithmetic textbooks sometimes have their sale prices inked on the front covers. See, for example, BL, C.115.n.43; CUL, M.6.58; UIUC, X513 w72p; and WL, 646/A.

> in this bad time of trade of Books, in less than ten months, I sold of them 1550. There being very few of this kind yet set forth by an Teacher of this Art; and as I am informed, those which are extant, of very little use to the *Learner*, without the help of an expert *Tutor*.... Now I desire your candid ingenuity further to observe, that these Books of the third Edition are sold and out of print, and now I present you with a 4th Edition.[15]

The longevity of these titles, most of which continued to be reprinted long after their original authors died, indicates popular demand for well-written arithmetic textbooks remained high throughout the seventeenth century.

Although Rooks denigrated textbooks that required the "help of an expert *Tutor*," many students learned arithmetic through the combined aid of textbooks and tutors. John Wallis, the third Savilian Professor of Geometry at Oxford University, described in his autobiography how his younger brother tutored him in arithmetic, explaining that "he had shewed me by steps, in the same method that he had learned them: and I had wrought over all the *Examples* which he before had done in his book." Wallis then continued his education through textbooks, studying "at spare hours; as books of *Arithmetick*, or others *Mathematical* fel occasionally in my way."[16] Both Wallis and his brother thus learned arithmetic out of some sort of book – either a printed arithmetic textbook or a handwritten book of arithmetical notes, problems, and solutions which served the same purpose.[17] Both brothers also had the benefit of a tutor to explain the methods taught in their shared textbook, though later in his education Wallis found books alone a sufficient teaching tool.

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[15] James Hodder, *Hodder's Arithmetick: or, That Necessary Art Made Most Easie* (London: J. Darby, 1667), a4v-a5r.

[16] John Fauvel and Jeremy Gray, ed, *The History of Mathematics: A Reader*, (New York: Palgrave Mac Millian, 1987), 317.

[17] For an example of a handwritten arithmetic textbook, see HEH, MS HA School Exercises Box 5, Folder 1, which is an educational common-place book dating to 1623. The book contains extensive notes on geometry and rules of measurement, as presented by the London mathematical tutor, John Speidell.

Wallis's autobiography also raises a significant point about the way arithmetic textbooks were used in the early modern period. Both Wallis and his brother did arithmetical scratchwork and practice problems "in his book," a practice which leaves considerable evidence in the form of marginalia. It is thus possible to make some educated guesses about book use – as opposed to book purchasing, which does not necessarily mean the book was ever read – by examining marginalia. William Sherman has surveyed the sixteenth and seventeenth books held by the Huntington Library and concluded that over 50% of surviving sixteenth-century books have substantive marginalia, indicating reader engagement with the texts. For certain subjects – such as practical guides to law, medicine, and estate management – the percentage of marginalia remains over 50% for the seventeenth century as well, though the overall marginalia rate for sixteenth- and seventeenth-century books, combined, is just over 20%.[18]

My own study of 365 surviving arithmetic textbooks indicates marginalia rates of about 75% for the sixteenth and seventeenth centuries. Slightly more than 50% of textbooks contain marginalia that clearly indicate arithmetical knowledge and engagement with text, including manicules, underlining, corrections to the text, marginal glosses, accounting, and scratchwork.[19] This engagement sometimes extended to commentary on previous annotators, such as one annoyed writer who complained about the strike-outs in the text: "The book is right, and needs not this blottinge."[20] The

[18] Sherman argues that the number of surviving books with marginalia is surely only a fraction of those books which were annotated during the sixteenth and seventeenth century. The more heavily used books would have been more vulnerable to decay. Furthermore, many book owners had no compunction about effacing the marks of previous users, particularly by cropping off marginalia or by bleaching the pages. William Sherman, *Used Books: Marking Readers in the Renaissance England* (Philadelphia: University of Pennsylvania Press, 2008), 5-6, 9.

[19] The remaining 25% consists mostly of ownership marks and handwriting practice.

[20] APS, 512 K47e, f. K1v.

percentage of marginalia remained relatively consistent from decade to decade, though some arithmetic textbooks apparently lent themselves to annotation more readily than others.[21] Assuming these percentages are also representative of books that did not survive, then a significant number of students must have learned arithmetic from or with the aid of a printed textbook.[22] The most popular of these arithmetic textbooks was also one of the earliest – *The Ground of Artes* or *Record's Arithmetic*, which became a byword for arithmetic textbooks in the seventeenth century.[23]

England's first arithmetic textbooks were published in the middle of the sixteenth century. An early Latin arithmetic textbook, Cuthbert Tunstall's *De Arte Supputandi,* was soon followed by vernacular competitors, beginning with the anonymously authored *An Introduction for to Learn to Reckon with the Pen & with the Counters*.[24] These early books were swiftly overtaken in popularity by Robert Recorde's *The Ground of Artes*, first published in 1543, and Humfrey Baker's *The Wellspring of Sciences*, first published in 1562. These later two textbooks proved to be extremely successful and together went

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[21] See Appendix A.

[22] One copy of Cocker's arithmetic textbook that is held in the Senate House Library contains a handwritten series of laments – probably inserted by Augustus DeMorgan – over the difficulty finding a copy of the same, with speculations that editions have vanished because they were used until they fell apart. SHL, [DeM] L.1 [Cocker] SSR.1700, f. 3r.

[23] See, for example, John Brinsley, *Lvdvs Literarivs: or, the Grammar Schoole; shewing how to proceede from the first entrance into learning, to the highest perfection required in the Grammar Schooles* (London: Felix Kyngston, 1627), 26.

[24] Historian Jean Vanes claims the printer John Herford produced this work from French and Dutch originals. Jean Vanes, *Education and Apprenticeship in Sixteenth-Century Bristol* (Bristol: Bristol Branch of the Historical Association, 1982), 21-2. However Herford only printed the 1546 edition. A 1539 edition was printed by Nycolas Bourman, and a fragment from 1526, which is possibly but not definitively the same work, was printed by Rychard Fakes and claimed to have been "Translated out of Fre*n*she in to Englyshe not without grete labour." Anonymous*, The arte and science of arismetique* (London: Rychard Fakes, 1526), f. 1r. Later editions were printed by John Waley, John Awdley, John Charlewood and James Roberts. On the frontispiece of a 1581 edition, held by Worcester College Library, Oxford, the annotator William Clarke notes the authorship is "ascribed to W. Awdley" however this is most probably a mistaken reference to the printer of two earlier editions, John Awdley.

through over seventy editions.[25] They only went out of print in the late seventeenth century, after being eclipsed by a new style of arithmetic textbooks that also included sections on decimal fractions, logarithms, and algebra.[26] However, marginalia in surviving editions of *The Ground of Artes* and *The Wellspring of Sciences* shows that they were often resold or passed down within families and thus they continued to be used throughout the eighteenth century, particularly by female students who had less access to institution-based education.[27]

Recorde and Baker were not simply interested in mathematics, they were mathematical tutors who drew on their teaching experience when writing their arithmetic textbooks. Recorde organized his *The Ground of Artes* in the form of a dialogue between a Master mathematician and the Scholar, his pupil, and the interactions between them deliberately mimicked an oral tutoring session. The Scholar challenged the Master's authority, made calculation errors that the Master had to correct, and asked questions about complicated ideas such as the Arabic numeral place-value system. The first edition of *The Ground of Artes* was even dedicated, with arithmetical instruction in mind, to a gentleman named Richard Whalley, in the hopes that it would "be some help unto your young chyldren, whose furtheraunce you desyre no lesse than your owne."[28] Only in the

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[25] For a list of early modern editions of Recorde and Baker's arithmetic textbooks, see Appendix B. For examples of early modern arithmetic according to Recorde, see Appendix C.

[26] James Hodder, Edmund Wingate, and especially Edward Cocker. See below.

[27] Ownership has been determined by names and other ownership marks. For example, one 1623 edition of Recorde's *The Ground of Artes* passed through the hands of at least half a dozen annotators, including "John Griffiths" and "Mary Griffiths: his Daaghter." HEH, 21793, f. 2v.

[28] Richard Whalley had 25 children by three different wives. At least the five children from his first marriage were of an age to be learning arithmetic at the time Recorde published his first edition of *The Ground of Artes*. Robert Recorde, *The Ground of Artes Teachyng the Worke and Practise of Arithmetike* (London: R. Wolfe, 1543), A1r. *ODNB*, s.v. "Whalley, Richard (1498/9-1583), *administrator*," by Alan Bryson.

1552 edition, once the success of his textbook had become apparent, did Recorde instead ambitiously dedicate his work to King Edward VI.[29]

After Recorde's death, *The Ground of Artes* continued to be published under the editorship of mathematicians with practical teaching experience, who used their work editing *The Ground of Artes* as a method to promote themselves. John Dee taught mathematics in London during the 1550's, while John Mellis and Robert Hartwell both advertised themselves as mathematical tutors. Mellis styled himself a "schoolmaster" and the 1582 to 1610 editions also

> giueth intelligence: That if any bee minded to haue their children or seruants instructed or taught in this noble Arte of Arithmetick, or any briefe practise thereof. [His] method is such by long custome of teaching, that (God to friend) he will bring them (if their capacitie be any thing) to their desire therein in a short time... Also after reasonable vnderstanding of Arithmeticke[30]

they might learn accounts of Debtor and Creditor, and the principles of Algebra. Hartwell styled himself a "Philomathematicus" and "Practitioner in the Mathematicks" who taught students in his school "In Fleetestreete, neere the Cundite, within Hanging Sword Court," which by 1632 had moved to "Great Saint Bartholomewes in the new street."[31] He advertised his arithmetical offerings in far more detail than Mellis: whole numbers and fractions, the extraction of roots, astronomical fractions, proportions, the rules of equation with algebra, and accounting. He also offered his students a variety of advanced lessons in the practical, real-world applications of mathematics, including

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[29] Robert Recorde, *The Ground of Artes* (London: Reynold Wolff, 1552), A2r.

[30] Robert Recorde, *The Grounde of Artes*, ed. by John Mellis and John Wade (London: William Hall, 1610), Mm8r.

[31] Robert Recorde, *The Grounde of Artes*, ed. by John Dee, John Mellis, and Robert Hartwell (London: John Beale, 1623), 596. Robert Recorde, *The Ground of Artes*, ed. by John Dee, John Mellis, and Robert Hartwell (London: Thomas Harper, 1632), 611.

geometry, trigonometry, logarithms, navigation, dialing, accounting, and mathematical instruments.[32]

Like Recorde, Humfrey Baker never explicitly advertised his tutoring services in his textbook, *The Wellspring of Sciences*. However a surviving broadside that advertises a detailed list of mathematical subjects Baker was able to teach, along with an example of his ability to reconcile merchant accounts, demonstrates the close correlation between his two instructional activities. The content and lesson order for both were largely similar: they began with numeration, addition, subtraction, multiplication, division, and progression in whole numbers, before covering the same ground with fractions. They then continued with commerce-based applications of these operations, including the various rules of three, the rule of gain and loss, the rules of fellowship and partnership, the rules of interest, the rule of allegation, and the rule of suppositions or false positions.

However towards the end of his textbook and his tutoring advertisement, Baker expanded upon his standard catalog of arithmetical skills in two different ways, choosing the subjects most appropriate to each informational medium. In a book that could be carried around in a pocket for reference, he included practical information on trading geared towards a merchant who might be travelling abroad and working with other merchants from across Europe. This consisted of rules about the trade of merchandise with tare and allowances, rules relating to bartering, examples of how to exchange money from one place to another, and information about weights and measures throughout Europe. By contrast, in person he taught more complicated mathematical subjects, as well as those requiring the use of instruments and other hands-on instruction. This

[32] Recorde, *The Grounde of Artes*, 1623: Rr8v.

included algebra, accounts of debtor and creditor, measurement of land and solid objects, the use of various mathematical instruments, and the "principles of geometry, to be applied to the ayde of all Mechanicall worke-men."[33]

Both Recorde and Baker's textbooks are typical of what Adam Martindale called the "old method" of arithmetic, which was commonly called cyphering in the sixteenth century and vulgar arithmetic in the seventeenth century. This method of arithmetical instruction focused on introducing Arabic numeral calculations to an English population more used to Roman numerals and counting boards. It always began with a presentation of the first five "parts" of arithmetic – numeration, addition, subtraction, multiplication, and division – and usually continued with progression and some variant of the rule of three. Beyond that, arithmetic textbooks' content varied, particularly with respect to the tables, practice problems, and other content that was meant to be of use in readers' daily lives. While Roman numerals occasionally appeared in these textbooks, they usually did so in the section on numeration, where the student first learned Arabic numeral symbols. Most seventeenth-century textbooks omitted Roman numerals entirely and related Arabic numerals back to English number words instead. The exception to this is Recorde's textbook which, until the 1699 edition, always included a second section on the counting boards used to perform arithmetical operations in tandem with written Roman numerals. However, neither Baker nor any subsequent authors offered instructions on counting boards, and counting boards are not mentioned in any of the printed advertisements.

Although the main structure of these textbooks remained the same, authors and editors constantly updated their textbooks' content and touted the most significant

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[33] The only known copy of this broadside is held by the Society of Antiquaries, London.

changes on their title pages in hopes of convincing potential buyers that their textbooks were more useful than anyone else's. Humfrey Baker edited several editions of *The Wellspring of Sciences* before his death, in which he included a variety of "most necessary Rules and Questions" aimed at an audience of merchants and artificers.[34] Starting in the 1591 edition he also included tables of "measures and waights of diuers places of Europe" that would also be of use to merchants who traded on the Continent.[35] John Mellis added "sundry new rules" including "a third parte of rules of practice" to his 1607 edition of *The Ground of Artes*. He appealed directly to merchants and traders by adding "diuerse such necessarie rules as are incident to the trade of merchandise" and "diuerse Tables and instructions that will bring great profit and delight vnto Merchants, Gentlemen, and others."[36] Of all his tables, the ones that set forth the current value of various coins must have been the most useful to readers because he specifically highlighted these tables in the title of the 1610 and all subsequent editions. Robert Norton added "the art and application of Decimall arithmetic" in 1615 but this failed to appeal to readers and was dropped from the next edition.[37] However, Norton's tables of board and timber measures survived and were mentioned prominently on the title page of subsequent editions. Norton's table for 10 percent interest found enough of an audience that Robert Hartwell replaced it with more extensive interest tables in 1631. Hartwell's

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[34] Humfrey Baker, *The Wellspring of Sciences* (London: Henry Denham, 1564), A1r.

[35] Humfrey Baker, *The Wel Spring of Sciences* (London: Thomas Purfoote, 1591), A1r.

[36] Robert Recorde, *The Grounde of Artes*, ed. by John Dee and John Mellis (London: John Harison, 1607), A1r.

[37] Robert Norton had previously translated a Dutch treatise on decimal arithmetic and published it in 1608. Simon Stevin, *Disme: the Art of Tenths, or, Decimall Arithmetike*, trans. Robert Norton (London: S. Stafford, 1608). Robert Recorde, *The Grounde of Artes*, ed. John Dee, John Mellis and Robert Norton (London: Thomas Snodham, 1615), A1r.

new tables were "of Interest vpon interest, after 10 and 8 per 100" as well as "the true value of annuities to be bought or sold present, respited, or in reuersion."[38]

In the second half of the seventeenth century, these changes became significant enough for Adam Martindale to call them a "new method" of arithmetic, which now included arithmetic in whole number and fractions alongside decimal fractions, logarithms, and algebra. Robert Norton's 1615 attempt to include decimal arithmetic into the *Wellspring of Sciences* might have failed, but Henry Phillips, editing the 1670 edition, proudly announced the inclusion – once again – of the "Art of Decimal Fractions, intermixed with Common Fractions, for the better Understanding thereof."[39] This time, subsequent editions continued to include Phillip's decimal arithmetic. In 1650, Jonas Moore published the first of several editions of his arithmetic, which included "ordinary operations in numbers, whole and broken" along with decimals, the "new practice and use of the logarithmes, Nepayres bones," algebra, and the mathematics of "the art military."[40] William Leybourn published his *Arithmetick: vulgar, decimal, instrumental, algebraical* in 1659, while in 1685 Edward Cocker first published his decimal arithmetic as a separate companion volume to his textbook on vulgar arithmetic. Cocker's arithmetic textbooks are particularly significant because they emerged as the new standard for English arithmetic textbooks in the eighteenth century. They were so

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[38] Robert Recorde, *The Grounde of Artes*, ed. John Dee, John Mellis, Robert Norton, and Robert Hartwell (London: Thomas Harper, 1631), A1r.

[39] Humfrey Baker, *Baker's Arithmetick*, ed. Henry Phillippes (London: E.C. & A.C., 1670), A1r.

[40] Jonas Moore, *Moore's Arithmetick* (London: Thomas Harper, 1650), A1r.

prominent they even became the basis for a figure of speech: "correct according to Cocker."[41]

Similar changes also occurred in late seventeenth-century tutoring advertisements. While tutors had offered lessons on decimals, logarithms, and algebra before, these subjects – especially decimals – began to take on new prominence in advertisements. In 1650, John Kersey, an editor of Edmund Wingate's arithmetic textbook, advertised his ability to teach arithmetic in whole numbers as well as arithmetic in three different types of "fractions" – vulgar, decimal, and astronomical. He also would teach logarithms but rated this skill less highly, burying it at the bottom of his advertisement in a note on his ability to teach the construction and use of mathematical instruments.[42] By 1683, Henry Mose placed decimals on par with whole numbers and fractions when he simply stated his ability to teach "arithmetick in whole numbers and fractions, vulgar and decimal, and merchants accompts."[43] Also by the 1680s, Adam Martindale promised to instruct students in all the parts of arithmetic: vulgar arithmetic – being whole numbers, fractions, and balancing accounts – and artificial arithmetic – being decimals, logarithms, instruments, and algebra.[44]

More dramatically, the second half of the seventeenth century saw the proliferation of dual arithmetic and writing tutors. The idea of a connection between

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[41] *ODNB*, s.v. "Cocker, Edward (1631/2-1676), *calligrapher and arithmetician*" by Ruth Wallis. See also the auction advertisement pasted inside the back cover of SHL, [D.-L.L]L2[Cocker]SR.

[42] Kersey's mathematical school, which ran from 1650 to 1677, was later carried on by his son – another John Kersey – who continued teaching until about 1698. It is unclear whether a third John Kersey, son of the second, also taught mathematics, but he was at least mathematically educated enough to edit Wingate's *Arithmetique* in 1720. Edmund Wingate, *Arithmetique Made Easie*, ed. John Kersey (London: J. Flesher, 1650), 462-5. *ODNB*, "Kersey, John, the elder (*bap.* 1616, *d.* 1677), *mathematician*" by Ruth Wallis. Also including "John Kersey the younger (b. c. 1660, d. in or after 1721)."

[43] James Hodder, *Hodder's Arithmetick*, ed. Henry Mose (London: Ric. Chiswell and Tho. Sawbridge, 1683), A8v.

[44] Martindale, *The Countrey-Survey-Book*, M3r.

specialized styles of writing and Arabic numerals' pen-and-paper methods of calculation was not entirely new. As early as 1582, Richard Mulcaster commented on the connection between drawing and arithmetic, and recommended teaching them side-by-side:

> bycause *drawing* vseth both nu*m*ber & figur, wherewithall to work, I will cull out so much nu*m*bring fro*m* out of *Arithmetik*, the mistresse of nu*m*bers, & so much figuring out of *Geometrie* the ladie of figurs, as shall serue fit for an Elementarie principle to the childes drawing, without either harnesse to fraie him, or le*n*gth to tire him.[45]

Between 1582 and 1610, John Mellis even ran a school "within the Mayes-gate in short Southwarke nigh Battle bridge" where "children or seruants" could be taught arithmetic, accounting, algebra, and "any manner of hand vsuall within this Realme of England."[46]

However, the number of these writing-cum-arithmetic schools expanded significantly after the Restoration. During the 1660s and 70s, James Hodder taught both writing and arithmetic in a house "next dore to the Sunne in Tokenhouse Yard, Lothbury, City of London" – aside from a 1666-71 interlude in Bromley by Bow – and his school was continued by Henry Mose, "late servant and successor to" Hodder, through 1720.[47] Similarly, Edward Cocker taught writing and arithmetic from 1657 to 1676, holding classes in St. Paul's churchyard, Northampton, and lastly Southwark. John Hawkins took over the Southwark school after his death, styling himself a "writing master," until his own death in 1692.[48] In 1680, he touted Cocker's arithmetic book by noting that it had been commended by "many eminent mathematician and writing-masters in and near

[45] Richard Mulcaster, *The First Part of the Elementarie Which Entreateth Chefelie of the right writing of our English tung* (London: Thomas Vautroullier, 1582), 58.

[46] Mellis advertised his school in the versions of Recorde's *The Ground of Artes* that he edited, from 1582 until 1607. His advertisement also appeared in the 1610 edition, "now lastly corrected by John Wade", but was replaced by N. Physhe in the 1615 edition. Recorde, *The Ground of Artes*: 1607, Mm8r. Recorde, *The Ground of Artes*, 1610: A1r. Recorde, *Records Arithmeticke*: 1615, Oo3v. For more on Mellis see the *ODNB*, s.v. "Mellis, John (*fl. c.* 1564-1588), *writer on arithmetic and bookkeeping*" by Thompson Cooper.

[47] *ODNB*, s.v. "Hodder, James (*fl*. 1659-1673), *arithmetician*" by Ruth Wallis.

[48] *ODNB*, s.v. "Cocker, Edward (1631/2-1676), *calligrapher and arithmetician*" by Ruth Wallis.

London," implying that the opinion of a writing master should have similar value to that of a mathematician when it came to teaching arithmetic.[49]

While there were fewer of these schools outside London, Cocker's Northampton school was not the only one. In 1677, Peter Perkins "taught Writing and Arithmetick, with any or all parts of the *Mathematicks* at easie Rates" near the grammar school at Guildford, in Surrey.[50] In Greenwich, the Grey-coat School was founded in 1643 by John Roan, who endowed it with about £700 per annum for teaching poor children reading, writing, and arithmetic. The similar Green-coat School was founded in 1672 by William Boreman, also in Greenwich, and modeled on the example of Christ's Hospital in London. These schools were, however, all geared towards teaching boys to write and calculate. A parallel Greenwich charity school for girls, the Blue-coat School, was not founded until 1732.[51]

During the sixteenth century, the increased production of printed books and rising literacy rates enabled the creation of a new genre of printed books – the vernacular arithmetic textbook. These books sold well enough that they were frequently reprinted over the years and marginalia suggests these books were heavily used by students, either through independent study or in the classroom. The overlap between textbook authors and private tutors led their curriculums to largely mirror one another, including parallel shifts to include new, advanced topics like decimals, logarithms, and algebra in the late seventeenth century. At the same time, tutors also expanded their classroom focus to

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[49] Edward Cocker, *Cocker's Arithmetick*, ed. John Hawkins (London: Thomas Passinger, 1680).

[50] William Lilly, *Merlini Anglici Ephemeris: Or, Astrological Judgments for the year 1677* (London: J. Macock, 1677), F8v.

[51] N. Plumley, "The Royal Mathematical School Within Christ's Hospital: The early years. – Its aims and achievements," *Vistas in Astronomy* 20 (1976): 58.

include learning specialty hands. This led to the proliferation of writing-cum-arithmetic schools and reinforced the increasing connection between writing and arithmetic, particularly the pen-and-paper based arithmetic of Arabic numerals.

Perceived Need and Student Interest

These new methods of mathematical education complemented, rather than competed with, the humanist education of England's existing schools. Starting in the 1580s, children were taught the fundamentals of arithmetic at petty schools. By the seventeenth century, this early exposure began to be seen as critical to the mathematical education of both male and female students. After the petty schools, students followed a variety of complicated educational trajectories, attending grammar schools and universities as well as finding private tuition through writing-cum-arithmetic tutors and apprenticeships. However, no matter what path a student followed, perceived necessity and the student's personal interests determined access to continuing mathematical education.

Much has been written about education in the early modern period, generally with a focus on the changes brought about by the Reformation, humanist learning, and growing literacy rates.[52] According to these narratives, the mathematical arts and sciences were relegated to the margins of English schools until at least the mid-seventeenth century. Grammar schools were attacked for their concentration on teaching boys Latin and Greek, and their failure to incorporate mathematical learning into the

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[52] For an excellent, recent discussion of these issues, see Ian Green, *Humanism and Protestantism in Early Modern English Education* (Burlington, VT: Ashgate Publishing Company, 2009).

mainstream of their curriculum. The Universities of Cambridge and Oxford have been even further denigrated as reactionary and antithetical to the "new sciences," including mathematics.[53] This portrayal of early modern mathematical education has not gone completely unchallenged; in particular, Mordechai Feingold definitively rebutted the case against university mathematics.[54] However, the view of grammar schools remains negative, emphasizing their failure to provide a universal mathematical education rather than noting the extra lengths to which they went to make certain that mathematical training was available – for the boys who needed it. Indeed, at several stages of a child's formal education, mathematical teaching was available for students who had a practical need for such training.

An early modern child's first exposure to formal education usually came from a petty school at around the age of five or six years old.[55] Children of both sexes could attend petty schools, where they were supposed to acquire at least a rudimentary knowledge of reading and writing in English.[56] These schools varied widely in form, ranging from "dame schools" run by women, often informally in their homes, to "song schools" attached to great cathedrals and intended to educate the boys of the choir.

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[53] For more on the universities' resistance to any new institutions of learning – regardless of proposed curriculum – which might challenge their supremacy, see Mordechai Feingold, "Tradition versus Novelty: Universities and Scientific Studies in the Early Modern Period," in *Revolution and Continuity Essays in the History and Philosophy of Early Modern Science*, ed. Peter Barker and Roger Ariew (Washington, D.C.: The Catholic University of America Press, 1991), 45-59.

[54] See Mordechai Feingold, *The Mathematicians' Apprenticeship: Science, Universities and Society in England, 1560-1640* (Cambridge: Cambridge University Press, 1984).

[55] Charles Hoole explains that children in cities began school around age four or five, while country children delayed until age six or seven because of the distance such children had to travel – often several miles – to reach the nearest school. Charles Hoole, *The Petty-Schoole, Shewing a Way to Teach Little Children to Read English with Delight and Profit, (especially) According to the New Primar* (London: J.T. for Andrew Crook, 1659), 2.

[56] A 1406 statute enabled both boys and girls to attend petty schools, though only boys could continue on to grammar schools. Helen M. Jewell, *Education in Early Modern England* (New York: St. Martin's Press, Inc., 1998), 17.

Falling somewhere in between were petty schools attached to a grammar school, which were intended to prepare boys for entrance to that grammar school. These latter petty schools could be run by ushers out of grammar school, or by more informally by masters in their private homes.[57] The quality of instruction available in petty schools varied depending on the skills of the schoolmaster. As schoolmaster Francis Clement complained,

> Children (as we see) almost euerie where are first taught either in priuate by men or women altogeather rude, and vtterly ignorant of the due composing and iust spelling of wordes: or else in common schooles most commonlie by boyes, verie seeldome or neuer by anie of sufficient skill, howsoeuer yet right spelling is but the least parte, or rather no part counted of learning.[58]

Thus even the most learned of teachers sometimes failed to provide their students with adequate instruction in reading and writing, particularly when they relied upon the assistance of older students to help tutor the younger students.

Starting in the last decades of the sixteenth century, petty schools also became a source of education in numeracy, arithmetic, and elementary accounting. Clement first wrote *The Petie Schole* in the 1570s – his preface is dated 21 July, 1576, and the work was entered into the stationer's register on 20 July, 1580.[59] The original edition was focused solely on English orthography, promising "to enable both a childe to reade perfectly within one moneth, & also the vnperfect to write English aright." However, by the time of its republishing in 1587, he felt the need to add – and advertise the addition of

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[57] This was not always to the benefit of, or encouraged by, the grammar school. For instance, Richard Mulcaster, schoolmaster of Merchant Taylors' School – London's largest grammar school – broke his school's statutes by teaching boys to read and write English out of his private residence. Richard DeMolen, *Richard Mulcaster and Educational Reform in the Renaissance* (Nieuwkoop: De Graaf Publishers, 1991), xviii.

[58] Francis Clement, *The Petie Schole with an English Orthographie* (London: Thomas Vautrollier, 1587), A2v.

[59] *ESTC*, record number 006176804.

– patterns for writing secretary and roman hands along with instructions on how "to number by letters, and figures" and "to cast accomptes, &c."[60] After introducing Roman and Arabic numerals, he alluded to the possibility of calculating with the latter, but felt it would be sufficient to teach jeton-based accounting, including "the due placyng, laying downe, and tykyng vp of counters."[61]

Clement was not the only petty schoolmaster to teach arithmetic to his students in the late sixteenth and seventeenth centuries. Of the eleven schoolmasters' licenses reproduced by David Cressy in his education sourcebook, three included arithmetic alongside reading and writing.[62] In 1583, a "literatus" named Will Bradley was licensed to "teach boys the art of writing, reading, arithmetic and suchlike at Bury St Edmunds." Four years later, Thomas Cullyer of Norwich was licensed "to teach boys and infants the abc, art of reading, writing, arithmetic and suchlike." Schoolmasters could be tradesmen as well as well as learned scholars. One 1599 license, which survived in full, authorized a fishmonger, William Swetnam of the parish of St Margaret Pattens in London, "to teach and instruct children in the principles of reading and introduction into the accidence, and also to write and cast accounts" within the city of London.[63] Continuing into the seventeenth century, Sir William Borlase founded a petty school at Marlow in 1624, specifically to teach twenty-four poor children to read, write, and cast accounts. This

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[60] Clement, *The Petie Schole*, A1r.

[61] In his section on accounts, Clement taught the conversion of monetary units, as well as addition and subtraction through the use of jetons on a counting board. He also explained the arithmetical origins of the common proverb, "but sta*n*d (we say) like a cypher in Algorisme." Clement, *The Petie Schole*, 65, 71-85.

[62] Schoolmasters' licenses rarely survived in full, as they were kept by individual schoolmasters in their private records. Instead, most instances of licenses come from ecclesiastical visitations, where the contents of licenses were summarized for the visitation record. Of the eleven licenses reproduced by David Cressy in his education sourcebook, three included arithmetic in addition to reading and writing. David Cressy, *Education in Tudor and Stuart England* (New York: St Martin's Press, 1975), 32.

[63] In this usage, *accidence* signifies the "branch of grammar which deals with the inflection of words, grammatical morphology." *OED*, s.v. "accidence, *n*^{2}." Cressy, *Education*, 33-4.

course of instruction was expected to take approximately two years, after which the boys would have acquired the skills prerequisite to being bound as apprentices.[64] And Charles Hoole, in his 1659 *The Petty-School*, desired his teachers to have "good skil in Arithmetick" so that students could be taught "to read English very well, and afterwards to write and cast accounts."[65]

By the end of the seventeenth century, educational theorists like John Aubrey were even arguing that this early exposure to numbers and arithmetic was the key to a successful mathematical education. There was something in the flexibility of the young mind that led children to master mathematics far more easily that a man grown. Arithmetic and geometry, in particular,

> ought to be instilled into Boyes: they will joyfully imbibe such demonstrative, delightfull, and usefull Learning: and being learn't so young; it sticks by them as long as they live, and becomes habituall: Otherwise when these 2 sciences are learn't by men of good years (as com*m*only it folls-out) it turns the edges of their witt, and they give it off: or if not, they make no great matter of it.[66]

Aubrey argued that boys should learn their multiplication tables as young as seven or eight years old and compared learning mathematics so late to trying to learn to play a lute once a man's fingers have become swollen with arthritis. Certainly his contemporary Samuel Pepys, who learned his multiplication tables as a grown man, sometimes struggled to make sense of his tutor's instructions, while another man, "one of the best Humanists, & Orators" in Cambridge, was incapable of learning division at thirty.[67] By contrast, learned men such as Sir Christopher Wren, Edmund Halley, and Thomas Ax,

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[64] Jewell, *Education*, 95.

[65] Hoole, *Petty-Schoole*, 30.

[66] Bodl., MS Aubrey 10, f. 8r.

[67] Samuel Pepys, *The Diary of Samuel Pepys*, ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1972), 1:326-9. Bodl., MS Aubrey 10, f. 8r.

learned arithmetic as small boys under the tutelage of their fathers – or in Halley's case, his father's apprentice.[68] Or in other words, as John Aubrey scribbled in the margins of his treatise on education,

> Boies will Adde, Mutiply & Diuide as
> fast as a Dog will trot: will run up an account
> Like a shop-keeper. A Barre-boy at an
> Ale-house will reckon faster & readier than
> a Master of Arts in a University, or a Justice of Peace[69]

Intriguingly, although Aubrey only ever wrote about educating boys, he chose to further argue about the need for early mathematical education by bringing up the accomplishments of two young girls. One Mr. Lidcot brought his eleven-year-old daughter before the Royal Society in Dublin to show off her mathematical skills. As reported to Aubrey, she "understands all Arithmetick, and Algebra, Trigonometrie, and the use of the Globes." Upon examination, the society did not "find any thing extraordinary in her natare to Mathematick: but doe impute all to her <u>timely</u> earlie <u>education</u>."[70] Lidcot's daughter was by no means unique – Aubrey also mentioned a Dr. Holder, who taught his six-year-old niece addition, subtraction, multiplication, division, and even "some few Definitions of Geometrie."[71]

Aubrey was not the first to notice girls' intellectual abilities. The achievements of sixteenth-century women such as Elizabeth I, Jane Grey, and Thomas More's daughters were well known, and many girls took advantage of their brothers' tutors to further their

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[68] Bodl., MS Aubrey 10, ff. 8v, 29r.

[69] Bodl., MS Aubrey 10, f. 29r.

[70] Bodl., MS Aubrey 10, f. 29v.

[71] Bodl., MS Aubrey 10, f. 36v. The niece is not identified in Aubrey's writing, but was most likely Jane Wren, daughter of Sir Christopher Wren. Kate Bennett, "John Aubrey and the 'Lives of our English mathematical writers,'" in *The Oxford Handbook of The History of Mathematics*, ed. Eleanor Robson and Jacqueline Stedall (Oxford: Oxford University Press, 2009), 333.

own education. In the 1580s, Richard Mulcaster was a strong advocate for further educating girls, so long as boys and girls were educated in separate institutions.[72] In 1673, Bathsua Makin – former tutor to Charles I's daughter Elizabeth, Duchess of Newcastle, as well as other noblewomen – published an essay defending her formation of a women's school. The curriculum included keeping accounts, arithmetic, and "all things ordinarily taught in other Schools."[73] And in 1686, the Royal Society in Dublin was fascinated by a ten-year-old girl "who is to a prodigy skill'd in ye Mathematicks," able to solve problems from Euclid, as well as having mastered "Arithmetick, Algebra, Trigonometry & Astronomy."[74] She was examined by the society for over two months, before the novelty of her accomplishments wore off.

While arithmetic thus became an enduring component of children's early education, it is important not to overestimate the quality or universality of petty school instruction. Edmund Coote – author of *The English Schoolmaster*, which was reprinted forty-eight times over the course of the seventeenth century – focused on teaching reading and writing, with special attention to orthography for those who would go on to grammar-schools. Though he felt obliged to include instruction on "the first part of Arithmetick, to know or write any number," he refused to spend more than a page on it, "my Book growing greater than I purposed."[75] Like Coote, many schoolmasters must not have taught anything beyond the most basic introduction to numeration by Roman and

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[72] Richard Mulcaster, *Positions Wherin Those Primitiue Circumstances Be Examined, Which Are Necessarie for the Training Vp of Children* (London: Thomas Vautrollier, 1581), 179-182. DeMolen, *Richard Mulcaster*, 176.

[73] Bathsua Makin, *An Essay To Revive the Antient Education of Gentlewomen, in Religion, Manners, Arts & Tongues,* (London: J.D., 1673).

[74] R.T. Gunther, *Early Science in Oxford* (Oxford: Clarendon Press, 1923), 12: 184.

[75] Edmund Coote, *The English School-Master* (London: B. Alsop, 1651), A2r, H2r.

Arabic numerals. Even those who taught addition or subtraction did not necessarily have to be skilled arithmeticians. As late as 1701, John White – the master of Mr. Chilcot's English-Free-School in Tiverton with "near Forty Years Practice in Teaching" – expounded the benefits of rote learning in his *The Country-Man's Conductor*:

> As to the Arithmetical Part (When your Children have gotten some Perfection in their English) let them learn it by heart, and if neither Teacher nor Learner understand the Use of the Rules, yet when they come to learn Arithmetick in earnest, it will be a great help to them and ease to their Master.[76]

Thus understanding the rules of arithmetic took second place to memorization and White argued that even the teacher did not need to understand what he taught. White further recommended that children be taught arithmetic "before or as soon as they are put to writing."[77] Given that a significant number of children, particularly in rural villages, must have dropped out of petty school after learning to read but before learning to write, even those who had access to arithmetical instruction might not have taken advantage of the opportunity.[78]

After children learned reading, writing, and at least basic enumeration, boys had several different options for continuing their education, including grammar schools, possibly followed by university degrees, apprenticeships, and other, specialized instruction such as public lectures and mathematical schools. These options were not mutually exclusive, as many boys first attended grammar schools or mathematical schools, and afterwards were bound apprentices instead of attending a university. Other

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[76] John White, *The Country-Man's Conductor in reading and writing true English... and some arithmetical rules to be learnt by children, before or as soon as they are put to Writing* (Exeter: Samuel Farley, 1701), A1r, A5v.

[77] White, *Country-Man's Conductor*, A1r.

[78] Thomas, "The Meaning of Literacy," 102-103.

boys traveled even more complicated educational paths. Sixteen-year-old Robert Ellison, a student at the prestigious grammar school of Eton, was supposed to begin an apprenticeship but was told that he "cannot come from thence [Eton] into a merchants' compting house without being some months at school in London to learn to write and also accounts."[79]

As the case of Robert Ellison implies, arithmetic was not a substantial component of the continuing education of boys who attended grammar schools. The humanist curriculum of grammar schools focused on Latin, Greek, and reading the classics, none of which required a great knowledge of arithmetic much less more complicated mathematics. As argued above, it was possible for a boy to enter grammar school having already obtained a rudimentary understanding of numbers and arithmetic through their petty school. However schoolmaster John Brinsley was probably only exaggerating slightly when he complained that complete innumeracy was "a verie ordinarie defect" and that he had seen "Schollers, almost readie to go to the Vniuersitie, who yet can hardly tell you the number of Pages, Sections, Chapters, or other diuisions in their bookes" nor "helpe themselues by the Indices, or Tables of such books."[80]

Many grammar schools sought to remedy the defects in their students' earlier education by arranging optional extra lessons on holidays and half-days. The grammar school at Rotherham offered writing and accounting lessons as early as the fifteenth century, while Bristol grammar school students were released early on Thursdays and Saturdays for lessons with the local scrivener.[81] Statutes written for Blackburn Grammar

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[79] Jewell, *Education*, 85-6.

[80] Brinsley, *Lvduvs Literarivs*, 25.

[81] Jewell, *Education*, 84.

School in 1597 – and confirmed again in 1600 – made provision for "petties" to be instructed and grammar school students could be forced to take remedial, petty-level lessons at any time in which they were not actively engaged in their primary curriculum:

> Uppon dayes and tymes excepted from teachinge, the Scollars may be caused by the Schoole Master and the Usher to larne to write, cipher, cast accounts, singe or such licke, and allso upon holidayes, and other convenient tymes.[82]

This section of the statutes was probably enforced in practice, as the statutes also assert a commitment to mathematical education in general: "The principles of Arithmeticke, Geometrie, and Cosmographie with some introduction into the sphere, are proffitable."[83] A set of 1629 statutes for the Chigwell school even required one of its schoolmasters to be proficient in both writing and arithmetic, in addition to Latin:

> I ordain that the second schoolmaster, touching his years and conversation, be in all points endowed and qualified as is above expressed touching the Latin schoolmaster; that he write fair secretary and Roman hands; that he be skilful in cyphering and casting of accounts and teach his scholars the same faculty.[84]

This schoolmaster was thus required to actively teach his students several different mathematical skills, including the use of Arabic numerals for calculations, jetons for "casting" accounts, and the bookkeeping skills necessary to record their accounts. But most grammar schools probably relied on outside writing and arithmetic tutors – men

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[82] Although the grammar school was teaching Arabic numerals and ciphering as early as 1597, the school's various accountants used Roman numerals to record monetary entries and sums until 1669/70. See Chapter Two for more on patterns in the transition from Roman to Arabic numerals. George Alfred Stocks, ed., *The Records of Blackburn Grammar School*, Remains, Historical and Literary, connected with the Palatine Counties of Lancashire and Chester, n.s., 66 (Manchester: Chetham Society, 1909), 1: 73.

[83] Stocks, *Blackburn*, 74.

[84] These schoolmaster specifications were written by Samuel Harsnet, later Archbishop of York. Cressy, *Education*, 65.

such as Peter Perkins, who lived adjacent to the grammar school at Guildford – to teach their remedial students.[85]

As with arithmetic lessons at the petty school level, the availability of arithmetic lessons at the grammar school level did not mean that all – or even most – students took advantage of those lessons. Schools that outsourced lessons to local scriveners or mathematical teachers – many of whom, as argued above, would have fulfilled both functions – charged extra fees to cover the costs of these lessons. Such lessons, particularly those focused on learning to cast accounts, were therefore geared more towards boys who would eventually be bound as apprentices rather than those headed for the universities. The mathematician John Wallis came home from grammar school one holiday and learned "to *Write and Cypher*, or *Cast account*" from a younger brother who was taking lessons "in Order to Trade." For the young Wallis, mathematics was a "pleasing Diversion, at spare hours," rather than something he took seriously or considered useful for his life and future career.[86]

The second half of Wallis' autobiographical description of his mathematical education is worth quoting at length, as it is often cited to support the argument that mathematics were not taught at the university level. According to Wallis, when he attended Cambridge,

> I had none to direct me, what books to read, or what to seek, or in what method to proceed. For Mathematicks, (at that time, with us) were scarce looked upon as *Accademical* studies, but rather *Mechanical*; as the business of *Traders, Merchants, Seamen, Carpenters, Surveyors of Land*, or the like; and perhaps some *Almanack-makers in London*. And amongst more than Two hundred Students (at that time) in our College, I do not

[85] Lilly, *Merlini*, F8v.

[86] Fauvel and Gray, *History of Mathematics,* 316-7. For more on Wallis, see *ODNB*, s.v. "Wallis, John (1616-1703), *mathematician and cryptographer*" by Domenico Bertoloni Meli.

> know of any Two (perhaps not any) who had more of *Mathematicks* than I, (if so much) which was then but little; And but very few, in that whole University. For the Study of *Mathematicks* was at that time more cultivated in *London* than in Universities.[87]

Thus, if we are to believe Wallis, less than one percent of Cambridge University's students in the 1630s had studied mathematics. Furthermore, there was no one he could apply to for assistance in learning more than he already knew, because the mathematical arts and sciences were denigrated as the province of tradesmen and only taught in London. However, two important factors must immediately lessen the strength of his claims. Firstly, Wallis was writing this in retrospect, decades later, when he had become a highly educated mathematician and Oxford's Savilian Professor of Geometry. Secondly, Wallis had already acquired significant mathematical learning through lessons with his brother and reading arithmetic textbooks, including the entirety of what most merchants and traders might need to know of arithmetic.

Mordechai Feingold has proved that a significant amount of mathematical instruction was available in early modern Cambridge and Oxford, as evidenced by college statutes and matriculation requirements. The 1570 statues at Cambridge include instructions for debates in which three questions will be proposed: "one in mathematics, the second in logic, the third in natural or moral philosophy."[88] When Sir Thomas Smith founded a mathematics lectureship at Queens' College, Cambridge, he insisted that no students obtain their B.A. "before that they be well expert in the parts of Arithmatique, addition, subtraction, multiplication, division, and the extraction of roots as well of whole

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[87] Fauvel and Gray, *History of Mathematics*, 317.

[88] Feingold, *The Mathematicians' Apprenticeship*, 26.

numbers as of fractions."[89] Oxford's *Nova Statuta* insisted students have three terms of arithmetic, and from 1619 onward the Savilian statutes required every student who had completed at least two years of study to attend geometry and arithmetic lectures which would be held twice a week. The two professors endowed by Savile were also required to "employ himself at his own lodgings, or in some pleace near, for the space of an hour in instructing young men (who chose to call on him for the purpose of learning) in practical logic or arithmetic of all kinds." Savile expected "the four ordinary lecturers in mathematics... may cease altogether after this foundation," in which case he hoped their salaries would be added to those of his endowed professors, however additional lectureships in arithmetic continued at several colleges.[90]

Mathematical lecturers, tutors, and textbooks proliferated at the universities during this period. Colleges like Exeter and Trinity sponsored additional lectures during vacations, including lectures on arithmetic, geometry, and elementary cosmography.[91] In 1577, a list of Cambridge lecturers for the "Younger Sort of Scholers" included "one Mathematical Reader to reade the Arte of Arithmeticke, of Geometry, of Cosmographie, or of Astronomy, in such sort as is fit for his Auditory."[92] In the late 1580s, Thomas Gataker was tutored in mathematics by Henry Alvey, while the surveyor George Atwell offered mathematical instructions and instrument-making services to Cambridge students from 1624 to 1649. Henry Briggs served as St. John's College's mathematical lecturer in 1592, before going on to become the first Professor of Geometry at Gresham College – a

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[89] Feingold, *The Mathematicians' Apprenticeship*, 40.

[90] Michael Van Cleave Alexander, *The Growth of English Education, 1348-1648: A Social and Cultural History* (University Park, PA: The Pennsylvania State University Press, 1990), 25, 38.

[91] Alexander, *Growth*, 37.

[92] Feingold, *The Mathematicians' Apprenticeship*, 27.

college specifically founded to advance the education of London's merchants and tradesmen – as well as the first Savilian Professor of Geometry at Oxford University.[93] Between 1618 and 1636, Joseph Mede gave money for purchasing mathematical texts to twenty-nine of the ninety-five Cambridge students he tutored, and it is likely that others either inherited books from parents and older siblings, or purchased books before coming to the university.[94] Over half the inventories of university men who died while in residence included basic arithmetical and geometrical treatises, and an additional quarter included cosmographical and astronomical manuals.[95]

By Wallis's own admission, things only improved further during the second half of the seventeenth century. In another treatise of 1700, Wallis chastised Lewis Maidwell[96] for his negative portrayal of university mathematics:

> I wonder, with what face it can be pretended (unless from great ignorance therein) that they were not to be learned in our universities: when it is well known, that within fifty or three score years last past, mathematicks have been more improved and advanced, in our universities, than for five hundred years before.[97]

Wallis then expounded upon the availability of mathematical instruction at Oxford, citing public lectures, publications, and private instruction by Oxford's mathematical professors. Other Oxford mathematicians provided supplemental instruction, such as John Caswell

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[93] Alexander, *Growth*, 237.

[94] Alexander, *Growth*, 85, 96-7, 110. My studies of annotated arithmetic textbooks have turned up numerous examples of books which were passed from father to son or from sibling to sibling, including sisters.

[95] Alexander, *Growth*, 115-6.

[96] Lewis Maidwell was the author of a turn-of-the-eighteenth-century proposal to Parliament for the establishing of a new academy in London. Nothing ever came of this proposal, as Maidwell wanted it to be publicly financed and attempted to acquire a monopoly over all printing in England as part of his educational scheme. See, for example BL, T.100*.(48.) and Lewis Maidwell, *A Scheme for a Public Academy* (London: 1700).

[97] CRL Fletcher, ed., *Collectanea: First Series*, (Oxford: Clarendeon Press, 1885), 320.

who "hath now, for many years last past, made it his busyness (and good part of his livelyhood) to teach mathematicks." Wallis was most concerned with advanced mathematical instruction, but he did occasionally mention arithmetic in passing. He explained that the professor Dr. Gregories assumed his students would be "pretty well acquainted with the *numerical arithmetick*" but if they were not and "desire[d] regular demonstrations, of the operations of integers and fractions, vulgar or decimal; any clas shall have it when they please."[98]

The amount of mathematical instruction any particular student received still depended on that student's interests. However, the widespread availability of such instruction combined with matriculation requirements meant that all interested students could have at least some exposure to mathematics through their universities. After 1619, both Oxford and Cambridge required students receiving their B.A. to be proficient in arithmetic and geometry, and the two universities went so far as to create professorships in mathematics in 1619 and 1663, respectively.[99] Thus while a student more interested in law, theology or medicine might matriculate without having encountered much in the way of mathematics, he would at least know the first five "parts" of Arabic numeral arithmetic in whole numbers and fractions.

While mathematical instruction was thus available for interested students via grammar schools and universities, the majority of boys did not continue formal schooling

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[98] Fletcher, *Collectanea*, 323.

[99] Oxford also created a professor of Arabic in 1636. Mark H. Curtis, *Oxford and Cambridge in Transition: 1558-1642* (Oxford: Clarendon Press, 1959), 116, 231. Feingold argues that Arabic studies even became something of a “fad” between 1580 and 1680. Mordechai Feingold, “Decline and Fall: Arabic Science in Seventeenth-Century England” in *Tradition, Transmission, Transformation: Proceedings of Two Conferences on Pre-Modern Science Held At the University of Oklahoma*, ed. F. Jamil Ragep and Sally Ragep, (Leiden: E.J. Brill, 1996): 441-3.

but rather obtained a vocational education as an apprentice to some trade.[100] The 1563 Statute of Artificers officially codified apprentice regulations and required the adoption of London apprenticeship customs throughout England. The age of apprentices varied, particularly after taking into account "poor apprentices" bound very young and for extended terms to keep them from being a burden to the local parish. Most Bristol apprentices were between the ages of 9 and 16 at the time of their indentures, with apprenticeships lasting between 7 and 10 years.[101] These apprenticeships could be restricted by income level, through fees levied on indenture, and prior learning. A thorough command of reading and writing in English was a prerequisite for many trades and thus a "youth brought up at school will be taken Apprentice with less mony then one illiterate."[102] Poor apprentices often had additional indenture clauses that required their masters to make up for educational deficits, particularly in reading and writing.

This relative silence on the subject of arithmetic in indentures was probably due to an assumption that accounting would necessarily be included in any apprentice's instruction; at least a rudimentary ability to calculate was necessary to trade. The seventeenth-century Southampton apprenticeship registers only record one instance where an indenture explicitly included arithmetic: in January 1630/1, the orphaned Giles New of Southampton was apprenticed to a clothier who promised to instruct him "in the

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[100] Green, *Humanism*, 310.

[101] Vanes, *Bristol,* 19.

[102] Christopher Wase, *Considerations Concerning Free-Schools as Settled in England* (London: Simon Millers, 1678), 33.

Frontispiece of the 1607 Robert Recorde's The Ground of Artes[103]

trade of clothier and to write and cipher."[104] In most indentures, it was understood that clauses such as "all other trades of sciences as the said [master] shall use" included the keeping of accounts.[105] Many apprentices began their apprenticeship in their master's counting-house, observing a counting-house clerk perform calculations. This was called "learning the lines" and would enable the apprentice to eventually calculate accounts on

[103] Ironically, this image was appropriated from an earlier German text in which the image was supposed to represent the irresponsibility of parents who allowed their children to be taught the "obsolete" system of jetons and counting board. Karl Menninger, *Number Words and Number Symbols: A Cultural History of Numbers*, trans. Paul Bronner (Cambridge, Massachusetts: MIT Press, 1969), 435.

[104] Arthur J. Willis and A.L. Merson, eds., *A Calendar of Southampton Apprenticeship Registers, 1609-1740* (Southampton: Southampton University Press, 1968), 19.

[105] John Rigges, apprenticed in 1611 to his uncle, was to be instructed in his uncle's trade and "alsoe to be enxtructed in all other trades or sciences as the said Frauncis Rigges shall use during the said terme." Willis and Merson, *Southampton*, 2.

his own.[106] The frontispiece of the 1607 edition of Recorde's *The Ground of Artes* illustrates this practice. In the image above, a small boy is being handed over into the care of a master who will teach him to perform calculations on a counting-board.

The Southampton apprenticeship register is similarly silent on the subject of other advanced mathematics that would be necessary for the practice of specific trades. For example, no mention is made of mathematical training for the poor apprentice John Jolliffee, who was apprenticed to a Southampton seaman in January of 1654/5. Given that his father was a weaver, he probably did not have extensive training in the use of mathematical instruments. Thus additional mathematical education would have been a necessary part of his master's "instruct[ing] him in y[e] art of navigacon &c."[107] Another boy, David Jenvy, who was apprenticed to a mercer in January of 1648/9, was to be instructed "in the art of merchandizing beyond the seas... Master to permitt ye apprentice to trade and trafficque for himselfe with a stocke of 50 li when he goes to sea, which is to be in ye two last yeares."[108] To trade overseas successfully, Jenvy needed to have training in advanced arithmetical subjects such as the rules for commuting and exchanging money. However, the inclusion of this training was understood to be part of his general education and there was no need to list it separately in his indenture.

Starting in the 1580s, elementary arithmetic began to be incorporated into the petty school curriculum for both male and female students. Early exposure to mathematics was seen as laying a critical foundation for later mathematical education, however whether or not a student received that further education depended on his needs

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[106] Merchants, vintners, drapers, and haberdashers were especially likely to follow this practice. Vanes, *Bristol*, 21.

[107] Willis and Merson, *Southampton,* 86.

[108] Willis and Merson, *Southampton*, 38.

and interests. For boys, grammar schools offered a combination of remedial and advanced lessons in arithmetic via tutors or writing-cum-arithmetic schools. During the seventeenth century, universities also insisted their students have a basic knowledge of arithmetic for graduation, while lectures, tutors, and textbooks proliferated in both Oxford and Cambridge. Boys who eschewed formal schooling for apprenticeships were similarly expected to acquire greater mathematical learning, particularly in accounting, though their indentures tended to silently include mathematics in trade-specific education clauses. There thus existed a variety of opportunities for boys with an active interest to acquire a mathematical education, while at the same time allowing students with neither a trade-specific need or personal interest for mathematics to escape formal schooling with only the most basic knowledge of numbers and arithmetic.

The Utility of a Mathematical Education

Although most mathematical tutors encouraged their students' interests, some also worried about the side-effects of too much mathematical education and urged students to limit themselves to the practical applications of mathematics in the real world. In particular, they advocated for students to focus on skills that would be useful to the English state, such as navigation or gunnery. Starting in the 1570s and continuing into the seventeenth century, similar arguments appeared in academy proposals related to the court of wards, London's public lectures, and the founding of the Royal Mathematical Society. By the end of the seventeenth century, however, tutors and textbook authors both shifted their focus from proclaiming the usefulness of mathematics to proclaiming the easiness of acquiring a mathematical education. Mathematical educators still made arguments about the general utility of mathematics, but they were more concerned with convincing their students that such skills could be mastered by even those with "mean Capacities."[109]

The most famous sixteenth-century tutor to express concern about mathematical education was Roger Ascham, who helped educate the future Queen Elizabeth. Despite having himself tutored mathematics in the late 1530s and early 1540s, Ascham worried about the dangers of too much mathematical learning.[110] His 1570 educational treatise, *The Scholemaster,* explained his reservations:

> Some wittes, moderate enough by nature, be many tymes marde by ouer moch studie and vse of some sciences, namelie, Musicke, Arithmetick, and Geometrie. Thies sciences, as they sharpen mens wittes ouer moch, so they change mens maners ouer sore, if they be not moderatlie mingled, & wiselie applied to som good vse of life. Marke all Mathematicall heades, which be onely and wholy bent to those sciences, how solitarie they be the*m*selues, how vnfit to liue with others, & how vnapte to serue in the world.[111]

Ascham thus equated an excess of mathematical education with a host of unwelcome personality traits, including antisocial behavior and unfitness for government service. In order to moderate the negative influence of mathematics, Ascham insisted they be taught with a focus on how they might be "wiselie applied" to some practical use. Only by emphasizing practical mathematics, and their "good vse of life," would prevent the mathematical mind from becoming a complete unfit member of English society.

The same decade saw the first of a series of proposals for the creation of academies and specialty schools, which similarly stressed the practical reasons for

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[109] Bodl., MS Aubrey 10, f. 32r.

[110] *ODNB*, s.v. "Ascham, Roger (1514/14-1568), *author and royal tutor*," by Rosemary O'Day.

[111] Roger Ascham, *The Scholemaster* (London: John Daye, 1570), D1v.

students to be instructed in a wide variety of subjects, including mathematics. In the early 1570s, Sir Humphrey Gilbert put forth a proposal for "the erection of an Achademy in llondon for educac*i*on of her Ma^{ts} Wards and others the youth of nobility and gentlemen."[112] Gilbert's main inspiration for his academy was the corruption of the court of wards, where noble children who had become wards of the queen were granted as rewards or outright sold to guardians who were supposed to care for their estates and education during their minorities. Instead, "thorough the defaltes of their guarders" these children are "for the moste parte brought vp to no small grief of their frendes in Idlenes & lascivious pastimes estranged from all serviceable vertues to their prince and Cowntry."[113] Gilbert envisioned an academy specifically for these wards, to train them up in service to the monarchy, and wished to erect the academy in London so that it could also educate the children of nobles and gentlemen attached to the queen's court.

Developing the practical skills necessary to provide service to both "prince and Cowntry" was central to Gilbert's educational philosophy. He justified this focus by citing Plato on education: "that the educac*i*on of children should not altogeather be vnder the puissaunce of their fathers but vnder the publique power and aucthority because the publique haue therein more Intereste then their parents." Gilbert also believed a solid education was the foundation of Protestant religion – and thus loyalty to the English monarchy – declaring that

> above all other this chiefly is to be accompted of, that by these meanes all the best sorte shalbe teamed vp in the knowledge of gods word (which is the onely fowndacon of true obedience to the prince) who otherwise thorough evill teachers might be corrupted with papistrie.[114]

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[112] BL, MS Lansdowne 98, f. 2r.

[113] BL, MS Lansdowne 98, f. 2r.

[114] BL, MS Lansdowne 98, f. 6v.

Ideally, Gilbert wished to raise a generation of well-educated gentlemen who would not only be fit to serve their monarch, but would also magnify the power of the English monarchy by being so well educated, to the point that "all the nations of the World knowe and say when the face of an English gentleman appeareth that he is eyther a sowldiour a philosophor or a gallant cowrtier."[115] Such gentlemen's personal glory would consequently enhance the reputation of the English monarch who ruled over them.

Gilbert therefore insisted that his academy's students learn only practical skills and justified the inclusion of subjects by explaining how each might be used in monarchical service. For example, the reader in logic and rhetoric was required to discourse on English politics, military exploits, and the occasional other history lesson, so that students would be prepared to provide "wise cownsell in dowbtfull matters of warre and state."[116] His reader of moral philosophy was similarly required divide his readings into "two sortes, The one councerning ciuill pollicie The other concerning martiall pollicy," again with the goal of preparing students for the "managing of matters of estate and pollicy."[117]

With respect to mathematics, Gilbert made provisions for a mathematician and two ushers to teach children arithmetic and geometry. His fiercely practical bent can be seen most clearly in his instructions for the teaching of geometry, which does not emphasize the standard geometrical textbook – Euclid's *Elements* – but rather, "shalbe onely employed to Imbattelinges fortificac*i*ons and matters of warre with the practize of Artiller[y]." An additional hundred pounds per annum was to go towards providing

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[115] BL, MS Lansdowne 98, f. 7r.

[116] BL, MS Lansdowne 98, f. 2v.

[117] BL, MS Lansdowne 98, ff. 2v-3r.

powder and shot for artillery lessons. A second mathematician was to teach the students cosmography and astronomy, and "tend the practizes thereof onely to the arte of Nauigac*i*on with the knowledge of necessary starres making vse of Instrumentes apertaining to the same." This would be done with the assistance of "one who shall teache to draw mappes, sea chartes &c." While not specifically called a mathematician, part of this latter instructor's duties included teaching the rules of proportion, perspective, and measurement.[118]

If the importance Gilbert assigned to various subjects corresponds to the salaries he assigned to their instructors, the mathematical arts were a crucial component of his ideal education.[119] Altogether the five mathematical instructors would have been paid 386 pounds, 13 shillings, and 4 pence per annum, with two mathematicians receiving salaries of, respectively, 100 pounds and 100 marks.[120] These are the two highest salary brackets offered by Gilbert and put one mathematician on par with the readers in medicine, civil law, and divinity. Furthermore, the five mathematical instructors outnumber every other group of instructors save for the five teaching Latin and Greek grammar, whose combined salaries only came to 146 pounds, 13 shillings, and 4 pence. Even combining the salaries for all twelve language instructors still falls short of the five mathematical instructors' salaries.

Gilbert's ideas about practical knowledge and service were not limited to the academy's students but extended to the instructors as well. All the readers of "arte and the com*m*on lawes" were required "once within every six yeares [to] set forth some new

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[118] BL, MS Lansdowne 98, ff. 3r-v.

[119] See Appendix D for a full roster of instructors in Gilbert's proposal, with the salaries assigned to each.

[120] BL, MS Lansdowne 98, f. 3r-4r.

bookes in printe according to their severall professions," thus making their instruction widely available to the English population. Every three years, those who taught languages were similarly required to publish "some Translation into the English tounge of some good worke as neare as may be for the advauncing of those things which shalbe practized in the said Achademy." And twice a year – on Queen Elizabeth's birthday and coronation day – the academy would be required to host a sermon "whereby the Awditory shalbe put in minde who was the fownder thereof." All of these books and sermons would be publicized as being by "the gentlemen of Queene Elizabethes Achademy" and by these means, "the tounge of man shall write for ever in the cares of the living to the honor of the [by then presumably] deade" Queen Elizabeth.[121]

Although Gilbert's academy never came to fruition, a similar impulse to teach the practical applications of mathematics, particularly those that would be of service to the government, found traction in the City of London around the same time. In 1588, as part of the aftermath of the Spanish Armada, London sponsored a series of public lectures in mathematics by Dr. Thomas Hood. The lectures covered the fundamentals of arithmetic, geometry, and astronomy, as well as their applications to subjects such as navigation and gunnery. While the lectures were sponsored with the intention of educating the captains of London's trained bands, over their four years' existence they also attracted interest from local artisans, soldiers, and seamen.[122] A more enduring source of public lectures in London was Gresham College. Although the merchant Sir Thomas Gresham originally pledged to bestow £500 on Cambridge for the founding of a new college, in 1575 he

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[121] BL, MS Lansdowne 98, f. 6r.

[122] Thomas Kelly, *A History of Adult Education in Great Britain* (Liverpool: Liverpool University Press, 1992), 24.

instead decided to establish a college in London. Gresham College was officially established in 1597 to teach the "seven liberal sciences" – divinity, law, medicine, rhetoric, music, geometry, and astronomy – all in the vernacular and free of charge.[123] The geometry professor was also expected to teach arithmetic and all seven professors were supposed to pay particular attention to teaching their subjects' application to geography, navigation, commerce, and medicine.[124]

In the first decades of the seventeenth century, the idea of an academy or school of arms for the monarchs' wards found new life among the members of Prince Henry's circle. Plans to establish such an academy continued to move forward even after his untimely death. In 1620, Admiral Buckingham proposed to the House of Lords that they should gather funds "for the erection and maintenance of an Accademy for the breeding and bringing up of the Nobility and Gentry of this kingdom." A long discussion ensued of "the Arts, Sciences, and Exercises, which should be there taught and practised" and a committee was appointed to further consider the matter. The teaching was to consist of "the learning of the Mathematickes and langwage; and for all kyndes of Noble Exercises, as well of Armes as other." Three years later, James I and Buckingham were still discussing "the glorious worke of a Royall Academe for all Heroick Ends," but the king's death in 1625 effectively ended all plans for the academy.[125]

Prince Charles was a member of the academy committee established by the House of Lords and, as king, provided fiscal support for a later academy proposal put forward by Sir Francis Kynaston for a Covent Garden academy he called the Musaeum Minervae.

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[123] Feingold, "Tradition versus Novelty," 47.

[124] Kelly, *Adult Education*, 27.

[125] Fletcher, *Collectanea*, 277-8, 80.

This academy was intended to provide a practical education based on French and Italian models to the sons of gentlemen and nobles in general, not just the king's wards. Kynaston acquired letters patent in 1635 and assigned himself to teach heraldry, law, antiquities, and husbandry. His additional staff consisted of six professors, two of whom were hired to teach mathematical subjects – John Speidell, the professor of astronomy, and Walter Salter, the professor of geometry. The house that contained the academy was "furnished with books, manuscripts, musical and mathematical instruments" for both book learning and practical, hands-on experience with instruments. The academy's list of studies included a variety of practical mathematical subjects, including optics, navigation, cosmography, arithmetic, analytical algebra, fortification, and architecture. Unfortunately, the academy found itself in serious financial trouble within two years and probably shut down near the end of 1637, after one of the six professors died of the plague.[126]

The outbreak of the civil wars and subsequent abolition of the Court of Wards eliminated the need for an educational academy specifically for the monarch's wards, but not for the sons of gentlemen in general. Sir Balthasar Berbier attempted – but swiftly failed – to run an academy at Bethnal Green in 1648. The academy was supposed to provide both lectures and printed notices on cosmography, navigation, fortification, and other practical mathematical subjects.[127] The same impulse to provide an education in practical mathematics was behind the 1673 formation of the Royal Mathematical School,

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[126] My thanks to Simon Healy for bringing Kynaston to my attention. A.D. Thrush and John Ferris, eds. *The House of Commons, 1604-29*, (Cambridge: Cambridge University Press, 2010), 5: 53. Fletcher, *Collectanea*, 280-1.

[127] Fletcher, *Collectanea*, 282.

which became a model for other navigational and mathematical schools in the eighteenth century and is the only seventeenth-century academy to survive to the present.

The Royal Mathematical School was originally intended to be as a school for "40 poor Male children to be... educated in Reading, Writeing, Arithmetic, and the Lattin Tongue," as stipulated by the will of Richard Aldworth, a London merchant who died in 1646. A subsequent dispute over the distribution of the £7000 endowment – including a significant sum being "lent" to Parliament to finance their army – meant that the school remained unfunded until after the Restoration. Even then, petitions to the king went unanswered until 1672, when Samuel Pepys argued "the publick importance it (at that time especially) appeared to be to the Crowne, that a Nursery might on this occasion be Erected of Children to be educated in Mathematicks for the particular Use and Service of Navigacon."[128]

The legal battles over the school's endowment, and the need to secure royal support to reobtain that endowment, thus led to the school's transformation from an ordinary charity school into a mathematical academy intended to provide a practical service for the Royal Navy – specifically the training of new navigators. In 1673, the school finally obtained a royal charter to teach eighty boys – forty charity students from Christ's Hospital and forty paying students – not the basics of reading, writing, and Latin but solely "the art of Arithmatique and Navigacon." This was not a school for beginning arithmetic students. Boys were required to "have attained to a competent skill in Grammar and comon Arithmatique as far as the Rule of Three" – the latter being almost the entirety of an arithmetic textbook's contents – before they would even be admitted to

[128] Plumley, "Royal Mathematical School," 52.

the school. Upon passing their final examination, boys would then be required to make use of their education in service to their country, by either joining the Royal Navy or apprenticing to ships' captains for a period of seven years.[129]

The initial effectiveness of the Royal Mathematical School should not be overestimated, especially in comparison to the long-standing Portuguese tradition of naval academies. Despite its lofty goals, the school got off to a rocky start. Even after having secured the endowment, the Royal Mathematical School had financial difficulties throughout the 1690s and it is likely that only its association with Christ's Hospital enabled it to survive its first decades.[130] The school had further difficulties finding a qualified schoolmaster. The first master, John Leeke, was dismissed in 1677 for failures as a teacher, specifically not being strict enough with discipline and instructing students "in a private clossett" as opposed to the school itself. The second schoolmaster was the eminently qualified Peter Perkins, who had previously run his own mathematical school, but he died shortly after taking up the position. His successor, Robert Wood, rarely appeared at the school and resigned for health reasons in 1682. Edward Pagett, the next schoolmaster, was not a particularly effective teacher and had no knowledge of navigation. He had to take a twenty-day vacation from teaching "to go to view our sea coasts." His successor, Samuel Newton, was similarly ineffective, as well as cruel to the boys. Only in 1709, with the appointment of James Hodgson, did the Royal Mathematical School again have an effective schoolmaster.[131]

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[129] Plumley, "Royal Mathematical School," 52, 56.

[130] Plumley, "Royal Mathematical School," 55.

[131] Plumley, "Royal Mathematical School," 55.

Despite its problems, the Royal Mathematical School was an inspiration for antiquarian John Aubrey, who complained that "no Nobleman's son in England is so well bred, (or can have so good Breeding) as the Kings Mathematicall Boys at Christ-church-Hospitall in London." Unfortunately for those noblemen's sons, the school was limited to taking only forty paying students, and "their Teacher is [by] the King's order to teach no other." Thus the kingdom still "want[ed] such a Nursery, or way of Institution for the Children of the Gentry."[132] It was with this need in mind that Aubrey wrote his *An Idea of Education of Young Gentlemen* between 1669 and 1684. Initially, this proposal was not meant for widespread circulation – the title page specifically declares it to be "a priuate Essay only," perhaps meant to be read within the Royal Society, of which he was a member.[133] However at some point he changed his mind and, in 1694, contacted a printer to produce 500 copies with the intention of putting his proposal into wider circulation.[134]

Aubrey's educational philosophy was similar to Gilbert's in its focus on preparing children for government service. Like Gilbert, he drew inspiration from Plato, claiming "that the Education of Children is the Foundation of Government: it will follow then, that the Education of the Nobles, must be the Pillars and Ornaments of it: they are the Atlasis that bea[reth] the weight of it." He therefore wished to create an academy for the "right breeding up of Gentlemen of Qualitie," specifically those aged nine to eighteen, and argued that a good education is "the root, & source of their good Administration of Justice." Aubrey furthermore defined "a compleat and generous Education [as] that

[132] Bodl., MS Aubrey 10, f. 7r.

[133] Bodl., MS Aubrey 10, f. 5r.

[134] Bodl., MS Aubrey 10, f. 1r.

which fitts a man to perform justly, spi[ritua]lly, and magnanimously all the offices both Private, and Publick of Peace, & War."[135]

The three core subjects of Aubrey's ideal education were Latin, arithmetic, and geometry. Latin was the "Universal language" of scholarship and Aubrey argued that "one cannot be sayd to be a well bred man, that is ignorant of that Language." He found fault with the otherwise admirable school of John Newton, Minister of Rosse, for failing to teach Latin alongside arithmetic and geometry. But while Latin was vital for communication, it was mathematics that formed the foundation for all human knowledge: "Arithmetic, & Geometrie are the Keys, that open unto us all Mathematicall and Philosophicall Knowledge: and by consequence (and indeed) all other Knowledge."[136] Mastering mathematics thus enabled a student to acquire any other type of human knowledge.

Like his predecessors, Aubrey felt the need to defend the practical utility of mathematics for state service, such as their use for gunnery and fortification.[137] However he spent the most of his ink advocating a mathematical skill that could be used by the majority of the English population – casting up household accounts. He dramatically claimed that "many men of good Estates have been undonne meerly for want of skill in a little plaine & common Arithmetick" and "most Tradesmen are ruined for want of skell in Arithmetick: for the Merchants sell to them by Wholesale, and the Retaylors (through Ignorance) overshoot themselves, and doe not make their money again."[138] But those

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[135] Bodl., MS Aubrey 10, f. 12r.

[136] Bodl., MS Aubrey 10, f. 8r.

[137] Bodl., MS Aubrey 10, ff. 40r, 42r.

[138] Bodl., MS Aubrey 10, f. 35r.

who could master the "Art of Accompts" had not only the skills necessary to run their own estates, but also to serve in the courts, for knowledge of accounting was

> a very good qualification for a Master in Chancery: or for a Solicitor in Chancery --- Otherwise they never understand Cause; but through ignorance, they harle and perlex the Cause more (w*hi*ch most commonly they doe) and then leave it (after a great deale of money spent) to be decided by the Merchants.[139]

Thus ignorance of accounting could be a costly error that led anyone from tradesmen to noblemen into ruin, especially once the law courts became involved, whereas knowledge of accounting could secure one's future in government service.

Intriguingly, Aubrey also briefly mentioned people who had been convinced of the utility of accounting, and numbers more generally, but failed to practice this skill out of fear. He gave as an example a colonel named Alexander Popham, who possessed a considerable estate worth £9000 a year. However, Popham "was wont to make his complaints of casting up of long Bills, and Accounts, which terrified him." This was such a problem that Popham often gave up on actually examining his accounts. Instead, he skipped over the valuation columns and "lookt only on the foot of the Account" to find the previously reckoned sum totals.[140] While Popham clearly understood the value of accounting, and even set himself to the task of reviewing his accounts, he grew confused and fearful when faced with the need to check and perform calculations.

Aubrey was not the only one to notice this problem and reassurances began to appear in arithmetic textbook titles starting in the 1670s. The long lists of minor differences disappeared and instead textbooks began to emphasize both the easiness of arithmetic and its suitability to all persons, regardless of mental capacity. The 1672

[139] Bodl., MS Aubrey 10, ff. 36r.

[140] Bodl., MS Aubrey 10, ff. 36v.

edition of Hodder's Arithmetic claimed to present "That necessary Art made most easie. Being explained in a way familiar to the capacity of any that desire to learn it in a little time."[141] Students were thus reassured that arithmetic was not difficult, and that it would not require great time and effort to learn. The 1678 edition of Cocker's arithmetic similarly claimed to be able to teach the whole of arithmetic to all students, by "a plain and familiar method, suitable to the meanest capacity for the full understanding of that incomparable art, as it is now taught by the ablest school-masters in city and country."[142] And even as the 1678 edition of Wingate's Arithmetic alluded to improvements – noting that it was "very much enlarged... as will appear by the Preface and Table of Contents" – it also reassured students that it still contained "A plain and familiar method for attaining the Knowledge and Practice of Common Arithmetick."[143]

However, while lists of practical skills and tables were dropped from title pages, these arithmetic textbooks still felt the need to argue for the general usefulness of mathematics in their prefatory material. In his letter to the reader, Hodder explained his purpose for publishing his arithmetic as "the better compleating Youth as to Clerk-ship, and Trades."[144] His chapters also bear titles that declare their subjects to be of practical use. For example, the book does not teach abstract addition, but the concrete "Addition of Money, Measures, Weights, &c."[145] Cocker claimed inspiration from "the numerous concerns of the honoured Merchants,"[146] while John Kersey "added an *Appendix*, which

[141] James Hodder, *Hodder's Arithmetick* (London: T.J., 1672), A1v.

[142] Edward Cocker, *Cockers Arithmetick*, ed. John Hawkins (London: Thomas Passinger, 1678), A1r.

[143] Edmund Wingate, *Mr. Wingate's Arithmetick*, ed. John Kersey (London: Samuel Roycroft, 1678), A1r.

[144] Hodder, *Hodder's Arithmetick*, 1672: A1v.

[145] Hodder, *Hodder's Arithmetick*, 1672: A3v.

[146] Cocker, *Cockers Arithmetick*, 1678: A3v.

is furnished with variety of choice and delightful knowledge in number, both Practical and Theoretical" for the 1678 of Wingate's arithmetic.[147] Thus arguments about the practical applications of mathematics remained important, even though their use in advertising had been superseded by reassurances about the easiness of learning mathematical skills.

During the early modern period, tutors encouraged their students to apply mathematical skills to some practical purpose. For many students, this involved service to the English state, particularly through skills such as gunnery or navigation. Beginning in the late sixteenth century, both elite academy proposals and London-sponsored public lectures attempted to encourage students to acquire practical mathematical skills in order to serve state interests. This impulse was most successful in the creation of the Royal Mathematical School, which aimed to train boys to serve as navigators in Royal Navy. However, by the end of the seventeenth century, rhetoric about the practical uses of a mathematical education began to be surpassed by reassurances about the ease of acquiring a mathematical education. Students understood the utility of mathematics; now they needed to be reassured that they, too, could master the arithmetic and other, more complicated mathematics that would be so useful to apply to the world around them.

Conclusions

During the late sixteenth and seventeenth centuries, there were important changes in mathematical education occurring in conjunction with the symbolic changes discussed

[147] Wingate, *Mr. Wingate's Arithmetick*, 1678: A4v.

in the previous chapters. The second half of the sixteenth century saw the rise of the arithmetic textbook, which made Arabic numeral arithmetic available to any literate person – male or female – with a shilling to spare for the purchase of a new or used book. This propagation of primarily Arabic numeral arithmetic was further reinforced by the growing association of writing and arithmetic, especially through the petty schools and the seventeenth-century rise of writing-cum-arithmetic schools. However, Arabic numerals were not the only system taught during this period; Roman numeral enumeration and jeton arithmetic were also taught in petty and grammar schools, in educational treatises, and in several arithmetic textbooks – namely, those published as edited reprints of Robert Recorde's original *The Ground of Artes.*

While this instruction was theoretically available to all, in practice it was particularly geared towards those who would need mathematical skills to satisfy the practical requirements of their various professions, including tradesmen as well as those in a position to advance the interests of the English state via war and exploration. Thus tutors, textbook authors, education tracts, and academy proposals all emphasized the utility of their mathematical subjects for a wide variety of purposes. However, at the end of the seventeenth century, advertisements about the benefits of learning arithmetic began to make way for advertisements about the ease of learning; there was thus a shift from convincing people that they ought to learn arithmetic, towards reassuring already-convinced people that they were capable of learning. This seventeenth-century understanding that numbers and arithmetic were not limited to the realms of trade and navigation, but could also be useful in people's daily lives, will be the focus of three case studies in the second part of this dissertation.

Chapter Five

"The Brevity and Uncertainty of Time It Self"[1]
Quantifying Time

On the "viij^{0} die Februar' 1609, anno 7^{0} et 43 Regis Jacobi &c.," the indenture of a young man named John Newell was enrolled in the Southampton apprenticeship register. Newell was to be bound an apprentice "for the Terme of seven yeres from the feast of St. Thomas Thappostle last past."[2] In other words, Newell was bound to serve his master for the seven years following December 21, 1609 of the old style, Julian calendar, which was also December 31, 1609 of the new style, Gregorian calendar. This was enrolled a little over a month later, on February 8 – or 18, new style – in the English legal year 1609, the Scottish legal year 1610, and 7th and 43rd years of James I/VI's reign of England and Scotland, respectively.

This chronological confusion illustrates both the uncertainty of time during the early modern period and the way people used numbers to locate themselves in time. The clerk who enrolled John Newell into the apprenticeship register used multiple calendars in his efforts to pinpoint two moments in time – moments that were crucial for Newell's hopes of a future career and social status in Southampton – as precisely as possible. All but one of these calendars were built on an explicitly numerical foundation and required at least basic counting skills to interpret.[3] Even the liturgical calendar of Christian holy days was implicitly numerical, with holy days either permanently fixed to the numerical

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[1] Daniel Featley, *Threnoikos, The House of Mourning*, (London: G. Dawson, 1660), 474.

[2] Arthur J. Willis and A.L. Merson, eds. *A Calendar of Southampton Apprenticeship Registers, 1609-1740* (Southampton: Southampton University Press, 1968), 1.

[3] Paul Glennie and Nigel Thrift, *Shaping the Day: A History of Timekeeping in England and Wales 1300-1800* (Oxford: Oxford University Press, 2009), 226.

days of other calendars or varying, according to known mathematical formulas, within a range of numerically-specified days. Time was thus closely associated with numbers and, as argued above, was even the first aspect of early modern life where people chose to explore the use of the new Arabic numerals.

At its most basic, time is a measurement of duration; it answers the question *how long*? The duration of an event is understood to be the length of time between its start and end, whether that length is measured quantitatively with numbers or interpreted qualitatively by comparison to some other duration. For example, "three quarters of an hour of length" and "as long as you can say a Avemary" are both measures of duration.[4] Time can also be used to order two or more events by measuring the duration between each event and a fixed reference event. Calendars are a formalized version of this; they establish an official reference event, or group of events, that are subsequently used to chronologically order all other events. In other words, calendars assign all events to a specific temporal location: a *date*.[5]

As evidenced by the Southampton apprenticeship register, there were multiple calendars and multiple ways of establishing temporal locations during the early modern period. These can be broken down into three basic types – linear, episodic, and cyclical. Linear time fixed a single important event as the center of its chronology and measured duration forwards and backwards from that event. Episodic time relied on multiple events, which were usually all the same type of event, and reckoned duration by each event only until the next fixed event occurred. That next event then became the new

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[4] Glennie & Thrift, *Shaping the Day,* 223.

[5] Alexander Philip, *The Calendar: Its History, Structure and Improvement* (Cambridge: Cambridge University Press, 1921), 83.

chronological reference point and the process repeated itself. Lastly, cyclical time consisted of an event or events that repeat in a regular pattern without a clear beginning or end. However, these three types of time were not completely independent and calendars often used them in conjunction with one another, particularly cyclical time. For example, linear calendars that enumerated the years from a specific event were also built on a foundation of repeating cycles of days and seasons that constituted a complete year. Similarly, the days of the month might be numbered sequentially, while the days themselves were also built on a repeating cycle of hours, minutes, and seconds.

Time was already highly quantified at the beginning of the sixteenth century. Numbers were an explicit part of most calendars while advanced mathematical knowledge was required to construct calendars and calculate time based on astronomical observations. However, the way ordinary people used numbers to locate themselves in time changed over the course of the early modern period. During the late sixteenth century, religiously motivated and contested calendar reforms led people to adopt the notation of mathematical fractions in order to deal with "broken" time. Over the course of the seventeenth century, the proliferation of almanacs brought the multiplicity of early modern calendars directly into the household and encouraged people to place themselves at the center of their own, personal calendars. Along with the increasing incidence of global travel, almanacs also raised popular awareness of the relativity of time and the interconnectivity of time and space. By the eighteenth century, calendars and time were understood to be first and foremost numerical constructs, not in and of themselves sacred, but rather important only so far as they helped people temporally locate themselves in order to conduct their mortal and immortal lives.

Breaking the Temporal Consensus

By the late middle ages, the European temporal consensus established during the Roman Empire had come to be viewed as increasingly flawed, particularly with respect to calculating the date of Easter. However, sixteenth-century attempts to reform the calendar were stymied by political and religious debates over who – or what – had the authority to alter time itself. In England, arguments against reform were further bolstered by comparing the different mathematical difficulties the general population would be forced to deal with, depending on whether or not England altered the existing calendar. The inability to come up with a new temporal consensus led to the proliferation of conflicting calendars during the seventeenth century. People responded by co-opting the notation of fractions – also known as "broken numbers" – to impose numerical order on their now-broken time.

Until the late sixteenth century, a temporal consensus existed throughout Christian Europe. The various European countries all agreed on what constituted the basic chronological units of their calendars: the year, month, week, and day. Since the eighth century, they had also agreed that the primary reference event by which they would calculate dates should be the incarnation of Christ.[6] The years calculated from the incarnation were known as *anno domini*, which was translated into English as years of grace or years of our Lord. While there was some disagreement on exactly when the year

[6] The method of reckoning the year from the incarnation of Christ was standardized in the eighth century by the Venerable Bede, who used chronicles and the gospels to establish the dates of creation and the incarnation. Robert W. Poole, *Time's Alteration: Calendar Reform in Early Modern England*, (London: UCL Press, 1998), 35. While the AD/BC distinction was also made by Bede, in his *Ecclesiastical History of the English Nation*, it was not used by other scholars until the fifteenth century and only came into widespread use in the seventeenth century. G.J. Whitrow, *Time in History: The evolution of our general awareness of time and temporal perspective* (Oxford: Oxford University Press, 1988), 70.

started, the months and days that made up this year were standardized throughout Europe. They followed the rules of the Julian calendar, which had been established throughout the Roman Empire during Julius Caesar's calendar reforms of 46-5 B.C. and which were increasingly seen as inherently flawed.

The main problem with the Julian calendar was astronomical. Its year was based on the solar year, calculated as the length of time required for the sun to travel from one equinox to the same equinox.[7] This did not divide evenly into any of its chronological subunits, as it consisted of approximately 365.25 days.[8] To accommodate the partial day, the Julian calendar included a "leap year" or "bissextile" – every fourth year added one extra day in the month of February.[9] However, even this did not completely reconcile the Julian year with the actual length of the solar year, leaving a difference of approximately 11 minutes. This difference did not create a discernable problem in the short term. However, as centuries passed, it caused the Julian calendar to slip increasingly out of alignment with the natural cycle of the equinoxes.

The Julian calendar was also completely divorced from the lunar time measurements that formed the basis for scheduling important Christian feasts. The twelve months of the Julian calendar were close in length to a single lunar cycle, or lunar

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[7] Other calendars are based on the lunar year, while the Hebrew calendar is lunisolar – accommodating both lunar and solar years.

[8] This is the tropical version of the solar year. Another possible way to calculate the solar year is according to the length of time it takes for the sun to return to the same place among a set of constellations – the sidereal version of the solar year. Neither of these methods for calculating the solar year presupposes a heliocentric model of the solar system.

[9] There was a great deal of confusion when the leap year was first instituted, and for several years the leap day was added to every third year instead of every fourth. Consequently, the calendar had to be adjusted again by Augustus Caesar, who caused the leap day to be dropped from 5 BC, 1 BC and 4 AD to bring the calendar back in line with the solstices. Augustus also reformed the Egyptian, Alexandrian calendar to synchronize with the Roman, Julian calendar. Walter F. Snyder, "When Was the Alexandrian Calendar Established?" *The American Journal of Philology* 64, no. 4 (1943): 387. T.C. Skeat, "The Egyptian Calendar under Augustus," *Zeitschrift für Papyrologie und Epigraphik*, Bd. 135 (2001): 153-4.

month – the time between two new moons being approximately 29.53 days – and can serve as a crude approximation. However, Julian months bore no actual relationship to lunar months and, over the course of a solar year, seventeen days of difference accrued between the Julian and lunar months. The Julian month was thus an artificial unit of time, arbitrarily fixed in length at 28, 29, 30 or 31 days, and could not be determined directly from natural, astronomical observations.[10] They were, however, at least fixed to the Julian year and thus could be indirectly determined by their relationship to the solar year. While ignoring lunar cycles immensely simplified calendar calculations, it also meant that the Christian feasts based on lunar cycles were similarly divorced from the Julian calendar. These feasts became known as the "moveable feasts" because they did not exist in fixed relationship with the rest of the calendar.

The most important – and also the most problematic – of these moveable feasts was Easter, the date of Christ's resurrection from the dead. In 325, the Council of Nicaea had officially fixed Easter to the Sunday following the first full moon after March 21, which was then the vernal equinox.[11] However, over the following centuries, the astronomical vernal equinox drifted further and further away from March 21. By the sixteenth century there was a difference of ten days between the natural cycle of the equinoxes and the artificial time of the Julian calendar. As a consequence, calculations

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[10] A rhyme for remembering the arbitrary lengths of each month was reproduced in early modern almanacs and dates back to at least the sixteenth century: "Thirty days hath September,/April, June and November:/All the rest have thirty one,/Save February alone/Which hath but 28 days meer,/And 29 in the Leap-year." Vincent Wing, *Wing's Ephemeris for Thirty Years* (London: J.C., 1669), K2r. Richard Huloet, *Huloets Dictionarie*, ed. John Higgins (London: Thomas Marsh, 1572), Aa5r.

[11] This was an extremely complicated calculation. While the lunar and solar cycles coincide every nineteen years, that does not take into account the requirement that Easter take place on a Sunday. Because of the leap year, it takes twenty-eight years for the solar cycle and the weekly cycle to coincide. Thus all three cycles – weekly, lunar and solar – only coincide every 532 years. Donald J. Wilcox, *The Measure of Times Past: Pre-Newtonian Chronologies and the Rhetoric of Relative Time* (Chicago: Chicago University Press, 1987), 133.

done according to the established calendar formulas no longer matched calculations done according to astronomical reality, with each producing a different date for Easter.

Although these issues led to repeated calls for calendar reform, it was not clear who had the authority to alter time. Various Popes considered the problem of calendar reform in the 1340s, 1430s, and throughout the sixteenth century.[12] However the twelfth-century schism that divided Christianity into two separate churches – the Eastern Orthodox and Roman Catholic – meant that any decision a Pope made on calendar reform might not be respected by the other half of Christianity. The Protestant Reformation further complicated questions of authority, but also led Pope Gregory to call the Council of Trent in 1563. This Council undertook the reform of the Catholic breviary and missal, with the understanding that this would necessitate some sort of calendar reform to fix the problems associated with calculating the date of Easter. Several options were considered, including a fourteen-day reform to return the Julian calendar to its original relationship with the equinoxes and an eleven-day reform to return the calendar to its state at the time of Christ. However, the council eventually decided to make a ten-day reform to the time of Nicaea.[13] By choosing Nicaea as the basis of their reformed calendar, they intended to both emphasize Trent's Nicaea-like power as a general church council as well as encourage the Greek churches to adopt the same reform.[14] In February of 1582, the new

[12] Medieval astronomers and philosophers who advocated for calendar reform included Roger of Hereford in the twelfth century, and Robert Grosseteste, Jean Sacrobosco, and Roger Bacon in the thirteenth century. Poole, *Time's Alteration*, 36.

[13] Aside from the wholesale deletion of ten days, the Gregorian calendar retained almost all the same features as the Julian calendar. This included all the Julian chronological units, with only a slight modification to the Julian month of February – February 29 was to be skipped in years divisible by 100 that were not also divisible by 400.

[14] The Eastern Orthodox churches only instituted their own reform of the Julian calendar in the twentieth century.

calendar was promulgated in the papal bull *Inter gravissimas* and, ten months later, October 4th was followed by October 15th, 1583.[15]

While the English acknowledged the faultiness of the Julian calendar, they were reluctant to adopt the Gregorian calendar because to do so meant acknowledging the Pope's authority over time and, implicitly, his authority over religion.[16] In response to a request from Secretary of State Walsingham, mathematician John Dee suggested that Queen Elizabeth promulgate her own calendar in her role as a British empress, much as the original Julian calendar had been promulgated by a Roman emperor. This would both neatly avoid the question of accepting the Pope's authority, while promoting Elizabeth's own authority as an imperial power. Dee advocated this reform be set not to Nicaea but to the time of Christ, for "Christians should regard his birth as the 'Radix of Time'" and thus the proper moment to form the basis of the reformed calendar.[17] Thus the English reform would be more correct than the Pope's, who surely must eventually "embrace the veritie" of the English calendar and thus acknowledge Elizabeth's authority.[18] However, upon further discussion with Lord Treasurer Burghley, Dee "yeldeth for conformitye with the rest of the world to assent to the reformation of our Engleshe calender, with the abridgement of x. daies onelie," so long as this practical concession was accompanied by

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[15] Intriguingly, the chronological unit of the week was not affected by this reform. October 4th was a Thursday and was followed by Friday – not Monday – October 15th. This was possible because the week is a completely artificial unit of time, based on the length of time it took God to create the world as opposed to any astronomical phenomenon. The cycle of Sundays was thus unaffected by the reforms.

[16] For Continental Protestants' reactions to calendar reform, particularly the German *kalenderstreit*, see Poole, *Time's Alteration*, 38-9; Rona Johnston Gordon, "Controlling Time in the Hapsburg Lands: The Introduction of the Gregorian Calendar in Austria Below the Enns," *Austrian History Yearbook* 40 (2009):28-36; and James Hodgson, *An Introduction to Chronology* (London: J. Hinton, 1747).

[17] John Dee, *A Playne Discourse... concerning the nedful Reformation of the Vulgar Kalendar for the civile years and daies accompting, or verifyeng, according to the time truely spent*, as cited in Poole, *Time's Alteration*, 47.

[18] Poole, *Time's Alteration*, 59-60.

theoretical arguments that the entirety of Christendom ought to subsequently find one more day to remove from their new calendar.[19]

This modified proposal was sent by Walsingham to Archbishop Grindal who, along with three other bishops, objected to the proposal using a combination of political, theological, and mathematical arguments. First and foremost, they rejected the idea that a monarch had the political authority to reform the calendar and insisted another ecumenical council like Nicaea would be required to make any necessary changes. As for the religious concerns around the calculation of moveable feasts, they argued that the date of Easter was a "thing indifferent," as it was only a commemoration rather than a reenactment of Christ's death and rebirth. Therefore the exact timing of Easter was a matter of historical convention, rather than doctrinal necessity. Even if it had not been, the Gregorian calendar retained a one-day error from the time of Christ, which meant its dates continued to be inaccurate, just like those of the current calendar. Given the choice between two calendars that were inaccurate in different ways, it was the duty of the Protestant churches to distance themselves from the Roman calendar, just as all Christians sought to distance themselves from the Jewish calendar.[20]

While these objections could have been overcome by a parliamentary act, the bishops also argued against reform by analyzing the mathematical consequences for the general population. Before submitting their opinion, they sought the advice of "some godly learned in the mathematicalls" as well as merchants who "have continual resort by

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[19] In practice, Dee also chose to conform to the Gregorian calendar while living in Bohemia. Glennie and Thrift, *Shaping the Day*, 277n8. Poole, *Time's Alteration*, 48.

[20] Because of the bishops' objections, the question of calendar reform was deferred to the next parliament. "An Act, giving Her Majesty authority to alter and make a calendar, according to the calendar used in other countries," was read several times but lost when parliament was dissolved less than a month after its introduction. Poole, *Time's Alteration*, 49-51.

cause of contracts and traffic for trade of merchandises" to the Continent. While having to accommodate different calendars would be inconvenient, "diverse marchants of best experience inhabiting within the citee of London do think and offer to prove, that they may use their traffic as well without that alteration as with it."[21] Subtracting ten days from the current date was definitely within the capabilities of merchants who were already used to making the complicated mathematical calculations necessary to exchange foreign currencies.

If the merchants did not need the calendar to be reformed then, for most of the population, the mathematical drawbacks of alteration would outweigh any possible benefits:

> the alternation will ease but a few, viz. – such as have traffick with foreyn nations; but to the rest of the realm it will be troublesome. For the old rules of the compound manual of the Golden number, of the epact and cycle of the sonne, &c. whereby generally the people of this realme doe find out the course of the year, the change of the moon, and consequently the tides and the Dominical letter, &c. (which hitherto have served them) will be wholly out of use, and hardly shall they learn new, which peradventure will also be more uncertain.[22]

Thus for the majority of the population, the calendar adhered to by the rest of Europe was irrelevant. However any attempt to alter the English calendar would result in widespread confusion, as the old rules for calculating dates by the golden number, the dominical letter, and the epact would be made invalid. Without these rules, farmers could no longer correctly calculate the seasons, nor mariners and fishermen the tides. Every moveable feast, fair, and law term would also have to be recalculated according to a new set of rules. While the population would eventually adjust to and memorize new rules for

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[21] Poole, *Time's Alteration*, 51.

[22] Poole, *Time's Alteration*, 51.

calculation, their grasp of these rules would remain less certain and more prone to mistakes than their calculations by the current rules.

Lest there be any doubt that even ordinary people had the mathematical skills necessary to handle the calendar conversions, the bishops also brought up a curious omission in Dee's plan: there was no mention of reforming New Year's Day. While Europe had previously been united under their use of the Julian calendar, there had never been a consensus as to when, within the repeating cycle of the Julian year, each new year should officially start. The original Julian calendar fixed March 1 as the first day of the Julian year, but was soon modified to January 1 to coincide with Roman election cycles. By the fifth century, some Christian countries had adopted March 25 as the start of the new year, to coincide with the Annunciation, or Lady Day, the beginning of Christ's incarnation on earth. This date had the advantage of being close to the vernal equinox, although it no longer coincided with the equinox because of accumulated slippage between the Julian and solar years.[23] However the calculation of Easter with respect to March 21, combined with a new year beginning on March 25, meant that it was possible for some years to have no Easter while others had two. This became one of many sources of frustration with the Julian calendar and the calculation of Easter.[24] The Gregorian calendar reform had therefore established January 1 as New Year's Day. To bring

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[23] December 25 was chosen as the date of Christmas to help stamp out pagan festivals associated with the winter solstice. Consequently, the Annunciation – the conception of Christ, nine months before Christmas – was fixed on March 25, which was then the vernal equinox. Whitrow, *Time in History*, 70.

[24] As Edward Chamberlayne complained, "yet cannot it be denied but that this old Computation is become erroneous; for by our Rules, two *Easters* will be observed within one year, as in the last 1667, and not one *Easter* to be observed this year," that is, 1668. Edward Chamberlayne, *Angliae Notitia, or The Present State of England,* (London: T.N. for John Martyn, 1669), 70. Or, as an anonymous wit remarked more pithily, "He'd rather have two *Easters* in a Year, / Than to disturb the *sacred Calendar*." Anonymous, *An Account of the solemn reception of Sir Iohn Robinson, Lord-Maior at St. Pauls Cathedral, the day of his inauguration* (London: Josuah Coniers,1662), 7.

themselves fully into alignment with the Gregorian calendar, the English would need to adopt the same New Year's Day.

Despite the issue of Easter, the English civil calendar still officially began on Lady Day, March 25, when reckoning the years since the incarnation of Christ. This date was also widely used by the general population throughout the sixteenth and seventeenth centuries. For example, Sir Edward Don acknowledged March 25th as the start of the new year in his household book for every year through to his death in 1551.[25] The first register of the parish of Prestbury, in Cheshire, also adhered to the March 25th new year from its inception in 1560 through to its end in 1636.[26] The funeral certificate of John Done of Utkingtone, Edsbury, indicates he died on “xxiijth of March, 1600, and was interred in Terperley Church vpon the vijth daye of Aprill, 1601."[27] There were thus fifteen days between his death and interment, not a year and fifteen days. Letters and receipts regarding the collection of ship money in 1635-6 Buckinghamshire indicate continued adherence to March 25th as the first date of the next year of the incarnation.[28] At the advent of the Interregnum, in 1650, Lawrence Wright of the county of Chester still dated his will "February 11, 1649."[29]

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[25] Although Sir Edward Don could have conceivably had someone to keep his books for him, internal evidence such as the use of first person pronouns indicate that the book was written by Don himself. Ralph A. Griffiths, ed., *The Household Book (1510-1551) of Sir Edward Don: An Anglo-Welsh Knight and his Circle*, Buckinghamshire Record Society Publications 33 (Amersham, Buckinghamshire: Buckinghamshire Record Society, 2004), xxviii.

[26] James Croston, ed., *The Register Book of Christenings, Weddings, and Burials within the Parish of Prestbury, in the County of Chester, 1560-1636*, Record Society of Lancashire and Cheshire 5 (Manchester: A. Ireland and Co., 1881).

[27] John Paul Rylands, ed., *Cheshire and Lancashire Funeral Certificates, A.D. 1600 to 1678,* Record Society of Lancashire and Cheshire 6 (London: Wyman and Sons, 1882), 71.

[28] Carol G. Bonsey and J. G. Jenkins, eds., *Ship Money Papers and Richard Grenville's Note-Book*, Buckinghamshire Record Society Publications 13, (Hertfordshire: The Broadwater Press Ltd, 1965).

[29] J.P. Earwaker, ed., *Lancashire and Cheshire Wills and Inventories at Chester*, Remains, Historical and Literary, connected with the Palatine Counties of Lancaster and Chester, n.s., 3 (Manchester: Charles E. Simms, 1884), 242.

However, in the late sixteenth century, the idea of beginning the new year on January 1 was also beginning to filter into English culture, thanks to the increasing production of yearly almanacs. Nearly all almanacs followed the astronomers' custom of beginning the year on January 1 and therefore ran from January 1 to December 31, treating the months from January to March as part of the new year. While both January 1 and March 25 were red letter days – printed in red, rather than black, ink to call attention to the holiday – the former was generally printed as "New Years Day" while the latter was referred to as the "Annunciation" or the "Annunciation of Mary." Scotland even officially adopted January 1 as the beginning of the year in 1600, just prior to the union of the English and Scottish monarchies.[30] The uncertainty surrounding New Year's Day had grown to such a point by the middle of the seventeenth century that Lady Anne Clifford of Westmorland, when having her tomb inscribed in 1654, felt the need to explain that her birthday was "y^{e} 30th of January (Being Fryday) in y^{e} yeare 1590 as y^{e} yeare begins on New Yeare's Day."[31]

To eliminate any possible confusion surrounding the two different dates for reckoning the new year, some people co-opted the notation of mathematical fractions, also known as "broken numbers." This was a relatively simple matter, as Humphrey Baker explained: "Fractions or broken numbers... are two noumbers with a line betwene them bothe."[32] As early as 1613, the first ledger book of High Wycombe gives the date

[30] This was the only way in which the Scottish and English calendars differed during the seventeenth century.

[31] Poole, *Time's Alteration*, 112.

[32] Humfrey Baker, *The Wellsprying of Sciences* (London: Ihon Kyngston, 1568), G3r.

as "22 January 1612/3."[33] This was not the only way to write a split year. Other writers, such diplomat Sir Thomas Roe, wrote out the entire Arabic numeral year above and below the line, thus even more closely mirroring fraction notation: "24 ffeb*ruary* 1631/1632" and "22. March 1635/1636."[34] This split-year notation thus acknowledged the numerical uncertainty of the calendar by conceding that a date could belong to either of two different years, depending on what day one chose as the start of the new year.

Split-year notation became more common as the seventeenth century wore on, though it was never universal. When the young gentleman Thomas Oxinden was in London, he wrote a letter to his mother in the countryside, using split-year notation to date his letter Feb: 5th 1660/61. When she sent her reply, a month later, Katherine Oxinden strictly adhered to March 25 as the new year, dating her letter "Wedensday. March.6.1660."[35] Indeed, in all the surviving family correspondence, Thomas appears to be the only member of his family who used split-year notation. In the Southampton apprenticeship registers, split-year notation only first appears when apprentice Thomas Wickham had his indenture enrolled on March 15 1671/2. Thomas Penn was subsequently enrolled on February 24 1672/3 for an indenture that started on February 2, 1672/3, while Richard Chapline was enrolled on March 12, 1696/7.[36] One printing of Robert Wood's *A New Almonac for Ever, or A Rectified Account of Time* advertised its

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[33] R.W. Greaves, ed., *The First Ledger Book of High Wycombe,* Buckinghamshire Record Society Publications 11 (Hertfordshire: The Broadwater Press, 1947), 108.

[34] Nadine Akkerman, ed., *The Correspondence of Elizabeth Stuart, Queen of Bohemia, Volume II: 1632-1642* (Oxford: Oxford University Press, 2011), 34, 399.

[35] BL, MS Additional 28004, ff. 197r, 207r.

[36] Willis and Merson, *Southampton*, 48-9, 56.

start date as "March 10 1680/1," however others were to begin on "March 10. 1680."[37] Others were more consistent, particularly at the end of the century; John Aubrey dated a letter regarding the printing of his manuscript as "London Febr. 27. 1693/4" and he dated the essay itself to "1683/4."[38]

For those who corresponded with or lived on the Continent, the same fraction notation could also be adopted to conveniently indicate the date in both the Gregorian and Julian calendars. Elizabeth Stuart, the exiled Queen of Bohemia and daughter of King James VI/I, was in constant communication with people on both sides of the calendar divide. Both Elizabeth and her correspondents thus usually employed fraction notation for the dates in their letters. There was no consensus as to which date should come first, the Julian or the Gregorian. Elizabeth herself used both interchangeably, writing letters on "3/13 of Januarie," "22/12 of April," and "31/21 of May."[39] Fraction notation for the day could even be used in conjunction with fraction notation for the year, such as a letter she received on "19/29 March 1638/9."[40]

The most complicated part of translating between the Gregorian and Julian calendars occurred when the calendars disagreed on the month, as well as the day. In these situations, some of the letter writers had no trouble subtracting across the months, giving dates such as "28 Jullet / 8 Aust 1632," "1 d'Aoust / 22 de Jul. 1639," and "30 Mars / 10 April 1640."[41] However, most of the letter writers preferred to use only one

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[37] Robert Wood, *A New Almonac for Ever, or A Rectified Account of Time* (London, 1680), A1r. Found in BL, MS Additional 4473, 2r. Robert Wood, *A Specimen of A New Almonac for Ever: or A Rectified Account of Time* (London, 1680), A1r.

[38] Bodl., MS Aubrey 10, f. 2r, 5r.

[39] Akkerman, *Correspondence of Elizabeth Stuart*, 20, 69, 183.

[40] Akkerman, *Correspondence of Elizabeth Stuart*, 777.

[41] Akkerman, *Correspondence of Elizabeth Stuart*, 118, 813, 899.

calendar and mark the date as following the old, Julian style – "24 of April st. v.," "26 Janu*uary* 1632 st. vet.," "24 of Julie St V," and "29 of Aug*ust* old st*yle* 1641"[42] – or new, Gregorian style – "4. Feb st. n. 1632," "5 of April st. N.," "1 of Februarie St. N.," and "Bruxel*les* 4th July 1636 n. st."[43] Only when the Gregorian date had advanced past the tenth of the month did they revert to using fraction notation. They were thus extremely fluent in translating between calendars and only rarely made errors in their dates, such as one letter corrected via strikeout to read "10/~~20~~ of October N stile."[44] Navigating between the various calendars was inconvenient, but well within their mathematical capabilities.

The late sixteenth century thus saw the shattering of the European temporal consensus. Attempts to create a universal reformation of the increasingly inaccurate Julian calendar foundered on disagreements about what type of people, or groups of people, could exercise authority over time. In England, political and religious arguments against reform were further bolstered by evidence that the population had sufficient mathematical skill to translate between two calendars, but not to learn new versions of the complicated rules for calculating moveable events that were not fixed to a certain day of the calendar. The refusal of England, and other Protestant countries, to adopt a Catholic-sponsored calendar reform resulted in the promulgation of competing calendars during the seventeenth century. To eliminate temporal confusion, English men and women adopted the notation of fractions – commonly referred to as "broken numbers" –

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[42] Akkerman, *Correspondence of Elizabeth Stuart,* 74, 164, 694, 997.

[43] Akkerman, *Correspondence of Elizabeth Stuart*, 27, 60, 163, 467.

[44] Akkerman, *Correspondence of Elizabeth Stuart*, 1004.

to convey multiple, conflicting dates for the same event. The Julian calendar had been both literally and notationally broken.

Almanacs and the Multiplicity of Time

During the late sixteenth century, the perpetual almanacs of the middle ages gave way to disposable almanacs that were designed to only last one year. The new design of these yearly almanacs gave authors the flexibility to present their readers with information on multiple early modern calendars, including tables meant to assist in translating dates between different methods of reckoning time. While the most common early modern calendar used Christ's incarnation as the reference event, almanacs also enabled people to temporally locate themselves with respect to a wide variety of events with either religious and national significance. Furthermore, almanacs put the reader at the center of their own personal time through both chronologies and the so-called "blanks" that enabled readers to record the details of their lives on the almanac's calendar.

Prior to the sixteenth century, most calendars were designed to work in perpetuity and required readers to either consult separate tables or use mathematical rules to calculate the moveable feast days for any particular year. The first printed almanacs to be prepared for specific time periods were still designed to last for decades.[45] In the late sixteenth century, however, the decreasing cost of printed books led to the rise of the yearly almanac, which achieved its standard form during the reign of Queen Elizabeth

[45] *OED*, s.v. "almanac, *n*."

and fell under the control of the Stationers' Company by 1571.[46] The limited temporal scope of these almanacs meant that authors could calculate the whole year's worth of moveable feasts and other astronomical phenomena, eliminating most of the reader's need to perform his or her own calculations.[47] The remaining calculations generally related to compensating for geographical differences, which will be discussed at length in the next section.

Costing only two pence, yearly almanacs appealed to all levels of society. William Woodhouse claimed his almanacs were "Necessarye for all men, chieflye for Gentlemen, Lawyers, Merchants, Mariners, Husbandmen, Trauellers, Arificers and all other."[48] Under the Stationers' monopoly, seventeenth-century almanacs were second in popularity only to the Bible, selling over 400,000 copies annually in the 1660s and 1680s.[49] Almanacs contained a wide variety of scientific information and particularly mathematical information geared towards popular consumption, ranging from tide tables to ready reckoners for calculating interest on loans to discussions of upcoming meteorological phenomena like eclipses.[50] As William Savage explained to his readers, his almanac "is not durable for longer time then a yeare, yet will that years vse recompence thy two-penny purchase."[51] While the vast majority of almanacs must have

[46] Bernard Capp, *Astrology and the Popular Press: English Almanacs 1500-1800* (Ithaca, New York: Cornell University Press, 1979), 29-30.

[47] Alison A. Chapman, "Marking Time: Astrology, Almanacs, and English Protestantism," *Renaissance Quarterly* 60 (2007): 1269-70.

[48] William Woodhouse, *Woodhouse. 1607. An Almanacke, and Prognostication* (London: Company of Stationers, 1607), A1r.

[49] Capp, *Astrology and the Popular Press*, 44.

[50] For an extensive treatment of medical information in almanacs, see Louise Hill Curth, *English Almanacs, Astrology and Popular Medicine: 1550-1700* (Manchester: Manchester University Press, 2007).

[51] William Savage, *Savage 1611. A new Almanacke and Prognostication, for the yeare of our Lord and Sauiour Jesus Christ, 1611* (London: Company of Stationers, 1611), B2r.

Vulgar notes of the English Kalender for this Iulian or Sosigenian yeare. 1611.		Romane Kalender for this Lilian or Gregorian yeare. 1611.	
The golden number	16	Aureus numerus	16
The circle of the sunne.	23	Cyclus Solaris	24
Dominicall letter.	F.	Litera Dominicalis	[illegible]
The Romain Indiction	9	Indictio Romana	9
The Epact	26	Epacta	16
From Christmas daye to Shroue-sunday, 5. weekes, 5. dayes.		Interuallum minus, siue numerus hebdomadarum et dierum inter natalem Domini, et esto mihi, hebd.7.dier.1.	
From Shrouesunday to the Annunc. of Mary, week.7.d.1			
First sunday in Lent.	Febr.10	Quadragesima	Feb.20
Easter day	March.24	Dominica paschatis.	Apr 3
Ascension day	May.2	Ascentio Domini.	May.12
Whitsunday	May.12	Pentecoste	May 22
Aduent sunday	Decemb.	Aduentus Domini.	Nou.27
Betwixt Trinity & Aduent sunday	weeks.27	Dominicae post Trinitatis,	25.

Dual Table of Moveable Feasts from Hopton's 1611 Almanac[52]

been thrown away at the end of every year, when their calendars became obsolete, a minority were kept and placed in bound collections for later reference. This was a common enough practice that Arthur Hopton could expect the readers of his 1611 almanac to refer back to "the directions in my Almanack 1608."[53]

At their core, almanacs always consisted of a calendar and a prognostication, which helped people use numbers to locate themselves with respect to past and present

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[52] Arthur Hopton, *Hopton 1611 An Almanack and Prognostication* (London: Company of Stationers, 1611), A2r.

[53] Hopton, *Hopton 1611*, A1v.

events. Until the 1750s, the English almanac adhered to the astronomical version of the Julian calendar, reckoned from Christ's incarnation and with a New Year's Day of January 1. After the Gregorian reform, many almanac writers also attempted to help readers calculate the differences between the two calendars by adding dual tables of Julian and Gregorian moveable feasts, such as the one pictured above. These generally included both a list of the main moveable feasts, listed side-by-side for easy conversion, but also gave the necessary information – namely the golden number, dominical letter, and epact – for readers who wished to make their own calculations. Some almanac writers also printed explanations of the calendar and its reform. In his 1612 almanac, Arthur Hopton dedicated several pages of his prognostication to "the Leape-year, and the cause thereof" followed by a discussion "Of the originall ground of these late Alterations of the yeares and times, with the Feastes moueable and fixed, whereby the Romans and we so differ."[54] Francis Perkins, in his 1671 almanac, explained the Gregorian calendar more briefly: "Note, That the Roman Account is always ten days before the English Account; so that their Eleventh day is our First day, and our Last day is their Tenth day" of the next month.[55] This enabled the reader to convert dates between the two calendars, but not calculate the dates of Gregorian moveable feasts like the dual tables did. Dual tables continued to be common until the English calendar reform of 1752, though some almanac writers provided incorrect tables in 1700, when they initially failed to realize the gap had widened to an eleven-day difference between the calendars.[56]

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[54] Arthur Hopton, *Hopton 1612. An Almanack and Prognostication* (London: Company of Stationers, 1612), B3r-B4v.

[55] Francis Perkins, *A New Almanack and Prognostication for the Year of Our Lord God 1671* (London: E.L. and Robert White, 1671), A1r.

[56] The year 1700 was a leap year in the Julian calendar, but not in the Gregorian calendar. Poole, *Time's Alteration*, 105.

As evidenced by the detailed information on moveable feasts, almanacs were useful for helping readers keep track of events associated with the liturgical cycle of Protestant holy days. The monthly calendar pages always listed the major holy days next to their respective Julian dates, particularly those that served a dual function as religious festivals and temporal markers for mundane civic activities. Four of these days, the so-called "Quarter Days," were also used to subdivide the year for the payment of rents. When translated into Julian months and days, the Quarter Days of Lady Day, Midsummer, Michaelmas, and Christmas became March 25, June 24, September 29, and December 25. These were, respectively, 91, 96, 87, and either 90 or 91 days apart depending on the leap year. The Quarter Days were therefore chosen for their importance as holy days, as opposed to their exact mathematical quartering of the year. The legal and university terms were similarly based on the cycle of holy days, however the four terms were calculated in part from the moveable feasts of Easter, Ascension Day, and Corpus Christi. Simply indicating the Julian date of these holidays on the monthly pages, as was possible to do with Quarter Days, would have left the reader responsible for calculating the term dates on his or her own. Therefore, almanacs included verbal explanations and tables in which their authors had already calculated the start and end date of that year's legal and university terms.[57]

While the Reformation had eliminated many of the old saints' days from the official liturgical calendar, the days themselves remained an integral part of the almanac calendar during the early modern period. This was a situation of no little embarrassment

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[57] Easter term took its name from its Easter-determined starting date, while Trinity term began the day after Corpus Christi day. As Richard Allestree explained to his readers, "Note that Corpus Christi day is alwayes the Thursday after Trinity Sunday." Richard Allestree, *Allestree. 1641. A New Almanack and Prognostication* (London: T. Coates, 1641), A2r.

to Protestant almanac writers, who felt the need to justify their inclusion of apparently Popish festivals. George Wharton, in his 1648 almanac, explained that some of these days:

> are appointed by the Church to be kept holy. Others, (such as *Cuthbert, Martin, Hilary, Thomas Becket, &c.*) because the principall Marts and Faires kept here in England are by them distinguished, and the Dates of old Evidences thereby the better discovered, and not for any superstitious use, as the ignorant suppose.[58]

Thus almanacs continued to provide information on saints' days to help their readers calculate the dates for annual fairs, which were traditionally held around the old festivals, as well as translate liturgical dates from old documents into Julian months and days. However, not everyone was self-conscious about using saints' days in lieu of Julian dates, and saints' days continued to appear in new legal documents. Throughout the seventeenth century, the Southampton apprentice registers listed boys as being bound both on important festival days cum Quarter Days such as Christmas and Michaelmas, as well as saints' days such as "St Thomas the apostole", "St Luke the apostle", "the feast of Saint Andrew the apostle", and "Allhallowtide" or all Saint's Day.[59]

While the incarnation of Christ was the primary reference point for the most prevalent early modern calendar, almanacs also helped readers temporally locate themselves with respect to other past events of major religious or national significance. The most common alternative to the year of the incarnation was the regnal year, an episodic calendar that reckoned time from the accession of each English monarch. This

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[58] George Wharton, *No Merline, nor Mercury: but a New Almanack after the Old Fashion* (London, 1648), A5r.

[59] Willis and Merson, *Southampton*, 1, 6-8, 15, 74.

had the political advantage of placing the monarchy at the center of a uniquely English method of reckoning time.

Regnal years were commonly found in the legal system because they were officially used to enumerate Acts of Parliament.[60] For example, the first Act of Supremacy was passed in November 1534, which was the 26th year of King Henry VIII. Thus the act was later referenced as 26 Hen. 8 c. 1. Acts passed during the reign of co-monarchs Philip and Mary were referred to with respect to both their regnal years, such as 2 & 3 Ph. & M. c.9 – an act against gaming passed in 1555, which was the second and third year of the reigns of Philip and Mary. Thus anyone who worked in or had recourse to the legal system would have encountered, and possibly become fluent in, the use of regnal years.

Regnal years also frequently appeared in private letters and accounts, particularly during the sixteenth century. In his household book, Sir Edward Don used regnal years exclusively from "Mensis Septembris anno H. viii ii^{o}" to "Novembyr anno xvi^{to}" which he also recorded as "Sic finit anno domini m^{lo}cccccxx^{o}iiii^{o}."[61] Sir Henry Savile wrote several letters to William Plumpton that he dated with regnal years – on "xxviij of November, anno 1544, 36 H.8," "xxviij of May, anno 1545, 37 H.8," and "vth of May, anno 1546, 38 H.8."[62] The Pyrton, Oxfordshire, churchwarden accounts begin in "the seconde yere of the reyne of owre sovereigne Lord Kynge Edward the syxt" then switch to anno domini years in 1554, return to regnal years in "the iiij yere off the rayne off our

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[60] This tradition continues to the present.

[61] Griffiths, *Sir Edward Don*, 1, 126.

[62] Joan W. Kirby, ed., *The Plumpton letters and papers,* Camden Fifth Series 8 (Cambridge: Cambridge University Press, 1996), 220-2.

ssoverentt lade Elysabeth" and begin mixing the two in “the yeare of oure lorde god 1566 and in the 8 yeare of the rayne of quene Elzabethe [sic].”[63]

Into the seventeenth century, the continued importance of regnal years can be seen in the 1649 declaration of the House of Commons forbidding their use. The day before the execution of Charles I, the Commons passed an act to establish a "New style and form in legal proceedings, writs, etc." to erase references to a monarch from all English legal proceedings. Their first concern was to remove the title of King from legal paperwork. Eliminating regnal years was an immediate, and vital, corollary. The Act declared that, within

> the Kingdoms of England and Ireland, Dominion of Wales, and Town of Berwick upon Tweed, Instead of the Name, Stile, Title and *Teste* of the King, heretofore used, That from henceforth the Name, Stile, Title, and *Teste* of *Custodes libertatis Angliæ authoritate Parliamenti*, shall be used, and no other; And the date shall be the year of the Lord, and none other.[64]

However, the continued appeal of a uniquely English alternative to the year of incarnation prompted the republican Henry Marten to introduce 1649 as "the first year of freedom," which reckoned successive years from 1649. This system was subsequently used for dating documents under the great seal during the Commonwealth.[65] After the Restoration, the use of regnal years was resurrected, and Charles II asserted the

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[63] This does not appear to be an artifact of the particular churchwardens recording each account, as there is crossover between churchwardens and different methods of reckoning the year. It is possible that this was done in protest, to avoid dating documents by Mary's regnal years, however the practice continued for several years after Elizabeth's accession. F.W. Weaver and G.N. Clark, eds., *Churchwardens' Accounts of Marston, Spelsbury, Pyrton*, Oxfordshire Records Series 6 (Oxford: Oxfordshire Record Society, 1925), 68-77.

[64] C.H. Firth, *Acts and Ordinances of the Interregnum, 1642-1660* (London: H.M. Stationery Office, 1911), 1262-3.

[65] Poole, *Time's Alteration*, 75.

legitimacy and continuity of his reign by deliberating back-dating his accession to the year his father died. Thus the year 1660 was styled as "the twelfth year of our reign."[66]

Regnal years frequently appeared side-by-side with years of the incarnation, probably as an attempt to achieve greater precision in pinpointing temporal locations through the simultaneous use of multiple calendars. The will of Edward Clegg of Lancashire was dated "Quinto die Martij Anno Tricessimo septimo Elizabeth Annoq*ue* domini 1594."[67] The gentleman farmer James Bankes began his memoranda book on the "Eyght daye of October in the xxviii yeare of quene Elezabeath." However three folios later that he also gives the date in the year of the incarnation as "the 8the daye of Julye 1598."[68] The first ledger book of High Wycombe regularly used both years of the incarnation from its inception in 1475 until the early years of King James I/VI. The year of the incarnation went in a header such as "28 April 1606" and the entry itself began with the regnal year.[69] Thus many writers were familiar with both calendars and understood the principles behind converting from one to the other.

Despite their popularity, regnal years were not the easiest calendars to use, particularly in conjunction with the years of incarnation, because their episodic construction required knowing the accession dates of a host of English monarchs. A survey of the Southampton apprenticeship registers demonstrates the possible confusions

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[66] Samuel Rawson Gardiner, *The Constitutional Documents of the Puritan Revolution 1625-1600* (Oxford: Clarendon Press, 1906), 467.

[67] This was actually 1595, if the year is reckoned with respect to a January 1st new year's day. J.P. Earwaker, ed., *Lancashire and Cheshire Wills and Inventories, 1572 to 1696, Now Preserved at Chester*, Remains, Historical and Literary, connected with the Palatine Counties of Lancaster and Chester, n.s., 28 (Manchester: Charles E. Simms, 1893), 12.

[68] Joyce Bankes and Eric Kerridge, eds., *The Early Records of the Bankes Family at Winstanley*, Remains, Historical and Literary, connected with the Palatine Counties of Lancaster and Chester, 3rd ser., 21 (Manchester: Manchester University Press, 1973), 13-5.

[69] Greaves, *High Wycombe*, 96, 104, 108.

and mistakes that could arise from calendar conversions, with over a dozen seventeenth-century enrollments bearing conflicting regnal years and years of the incarnation.[70] John Grannt's [sic] indenture was dated 'decimo septimo die Februarii anno domini 1613 annoque regis Jacobi Anglie etc xij et Scotie xlviij' – that is, February 17, 1613/4, which was in fact the 11th and 46th year of James I/VI. Thus either the regnal year or the year of the incarnation was recorded incorrectly. The indenture was enrolled on February 4 of 1614/15, making it impossible for the indenture to be dated February 17, 1614/15 – thirteen days after the indenture was enrolled. The error was therefore most likely in the regnal years. A few months later, one John Rigges was indentured on the "secundo die Junii 1613 annoque regni regis Jacobi Anglie xij^0 et Scotie xlviij^0." By this time, the regnal years were correct with respect to the year of the incarnation.[71]

Conversion between regnal years and years of the incarnation was also complicated by the fact that regnal years had a different New Year's Day for every monarch. The regnal years of James I/VI and Charles I were particularly problematic in the registers, as they began on March 24 and March 27 respectively and thus were in close proximity to the March 25th New Year's Day for the year of the incarnation.[72] James also had the added complication of different New Year's Days for both his English and Scottish regnal years, as he ascended the two thrones on different dates.[73] March of 1624/5 would have been especially difficult for record-keepers because there were three

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[70] There is approximately a 1% error rate between the various calendars, most of which occur around the beginning of a new year during the reigns of James I/VI or Charles I. Willis and Merson, *Southampton*, 24-26, 38, 46, 49, 55, 78, 101, 107.

[71] Split years are used in this paragraph for the reader's convenience and, in this instance, do not reflect historical usage. Willis and Merson, *Southampton*, 4.

[72] Willis and Merson, *Southampton*, lxxxi.

[73] The regnal years of Mary and Philip had a similar construction, as Mary only married Philip after she ascended the throne of England. Their regnal years thus also had different starting dates.

New Years' Days within a five-day period: March 23 was in 1624 and 23 James I; March 24 was in 1624 and 24 James I; March 25 was in 1625 and 24 James I; and March 27 was in 1625 and 1 Charles I. Thus, it is not surprising that the apprentice Thomas Bridgwater was listed as having been indentured on "xxvj die Martii 1625, anno regni regis Caroli primo," when Charles I did not actually become king until the next day, the 27th of March.[74] While some of the errors probably arose from habit, as the writer simply forgot to increase the number for the year after New Year's Day, others must have resulted from confusion over the start dates of each regnal year.

Almanacs thus undertook to supply readers with regnal tables like the one below, listing every English monarch from William the Conqueror to the present, along with the date their reign began and the length of their reign. Readers could use these tables to confidently translate half a millennium's worth of regnal dates into their corresponding year of the incarnation. Regnal tables became a standard almanac feature during the 1570s and continued to be printed throughout the seventeenth century.[75] Given the limited space available to almanac authors – generally only three sheets – the continued dedication of an entire page to the regnal table indicates readers must have found it extremely useful. It formed one of the standard features of the almanac, much like the Zodiac Man or the prognostication.[76] Without these expected features, potential readers would see the almanac as deficient. "He with contempt would straight refuse to buy This book, and 't is no Almanack contend."[77]

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[74] Willis and Merson, *Southampton*, 19.

[75] Capp, *Astrology and the Popular Press*, 36.

[76] The Zodiac Man was an image that explained the relationship of the heavens to parts of the human body.

[77] Edward Pond, *Pond's Almanack for the Yeare of Our Lord God 1641* (Cambridge: Roger Daniel, 1641), A2r. Also quoted in Hill Curth, *English Almanacs*, 120.

A most plaine and easie Table shewing the true time of the beginning, continuance, and yeares, since the reigne of each King in this Land, from the Conquest, untill this yeare, 1625. Note, that each King ended his reigne at such time as the next K. following, began his.

The Kinges names.	Began theyr reigne.	The time they reigned.	Since theyr reigne.
Wil. Conq.	1067, oct. 24	19 y. 10 m. 11 d	538 Sept. 9
Will. Rufus	1087 Sep 9	12 y. 10 m. 22 d	525 August 1
Henr. the first	1100 Aug. 1.	35 y. 4 mo. 1 da	490 Decem. 2
King Stephen.	1135 Dec. 2.	13 y. 10 mo. 8 d.	471 Octob. 25
Henrie the 2.	1154 Oct. 24	34 y. 7 mo 12 d	436, July 6
Richard the 1	1189 July 6	9 ye. 9 mon. 0 d.	426, Aprill 6
King Iohn	1199 Aprill 6	17 y. 6 mo. 13 d	409, Octo. 19
Henrie the 3.	1216 Oct. 19	56 y. 0 mo. 27 d	353, Noue. 16
Edward the 1	1272 No. 16	34 ye. 7 m. 21 d	318, July 7
Edward the 2	1307 July 7	19 ye. 6 m. 18 d	299, Janu. 25
Edward the 3	1326 Ja. 25.	50 ye. 3 m. 27 d	248, June 21
Richard the 2	1377 Ju. 21	22 ye. 3 m. 14 d	226, Sept. 29
Henry the 4	1399 Se. 29	13 ye. 6 mo. 9 d	213, March 10
Henry the 5	1412 mar. 20	9 ye. 5 mo. 24, d	203, Aug. 31
Henry the 6	1422 Aug. 31	38 ye. 6 mo. 8, d	165, March 4
Edward the 4	1460 Mar. 4	22 ye. 1 mo. 8, da	142, Aprill 9
Edward the 5	1483 Aprill 9	0 ye. 2 mo. 11 d	142, June 22
Richard the 3	1483 Jun 22	2 ye. 2 mon. 2 d	140, Aug. 22
Henry the 7	1485, Au. 22	23 ye. 8 mo. 2, d	116, Aprill 22
Henry the 8	1509 Ap. 22	37 ye. 9 m. 6, da	079, Janu. 28
Edward the 6	1540 Jun 28	6 ye. 5 mo. 19 d	072, July 6
Queen Marie	5253 July 6	5 ye. 4 mo. 12, d	067, Nou. 17
Elizabeth	1558 No. 17	44 ye. 4 m. 15 d	023, March 24
King Iames	1602 mar 24	Whom God grant long to reigne.	

Regnal Table from Browne's 1625 Almanac[78]

[78] Note that, in this chart, Browne employs March 25th as New Year's Day for years of the incarnation, despite denoting January 1 as New Year's Day for the almanac's monthly calendar pages. Daniel Browne, *Browne. 1625. A New Almanack and Prognostication* (London: Company of Stationers, 1625), A4v, B8v.

Intriguingly, the regnal table reproduced above also had a third column that measured the number of years "Since their reign." Unlike the dates that monarchs' reigns started, which were vital for computing regnal years, or the lengths of their reigns, which might be useful for discussing the longevity of monarchs, there is no immediately apparent reason to calculate how many years had passed since their deaths. Their death dates also corresponded to the starts of their successors' reigns and thus the table duplicated information about months and days, while performing only the simplest of calculations – subtraction – on the year of each monarch's death. By doing so, the authors inverted the usual flow of time. Rather than reckoning the date of each monarch's death in reference to some prior event, such as the incarnation of Christ, they reckoned the date of each monarch's death in reference to the present, the reader's own personal time.

Almanacs further encouraged readers to think of important religious and national events in relationship to the present through their inclusion of a table of historical events, known as a chronology. Rather than being reckoned according to the year of the incarnation, events in a chronology were all temporally situated with respect to the publication date of the almanac. This was also, presumably, the year in which the almanac was being read. Therefore the underlying question for each entry in a chronology was always *how long since*. Readers were not told that a great plague decimated London in 1665, they were told that it had been six years since that plague. Similarly, a Norman duke did not conquer England in 1066, but rather it had been 605 years since the William the Conqueror's invasion.

A Chronologie of things Memorable to 1671.

Since

THe Creation of the World	6384
Noah's Floud	3914
The destruction of *Troy*	2873
Brute entred *England*	2779
Cambridge builded	2485
The building of *Rome*	2423
Julius Cæsar treacherously slain	1714
The Birth of JESUS CHRIST	1671
The Tower of *London* builded	1103
England made a Kingdom by *Egbert*	8[illegible]6
The Norman Duke conquered *England*	605
Saint *Paul's* Church burned	585
Westminster Hall built	571
The Order of the Knights of the Garter	325
Printing brought into *England*	230
Martin Luther oppos'd the Pope	153
Registers appointed in each Parish	133
Coaches first used in *England*	11[illegible]
Saint *Paul's* Steeple burnt	110
The Royal Exchange builded	105
The Kalendar reformed by Pope *Gregory* 13.	89
Virginia first Planted	65
The New Exchange built	58
The Founding of *Sutton's* Hospital	57
King *James* (of blessed Memory) died	46
Our Gracious Soveraign King *Charles* II. born	41
Pious *Laud* began to Repair *Paul's* Church	37
The Long Parliament began	31
Cheapside Cross pull'd down	28
Archbishop *Laud* beheaded	27
King *Charles* I. beheaded	23
King *Charles* II. Returned	11
King *Charles* II. Married	9
The War began between *England* and *Holland*	7
The great Plague, whereof died above 100000	6
London neerly consumed by Fire	5
London almost built again, and the Merchants come again to the Royal Exchange	2
The Duke of *Albemarle* died	1
The Durchess of *Orleans* at *Dover*	1

Chronology from Gadbury's 1671 Almanac[79]

[79] John Gadbury, *Ephemeris: or, A Diary Astronomical, Astrological, Meteorological, for the Year of Grace 1671* (London: J.C., 1671), A8v.

Some of the chronology events were from the world's legendary past and, while they were dated with numerical specificity, no firm consensus existed across almanacs as to exactly how long ago they had been. This could include secular events, like a notice that it had been 2485 years since Cambridge was built – which just beat out Rome, at a mere 2423 years old. However they were more often religious events, such as Noah's flood or the creation of the world. The creation was especially popular and often appeared in both chronologies and on almanac title pages, such as Francis Perkin's 1671 almanac for "The year of our Lord God 1671. BEING The third after *Bissextile* or Leap-year. And from the Worlds creation 5634."[80] It is here that the discrepancies between almanacs are most apparent. John Gadbury calculated that 4713 years had elapsed between the creation and the incarnation, while Francis Perkins thought it had only been 3963 years. Thomas Bretnor set the difference at 3982 years, while George Wharton and Henry Coley both argued it was instead 3949 years.[81]

However most events fell within the span of recorded history, or even living memory, and were generally agreed upon across all almanacs. These included religious events, such as the burning of Saint Paul's church or Martin Luther's opposition to the Pope, as well as events of political or technological significance. In 1679, Coley helpfully pointed out on his title page that the year could also be "Numbred From the Constitution of the *Kalendar* by *Julius Caesar* 1722," as well as from the "Reformation thereof by *Pope Gregory*. 97."[82] The internal chronologies added even more events that

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[80] Perkins, *Almanack and Prognostication*, A1r.

[81] Gadbury, *Ephemeris*: 1671, A8v. Perkins, *Almanack and Prognostication*, A1r. Thomas Bretnor, *Bretnor 1609 a new almanacke and prognostication* (London, 1609), A1v. George Wharton, *Calendarium ecclesiasticum: or A New Almanack after the Old Fashion* (London: John Grismond, 1657), A2r; Henry Coley, *Nuncius Coelestis: or Urania's Messenger* (London: J. Grover, 1679), A1r.

[82] Coley, *Nuncius Coelestis*, A1r.

would specifically appeal to English readers, such as the Norman conquest, Guy Fawkes' attack on Parliament, the execution of Charles I, and the Restoration of Charles II. They also emphasized several important technological inventions, particularly the invention of printing that enabled the production of almanacs in the first place. By doing so, the chronology did not merely provide a brief history of England and the world. It consistently located historical events in relationship to the present and thus the reader's own, personal time.

Around the turn of the seventeenth century, yearly almanacs further evolved to enable their use as a combination of diary and planner, the ultimate locus of personal time. This change appears to have been driven by readers, more than authors or publishers. The monthly pages of early almanacs were crammed full of dates and events, leaving as little blank space as possible on the page. Some readers therefore began to interleave the pages of the almanac calendar with extra pages that they subsequently used to record events of personal significance. These could range from noteworthy events that would become part of an annual schedule of familial celebrations, such as marriages and the birth of children, to the minutia of daily life, such as travel schedules and financial transactions.[83] At the turn of the seventeenth century, almanac makers responded to this trend by modifying the format of their monthly calendar pages to include significant amounts of blank space, such as in the almanac pictured below.[84]

In this almanac, the left-hand page is still full of useful information relating to the days of the month. Note the inclusion of festival days, as well as times – down to the minute – for sunrise and high tide at London Bridge on the left-hand page. The festival

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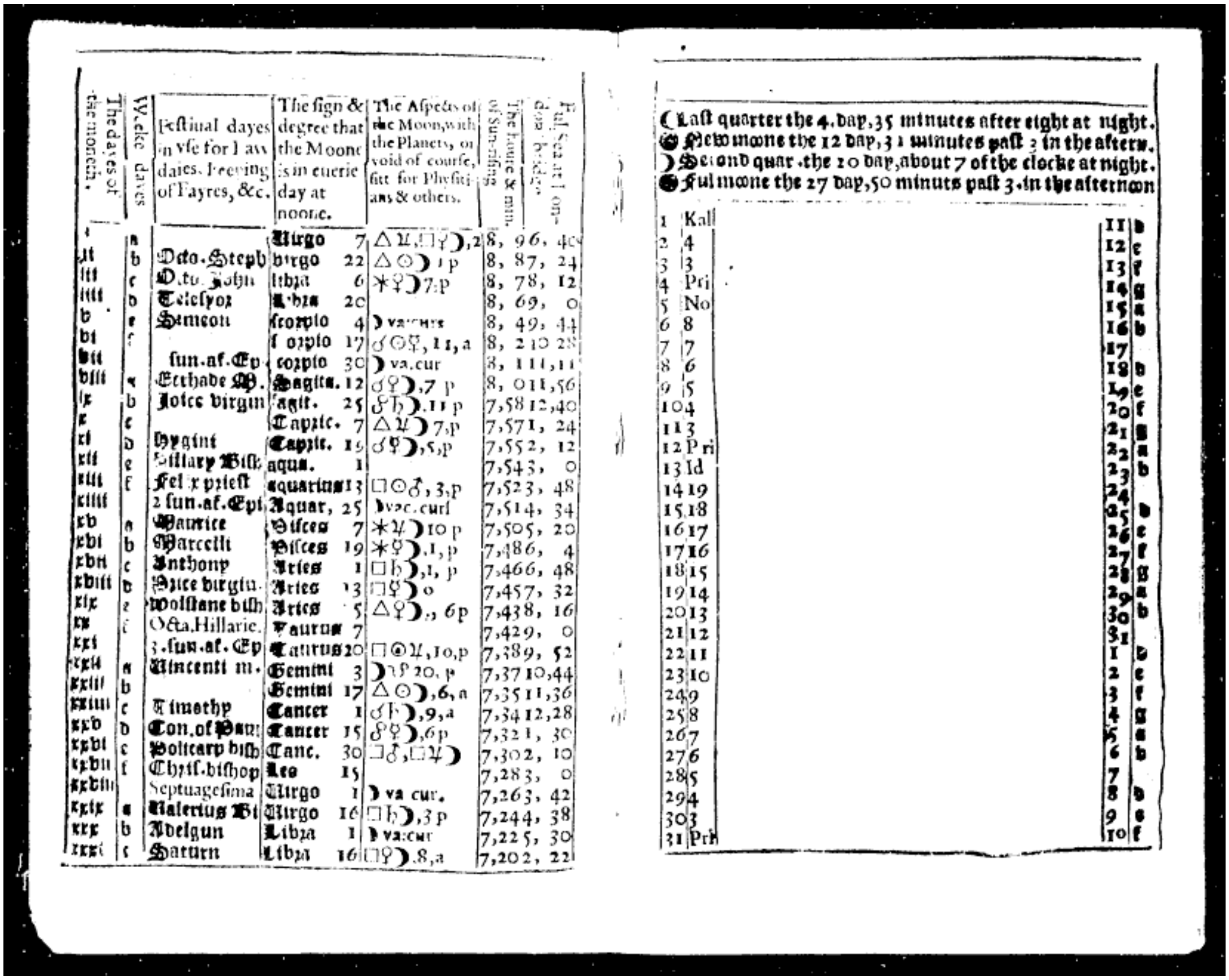
[83] See, for example, HEH, 30925 and HEH, 30067, A4r-A8r.

[84] Chapman, "Marking Time," 1282.



Calendar Page: the Month of January in Allestree's 1621 Almanac[85]

day associated with January 1 does not appear in this image because it was denoted in red ink, which either faded or was not picked up by the scanner. By contrast, the right-hand page consists almost entirely of whitespace so that the reader can make diary entries next to, and thus temporally locate events in, every day of the month. This type of almanac, called a "blank," enabled and encouraged readers to fill their calendar pages with events

[85] Richard Allestree, *Allestree. 1621. A New Almanack and Prognostication* (London, 1621), A4v-A5r.

of personal significance, creating a record of their life that was firmly tied to specific moments in the passage of time.

The late sixteenth century thus saw the rise of a new type of yearly almanac, an immensely popular type of cheap literature that supported a variety of methods for reckoning time. These almanacs helped reconcile the Gregorian and Julian calendars, while also supporting conversions to and from an explicitly English time in the form of regnal years. Almanacs further encouraged readers to think in terms of present-oriented, personal time through the inclusion of chronologies and blank space intended for reader diaries. While the Stationers' monopoly theoretically gave them complete control over almanac content, both authors' comments and the development of blanks suggests popular demand for specific features played a significant role in determining the standard form of the yearly almanac. Therefore almanacs likely reflected, as much as shaped, popular modes of thinking about time.

The Relativity of Local Time

In addition to helping people temporally locate themselves, almanacs also helped people determine their location in time as it existed relative to space. By the sixteenth century, canonical hours had largely given way to clock hours that theoretically standardized time. However, the numerical precision of seventeenth-century almanac predictions, combined with the increasing incidence of global travel, made it clear that time was actually relative, depending on one's geographical location. Questions over the temporal boundaries of the Sabbath day led some puritan divines to conclude that universal religious ceremonies could safely be adapted to the astronomical relativity of local time. This also led them to draw parallels between time lost circumnavigating the world and the still-contested issue of English calendar reform.

By the early modern period, the practice of dividing the day into twenty-four hours of equal length had largely replaced canonical hours throughout England.[86] Parish churches in both country and city had clocks and bells that rang out the hour – and sometimes even the half and quarter hour. School statutes listed the hours "of the clock" during which students were expected to be at their studies, and people recorded both births and deaths to the hour, or even minute.[87] Almanacs also predicted sunrises, sunsets, the tides, and other astronomical phenomenon with exact times listed by both the hour and minute. However, this very precision made it apparent to almanac readers that such predictions did not always hold for their location, sometimes varying minutes or even hours from their appointed times. Or, as various almanac writers explained it, their almanacs only served "indifferently" for various parts of the British Isles.

Instead, almanacs were calculated to serve a specific geographical location, usually "the place where the rectifier hereof was borne" or lived, and numerically described in terms of longitude and "meridian."[88] Many almanacs were printed in London, with astronomical and astrological calculations based on London's longitude. As one London writer explained, his almanac "principally referred to the Meridian of LONDON" but could be used throughout the "*Kingdoms* of *England, Scotland,* and

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[86] Canonical hours changed in length as the amount of daylight lengthened and shortened throughout the year.

[87] Glennie and Thrift, *Shaping the Day*, 189-92, 199.

[88] Henry Alleyn, *Alleyn 1607. A double Almanacke & Prognostication* (London: Company of Stationers, 1607), A1r.

Ireland."[89] There were also a number of regional almanacs that were calculated for other cities throughout England, including York, Shrewsbury, Yarmouth, Canterbury, Gloucester, Derby, Wolverhampton, Horsham, and Reigate.[90] A few almanacs even explained to their readers how to translate the almanac into local time, providing tables and instructing the reader to "ad the houre & min. standing after the name of the place you desire according as this little subscribed table instructs thee, vnto the houre & min. of the Moones being South that day" according to the almanac's monthly pages.[91]

Global travel, particularly to the Americas, provided extreme examples of the geographical relativity of time, with the British colony of Jamaica becoming one of the most popular. The hydrographer royal, globe maker Joseph Moxon, printed a treatise on geography in which he explained that this "difference of Time is reckoned by the access and progress of the Sun: for the Sun gradually circumvolving the Earth in 24. hours, doth by reason of the Earths rotundity enlighten but half at one and the same moment of Time." By using a globe, his readers could calculate the difference in time based on the difference in longitude and discover the temporal difference between London and Jamaica was five hours and fifteen minutes: "so that when with us it is Noon, with them it will be but three quarters of an hour past 6. a clock in the Morning; and when with them it is Noon, with us it will be one quarter past 5. a clock after Noon, &c."[92]

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[89] Henry Seaman, *Kalendarium Nauticum: The Sea-man's Almanack* (London: T.N., 1677), A1r. Curth Hill, *English Almanacs*, 47-8.

[90] Chapman, "Marking Time," 1263.

[91] Arthur Hopton, *Hopton. 1606. An almanack and prognostication for this the second yeare after leape yeare* (London: Company of Stationers, 1606), A2r.

[92] *ODNB*, s.v. "Moxon, Joseph (1627-1691), *printer and globe maker*." Joseph Moxon, *A Tutor to Astronomie and Geographie* (London, 1659), 62-3.

One enterprising almanac-writer, John Seller, even wrote an almanac specifically for Jamaica, while John Gadbury published a Jamaican "nativity" for 180 years. Gadbury also included instructions within his London almanac on "how to make this *Ephemeris* serviceable to the *West-Indies*."[93] He explained the time conversions as follows:

> [t]he Days of the Month and Week are the same in *Jamaica* as in *England*, with respect had to Longitudinary difference, which is near 6 hours in time... So that we differ from each other, not in the day, but in a part thereof only. And as to the difference of the Planets motions between *England* and *Jamaica*, it is but adding to the *Suns* place 15 min. as you find him in this Ephemeris; and to the *Moons* place 3 degr. or thereabouts, in common figures, and it will be exact enough. And in the Planets Aspects, and in the *New* and *Full Moons,* together with their waxing and waning Quarters, it is but substracting 6 hours from the time mention'd in our Ephemeris, and so you have the Motions, Lunations, and Aspects of the *Sun, Moon*, and Planets each day in *Jamaica* as exactly as in *England*. In a thing so easie, examples are needless.[94]

The day, month, and week remained the same, so that translating English time into Jamaican time was a simple matter of addition or subtraction and well within the presumed capabilities of all Gadbury's readers. While there was not – quite – a six hour time difference between England and Jamaica, the approximation was close enough to serve for most purposes. For any readers who desired more exactitude in their astronomical calculations, Gadbury encouraged them to buy his Jamaican nativity.

Like Gadbury, New England divine Thomas Shepard noticed the variability of local time and reassured his fellow colonists that, though the hours may differ, the day itself remained the same at all longitudes around the world.

> Although the nations issued out of *Noahs* ark, and spread themselves over the face of the whole earth, some farther, some at a shorter distance, and thereby changing their longitude altered the differences of time, some

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[93] John Seller, *Jamaica Almanack* (London: 1684). John Gadbury, *Ephemeris: or, a Diary Astronomical & Astrological* (London: J.D., 1677), A1r, C8r.

[94] Gadbury, *Ephemeris*, 1677: C8r.

> beginning the day sooner, some later, yet they might observe the same day; for the day is regulated and measured by the Sun, and the Sun comes to one meridian sooner or later then to another, and hence the day begins in one place sooner or later then in another, and so the beginning of the day is (respectively) varied, but yet the day it self remains unchangeably the same.[95]

The day itself was thus not defined by a universal grouping of twenty-four hours, but rather by the movements of the sun as observed in each particular locality. The exact hour, as defined in local time, varied from longitude to longitude while the day itself remained universal. As a consequence, Shepard concluded that "a day is not properly time but a measure of time."[96] In other words, the day need not be universally fixed with relationship to a specific point in time, consisting of the same twenty-four hours everywhere across the globe; rather, the day was a duration – twenty-four hours, or one full "rotation" of the sun – that could, and naturally should, be observed differently at each longitude.

Even within England, the day was already a matter of some concern and contention, as the day – like the year – was a cyclical chronological unit with no definitive start or end point. This was particularly problematic given the legal and religious restrictions on activities during certain days of the week, such as fast days and Sundays. To some men, such as the divine Richard Baxter, the official boundaries of the day were irrelevant to how people should conduct their affairs. Indeed, it was Satan himself who caused men "to trouble themselves with scruples at what hour the day begins and ends, and the like."[97] However to others, including the divine William Prynne, this

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[95] Thomas Shepard, *Theses Sabbaticae, or, The Doctrine of the Sabbath* (London, 1650), 182.

[96] Shepard, *Theses Sabbaticae,* 182.

[97] Richard Baxter, *The Right Method for a Settled Peace of Conscience, and Spiritual Comfort in 32 Directions* (London: T. Underhil, F. Tyton, and W. Raybould, 1653), 373.

was a matter of such importance to how men conducted their daily lives that he dedicated an entire treatise to the subject.[98]

Common parlance generally referred to days as beginning at sunrise. As one poet put it, "Aurora expels Night: and Day, begins:" or, in other words, day dawns or breaks at sunrise.[99] Dawn was not just the beginning of each new day, but also a liminal moment between night and day, for "we do not jump from *darkness* into *full light*... in an instant. The *day* begins in an *insensible* dawn."[100] In a 1657 almanac, Thomas Wilkinson explained that, "In matters of *Law*, we the Inhabitants of *Great Britain* account the day to begin at Sun-rising, and to end at Sun-setting; wherefore, whosoever is bound to pay a sum of Money on a set or certain day, need not tender it before Sun-rise, nor after Sunset."[101]

Such language implied that days and nights were two distinct chronological units that followed, one upon the other. Terms such as sennight – seven nights – and fortnight – fourteen nights – had their origin in this convention.[102] However there is no evidence in early modern almanacs to support this as a widespread view of time. For example, the monthly calendar page of the almanac pictured above has thirty-one days in January, numbered sequentially, with no gaps to insert thirty-one corresponding nights. It was thus generally understood that the use of the word *day* to mean the period when it was light out, and *night* to mean the period when it was dark, "doth not in this account

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[98] William Prynne, *A Briefe Polemicall Dissertation, Concerning the True Time of the Ichoation and Determination of the Lordsday-Sabbath* (London: T. Mabb, 1654).

[99] Thomas Pecke, *Parnassi Puerperium* (London: James Cottrel, 1659), 104.

[100] Joseph Glanvil, *Some Discourses, Sermons, and Remains of the Reverend Mr. Jos. Glanvil,* (London: Anthony Honreck, 1681), 75.

[101] Thomas Wilkinson, *Wilkinson, 1657. A Kelander and Prognostication*, (London: G. Dawson, 1657), C8v.

[102] *OED*, svv. "fortnight, *n*." "sennight*, n*."

exclude the Night before as part of this first Day, and consequently the Naturall Day consisting of Night and light."[103]

In contrast to the general population, astronomers started their day at noon.[104] This had the mathematical advantage of remaining relatively constant throughout the year, as opposed to dawn and dusk, which fluctuate as the days lengthen and shorten. Samuel Foster, Gresham professor of astronomy from 1641 to 1652, put forth several criteria for "the accomodation of time to calculation," which include the stipulations that "A day begins upon its own noon, and ends upon the noon of the next day. So that... the noon of the first day of Ianuary is the common term of the old and new years, being the end of the former and the beginning of the latter."[105] Astronomers also had their own associated numbering of hours; they "begin the day at Noon, and end at Noon, accounting from 1, to 24 hours."[106]

Still others placed the day's beginning at midnight. John Goad, a meteorologist and headmaster of the Merchant Taylors School in London, explained that there were actually two days – one natural, the other artificial. His natural day began at midnight, while his artificial day began at sunrise.[107] Pierre Du Moulin, in a treatise mocking monks, more seriously noted that "their day begins at midnight," at which time they wake

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[103] Shepard, *Theses Sabbaticae*, 50.

[104] This practice continued, in nautical almanacs, through the early twentieth century. Poole, *Time's Alteration*, 24.

[105] Samuel Foster, *Of the Planetary Instruments: To what end they serve, and how they are to be used,* (London, 1659), 4.

[106] Wilkinson, *Wilkinson, 1657,* C8v.

[107] John Goad, *Astro-meteorologica, or, Aphorisms and Discourses of the bodies coelestial* (London, 1686), 94.

and "go into the Choire to sing *Matines*."[108] And in legal cases, Wilkinson admitted to one very important exception to the rule for defining the day: "in Indictments of Murther we reckon the day from midnight to midnight."[109]

For English divines, however, there could be no question but the day began at sunset. As it said in the Bible, "And God called the light, Day, and the darknesse he called Night: and the euening and the morning were the first day."[110] Further examination of the Bible proved that "all dayes in Scripture and divine computation do alwayes begin and end at Evening, (not morning or midnight)" and in particular that "the Lords-day (being the first day of the week, and included in the universality of dayes) must do so too."[111] Thus any argument for another start time to the day was "unsound, absurd, frivolous" and groundless.[112]

If the religious restrictions surrounding Sundays definitely began at sundown, then the next logical question was – sundown *where*? As Shepard noticed in New England, "our countreymen in old *England* begin their Sabbath above 4. hours before us in new, they beginning at their evening, we at our evening, yet both may and do observe the same day." Thus it was local time, rather than some sort of universal or England-based time, that determined the start of the local Sunday. But while the hours of the day could be calculated relative to one's location, Shepard was also adamant that the day itself

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[108] Pierre Du Moulin, *The Monk's Hood Pull'd Off, or, The Capvcin Fryar Described in Two Parts*, (London, 1671), 3.

[109] Wilkinson, *Wilkinson, 1657,* C8v.

[110] Genesis 1:5 (KJV).

[111] Prynne, *Polemicall Dissertation*, 20.

[112] Prynne, *Polemicall Dissertation,* A1r.

remained the same throughout the globe: "although the time of the beginning of the day be varied, yet the day it self is not, cannot be varied or changed."[113]

Shepard further argued that any apparent irregularities in the nature of the day were instead the product of faulty human observations. For example, people who circumnavigated the globe in a westward direction returned home to find "by comparing their accounts with their countreymen at home, that they had lost a day, having gone Westward, and so compassed the earth round." However, Shepherd explained that the traveler who "opposing the Suns diurnall course continually shortens somewhat of his day, till at last in compassing the earth round he gains a whole day, should cut off in his accounts that day which he hath gained by anticipating the Suns course, and so rectifie his account of the day." [114] Significantly, Shepard justified this alteration of the traveler's account by comparing it to the Gregorian calendar reform, arguing that both simply brought the faulty calendar deriving from human observation back into alignment with natural, astronomical time. While one of the greatest concerns in calendar reform had always been the religious implications, Shepard argued these alterations in time need not concern the religiously minded, as "the morality of the Sabbath is not built upon Astronomicall or Geometricall principles."[115] Thus an alteration of the calendar could not affect either the Sabbath or holy feasts. This included both small alterations – such as the few hours time difference between England and Jamaica, or the day gained by

[113] Shepard, *Theses Sabbaticae*, 182.

[114] Shepard, *Theses Sabbaticae,* 182.

[115] Or, as astronomer Johannes Kepler more famously said, "Easter is a feast, not a planet. You do not determine it to days, hours, minutes and seconds." Poole, *Time's Alteration*, 99. Shepard, *Theses Sabbaticae,* 182.

circumnavigating the world – as well as larger alterations – such as the wholesale deletion of days by the Gregorian calendar reform.

The regularity of clock hours made it possible for yearly almanacs to make extremely precise predictions about astronomical phenomena such as sunrises and the turning of the tides, however this very precision enabled people to see how time varied according to geographical location. Almanacs were rectified to specific geographical areas and while they could still be used to approximate times for the rest of the British Isles, the time difference was readily apparent in the American colonies. Religious concerns over the varying beginnings of the day, particularly the Sabbath, led puritan divines to declare that the relativity of local time did not affect the universality of chronological units such as the day. Furthermore, they argued that any apparent contradictions or faults in time were due to the unreliability of human observation. Therefore it was always acceptable to correct human timekeeping to match astronomical reality – whether it be hours, days, or the calendar. The morality of Christian holy days was not reliant on astronomy and, increasingly, the time itself began to be seen as a matter of mathematics more than religion.

Conclusions

At the turn of the century, in 1699, the question of calendar reform was again raised in England and other Protestant countries, spurred by the prospect of 1700 being a leap year in the Julian calendar – but not in the Gregorian calendar. In England, the calendar reform failed in part because of the dedicated opposition of mathematician John

Wallis, the Savilian professor of geometry at Oxford. Wallis made familiar religious arguments about how changing the calendar would be "a kind of tacit submission to the Pope's Supremacy" and, if calendar reform was truly wanted, it should be to the time of Christ, for "We do not say *Anno Niceni Consilii*, but *Anno Domini*." However, not all Wallis's arguments were echoes of those earlier bishops. Instead, Wallis worried about the internal, political consequences of calendar reform, particularly provoking a chronological schism with Protestant dissenters. He also pointed out the potential consequences for England's global territories, as reform would put the English calendar at odds with "all our *Foreign Plantations*... and particularly from *Scotland*."[116] Discussions dragged out and eventually came to nothing as February 29, 1699/1700 passed and the Julian calendar fell one day further out of step with the Gregorian calendar.

However, over the next forty years calendar reform remained a topic discussed in the publications of divines and astronomers, as well as periodicals such as the *Gentleman's Magazine*. This discussion was not centered around religion, but the practicalities of being temporally at odds with the Continent.[117] In the 1740s, those who supported calendar reform found a dedicated advocate in Lord Chesterfield, who drew up a calendar reform bill over the course of 1749-50 – *An Act for regulating the commencement of the year, and for correcting the calendar now in use.* As this twofold title suggests, Chesterfield intended to finally resolve both the question of New Year's Day as well as the inconvenience of being chronologically out of step with the Continent. While the reform would be of some inconvenience itself – as it required the simultaneous

[116] The issue of Scotland, at least, would be put to rest with the unification of England and Scotland in 1707. Poole, *Time's Alteration*, 86-7.

[117] Poole, *Time's Alteration,* 112.

reform of all England's other, Julian-based calendars – this was presented to Parliament as a mathematical inconvenience, not a religious one. The bill passed, easily and with little debate.[118]

The Elizabethan bishops had not underestimated the mathematical difficulties of reforming the calendar; the liturgical calendar proved to be especially problematic, despite its lack of explicit numerical specificity. A host of "old" holy days continued to be celebrated or used for dating throughout the eighteenth century. This was generally for practical reasons – such as not eliminating 11 days from the wages of workers or contract terms, or to keep harvest fairs aligned with the seasons – and confusion reigned for several years as to whether or not specific events were to retain their customary calendar date or needed to be shifted backwards in time 11 days to maintain their relative date with respect to the old calendar. The enduring image of the 1752 calendar reform is part of William Hogarth's *An Election Entertainment*, in which a mob of people carries a banner demanding, "Give us our eleven days!" However this was only a satire on both a specific election as well as the mathematical confusion arising from the calendar; there were no actual calendar riots in England and the reform itself was uncontentious, albeit mathematically complicated.[119]

England's chronology was thus finally reunited with the mass of Europe, after over a century and a half of schism. The new calendar was disseminated throughout both England and her colonies in almanacs, which helped people navigate through the increasing intricacies of the Gregorian calendar and its relationship to other, older

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[118] Poole, *Time's Alteration*, 113-4.

[119] For an extensive debunking of the English calendar riots myth and discussion of the myth's origin, see Poole's *Time's Alteration*, particularly Chapter One.

English calendars. The compromises and jury-rigged solutions to make those calendars compatible resulted in the adoption of odd dates – neither astronomically determined events nor holy days, but rather what would have been holy days in the old calendar – to mark the new cycles of festivals, ceremonies, and terms. The "broken" time of the seventeenth century had finally been repaired, but the old fractures left their mark.

Chapter Six

"It Is Odds of Many to One"[1]
Quantifying Chance and Risk

On August 11th, 1634, "a Captain, a Lieutennant, and an Ancient... of the Military Company in Norwich" set out on a tour of England.[2] During their seven weeks of adventures, they passed through Cumbria, where they became completely lost upon the fells. They traveled "through such wayes, as we hope wee neuer shall againe, being no other but climing, and stony, nothing but Bogs, and Myres, or the tops of those high Hills, so as we were enforc'd to keepe these narrow, loose, stony, base wayes."[3] Eventually, they "happily lighted on a good old Man" who gave them directions to escape the fells, for otherwise "[i]t was a hundred to one, that wee should so escape this eminent land danger, as this good old Man made it plainly, and euidently appeare to vs: well, through his help (thanks be to God) wee escaped."[4]

Two different ideas underlay their analysis of the danger they had faced and the likelihood of their rescue. First and foremost, they expressed the risk of their deaths on the fells in terms of quantified chance. They set the "odds" of their survival, without assistance, at one hundred to one. Yet when their unlikely rescue did arrive in the form of directions from an old man, they thanked God. They thus ascribed the ultimate cause of their rescue not to a chance encounter with an old man, but to God's providence.

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[1] George Abbot, *An exposition vpon the prophet Ionah. Contained in certaine sermons, preached in S. Maries Church in Oxford* (London: Richard Field, 1600), 591.

[2] L.G. Wickham Legg, ed., *A Relation of A Short Survey of 26 Counties Observed in a seven weeks Journey begun on August 11, 1634 By a Captain, a Lieutenant, and an Ancient All three of the Military Company in Norwich* (London: F.E. Robinson & Co, 1904), 1. Transcribed from the original in BL, MS Lansdowne 213. My thanks to Anne Throckmorton for bringing this source to my attention.

[3] Legg, *Short Survey,* 41.

[4] Legg, *Short Survey*, 42.

None of the military trio saw anything amiss in juxtaposing the language of quantified chance and divine providence, despite their derivation from two different worldviews. A probabilistic mode of thought, which relied on quantified chance, was closely associated with gambling – or, in early modern terms, gaming.[5] This was a necessary precursor of, but not equivalent to, the mathematical theory of probability developed in the late seventeenth and eighteenth centuries.[6] Rather, a probabilistic mode of thinking acknowledged the existence of chance, which followed natural and quantifiable laws, even if the arithmetic necessary for dealing with complicated real-world situations did not yet exist. In comparison, the older, providential mode of thought saw God's active, directing will in all earthly events. God's providence could not be limited by natural laws as God was free to intervene in human affairs whenever and however He desired. However, despite their potential differences, these two ways of thinking coexisted not only in the minds of three military adventurers, but also in the popular culture of seventeenth-century England.

Gaming was a socially pervasive activity in early modern popular culture that provided the language and context for a probabilistic concept of quantified chance. Over the course of the sixteenth century, quantified chance emerged in gaming language through the term *odds*, which English men and women subsequently began to apply to

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[5] The *OED* defines “gaming” as “the action or habit of playing at games of chance for stakes; gambling.” The term “gaming” was prevalent throughout the sixteenth and seventeenth centuries, while the currently used term “gambling” did not appear in print until 1726. *OED*, s.vv. “gambling, *n*.” “gaming, *n*.”

[6] Ian Hacking has written an excellent study of the sixteenth- and seventeenth-century rise of mathematical probability in *The Emergence of Probability: A Philosophical Study of Early Ideas About Probability Induction and Statistical Inference, Second Edition* (Cambridge: Cambridge University Press, 2006) while Barbara Shapiro provides an intellectual history of probability, more generally conceived, in *Probability and Certainty in Seventeenth-Century England: A Study of the Relationships Between Natural Science, Religion, History, Law, and Literature* (Princeton: Princeton University Press, 1983). Lorraine Daston’s *Classical Probability in the Enlightenment* (Princeton: Princeton University Press, 1998) thoroughly covers mathematical probability in the seventeenth and eighteenth centuries.

situations in their everyday lives. This brought quantified chance into potential conflict with established views of divine providence at the turn of the seventeenth century. Debates over the nature of chance and providence led to the formulation of a subtype of providence that relied upon natural – and hence potentially quantifiable – laws that could include laws of chance. Throughout the seventeenth century, people used ideas about quantified chance to predict their futures and minimize risks, as seen particularly in the adoption of insurance outside merchant circles and the rise of public mortality statistics. At the same time, however, they maintained their belief in an all-knowing, all-powerful God. It was God who made the world to function by natural, numerical laws, and thus it was because of God's providence that people could use those numbers to calculate the likelihood of future events and avoid the undesirable ones.

Popular Gaming and Predictive Odds

Gaming was a long-standing aspect of English popular culture. Although early Tudor Parliaments promulgated laws to restrict gaming, they were largely concerned with the socioeconomic consequences of gaming practices rather than gaming per se. Men, women, and children of all ages and social statuses played games of chance, betting on their outcomes with stakes that ranged from nuts and pins to shillings and pounds. It was through this casual gaming that people developed the term *odds*, which came to mean the quantified likelihood of a future event. Around the turn of the seventeenth century, English people began to appropriate the gaming-based language of quantified chance and apply it to events in their daily lives, regardless of whether or not they possessed the arithmetic necessary to analyze those events.

During the sixteenth and seventeenth centuries, most games of chance fell into one of three main categories. The oldest category consisted of dice games, which were almost purely dependent on chance. Evidence of dice games can be found in documents dating back to the Roman occupation of Britain.[7] Tables, which included more skill-based games like backgammon and chess, only first appeared in England during the twelfth century.[8] Lastly, card games were more of a mixed lot and could range from those based almost entirely on chance to those that required a great deal of skill. Card games were the relative newcomers. The first verifiable English reference to cards dates to the third year of the reign of Edward IV, whose Parliament banned the importation of foreign "dice, tenis-balls... chessmen, [and] playing cards."[9]

Many of the late fifteenth- and early sixteenth-century references to games of chance came from statutes restricting the practice of gaming. These were not universal bans on games of chance, but rather limitations on where and when the more financially vulnerable segments of society could play. The text of 11 Hen. 7 c.2 forbade artificers, laborers, and servants from playing cards outside of the Christmas holidays, and even during the holidays they could only play within their master's house.[10] Several statutes

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[7] John Ashton, *The History of Gambling in England* (Chicago: Herbert S. Stone & Company, 1899), 12.

[8] Richard the Lionhearted later played chess while on Crusade: "And Kynd Rychard stode and playe/At the Chesse in his galley." Catherine Perry Hargrave, *A History of Playing Cards and A Bibliography of Cards and Gaming* (Boston: Houghton Mifflin Company, 1980), 169.

[9] 3 Ed. 4, c. 4. This ban was intended to encourage domestic manufacture of these and other items. Joseph Keble, *The Statutes at Large in Paragraphs and Sections or Numbers, from Magna Charta Until This Time* (London: John Bill, Thomas Newcomb, Henry Hills, Richard Atkins, and Edward Atkins, 1681), 278-9.

[10] Ed. S. Taylor *The History of Playing Cards with Anecdotes of their use in Conjuring, Fortune-Telling and Card-Sharping* (London: [Jo]hn Camden Hotten, Piccadilly, 1865), 103.

against unlawful gaming were promulgated during the reign of Henry VIII, culminating in 33 Hen. 8 c. 9, which allowed the noble and rich to play games at will but banned the

> Artificer or Craftsman of any handy-craft or occupation, husbandman, apprentice, labourer, servant at husbandry, journeyman or servant of Artificer, mariners, fishermen, watermen, or any serving-man... [from playing] at the tables, tennis, dice, cards, bowls, clash, coyting, logating, or any other unlawful game, out of Christmas, under the pain of xx. s. to be forfeit for every time.[11]

As with earlier laws, even this Christmas gaming was only allowed to occur within a master's house or in the master's presence.

The restriction of popular gaming to the Christmas season was an attempt to preserve social order by limiting the amount of gaming enjoyed by ordinary English men and women, while at the same time conceding to the reality that people would play games of chance in their leisure time, regardless of its legality. Charles Cotton – a seventeenth-century poet who wrote a treatise on the various types and rules of gaming – explained that the professional gamester, who had no occupation other than gaming, "loves Winter more than Summer, because it affords more Gamesters, and Christmas more th[a]n any other time, because there is more gaming then."[12] Cotton argued that gaming was more prevalent during the winter, when days were shorter and nights longer, which allowed more time for the generally nocturnal activity of gaming. Furthermore, the agricultural activities of the summer would keep men and women well-occupied, whereas winter – and the Christmas holidays in particular – allowed people the time to play games of chance.

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[11] This statute, entitled "The Bill for the maintaining of Artillery, and the debarring of unlawful Games" was particularly intended to encourage able-bodied men and boys to practice the useful skill of archery rather than "waste" their time playing games of chance. Keble, *Statutes at Large*, 542-3.

[12] Charles Cotton, *The Compleat Gamester, or, Instructions How to play at Billiards, Trucks, Bowls, and Chess Together with all manner of usual and most Gentile Games either on Cards or Dice* (London: A.M., 1674), 21.

During the rest of the year, gaming came under much stricter regulation, but there were still ways for common people to play games of chance legally. Clergyman Thomas Gataker noted that the laws against gaming allowed "any seruant to play at cards, dice or tables with his Master, or any Gentleman repairing to his house openly in his house and in his presence" at any point during the year. Furthermore, "any Nobleman or Gentleman of a hundreth pound lands per annum [could] licence his seruants at his discretion" to play games of chance even outside of his presence.[13] Even those servants without such socially respectable backers could play games of chance, so long as the stakes were kept low enough: the law forbade a "seruant or labourer [to] play at tables saue for meate and drinke."[14] However, those without any social ties could not play regardless of the stakes, a restriction which was aimed against professional gamesters, who comprised a portion of the worrisome vagrant population: "all wandring persons vsing vnlawfull games [are] to be punished as Rogues and Vagabonds."[15]

While the language of gaming laws was exclusively masculine and adult – referencing husbandmen, serving-men, gentlemen, and noblemen – women and children also played games of chance. Cotton denigrated the card game Bone-Ace, calling it "trivial and very inconsiderable, and so it is by reason of the little variety therein contein'd," however he admitted that both "Ladies and Persons of quality [play] at it for

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[13] Thomas Gataker, *Of the Natvre and Vse of Lots; A Treatise Historicall and Theologicall* (London: Edward Griffin, 1619), 206.

[14] Gataker, *Lots,* 205.

[15] Gataker, *Lots*, 206. Professional gamesters were often categorized with a host of other, wandering undesirables: "If these [vagrancy laws] and such lyke lawes were executed iustlye… this dung and filth of ydleness woulde easily be reiected and cast oute of thys common wealth; there woulde not be so many loytering, ydle persons, so many ruffians, blasphemers, and swinge bucklers, so many drunkardes, tossepottes, whooremaisters, dauncers, fydlers, and mistrels, diceplayers and maskers, fencers, theeves, enterlude players, cutpurses, cosiners, maisterlesse seruauntes, jugglers, roges, sturdye beggers, counterfaite Egyptians, &c." John Northbrooke, *A Treatise Against Dicing, Dancing, Plays, and Interludes*, *From the Earliest Edition, About A.D. 1577* (London: Shakespeare Society, 1843), 76.

their diversion."[16] Gaming was also an acceptable activity for young girls. When James IV of Scotland went to meet his future bride, the fourteen-year-old daughter of Henry VII, he arrived at her residence and found her playing at cards.[17] Children might not have as extensive a knowledge of gaming as adults, however games such as "Honours (alias Slamm) and Whist, are Games so commonly Known in England in all parts thereof, that every Child almost of Eight years old hath a competent knowledge in that recreation."[18]

Children did not often have the same financial resources as adults, however they still bet on the outcome of their games. One Bristol child admitted engaging in a number of different entertainments on his way to school, including gaming: he "did slide upon the ice, cast snow, fought with his fists and balls of snow, scourged his top, [and] played for pennies, cherry stones, counters, dice, and cards."[19] Other common stakes included points, pins, cobnuts, and counters. More well-to-do children did play for money like adults. At age ten, Prince Arthur lost forty shillings playing at dice while two years later his younger brother, the future Henry VIII, had more luck and won six shillings eight pence.[20]

Adults actually encouraged children's early forays into gaming. At age ten, Edward the Black Prince was supplied with money so that he could play dice with his mother, Sir John Chandos, and the boys of his household.[21] One early sixteenth century schoolbook, William Horman's *Vulgaria*, devoted an entire section to teaching grammar

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[16] Cotton, *Compleat Gamester,* 129.

[17] "The kynge came prively to the said Castell (New bottle) and entered within the chammer with a small cumpany, whare he founde the queene playing at cardes." Taylor, *History of Playing Cards*, 104n*.

[18] Cotton, *Compleat Gamester*, 114.

[19] Jean Vanes, *Education and Apprenticeship in Sixteenth-Century Bristol* (Bristol: Bristol Branch of the Historical Association, 1982), 10.

[20] Nicholas Orme, *Medieval Children* (New Haven: Yale University Press, 2001), 177-8.

[21] Orme, *Medieval Children*, 178.

school students how to discuss their gaming activities in Latin. This included translations for phrases such as "Me*n* pley with .III. dice: and childre*n* with .iiij. dalies," "A sengle ace is a losynge caste," "Syseace wynneth all," and "Let ws pley euen and odde."[22] For Horman, childhood gaming was not simply an activity to be tolerated but rather something that he officially incorporated into his Latin curriculum, exposing boys to the concepts and methods of various games of chance.

This widespread familiarity with gaming, among people of all ages and social stations, facilitated an increasing understanding of chance. The repeated tossing of a six-sided die – an act with six equally possible outcomes – lent itself particularly well to studying the likelihood of future events and was often used as an example by mathematicians studying chance.[23] As early as 960, Bishop Wibold of Cambrai created a list of all the possible outcomes that could result from throwing three such dice simultaneously, while a thirteenth-century Latin poem did the same for consecutive dice throws.[24] Contemporaries both acknowledged and deplored the link between gaming and chance. As the royal tutor Roger Ascham, in his 1545 treatise *Toxophilus*, sarcastically explained, "Cardinge and dysinge, haue a sorte of good felowes also, goyng commonly in

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[22] William Horman, *Vulgaria uiri doctissimi* (London: Richard Pynson, 1519), 280v-281r. The full section on games of chance, "de exercitamentis et ludis," runs from 276v-282v.

[23] The relationship between gaming and probability has long been acknowledged by historians of science, though they still debate how much influence popular gaming had on the development of a mathematized model of probability. Lorraine Daston, for example, argued that early probabilists theorized on equity and expectation more than chance and probability. While gaming was of interest to these probabilists, in general "the combination of skills and chance in many games, the irregular casting of dice and other gambling devices, belief in streaks of good and bad luck, and sharp dealing must have all conspired to obscure the idea of equiprobable outcomes" from ordinary gamesters. Daston, *Classical Probability*, 12-13, 124.

[24] Keith Devlin, *The Unfinished Game: Pascal, Fermat, and the Seventeenth-Century Letter that Made the World Modern* (New York: Basic Books, 2008), 8.

theyr companye, as blynde Fortune, stumbling chaunce, spittle lucke, false dealyng, crafty conueyaunce, braynlesse brawlynge, [and] false forswerynge."[25]

Understanding the vagaries of chance was particularly important for uncovering false dealing and other types of cheating.[26] Variations in dice structure could negate the supposed equality of each potential outcome, and gamesters were often quick to notice when dice did not turn up all numbers with the expected frequency. Girolamo Cardano, a compulsive gambler and mathematician who spent several months travelling in England and Scotland, calculated the odds of throwing the same number repeatedly and explained his own in-game mental processes as follows:

> To throw in a fair game at Hazards only three spots, when something great is at stake, or some business is the hazard, is a natural occurrence and deserves to be so deemed; and even when they come up the same way for a second time, if the throw be repeated. If the third and fourth plays are the same, surely there is occasion for suspicion on the part of a prudent man.[27]

Sir Nicholas L'Estrange, an avid collector of anecdotes, related a similar mentality in a dice game that devolved into an argument over what numbers the dice had shown. One gentleman swore the numbers had been a four and five, while the other said they had been a five and a six.

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[25] Roger Ascham, *Toxophilus* (Tempe, Arizona: Arizona Center for Medieval and Renaissance Studies, 2002), 65.

[26] Indeed, cheating was of such concern that Cotton intended his *The Compleat Gamester* to both explain the rules of games as well as help his readers "observe the cheats and abuses, and so be arm'd against the injuries [that] may accrue thereby." Cotton, *Compleat Gamester*, A4v.

[27] From Cardano's *De Vita Propria Liber* as quoted in F.N. David, *Games, Gods and Gambling: The origins and history of probability and statistical ideas from the earliest times to the Newtonian era* (New York: Hafner Publishing Company, 1962), 55. Cardano might not have expected his readers to be able to calculate these odds, but he was perfectly capable of doing so himself: "If three throws are necessary, we shall multiply 3 times; thus, 6 multiplied into itself and then again into itself gives 216." By contrast, the odds of rolling the number four times in a row with a single die are 1 in 1296 (6 to the fourth power). Oystein Ore, *Cardano the Gambling Scholar* (Princeton: Princeton University Press, 1953), 205.

> Sir William then replied, 'Thou art a perjured knave; for, give me a sixpence, and if there be a four upon the dice, I will return you a thousand pounds'; at which the other was presently abashed, for, indeed, the dice were false, and of a *high cut*, without a four.[28]

Sir William had made enough observations, throughout the course of their game, to believe it likely that his opponent was cheating. He thus wagered an outrageous sum on the outcome of a future event, namely his search of the dice for abnormalities. In particular, he assigned a quantitative value to the likelihood that he would find fours on the dice – he laid down 40,000 to 1 odds.

Both the word *odds* and its use to describe quantified chance, or the probability of a future event, first appeared during the sixteenth century. The word itself dates to the beginning of the century, when its primary definitions related to inequality and proportion, rather than probability: "the condition or fact of being unequal; disparity in number, amount, or quantity; dissimilarity, inequality."[29] For instance, George Best, in describing temporal differences across the globe, asked his readers to "looke what oddes and difference of proportion there is betweene the Sunnes abode aboue the Horizon in *Paris*, and the abode it hath vnder the Equinoctiall."[30] Best's odds are thus the proportional difference between the sun's position in Paris and at the equator, a number based on the mathematical operation of division.

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[28] Ashton, *History of Gambling*, 16. While these anecdotes were collected during L'Estrange's lifetime – the first half of the seventeenth century – they were not published until 1839 and even then only 141 of them found their way into William John Thoms' *Anecdotes and traditions, illustrative of early English history and literature, derived from ms. sources. ODNB* , s.v. "L'Estrange, Sir Nicholas, first baronet (*bap.* 1604, *d*. 1655), *collector of anecdotes.*"

[29] This meaning still survives in phrases that describe people as being "at odds" with one another. *OED*, s.v. "odds*, n.*"

[30] George Best, *A Trve Discovrse of the late voyages of discouerie, for the finding of a passage to Cathaya, by the Northvveast, vnder the conduct of Martin Frobisher Generall* (London: Henry Bynnyman, 1578), 26.

This original definition was also the basis for the prevalent use of the term *odds* to indicate the difference in size between two groups of people, most commonly armies. John Foxe described one Anglo Saxon battle, noting "that fight was great oddes of number, as 6. or 8. against one, yet *Egbert*... had the better and wan the field" despite the great disparity in the size of the armies.[31] Fifty years later, Charles Aleyn wrote about the battles of Crécy and Poitiers and claimed that the English were not dismayed at the sight of their enemy, even though the French "had the odds of number sixe to one."[32] Other authors used the same language to write about the "odds of at least *Thirty* for *One*" between those who did and did not conform to the Book of Common Prayer; the "odds of Ninety of their Ships against Fifty of ours"; and a vote in the House of Lords which threw out the Bill of Exclusion "with the odds of 63 aginst [sic] 31."[33]

While this use of the term *odds* was mathematical, in the sense of being expressed numerically, it was not probabilistic and made no attempt to predict the outcome of future events. The distinction between the initial formulation of odds and a probabilistic, gaming-based formulation can best be illustrated by Roger Castlemaine's 1666 analysis of the Venetian navy. Though the Venetian "great ships" were only sixteen in number, "with this they so affright the *Turk*, that now, on purpose to engage, he dares not appear; and should he set to Sea 200 of the best Vessels he could get, they would not only attaque him, but be all more assured of a Victory then the odds of two to one can give a sober

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[31] John Foxe, *Actes and Monuments of matters most speciall and memorable, happenyng in the Church, with an Vniuersall history of the same* (London: Iohn Daye, 1583), 135.

[32] Charles Allen, *The Battailes of Crescey, and Poictiers vnder the leading of King Edward the Third of that name; And his Sonne Edward Prince of Wales, named the Blacke* (London: Thomas Purfoot, 1631), D5r.

[33] Roger L'Estrange*, A Caveat to the Cavaliers: or, An Antidote Against Mistaken Cordials* (London: Henry Brome, 1661), 18. William Temple, *Observations upon the United Provinces of the Netherlands* (London: A. Maxwell, 1673), 232. George Halifax, *A Seasonable Address To both Houses of Parliament Concerning the Succession, The Fears of Popery, and Arbitrary Government* (London, 1681), 14.

Gamster."[34] The odds, or proportional difference, between the Turkish and Venetian fleets were technically 12.5 to one. Yet despite the Venetian's being at a numerical disadvantage, the odds, or likelihood, of their victory were calculated to be greater than two to one.

The use of the term *odds* became associated with gaming and probability within a few decades of its first use. Its gaming definition was a logical outgrowth of its initial formulation: "the ratio between the amounts staked by the parties in a bet, based on the expected probability either way."[35] These odds were also based on the idea of a proportional difference, or inequality, between two or more stakes. This difference in stakes was then conflated with the predicted outcome of the wager. Unlike odds that specified the numerical difference between groups of men or ships or other physical objects, these new odds were based on the idea of prediction and the perceived likelihood of future events.

Thomas Churchyard used the predictive language of gaming odds as early as 1552: "I durst lay odds who trust you long, full false he shall you finde." By the 1590s, the predictive definition of odds had become pervasive enough that it was utilized in non-gaming contexts, and even turned up in tracts written by two clergymen. Bishop Gervase Babington alluded to the likelihood of God's vengeance: "surely it is many to one, that neyther in the coole of the day the Lorde will visit vs, but euen cast vs away for euer."[36] George Abbot, Professor of Divinity and Master of University College, also used the

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[34] Roger Castlemaine, *An Account Of the Present War Between the Venetians & Turk; with the State of Candie* (London: J.M., 1666), 26-7.

[35] The phrase "to lay odds" was used solely in the sense of gaming odds, never with respect to the original definition. *OED*, s.v. "odds, *n*."

[36] Gervase Babington, *Certaine plaine, briefe, and comfortable notes vpon euerie chapter of Genesis* (London: A. Jeffes and P. Short, 1592), D2v.

language of odds to describe the likelihood of punishment for sin: "It is oddes of many to one, but that thy wantons, afterward will worke thee as much ioy, as Elies children did to their doting father, that is, bring a curse on thee or them."[37] Other clergymen were more explicit about the predictive nature of their odds, such as Donald Lupton who in 1642 parenthetically explained odds of five to one as "a mighty odds to all probability."[38]

While these predictive odds theoretically mathematized chance, early modern men and women often framed odds in a quantitative but non-numerical fashion. In 1659, Roman Catholic philosopher John Sergeant used the language of odds to mock Bible-reading Protestants, declaring that "it would puzzle any mans Arithmetick, to count how many to one it is, there is not one true word of *Scripture* in *Scripture*."[39] He understood the concept and rhetorical power of mathematically calculable odds, but lacked either the skill or the inclination to be numerically specific. Eighteen years later, however, he had no trouble using specific numbers when he similarly relied on the language of odds to assert that "a Protestant may with a safe Conscience lay odds, and wager two to one at least, his Faith is all a Flshood."[40]

Even those who assigned quantitative values to their predictive odds may or may not have done so via mathematical calculations. In 1610, Barnabe Rich wrote of his surprise at discovering Saint Patrick had been born in England: "I would haue layed two to one, that S. *Patrick* had bin an *Irishman* borne. But I will be better aduised hereafter,

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[37] George Abbot, *Ionah*, 591.

[38] Donald Lupton, *A Warre-like Treatise of the Pike, or, Some Experimentall Resolves, for lessening the number, and disabling the use of the Pike in Warr*e (London: Richard Hodgkinsonne, 1642), 26.

[39] John Sergeant, *A vindication of the doctrine contained in Pope Benedict XII, his bull and in the General Council of Florence, under Eugenius the iiii concerning the state of departed souls* (Paris: 1659), 102.

[40] John Sergeant, *Faith vindicated from possibility of falshood, or, The immovable firmness and certainty of the motives to Christian faith* (Lovain: 1667), 104.

both how I lay any wagers, & how I beleeue any such authorities."[41] After his ill-informed prediction proved false, Rich intended to become more careful about his research before assigning quantitative values to any future predictions. John Wilkins, Bishop of Chester, was more cautious in his own predictions. He explained to his readers that only "Such kinds of things or events, whether Good or Evil, as will certainly come to pass, may fall under computation, and be estimated as to their several degrees, as well as things present." He encouraged his readers to perform their own calculations by providing an illustrative example: "for a man to be one amongst four or five equal Competitors for a place, to be the fourth or fifth expectant of an inheritance; ... in such cases there be the odds of three or four to one."[42]

Gaming thus formed an integral part of early modern popular culture, an activity that was taught to children across the social spectrum and that was legally enshrined as part of the yearly Christmas festivities. Through games of chance, the people of early modern England developed the language of predictive odds, which usually were conveyed by quantitative – if not necessarily mathematically calculated – means. Odds were not restricted to alehouses and back-alley gamesters but formed a part of the everyday English language and indicate a probabilistic mode of thought existed in the second half of the sixteenth century. By the turn of the seventeenth century, this type of thinking had already become pervasive enough in English popular culture that some clergymen saw it as a challenge to established providential modes of thought.

[41] Barnabe Rich, *A nevv description of Ireland vvherein is described the disposition of the Irish whereunto they are inclined* (London: William Jaggard, 1610), 50.

[42] John Wilkins, *Of the principles and duties of natural religion* (London: A. Maxwell, 1675), 13-4.

Providence and Chance

Early modern men and women drew upon a variety of concepts to explain the occurrence of contingent events, much to the dismay of English clergymen who argued that God's providence necessarily determined the outcome of all earthly events. However, clergymen were not in universal agreement on the mechanism of providence, including whether or not it could exist in tandem with any sort of natural laws. In the late 1610s and early 1620s, the Balmford-Gataker debate over the legality of gaming led to particular scrutiny of the relationship between providence and chance. The eventual acceptance and general adoption of Gataker's pro-gaming argument enabled the reconciliation of God's providence and quantified chance during the seventeenth century.

For the Protestant population of early modern England, God's providence was supposed to determine the course of all earthly events, including those whose outcome was uncertain.[43] This providence was twofold, reflecting God's status as both omniscient and omnipotent. On the one hand, God stood outside time and thus one aspect of His providence was knowledge of the past, present, and especially future. On the other hand, God was also all-powerful and used that power to direct events ranging from awe-inspiring miracles to the simple roll of a die. In theory, there was no room in this providential worldview for any other forces. In practice, however, God's providence was only one of several forces that early modern people used to explain the outcome of contingent events.

[43] For an excellent and extensive treatment of early modern providence, see Alexandra Walsham, *Providence in Early Modern England* (Oxford: Oxford University Press, 1999); also Keith Thomas, *Religion and the Decline of Magic: Studies in Popular Beliefs in Sixteenth and Seventeenth Century England* (London: Penguin Books Ltd, 1991), 90-133.

English clergymen did their best to discredit beliefs that undermined the supremacy of God's providence. William Gouge, minister of St. Ann Blackfriars, London, denounced the popular belief in fortune, which led to "those things which are done by God, [being] attributed, then to *fortune*, or *chance*, or *lucke*, (for these are but severall titles which are used to set out one and the same thing.)" While it was acceptable to use the words *fortune* and *chance* to indicate "the hiddennesse or secrecy of a cause... whereby is meant the secret appointment, disposing, and providence of God," more often people used the terms to indicate "a cause of it selfe, opposed to the divine providence." Not only was this latter concept of fortune "a meere fancy, and vaine conceit, or rather a plaine deceit of mans idle braine" but it was potentially blasphemous, for "the Heathen have set her in the number of their goddesses, and placed her in heaven."[44] Consequently, even those people who professed a lesser belief in good fortune or ill fortune were only a short step away from ascribing the work of God to the pagan goddess Fortuna.

Clergymen also loudly condemned the popular astrology of the yearly almanacs. Judicial astrology, which used the course of the stars and planets to make predictions about the future, was predicated upon the idea that heavenly bodies had a direct influence upon earthly events, including human actions and decisions.[45] One of the most scathing condemnations of almanacs and astrology came from the theologian William Perkins, who wrote a tract denouncing the four most popular almanacs of his time and declaring it "vtterly vnlawfull to buye or vse our yeerly Prognostications." After side-by-side

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[44] William Gouge, *The Extent of Gods Providence, Set out in a Sermon, Preached in Black-Fryers Church, V. Nov. 1623* bound with *Gods Three Arrowes: Plagve, Famine, Sword, In three Treatises* (London: George Miller, 1631), 379-80.

[45] Bernard Capp, *Astrology and the Popular Press: English Almanacs 1500-1800* (London: Faber and Faber, 1979), 16.

comparison of the almanacs' contradictory predictions, Perkins condemned the writers for their inability to actually deliver true predictions, particularly their "ignorance of perticular causes... manifold vntrueths... impieties and prophane speaches, and actions, not seeming a Christian... [and] trickes of deceit." Almanac buyers, on the other hand, were castigated for believing human prognostications, which demonstrated their "Immoderate care, ioyned with distrust in God [and] Contempt of the prouidence of God, in not reuerently regarding it."[46] While royal injunctions in 1559 and 1568-9 did restrict almanac writers and printers from publishing certain kinds of predictions, such injunctions were primarily aimed at potentially seditious political predictions and did nothing to curtail the general practice of judicial astrology.[47] Almanacs continued to include "prognostication" sections throughout the seventeenth and eighteenth centuries.

A less overtly problematic, but no less troublesome, belief could be found in the idea of a natural order. George Herbert, rector of Bemerton, complained of "the great aptnesse Countrey people have to think that all things come by a kind of naturall course." In his treatise on country parsons, he lamented how difficult it was for the parson to educate his parishioners, "to reduce them to see Gods hand in all things, and to beleeve, that things are not set in such an inevitable order, but that god often changeth it according as he sees fit, either for reward or punishment." It was not feeding and caring for their cattle that led to milk, nor sowing and tending the ground that made corn grow, but rather God's providence, which possessed manna-like properties:

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[46] William Perkins, *Fovre Great Lyers, Striuing who shall win the siluer Whetstone* (London: Robert Walde-graue, 1585), _1r, A8v.

[47] Each of the Tudor monarchs, from Henry VII to Elizabeth, patronized a favorite astrologer. Elizabeth famously consulted mathematician and astrologer John Dee to help set the date of her coronation. Capp, *Astrology and the Popular Press*, 19.

> By his sustaining power he preserves and actuates every thing in his being; so that corne doth not grow by any other vertue, then by that which he continually supplyes, as the corn needs it; without which supply the corne would instantly dry up.[48]

This sustaining power was continuously present, as opposed to his governing power, which God used to create disasters such as fires or earthquakes. Herbert's God used His governing power to further impress upon mankind that nothing in life could ever be certain: "God delights to have men feel, and acknowledg, and reverence his power, and therefore he often overturnes things, when they are thought past danger; that is his time of interposing."[49] Thus it was God, not nature, that deserved the ultimate credit for the uncertain survival of a farmer's crops and livestock.

However, while English clergymen were quick to defend the supremacy of God's providence, they did allow that providence was not completely antithetical to the existence of a natural order. Like Herbert, most divided the active component of providence into two further parts – a general, sustaining, or universal providence, and a special, governing, or particular providence. The former referred to God's maintenance of the world and could be interpreted to include a natural order that He had established during the Creation. This general providence operated through secondary causes. God did not act directly but rather employed intermediary forces, including so-called laws of nature. However, God was not in any way limited by these laws. He could, and did, violate them at will and function as a primary cause of earthly events. Thus God's special providence encompassed His dealings with His chosen people and His direct actions to

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[48] George Herbert, *A Priest to the Temple, Or, The Countrey Parson His Character, and Rule of Holy Life* (London: T. Moxey, 1652), 122-3.

[49] Herbert, *Countrey Parson*, 124.

punish or reward, particularly miraculous interruptions of the natural order.[50] This distinction between God as a primary or secondary cause was crucial in the early seventeenth-century debates over the relationship between chance and providence, particularly as manifested in games of chance.

At the turn of the seventeenth century, within the context of increasing differentiation between the religious practices of puritans and prayer-book Protestants,[51] popular gaming became a flashpoint for those with puritan leanings.[52] In 1594, clergyman James Balmford launched an all-out assault on gaming in a short treatise intended to prove "the vnlawfulness of playing at cards or tables, or any other game consisting in chance."[53] A decade later, puritans associated gaming with the 1603 outbreak of plague. Some went so far as to claim that God ended the plague in response

[50] Not all clergymen agreed on the mechanisms of providence and the division between secondary and primary causes. They also argued about the implications of God's omniscience, particularly whether or not miracles were improvised interventions to keep God's plan for humanity on track, or a pre-existing part of that plan. Walsham, *Providence*, 13.

[51] I use the term "puritan," in the sense of a "hotter sort of Protestant" rather than a defined social group with set characteristics. For more on this usage see Patrick Collinson, *The Elizabethan Puritan Movement* (Oxford: Clarendon Press, 1967). The term "prayer-book Protestant" is Judith Maltby's, from *Prayer Book and People in Elizabethan and Early Stuart England* (Cambridge: Cambridge University Press, 1998), and indicates all those with a genuine attachment to the rituals of the 1559 Book of Common Prayer.

[52] For more on puritan ideas about chance, see D.R. Bellhouse, "Probability in the Sixteenth and Seventeenth Centuries: An Analysis of Puritan Casuistry," *International Statistical Review* 56, no. 1 (Apr., 1988): 63-74, particularly pp. 67-8.

[53] James Balmford, *A Short and Plaine Dialogve Concerning the Vnlawfulnes of playing at Cards, or Tables, or any other Game consisting in chance* (London: Richard Boile, 1593), A1r. The shortness of the anti-gaming tract, which was published as both a book and a broadside, combined with its blackletter type – the font most accessible to poor men and women – indicates that Balmford was attempting to reach the widest possible audience. Intriguingly, Balmford has only written the lines of the Preacher – the voice of the dialogue through which he himself speaks – in blackletter, putting his opponent's words in the less-legible italic type throughout. The only time where the Professor gets to speak in blackletter is when he asks an all-important question: "Why not for pleasure?" Balmford, *Dialogve*, A6r. *ODNB* s.v. "Balmford, James (b. c. 1556, d. after 1623), *Church of England clergyman*)." For more on early modern fonts, see Keith Thomas, "The Meaning of Literacy in Early Modern England," in *The Written Word: Literacy in Transition, Wolfson College Lectures 1985,* ed. Gerd Baumann, (Oxford: Clarendon Press, 1986).

to the mayor of Northampton's campaign against gaming and alehouse-haunting.[54] Throughout the reign of James I, puritans took such a firm stance against certain forms of recreation – including gaming – that in 1618 James I issued a declaration that

> rebuke[d] some Puritans and precise people, and took order that the like unlawful carriage should not be used by any of them hereafter, in the prohibiting and unlawful punishing of our good people for using their lawful recreations and honest exercises upon Sundays, and other holy days, after the afternoon sermon or service.[55]

This was followed, the next year, by the beginnings of a puritan pro-gaming counter-movement in the form a treatise by clergyman Thomas Gataker. This treatise attacked Balmford's arguments and set off a debate within the puritan community over the theological propriety of gaming, focusing on the nature of chance and its relationship to providence.

Balmford's original arguments against games of chance were entirely rooted in the concept of providence. Pure chance, such as the drawing of lots, "necessarily suppose[s] the special prouidence and determining presence of God." Consequently, playing games of chance for sport "tempt[s] the Almightie by a vaine desire of manifestation of his power and speciall prouidence." Balmford focused his arguments on playing cards, rather than dice, as he took for granted "that Dice (condemned both by the Ciuill lawes, and by the Fathers) are therefore vnlawfull, because they depend vpon chance." He then sought to prove, by logic, that "if Dice be wholly euill, because they wholly depend vpon

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[54] Walsham, *Providence*, 140. Ironically, Balmford's response to the plague outbreaks was to publish a pamphlet that emphasized a medical interpretation of plague, focusing in particular on plague's contagiousness and the need for infected victims to quarantine themselves, rather than giving a providential interpretation of plague as God's displeasure. This pamphlet was also republished during 1625 outbreak. James Balmford, *A Short Dialogve Concerning the Plagves Infection* (London: Richard Boyle, 1603).

[55] James I, *Declaration to His Subjects Concerning Lawfull Sports* in David Cressy and Lori Anne Ferrell, *Religion and Society in Early Modern England: A Sourcebook – Second Edition* (New York: Routledge, 2005), 169-70.

chance, then Tables and Cards must needes be somewhat euill, because they somewhat depend vpon chance."[56] While it was true that such games were popular among the nobility and royalty, that was no excuse for allowing such abuses of God's providence to continue, for "wee must liue by precepts, not by examples, except they be vndoubtedly good."[57] Thus, Balmford concluded that playing any game that contained an element of chance was theologically unlawful and gaming in general ought to be banned.

In his reply to Balmford, Gataker began by shifting the focus of the debate away from games of chance or "games of hazard, as they are termed, wherein a Lot is thus vsed, and there is therefore a kind of Lotery in them."[58] Instead, Gataker addressed the underlying assumption of Balmford's argument: activities that involved lots were theologically unlawful because they relied on chance, which relied in turn on God's special providence. In deconstructing this idea, Gataker argued that most lots rather relied on God's general providence, as enacted through natural, secondary causes. He agreed that it was indeed unlawful to frivolously call upon God's special providence in casting a lot, however the lots in games of chance were not cast with any assumption of God's direct intervention.

To make this argument, Gataker first distinguished between three different categories of events – necessary, contingent but not casual, and contingent and casual.[59] A contingent event was uncertain and variable, "not directed or determined by the skill, counsell, or fore-craft" of man and "not effected and produced by knowne naturall causes," as opposed to a necessary event, which was certain, determined, and

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[56] Balmford, *Vnlawfulnes*, A4r-A5r.

[57] Balmford, *Vnlawfulnes*, A8v.

[58] Gataker, *Lots*, 125.

[59] Gataker treats “chance” and “casualtie” as essentially synonymous: e.g., Gataker, *Lots*, 3, 12.

predictable.[60] Contingent events could be further divided into two types: those that were and were not dependent on chance or "casualty." Under this schema, a lot was defined as "a casualty or casuall euent purposely applied to the deciding of some doubt,"[61] however casualty was not limited simply to lotteries.

> For many things fall out casually, and do befall men so continually in the whole course of their liues, which yet come not the most of them within compasse of a Lot: as, meeting of those by the way that they neuer minded or once dreamed of; lighting on some one in the street or at the market, whom they desired to speak with, while they are going about other business.[62]

Thus, while lots were the canonical example of a casual event, they formed only one part of a larger category of casual events.

Gataker then addressed the issue of providence, noting that if God's providence directed all earthly events, then it necessarily directed casual events. Like Balmford, Gataker conceived of providence in a twofold fashion, consisting of both a "disposing will, and a directing will; a will enforming and a will ouer-ruling," or, in other words, a general providence that sustained the ordinary course of nature and a special providence that overruled it when necessary. However, Gataker argued that since it was God's general providence that directed earthly events, it was also general providence that directed casual events: "If a prouidence of God [is] therefore in all things, then in casuall euents also: and as in all things, so in casuall euents ordinarily, and no otherwise."[63] As lots were merely one type of casual events, they were also directed by general

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[60] Gataker, *Lots*, 12.

[61] Gataker, *Lots*, 2.

[62] Gataker, *Lots*, 4-5.

[63] Gataker, *Lots*, 15.

providence. To clinch his argument, Gataker proposed the following proof by contradiction:

> if in euery Lot there be necessarily an immediate worke and prouidence of God, then it is in the naturall power of man to make God worke immediately at his pleasure: for it is in mans power naturally to cast Lots at his pleasure. But to say that it is in mans power naturally to set God on working immediately at his pleasure, is absurd. There is not therefore an immediate worke and prouidence in euery Lot.[64]

Thus, to argue that God's special providence directed the outcome of every lot was to argue, by implication, that a man had the power to force God to be the immediate, primary cause in every roll of a die or random drawing of a lottery ticket. This assertion was patently absurd to Gataker, and thus "it may be truly said, that it was Gods will, to wit, his disposing will, that the Lot should go as it hath gone."[65]

Although most of Gataker's lots relied on God's general providence, he did differentiate between lots intended to simply decide some matter of contention and those intended to divine God's will on the matter. The former he called ordinary lots, being "those whose full worke may be effected by the ordinary or naturall power of the creature vsing them and vsed in them," while the latter were extraordinary lots, since "extraordinary power or prouidence is required for the direction of the action to that end wherevnto it is applied."[66] It was the intention of the lot user – namely whether or not they intended to invoke God and ask Him to make His will known – that differentiated an ordinary from an extraordinary lot.

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[64] Gataker, *Lots*, 146.

[65] Gataker, *Lots*, 116.

[66] Gataker, *Lots*, 35.

While Gataker defended gaming as an ordinary lot which relied on general providence and natural laws, he also came to a traditional condemnation of extraordinary lots that demanded answers of God. Regardless of human desires and intentions, God

> hath no where promised any speciall prouidence in such cases, to doe men right by such meanes, to iustifie their quarrels, to direct the Lot as the equitie of the cause shall require, or to interpose himselfe and his prouidence in such courses otherwise then in any other of our actions, be they casuall, contingent or necessarie. And therefore to put ought to hazard with expectation of such an act of Gods prouidence is to presume of that which God hath not promised.[67]

Consequently, Gataker argued, not only were most lots directed by general providence, rather than special providence, but also it was presumptuous to assume that God should directly involve himself in a lot in the first place. While divinatory lots had been used during ancient times, and even in the Bible, "none of them are now lawfull"[68] and anyone who attempted to divine the future with cards or lots was to be condemned both by man and by God.[69]

Gataker thus concluded that ordinary lots could be used without fear of offending God. This category included both games such as dice, which involve pure lots, and games of tables or cards, which were casual events that included some level of skill in addition to the luck of the draw and hence could be called “a mixt Lot.”[70] While he agreed that it was theologically unlawful to call upon God's special providence for frivolous reasons, he distinguished games of chance as another type of lot altogether. In

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[67] Gataker, *Lots*, 113.

[68] Gataker, *Lots*, 298.

[69] Gataker, *Lots*, 306. Among Christians, generally, divination was considered impious as only God was privileged to know the future. This, of course, did not always stop Christians from employing divination for purposes as varied as finding a thief or determining the wisdom of a future activity. Thomas, *Religion and the Decline of Magic*, 253-64.

[70] Gataker, *Lots*, 126.

these games, the lot was not determined by the active intervention of God, but rather by a "natural power" inherent in every creature and hence a product of God's creation and general providence. He condemned the extraordinary lot, "as it well deserueth, to the dunghill" and called for the ordinary lot to "be so wisely and warily vsed, that God be not dishonored, who has giuen vs the free vse of them."[71]

Balmford did not mount a written defense of his position for four years. Only after Gataker continued to press his arguments, going so far as to incorporate them into his sermons "and to confute me *by name* in open pulpit," did Balmford succumb to the urging of his friends and publish an extensive rebuttal of Gataker's claims.[72] This consisted of both a reprint of his original treatise and an extended "modest reply" to Gataker's arguments about the lawfulness of lots in games of chance, in which he claimed that games of chance – and indeed, all lots, by definition – relied on special providence and thus were unlawful when used for non-religious purposes.

While willing to adopt Gataker's distinction between ordinary and extraordinary lots, Balmford insisted that both were guided by God's special providence. He thus gave them his own, slightly altered, definitions: "The subiect-matter of an ordinary Lott, is, by God's allowance, A Controversy to be ended: The subiect-matter of an extraordinary Lott is any other matter, whereabout a Lott is imployed by God's speciall direction." While humans instigate the use of ordinary lots, the lot only ends their controversies because God allows it. By contrast, God especially directs humans to use extraordinary lots in other situations. In both cases, however, God is an active participant in the casting of the

[71] Gataker, *Lots*, 360.

[72] James Balmford, *A Modest Reply to Certaine Answeres, which Mr. Gataker B.D. in his Treatise of the Nature, & vse of Lotts, giveth to Arguments in a Dialogue concerning the Vnlawfulnes of Games consisting in Chance* (London: William Jaggard, 1623), 26. Bellhouse, "Puritan Casuistry," 71.

lot: "the vse of all Lottes, (as they be Lottes) whether ordinary, or extraordinary, directly, or of it selfe, & in speciall manner, tendeth to the advauncing of the Name of God."[73]

To further his argument, Balmford expounded on an analogy between oaths and lots. "As an Oath, in the nature therof, supposeth the testifying presence of God: so a Lot, in the nature thereof, supposeth the determining presence of God."[74] Thus just as an oath sworn before a legal court, by definition, implies God's approval and verification of a witness's truth, a lot cast to resolve a controversy, by definition, implies God's approval of the lot's resolution. Given this necessary connection between God's special providence and the use of lots, Balmford argued that lots could not be used for non-religious ends, any more than prayer or swearing oaths.[75]

> Whatsowever directly, or of it selfe, or in a speciall manner tendeth to the advaunceing of God's Name is to be vsed religiously, & not to be vsed in sporte, as we may not pray, or sweare in sporte: But the vse of Lotts directly, or of it selfe, and in speciall manner tendeth to the advauncing of the name of God in attributing to his special Providence in the whole, and immediate disposing of the Lot, & expecting the event.[76]

Thus gaming of any sort – whether dice games wholly consisting of lots, or card games partially consisting of lots – should be shunned for its vain appeal to God's special providence.

Writing at incredible speed, Gataker composed his own reply to Balmford's "modest reply" in less than three weeks and published it that same year, 1623. Gataker's blistering reply took Balmford's arguments apart, point by point, to demonstrate "the

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[73] Balmford, *Modest Reply*, 89-91.

[74] Balmford, *Modest Reply*, 109.

[75] The use of oaths in gaming was actually a common practice. A "penitent gamester" wrote a sonnet in 1580, which explains how gamesters called upon God's assistance when they cast their dice: "By *wounds* and *nails* they think to win, / But truly 'tis not so; / For all their frets and fumes in sin / They moniless must go." Cotton, *Compleat Gamester*, 20.

[76] Balmford, *Modest Reply,* 87-8.

insufficiencie of his answers" and "the imbecillitie of his arguments."[77] His central argument remained unchanged – that lots were casual events and, as such, were no different in causation from other types of casual events.

> What is there in the casuall falling of the Dye, or dealing of the Cards, more than in the fall of a Coyte, or lighting of an Arrow neerer or further, or the turning of a Boule, to ensnare the Conscience? Art more ruleth the one, and Nature the other; Gods prouidence and concurrence being equall in either.[78]

Thus Gataker explicitly linked together all casual events. If gaming was blasphemous, then shooting at game while hunting or counting the number of flies circling an unattended plate of food should be considered equally evil. Through reiterating the presence of chance in nature, Gataker concluded once again that "to impose a speciall and immediate worke of Gods prouidence, vpon the casuall euent of the Lot, more than vpon other naturall accidents and deliberate actions of men, is a temerarious and groundlesse assertion."[79]

While Balmford did not dignify Gataker's second treatise with a direct reply, it is unlikely that he was ever convinced by Gataker's arguments. Two years later, in 1625, he reprinted his 1603 treatise on the infectiousness of plague wherein he discussed the ways in which God's providence manifested during plague epidemics. While he admitted that "there be causes both naturall and diuine" for surviving the plague, he castigated those survivors who "obscure Gods prouidence by attributing thine escape to this, that the

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[77] Gataker's temper also manifested in the conclusion of his treatise, where he wrote "An Advertisement to Mr. Balmford" in which he lectured his opponent on the proper rules of debate, demanding that any reply from Balmford "*deale* more *faithfully*... in relating either mine *Arguments* or mine *Answers*." In particular, he wished Balmford to "*alter* not *my phrase*, but giue me leaue, as I doe him, to vtter my *minde* in mine owne *termes*" and "*to keepe* close *to the point*." Thomas Gataker, *A Ivst Defence of Certaine Passages in a former Treatise concerning the Nature and Vse of Lots* (London: John Haviland, 1623), A1r, Mm4r.

[78] Balmford, *Plagues Infection*, 67.

[79] Gataker, *Ivst Defence*, 3-4.

plague is not infectiue."[80] Most intriguingly, he also claimed that it was unlawful for clergymen to go among the sick for the purpose of Christian charity, using familiar arguments about God's special providence:

> A wanton or vnnecessary putting of God to the manifestation of his power or speciall prouidence, is a tempting of the Almighty... to runne into danger of the plague without necessary cause, as they do, who resort as boldly and freely to them that are sicke of the plague, as to those that are sicke of any other disease, is wantonly and vnnecessarily to put God to manifest his power and speciall prouidence in preseruing them from the Plague: therefore to runne into danger of the plague without necessary cause, as they do, who resort as boldly, &c. is a tempting of the Almighty.[81]

It was thus God's special providence, not general providence, that was responsible for averting the plague, specifically, and risks in general. Consequently, in both the gaming debates and in discussions about plague, Balmford equated taking unnecessary risks – either of one's money or one's life – with tempting God.

Despite Balmford's disengagement, Gataker did not get the final word. The debate over chance, providence, and gaming continued into the next decade as Gataker's arguments came under attack by the exiled William Ames.[82] Enough criticism of gaming remained that Charles I felt the need to reissue his father's declaration on sports, causing a wave of protests from puritan clergymen. Yet at the same time, other people began to adopt Gataker's views on chance. As early as 1633, clergyman John Downe reproduced Gataker's arguments in his own defense of lots.[83] While Gataker's arguments did not

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[80] Balmford, *Plagues Infection*, 45, 49.

[81] Balmford, *Plagues Infection*, 67.

[82] For more on the debates among Gataker, Balmford, and Ames, see Bellhouse, "Puritan Casuistry," 68-72.

[83] John Downe, *A Defense of the Lawfulnesse of Lots in Gaming Against the Arguments of N.N.* printed in *Certaine Treatises of the Late Reverend and Learned Devine, Mr Iohn Downe, Rector of the Church of Instow in Devonshire* (London: Iohn Lichfield, 1633). For more on reactions to Gataker's work, see Thomas, *Religion*, 143-5.

immediately defeat older arguments against gaming, they did provide people who wished to reconcile chance and providence with an alternative, natural-law based framework for thinking about the nature of chance.

Clergymen's attempts to explain the nature of contingent events led to the splitting of God's providence into a special and general providence, with the latter allowing natural laws to be the secondary causes God used to direct earthly events. Gataker used the concept of general providence to defend the theological propriety of gaming during the early seventeenth century. In doing so, he unyoked chance from the active intervention of God and argued for the existence of natural laws that governed chance in all things, from throwing dice to unexpected encounters in the marketplace. At the same time, by arguing for the interchangeability of gaming and other chance events, he provided theological justification for both quantified chance in gaming and its more general use in people's daily lives. While quantified chance was applicable to any real world situation, it would prove especially useful for calculating risk and, consequently, for risk aversion. The popular adoption of quantified chance for risk aversion was particularly apparent in the seventeenth-century mainstreaming of insurance and rise of mortality statistics.

The Quantification of Risk Aversion: Insurance

While insurance was a longstanding practice in merchant communities, it remained limited to those with maritime interests until the invention of life insurance. On the Continent, popular life insurance became a variant of gaming, which led to the creation of laws banning the practice in the late sixteenth century. By contrast, life insurance in England remained largely a merchant affair and the first popular insurance was against fire, which was a more easily quantified risk. While life insurance experienced a boom of popularity beginning at the turn of the eighteenth century – temporarily taking on the same gaming characteristics of earlier, Continental life insurance – the simultaneous development of the first life annuities based on mortality statistics helped provide insurance with a mathematical foundation and differentiate it from gaming.

The insurance of trade, particularly maritime cargo, was a longstanding practice in the early modern mercantile community. The distant origin of maritime insurance lay in bottomry – borrowing money against a ship, which would be repaid only if the ship safely made port – which had been practiced by the ancient Babylonians, Greeks, and Romans. During the medieval era, merchant guilds provided a form of mutual assurance for its members while non-mutual forms of maritime insurance appeared on the Continent around the thirteenth century.[84] This latter insurance was probably adopted by English merchants shortly thereafter, as one Elizabethan law declared

> it hath been time out of mind an usage amongst Merchants, both of this Realm, and of foreign Nations, when they make any great Adventure (especially into remote parts) to give some consideration of money to other persons (which commonly are in no small number) to have from them assurance made of their Goods, Merchandizes, Ships, and things adventured... which course of dealing is commonly termed, A policy of assurance.[85]

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[84] For more on ancient and medieval insurance practices, see C.F. Trenerry, *The Origin and Early History of Insurance* (London: P.S. King & Son, Ltd., 1926). The earliest surviving insurance policies, from Genoa and Palermo, date back to 1343 and 1350 respectively. James Franklin, *The Science of Conjecture: Evidence and Probability Before Pascal* (Baltimore: Johns Hopkins University Press, 2001), 274.

[85] Keble, *Statutes at Large*, 952-3.

Maritime insurance formed an integral part of early modern merchant trade. Policies survive in the Admiralty Court records, starting in 1547, and were numerous enough that Elizabeth I established a special Chamber of Assurances for the "good and orderly keeping in registers the assurances made within the Realm of England among merchants."[86]

While maritime insurance was of strictly limited interest, intended primarily for merchants shipping goods abroad, the intersection of maritime insurance and the slave trade led to the creation of a new form of insurance with potentially much broader appeal: life insurance. Although maritime insurance was originally limited to covering the ship and its cargo, rather than the lives of the crew, life insurance evolved out of the inclusion of human cargo on Mediterranean trade ventures. Slaves' lives were insured against the usual marine hazards, including shipwrecks and piracy, but policies generally excluded any sort of hazard that was specific to carrying human cargo, such as slave insurrections or illness.[87]

The idea of insuring human life proved popular on the Continent, where merchants began insuring themselves against death or capture by pirates in their journeys abroad. They also adopted life insurance policies as a form of collateral in money lending. Creditors could increase the security of their loans by taking out policies in the name of their debtors, or by having debtors take out policies and name the creditors as

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[86] David Jenkins and Takau Yoneyama, eds. *History of Insurance* (London: Pickering & Chatto, 2000), 1:xxix. Geoffrey Clark, *Betting on Lives: The Culture of Life Insurance in England, 1695-1775* (Manchester: Manchester University Press, 1999), 20.

[87] These sorts of exclusions would eventually lead to the infamous eighteenth-century case of Luke Collingwood, who threw 122 sick slaves overboard so as to be able to reclaim the loss from his insurers. The British Parliament subsequently passed a series of laws specifically to forbid the practice of jettisoning slaves for insurance purposes. Clark, *Betting on Lives*, 17.

beneficiaries.[88] In the sixteenth century, insuring the lives of debtors morphed into thinly veiled wagers and became heavily associated with the disreputable practice of gaming. One could purchase a whole host of "wager insurances," such as insuring the lives of children or strangers in whom the policyholder had no direct financial interest – including, much to their dismay, kings and queens. This conflation of insurance and gaming led to a transnational movement against life insurance in the 1570s and 1580s, which culminated in a series of laws that made life insurance largely illegal on the Continent.[89]

In late sixteenth-century England, life insurance survived this backlash largely because it was still only a subset of mercantile insurance and thus limited to the mercantile community. While the practice of life insurance was not widespread, English men and women were aware of the ways it could be used. For example, the former royal tutor Thomas Wilson published a 1572 treatise that, among other things, equated purchasing life insurance for a child with usury.[90] However the oldest surviving example of a non-marine life insurance policy was issued to a London slater at the relatively late date of 1583, while the sample life insurance policy listed in William West's popular legal handbook, *Symboleography*, bore the dates of May 14, 1596.[91] Furthermore, West

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[88] Clark, *Betting on Lives*, 14-18.

[89] Trenerry, *Early History*, 277-8.

[90] Thomas Wilson, *A Discourse Vppon Vsurye* (London: Rychardi Tottelli, 1572), 104v-105r. Frederick Hendricks, *Contributions to the History of Insurance, and of the Theory of Life Contingencies, with a Restoration of the Grand Pensionary De Wit's Treatise on Life Annuities* (London: C. & E. Layton, 1851) reproduced in Jenkins and Yoneyama, *History of Insurance*, 3:36.

[91] The marine policy insured against "War, Fire, Enemies, Reuers, Jetteson, letters of Mark, deteinment, arrest, and restraint of Princes, or of any other person or persons, Battarrie of the Master and Mariners, and of all other perils and fortunes whatsoeuer they be, or howsoeuer it shall chance, to the hurt of the said goods, or any part thereof." The life insurance policy, by contrast, was for a man "now in health and well, and meaneth not to trauaile out of England" and insured against death "by any waies or meanes whatsoeuer, before the ful end of the said sixe moneths" of the policy. William West, *The First Part of Simboleography* (London: Companie of Stationers, 1610), Qq5r-v.

only included sample insurance policies beginning with the second edition of his handbook, in 1603. Rather than form part of the main handbook, these policies were tucked away at the end, in an addendum of miscellaneous subjects which were of use in "Merchants Affairs." The section on merchant affairs was included in all subsequent reprints, throughout the first half of the seventeenth century, but it remained distinct from the main body of the handbook where documents of more general concern, such as last wills and testaments, could be found. While insurance thus remained largely a merchant affair in the first half of the seventeenth century, there was a budding interest in life insurance among the wider English population, enough so that the merchant-oriented court attached to the Chamber of Assurances lost jurisdiction over life insurance to the common law courts by 1649.[92]

While the concept of life insurance became more familiar to the wider English population during the mid-to-late seventeenth century, the first popular insurance was a closer analog to marine insurance: fire insurance, which proliferated in the wake of the Great Fire of London. As one 1680 insurance scheme explained, since "the Original of Assurances amongst Merchants" was an agreement that "a Loss might be made Good, and divided amongst Many; which otherwayes might have fallen to a Particular Person, or some few Persons, to his, or their great Detriment, and Ruin," a logical parallel might be drawn between maritime disasters and land-based ones. For example, "[t]he Demolishment by Fire of the City-Buildings, may be of like Detriment, and Impoverishment to those Proprietors" as the destruction of a merchant's ship and cargo. Thus "Reason and Experience... will direct the like Security to be admitted of, for Re-

[92] Clark, *Betting on Lives*, 20.

building and Repairing the Casualties of Houses by Fire, to those Proprietors and Inhabitants; both being Adventurers at a Hazard, though in a different kind and Element."[93] The key motivator behind buying into such insurance schemes was the desire to avert the risk of financial disaster, such as the loss of a ship or a house due to fire.

Seventeenth-century fire insurance schemes had two main components: an assessment of risk in quantitative terms through the size of the insurance premium and a series of actions taken to reduce the overall risk of fire for their policyholders. The calculation of premiums was performed by a relatively simple rubric that took into account both the value of the house and the materials with which it was built. The latter was particularly important as it was well known that "[t]he Casualties which may happen by *Fire* amongst the Timber-Houses, are in a greater Proportion, more Violent, and Hazardous" and thus could not be given "equal Terms" with brick houses.[94] Nicholas Barbon – who established the first successful fire insurance scheme in an effort to protect the houses he had rebuilt after the Great Fire of 1666 – set the terms for his policies at "*sixpence per pound rent* for brick houses, and twelvepence for timber."[95] By calculating premiums based on the building rent and changing the percentage of the rent based on building materials, Barbon accounted for both the increased flammability of timber houses as well as the varying cost of rebuilding based on the size and quality of the house – aspects most easily assessed numerically by rent. A close contemporary to Barbon's

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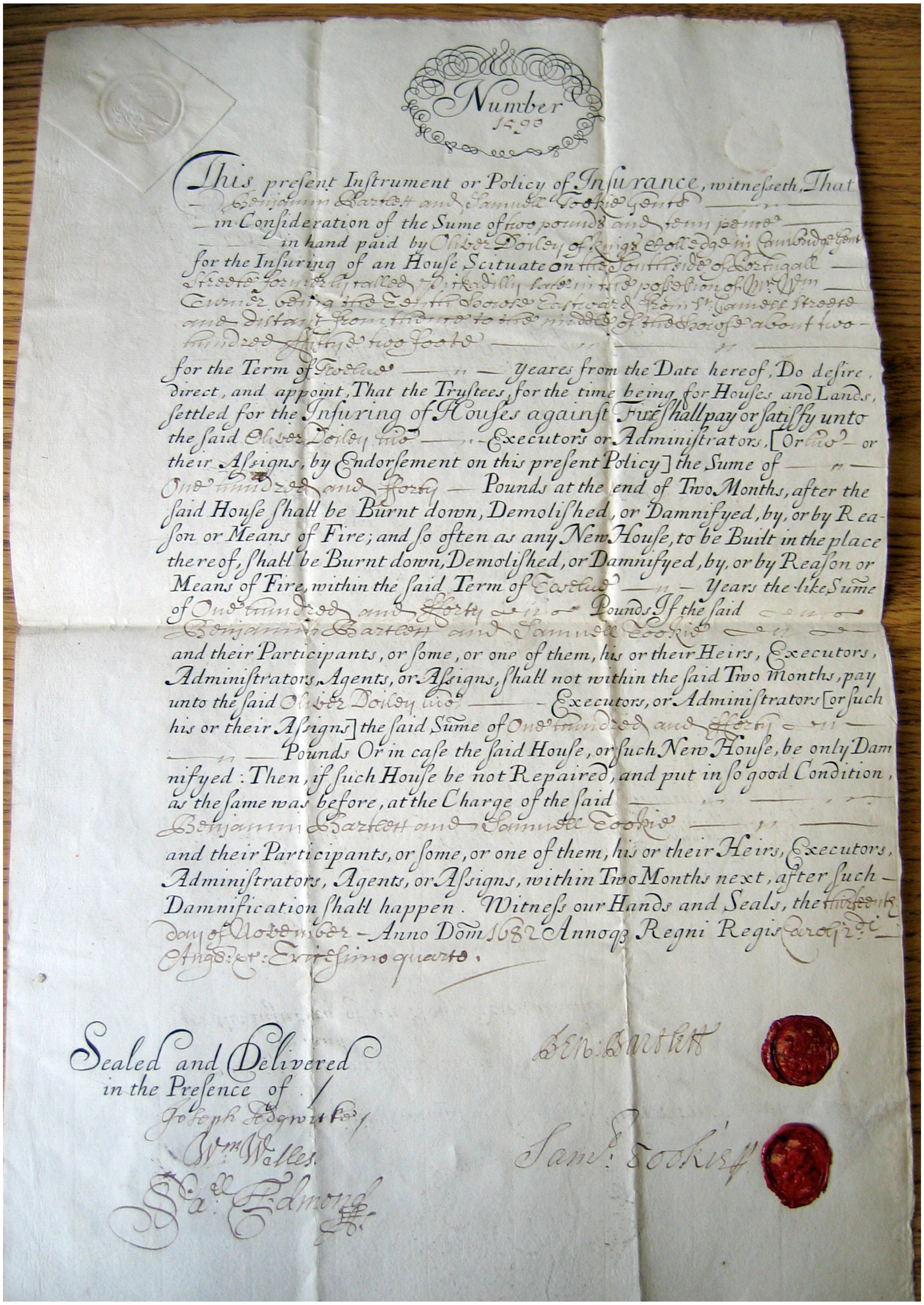
[93] A. Newbold, *Londons Improvement, and the Builders Security, &c.*(London: Thomas Milbourn, 1680) reproduced in Jenkins and Yoneyama, *History of Insurance*, 1:5.

[94] Newbold, *Londons Improvement*, in Jenkins and Yoneyama, *History of Insurance*, 1:8.

[95] Harry M. Johnson, "The History of British and American Fire Marks," *The Journal of Risk and Insurance* 39, no. 3 (Sept. 1972), 406. These insurance rates were advertised in the *Mercurius Civicus* on May 12, 1680. Jenkins and Yoneyama, *History of Insurance,* 1:14.


Number
1590

This present Instrument or Policy of Insurance, witnesseth, That Benjamin Bartlett and Samuel Tookie Gent in Consideration of the Sume of two pounds and tenn pence in hand paid by Oliver Doiley of Kings Colledge in Cambridge Gent for the Insuring of an House Scituate on the South side of Portugall Streete formerly called Pickadilly late in the possession of Mr Wm Turner being the Eighth doore Eastward from St Jameses Streete and distant from thence to the middle of the house about two hundred fifty two foote for the Term of Twelve Yeares from the Date hereof, Do desire, direct, and appoint, That the Trustees, for the time being, for Houses and Lands, settled for the Insuring of Houses against Fire shall pay or satisfy unto the said Oliver Doiley his Executors or Administrators, [Or his or their Assigns, by Endorsement on this present Policy] the Sume of One hundred and forty Pounds at the end of Two Months, after the said House shall be Burnt down, Demolished, or Damnifyed, by, or by Reason or Means of Fire; and so often as any New House, to be Built in the place thereof, shall be Burnt down, Demolished, or Damnifyed, by, or by Reason or Means of Fire, within the said Term of Twelve Years the like Sume of One hundred and forty Pounds If the said Benjamin Bartlett and Samuel Tookie and their Participants, or some, or one of them, his or their Heirs, Executors, Administrators, Agents, or Assigns, shall not within the said Two Months, pay unto the said Oliver Doiley his Executors, or Administrators [or such his or their Assigns] the said Sume of One hundred and forty Pounds Or in case the said House, or such New House, be only Damnifyed: Then, if such House be not Repaired, and put in so good Condition, as the same was before, at the Charge of the said Benjamin Bartlett and Samuel Tookie and their Participants, or some, or one of them, his or their Heirs, Executors, Administrators, Agents, or Assigns, within Two Months next, after such Damnification shall happen. Witness our Hands and Seals, the thirteenth day of November Anno Dom 1682 Annoq Regni Regis Caroli 2di Angl &c: Tricesimo quarto.

Sealed and Delivered in the Presence of
Joseph Edgworth
Wm Walles
Saml Edmonds

Ben: Bartlett
Saml: Tookie

1682 Fire Insurance Policy from Barbon's "Fire Office"[96]

[96] LMA, E/PYM/626.

scheme was promulgated by the City of London, which assessed their premiums based on the value of the house, not the rent. However, the City's scheme agreed with Barbon's assumption that timber houses were twice as risky an investment as a brick house and thus should be charged twice as high a premium.[97]

The second component of fire insurance schemes was the establishment of fire-fighting brigades to mitigate the overall risk faced by all their insured properties. As early as 1638 – in the wake of a fire that destroyed a large portion of London Bridge – a pair of gentlemen named William Ryley and Edward Mabb presented a petition to Charles I, detailing a plan to prevent, with God's assistance, the "dayly many great losses by the lamentable fires hapned in and about the Citty of London." In addition to insuring houses, the company would also establish "a continual watch in all parts of the Citty and suburbs all night" as well as providing both fire engines and reserves of water to aid in fire-fighting efforts.[98] While Ryley and Mabb's company was never actually founded, fire brigades became a component of all the fire insurance companies founded in the wake of the Great Fire of London. Each insurance company established its own fire brigade and "maintained them in livery with badges" to fight fires throughout the city.[99] These firemen were usually watermen by trade and were paid anywhere between 6*p* and

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[97] Anonymous, *At a Common Council holden in the chamber of the Guildhall. Proposals... for Insuring of Houses in Cases of Fire,* (London, 1681), reproduced in Jenkins and Yoneyama, *History of Insurance*, 1:32-3.

[98] Although the petition was favorably received at court, and the Attorney General was ordered to prepare a warrant for the king's signature, nothing more seems to have come of the scheme. This was most likely due to the outbreak of hostilities in Scotland, and the subsequent civil wars. Francis Boyer Relton, *An Account of the Fire Insurance Companies* (London: Swan Sonnenschein & Co, 1893), 11-13. Brian Wright, *Insurance Fire Brigades 1680-1929: The Birth of the British Fire Service* (Chalford, England: Tempus Publishing, 2008), 19.

[99] Johnson, "Fire Marks," 406.

2*s*6*d* per fire, depending on the size of the fire.[100] These costs generally formed only a small amount of the insurance premiums; for example, the Sun Fire Office limited itself to spending approximately 3-5% of its premiums on fire-fighting efforts, reserving the rest for insurance claims and shareholder dividends.[101] In this way, early fire insurance both mitigated the financial effects of a fire – the risk of which was quantitatively assessed through insurance premiums – as well as used the money from premiums to support fire brigades in an effort to reduce the risk of disaster.

During the last decade of the seventeenth century, England finally experienced the same boom in popular insurance that the Continent had experienced over a century earlier. A half dozen fire insurance schemes were established in London alone and one company – the Amicable Contributors – insured over 13,000 houses by 1708.[102] By 1694 insurance policies had grown so numerous that the Crown sought to raise revenues by imposing a stamp duty upon them, while over sixty different life insurance schemes were formed between 1696 and 1721.[103]

Many new insurance schemes were thinly veiled wagers, rather than an attempt to protect something in which the insurer had a viable financial interest. In 1702, Daniel Defoe complained that "WAGERING, as now practis'd by Polities and Contracts, is

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[100] This fee was paid by whatever company had insured the building, regardless of what company the fire brigade was sponsored by. In the case of uninsured buildings, their fees could be paid by the city or by their own company. A series of legislation passed in 1707-8 provided rewards for the first three fire engines to show up at any fire, thus providing another possible income stream for the fire brigades. Some firemen had a further retainer from their companies and all firemen were officially exempt from being impressed by the Navy. Wright, *Fire Brigades*, 42-4, 73-4.

[101] Approximately half of the early insurance companies were established on a mutual basis. The Sun Fire Office had approximately 130 shareholders. Robin Pearson, *Insuring the Industrial Revolution: Fire Insurance in Great Britain, 1700-1850* (Burlington, VT: Ashgate Publishing Company, 2004), 62-3. Wright, *Fire Brigades*, 38.

[102] Johnson, "Fire Marks," 406. Jenkins and Yoneyama, *History of Insurance*, 1:xx.

[103] Clark, *Betting on Lives*, 21, 33. Jenkins and Yoneyama, *History of Insurance*, 1:xxx.

become a Branch of *Assurances*; it was before more properly a part of Gaming," and estimated that no less than £200,000 had been wagered on the outcome of the second siege of Limerick, in 1691.[104] Sieges proved a particularly popular subject for wager insurance policies, and the siege of Namur in 1694 was also a source of insurance policies, which offered 30% premiums against the town falling by the end of September. In the eighteenth century, it was possible to purchase insurance on the likelihood of births, marriages, cuckoldry, highway robbery, the fall of a besieged city, or even death by drinking gin.[105] Only in 1774, with the passage of the Gambling Act, were wager insurance policies curtailed.

As popular interest in all types of insurance increased, mathematicians worked with mortality statistics to put life insurance premiums on a firm mathematical basis for the first time. Early premiums for all types of insurance were based on educated guesses that insurers adjusted according to the season of the year and reports of piracy, location and building materials, or age and health. Both insurers and policyholders agreed that risks could be gauged quantitatively, but they lacked a method for precisely calculating those risks. In 1671, a Dutchman John de Witt became the first person to attempt to calculate life annuities based on mortality statistics. In England, the mathematician Edmund Halley performed similar calculations in the 1690s, using information gleaned from Silesian Bills of Mortality.[106] De Witt and Halley's use of the bills was a new innovation that helped set life insurance on firm mathematical ground for the first time.

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[104] Daniel Defoe, *Essays Upon Several Projects: Or, Effectual Ways for advancing the Interest of the Nation* (London: Thomas Ballard, 1702), 171-2.

[105] Clark, *Betting on Lives*, 1, 45.

[106] Jenkins and Yoneyama, *History of Insurance*, 1: xxv-xxvi.

However public mortality statistics also had a long history of being analyzed for a much simpler purpose – tracking plague epidemics.

The Quantification of Risk Aversion: Mortality Statistics

Plague first entered England in 1348, as part of a continent-wide epidemic that killed approximately one third the population of Europe.[107] Thereafter, England suffered continuous outbreaks of plague until 1679 and fear of plague lasted well into the eighteenth century.[108] The most well-documented of the early modern epidemics were in England's cities – particularly London, which suffered six major epidemics in the century between 1563 and 1665, and lost an estimated 225,000 people to plague.[109] During the mid-sixteenth century, in response to these epidemics, some city officials began to compile numerical summaries of local deaths and circulated those mortality statistics in manuscript form.[110] By the turn of the seventeenth century, there was enough popular interest in these numbers that the Worshipful Company of Parish Clerks began publishing London mortality statistics in a series of weekly broadsides known as the Bills of

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[107] For an analysis of the 1/3 estimate for the 1346-51 plague outbreak, see Philip Ziegler, *The Black Death* (New York: Harper Torchbooks, 1969), 224-30.

[108] Plague was not endemic to England, however repeated reintroduction of the plague from the Continent ensured that there was almost always plague somewhere in the country. The years 1612-24 and 1654-64 were notable for being the only extended periods free from plague until it vanished from England in 1679. Paul Slack, *The Impact of Plague in Tudor and Stuart England* (Oxford: Clarendon Press, 1990), 13-4, 68-9.

[109] Paul Slack estimated at least 658,000 people died of the plague nationwide, meaning one in three English plague deaths occurred in London. Slack, *Impact of Plague*, 174.

[110] Outside of England, Geneva began to circulate Bills of Mortality during this same period, starting in 1551. Other cities started their own bills during the latter half of the seventeenth century. Dublin created its first Bill of Mortality was in 1662, Paris followed in 1670, and Breslau, Silesia – which famously came to the attention of Edmund Halley for its inclusion of age of death in its bills – began in 1687. Cornelius Walford, "Early Bills of Mortality," *Transactions of the Royal Historical Society* 7 (1878): 234, 245.

Mortality.[111] The main impetus behind these bills was the desire to track the severity of plague outbreaks and most of London's population embraced the bills as a quantitative tool for evaluating their risk of imminent death.

It is possible that the first mortality statistics for London were compiled as early as 1518, as part of Cardinal Wolsey's creation of England's first official plague policy.[112] The earliest reports simply noted whether or not a death was due to plague, and were circulated to the London mayor and aldermen, as well as the King and Privy Council. Two references survive to such reports in the 1528 Calendar of State Papers Domestic, while a 1555 London ordinance required the clerks to provide the mayor with a weekly mortality report "in like manner and custom as heretofore hath been accustomed."[113] John Stow's *Annales*, published in 1580, contains numbers related to the 1563 epidemic, and it is probable that he obtained them from manuscript sources such as the ones alluded to by the London ordinance.[114] However, such reports were never widely available and, a century later, John Graunt had to omit the 1563 epidemic from his seminal analysis of London mortality statistics.[115]

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[111] The Worshipful Company of Parish Clerks were originally known as the Ancient Fraternity of Saint Nicholas, but were subsequently incorporated as a company during the reign of James I.

[112] Slack, *Impact of Plague*, 201.

[113] Stephen Greenberg, "Plague, Printing, and Public Health," *Huntington Library Quarterly* 67, no. 4 (Dec. 2004): 513, 516.

[114] John Stow and Edmund Howes, *Annales, or A Generall Chronicle of England* (London: Richardi Meighen, 1631), 656-7. William Ogle, "An Inquiry into the Trustworthiness of the Old Bills of Mortality," *Journal of the Royal Statistical Society* 55, no. 3 (Sept. 1892): 437-9.

[115] Graunt deliberately dropped the 1563 epidemic from his narrative. In his 1662 treatise, he discussed the four plague epidemics "within this Age," namely the 1592-3, 1603, 1625, and 1636 epidemics. A related 1665 treatise – which was either published by Graunt or possibly pirated from his work – spoke of four epidemics "within this generation, or one hundred years," conveniently excluding the 1563 epidemic which then fell 2 years outside of the chronological boundary. John Graunt, *Natural and Political Observations Mentioned in a following Index, and made upon the Bills of Mortality* (London: Thomas Roycroft, 1662), 33. John Graunt, *Reflections on the Weekly Bills of Mortality For the Cities of London and Westminster* (London: Samuel Speed, 1665), 1.

This interest in local mortality was not confined to London. Outside of the capital city, the 1538 establishment of nationwide parish registers made it theoretically possible to begin tracking every birth, marriage, and death in England – at least those that occurred within the official church. The civic annals of Bristol reported only "great plague and "mortality by pestilence" in 1544-5 and 1551-2, but city officials began to collect mortality statistics in the second half of the century. They entered numerical death tolls into the annals in 1565, 1575, and 1603.[116] In 1579, the city of Norwich suffered an epidemic that was worse than any other epidemic since the Black Death of 1348-9; the Mayor's Court responded by having clerks compile weekly mortality reports out of their parish registers. These reports continued almost without interruption until 1646, but only differentiated plague deaths from other kinds of death beginning in 1590.[117]

Despite the ongoing interest in these manuscript reports, no one saw the need to make quantitative data on deaths – by plague or any other disease – available to the general population until the beginning of the seventeenth century. The first London Bills of Mortality were published in response to the 1603 plague outbreak, which remained endemic in London for the next eight years.[118] During the same outbreak, the Exeter civic annals reported numbers derived from "the Church books and printed tickets," which suggests that printed Bills of Mortality were also circulated in that city, though no

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[116] Slack, *Impact of Plague*, 111.

[117] Slack, *Impact of Plague*, 128-9.

[118] In 1603, of the 37,204 London deaths, 30,561 were due to plague, marking both the outbreak of the epidemic and the worst year for mortality. However, the epidemic did not end that year – another 14,752 Londoners died of plague in the years 1604 to 1611, with yearly deaths ranging from a minimum of 444 in 1605, to a maximum of 4140 in 1609. Only in 1612 did the annual London plague deaths drop back into double digits. Graunt, *Reflections*, 10.

16

THE TRVE COPIE OF ALL THE BVRIALS AND CHRISTNINGS

aswell within the City of LONDON as the Liberties thereof, as in other Parishes in the skirts of *the City, and out of the Freedome, according to the report made to the Kings most excellent Maiestie*, by the Company of Parish Clearkes of the said Citie, From the 27. of October, 1603. to the 3. of Nouemb. Whereunto is added the true Relation of the whole number of all that haue dyed *of this Visitation, from the 17. of December, 1602. to the 3. of this present moneth of Nouember 1603. with the whole number of all that haue dyed in Westminster, in the* Sauoy, in Stepney, Newington, and sundry other places, since the sicknesse began there.

London within the Walles.

Parish	Buried in all	Of the Plague	Parish	Buried in all	Of the Plague
Albones in Woodstreet	6	4	*Margrets Pattons*	3	3
Alhallowes Lumberstreet	2	1	*Margrets Moyses*	2	2
Alhallowes the great	6	4	*Margrets Lothbery*	7	6
Alhallowes the lesse	3	3	*Martins in the Vintry*	8	6
Alhallowes Bredstreet	3	3	*Martins Orgars*	3	3
Alhallowes staynings	2	2	*Martins Iremonger lane*	4	4
Alhallowes the Wall	3	2	*Martins at Ludgate*	4	4
Alhallowes Hony-lane	0	0	*Martins Outwich*	0	0
Alhallowes Barking	6	4	*Mary le Booe*	2	2
Alphage at Cripplegate	4	3	*Mary Bothawe*	1	1
Androwes by the Wardrope	2	0	*Mary at the hill*	2	1
Androwes Eastcheape	6	6	*Mary Abchurch*	2	2
Androwes vndershaft	8	7	*Mary Woolchurch*	5	5
Annes at Aldersgate	4	2	*Mary Colchurch*	0	0
Annes Blacke Fryers	10	9	*Mary Woolnoth*	3	3
Auntlins Parish	1	0	*Mary Aldermary*	6	5
Austines Parish	3	3	*Mary Aldermanberry*	8	8
Barthelmew at the Exch.	4	4	*Mary Staynings*	0	0
Bennets at Pauls-Wharf	7	5	*Mary Mountawe*	1	1
Bennets Grace-Church	0	0	*Mary Sommersets*	6	5
Bennets Finck	0	0	*Mathew Friday street*	1	1
Bennets Sherhogg	0	0	*Maudlins Milke street*	1	1
Buttols Billingsgate	6	6	*Maudlins by Oldfishstreet*	3	1
Christ Church Parish	16	14	*Mighels Bassieshawe*	1	1
Christophers Parish	4	4	*Mighels Corne hill*	4	3
Clements by Eastcheape	4	4	*Mighels in Woodstreet*	5	5
Dennis Backe Church	7	6	*Mighels in the Ryall*	1	0
Dunstones in the East	8	7	*Mighels in the Querne*	4	4
Edmunds in Lumbard-st.	5	3	*Mighels Queene-hithe*	3	2
Ethelborow within Bishopsg.	4	4	*Mighels Crookedlane*	8	5
S. Faithes	10	8	*Mildreds Poultry*	4	3
S. Fosters in Fostar-lane	0	0	*Mildreds Bredstreet*	1	1
Gabriel Fan-Church	3	2	*Nicholas Acons*	2	2
George Botolph lane	2	2	*Nicholas Cole-abbay*	6	6
Gregories by Paules	8	7	*Nicholas Olaues*	2	2
Hellens within Bishopsg	0	0	*Olaues in the Iury*	1	1
Iames by Garlike hithe	4	3	*Olaues in Hartstreet*	4	4
Iohn Euangelist	1	0	*Olaues in Siluer street*	4	3
Iohn Zacharies	3	3	*Pancras by Soperlane*	0	0
Iohns in the Walbrooke	2	2	*Peters in Cornehill*	5	2
Katherines Cree-Church	12	11	*Peters in Cheape*	0	0
Katherine Colemans	3	3	*Peters the poore in broadst.*	1	1
Laurence in the Iury	1	0	*Peters at Pauls wharf*	3	3
Laurence Pountney	2	0	*Stephens in Colemanstreet*	13	12
Leonards Foster-lane	1	1	*Stephens in the Walbrook*	2	2
Leonards Eastchape	2	2	*Swithins at London-stone*	3	2
Magnus parish by the Bridge	0	0	*Thomas Apostles*	0	0
Margrets New fishstreete	5	3	*Trinityparish*	1	1

The number buried within the Walles of London is 343. Whereof of the Plague 286

London without the Wals, and within the Liberties.

Parish	Buried in all	Of the Plague	Parish	Buried in all	Of the Plague
Androwes in Holborne	31	27	*Dunstones in the West*	17	13
Barthelmew the lesse Smith.	1	1	*Georges in Southwarke*	15	10
Barthelmew the great Smith.	2	2	*Giles without Cripplegate*	34	21
Brides parish	22	18	*Olaues in Southwarke*	24	17
Buttols Algate	17	7	*Sauiours in Southwarke*	27	24
Bridewell Precinct	6	4	*Sepulchers parish*	48	43
Buttols Bishopsg	4	3	*Thomas in Southwarke*	4	3
Buttols without Aldersg.	13	11	*Trinity in the Minories*	1	1

The number buried without the wals, and within the liberties is 266. Whereof of the Plague, 205.

Out Parishes adioining to the City.

Parish	Buried in all	Of the Plague	Parish	Buried in all	Of the Plague
Clemets without Templeb.	33	30	*Martins in the Fields*	36	31
Giles in the fields	13	10	*Mary Whitechappell*	21	18
Iames at Clarkenwell	7	4	*Magdalens in Barmondsey streete*		
Katherines by the Tower	8	5			
Leonards in Shordich	8	2	At the Pest-house	2	2

Buried without 128 Whereof, Of the Plague 103

Christnings — 70 — *Parishes cleere of the Plague* — 18 — *Parishes infected* — 94

Buried in all, within the places aforesaid — 737

Whereof, of the Plague — 594

From the first great plague in our memory, after the losse of Newhauen, from the first of January, 1562. to December, 1563. there died of the plague twenty thousand one hundred thirtie sixe.

And in the last visitation, from the 23. of December, 1592. to the 23. of the same moneth in the yeare 1593. died in all, 25886. of the Plague in and about London, 15003. And in the yeare before 2000.

And now in this present visitation which it pleaseth God to strike vs with, there hath died from the 17. of December 1602 to the 14. of July, 1603. the whole number in London and the Liberties, 4314. whereof, of the Plague, 3310. The rest are set downe, as they haue followed weekely.

From the 14 of Iuly, to the 21. of the same — 867. Whereof, of the plague — 646. In the out parishes — 319. Whereof, of the plague — 271.
Buried in all this weeke 1186. *Whereof, of the plague* 917.

From the 21. of Iuly, to the 28. of the same — 1312. Whereof, of the plague — 1025. In the out parishes — 398. Whereof, of the plague — 354. Out of the pesthouse — 18.
Buried in all this weeke, 1728. *whereof, of the plague* 1396.

From the 28. of Iuly, to the 4. of August — 1700. Whereof, of the plague — 1439. In the out parishes — 537. Whereof, of the plague — 464. pesthouse — 19.
Buried in all this weeke 2256. *Whereof, of the plague* 1922.

From the 4. of August, to the 11. of the the same — 1655. Whereof, of the plague — 1372. In the out parishes — 410. Whereof, of the plague — 361. pesthouse — 12.
Buried in all this weeke 2077 *Whereof, of the plague* 1745.

From the 11. of August, to the 18. of the same — 2486. Whereof, of the plague — 2199. In the out parishes — 568. Whereof, of the plague — 514. In Bridewell — 7. pesthouse — 21.
Buried in all this weeke 3054 *Whereof, of the plague* 2713.

From the 18. of August, to the 25. of the same — 2343. Whereof, of the plague — 2091. In the out parishes — 510. Whereof, of the plague — 448. In Bridewell — 8. pesthouse — 12.
Buried in all this week 2853 *Whereof, of the plague* 2539.

From the 25 of August, to the 1 of September — 2798. Whereof, of the plague — 2495. In the out parishes — 587. Whereof, of the plague — 540. In Bridewell — 5. pesthouse — 6.
Buried in all this weeke 3385 *Whereof of the plague* 3035

From the 1. of September, to the 8. of the same — 2583. Whereof, of the plague — 2283. In the out parishes — 495. Whereof, of the plague — 441. In Bridewell — 17. pesthouse — 5.
Buried in all this weeke 3078 *Whereof, of the plague* 2724.

From the 8 of September, to the 15 of the same — 2676. Whereof, of the plague — 2411. In the out parishes — 453. Whereof, of the plague — 407. In Bridewell — 7. pesthouse — 10.
Buried in all this weeke 3129 *Whereof, of the plague* 2818.

From the 15. of September, to the 22. of the same — 2080. Whereof, of the plague — 1851. In the out parishes — 376. VVhereof, of the plague — 344. In Bridewell — 19. pesthouse — 10.
Buried in all this weeke 2456 *VVhereof, of the plague* 2195.

From the 22. of September to the 29. of the same — 1666. whereof, of the plague — 1478. In the out parishes — 295. whereof, of the plague — 254.
Buried in all this weeke 1961 *VVhereof, of the plague* 1732

From the 29 of September, to the 6. of October — 1525. whereof, of the plague — 1367. In the out parishes — 306. whereof, of the plague — 274.
Buried in all this weeke 1831 *VVhereof, of the plague* 1641

From the 6. of October to the 13. of the same — 1109. whereof, of the plague — 962. In the out parishes — 203. whereof, of the plague — 184.
Buried in all this weeke 1312 *VVhereof, of the plague* 1146.

From the 13. of October to the 20. of the same — 647. whereof, of the plague — 546. In the out parishes — 119. whereof, of the plague — 96.
Buried in all this weeke, 766 *whereof, of the plague* 642

From the 20. of October, to the 27. of the same — 536. whereof, of the plague — 432. In the out parishes — 89. whereof, of the plague — 69.
Buried in all this weeke 625. *Whereof, of the Plague* 508.

From the 27. of October, to the 3. of Nouember — 609. whereof, of the plague — 491. In the out parishes — 128. whereof, of the plague — 103.
Buried in all this weeke 737 *whereof, of the Plague* 594

Buried in all within London and the Liberties and Suburbes, since the sicknesse began, 36748. VVhereof, of the plague. 31477.

The time when it began in the City of Westminster, *and these places following.*

Buried in VVestminster, from the 14. of Iuly to the 3. of Nouember, in the whole number, 916. whereof of the plague 795.

Buried in the Sauoy, from the first of Iune to the 3. of Nouember, in the whole number, 195. whereof, of the plague, 183.

Buried in the parish of Stepney, from the 25. of March, to the 3. of Neuember, in all 2016. whereof, of the plague 1947.

Buried at Newington-buts from the 14. of Iune to the 3. of Nouember, in al 635 whereof, of the plague 569.

Buried in Islington, 247. whereof, of the plague, 213

Buried in Lambeth 394. whereof, of the plague, 373.

Buried in Hackney, 198. whereof, of the plague, 175.

¶ *Buried in all, within the 7 seuerall places last aforenamed.* 4601 *VVhereof, of the Plague.* 4255.

The whole number that hath beene buried in all, both within London, and the Liberties, and the 7. other seuerall places last before mentioned is, 41349. whereof, of the number of the plague. 35732.

Printed by Iohn Windet, Printer to the Honourable City of London.

Weekly Bill of Mortality from 1603[119]

[119] Guildhall Library, 424.9 (Bills of Mortality 1602-1666), 2.

copies are currently known to be extant.[120] They were probably similar in form to the London bills, which included a parish-by-parish list of total deaths and plague deaths, along with running tallies of christenings, deaths, plague deaths, and infected parishes. London's weekly bills were also supplemented annually with a general account of the preceding year, published on the Thursday before Christmas.[121] Over the next several decades, more parishes were added to the bills, including the parishes of neighboring Westminster, until the "Bills of Mortality" formed a recognized geographical unit that included all of London and its suburbs.[122]

During the seventeenth century, there was sustained interest in acquiring either the Bills of Mortality themselves or at least the quantitative information contained within them. Individual bills could be purchased for a penny apiece, or families could purchase an annual subscription for 4*s*.[123] Charles I and the future Charles II both availed themselves of annual subscriptions during the civil war, as Parliamentary agents discovered – to their chagrin – when they intercepted two suspicious packages and discovered the packages contained "no more nor no less, then the Bills of Mortality bound up in a bundle, of the whole years burials in *London*, &c. usually sent heretofore to the King."[124] London preacher Francis Raworth also followed the weekly bills and

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[120] Slack, *Impact of Plague*, 120.

[121] Graunt, *Natural and Political Observations*, 4.

[122] Many of the English Parliament's civil war ordinances reference the Bills of Mortality when defining the geographical limits of the capital. These ordinances were generally said to affect "the Cities of *London* and *Westminster*, with the places and parishes adjoyning, within the line of Communcation, and bils of Mortality." England and Wales, *Whereas An Ordinance Was Lately Made By Both Houses of Parliament, For the Speedy Supply of the Cities of London and Westminster* (London, 1643), A1r.

[123] The 4*s* per annum price appears to have remained consistent across the seventeenth century. Greenberg, "Plague," 510. Walford, "Early Bills," 216. Graunt, *Natural and Political Observations*, 11.

[124] William Sanderson, *A Compleat History of the Life and Raigne of King Charles From His Cradle to his Grave* (London: Humphrey Moseley, Richard Tomlins, George Sawbridge, 1658), 897

included them in some of his sermons, exhorting his congregation to thank God for ciphers:

> When I take a view of our weekly Bills of Mortality in *London*, I finde a report of so many dying in one Parish of a Fever, of so many dying in another Parish of a Consumption, &c. But when I cast my eye down to the bottom of the Leaf, suspecting still that I should see some Funerals of the Plague, contrarily for these 12. moneths and above, I finde there nothing but Ciphers: Ah Lord, how unthankful are we for such a blessing! when thou might'st as justly as suddenly, turn our *Ciphers* into *Figures*.[125]

Thus for Raworth, as for many people in seventeenth-century London, the numerical information contained within the bills was vital for tracking the incidence of disease – especially the dreaded plague.

Popular interest in both historical and current Bills of Mortality always increased dramatically during plague epidemics. Though surviving copies are rare – during the 1660s, the Company of Parish Clerks lamented their inability to "Recover all the particular Weekly Bills thereof; the sight of them hath been much desired these times; but it is beyond my power, as yet, to answer mens expectations"[126] – evidence suggests that plague-time demand for the bills resulted in unusually large print runs. Stephen Greenberg convincingly argued that the early bills of 1603 were printed using two different presses, thus increasing the number of bills that could be printed during the single day the printer had to produce each week's bill. This would have resulted in a production run of somewhere between 5000 and 6000 bills per week in a city of 141,000.[127] Only at the end of the year and into 1604, when the worst of the epidemic

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[125] Francis Raworth, *Blessedness, or, God and the World Weighed in the Balances of the Sanctuary and the World found too light. Preached in a Sermon at Pauls* (London: T. Maxey, 1656), 7.

[126] This was the company's motivation for collecting all of the weekly bills from the 1665 epidemic and printing them together in book format. Company of Parish Clerks, *London's Dreadful Visitation: Or, A Collection of All the Bills of Mortality For this Present Year* (London: E. Cotes, 1665), A2v.

[127] Greenberg, "Plague," 517-22. Slack, *Impact of Plague*, 151.

was past, did the printer reduce his production to the approximately 2500 bills that could be printed on a single press in one day.[128]

Londoners assiduously collected and evaluated the weekly mortality statistics printed in the bills over the course of plague epidemics. During the 1636 plague, one preacher noted how his parishioners "haue beene and are very diligent in enquiring after the weekly Bils of mortality, and they that could first obtaine the Bill from their Parish Clarks, haue acknowledged to be most beholden vnto them."[129] One anonymous Londoner faithfully filled out a comparative chart of weekly death tolls, subdivided by geographical area, in a printed broadside that listed remedies for the plague and exhorted its readers to "Live well. Die well." Merchants such as Edward Wood, who lived in Littleton but had business dealings in London, followed the bills just as carefully and requested their local factors send them copies with their letters.[130] Others acquired the same information by subscribing to newspapers such as the *London Gazette*, which printed summaries of the Bill of Mortality on the back of their 1665-6 broadsides.[131] The newspapers were also a source of provincial statistics, so that people could compare the extent of the infection in various localities.[132] Even Daniel Defoe, in his fictional account of the 1665 plague, maintained a running commentary on the Bills of Mortality.[133]

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[128] Greenberg, "Plague," 525.

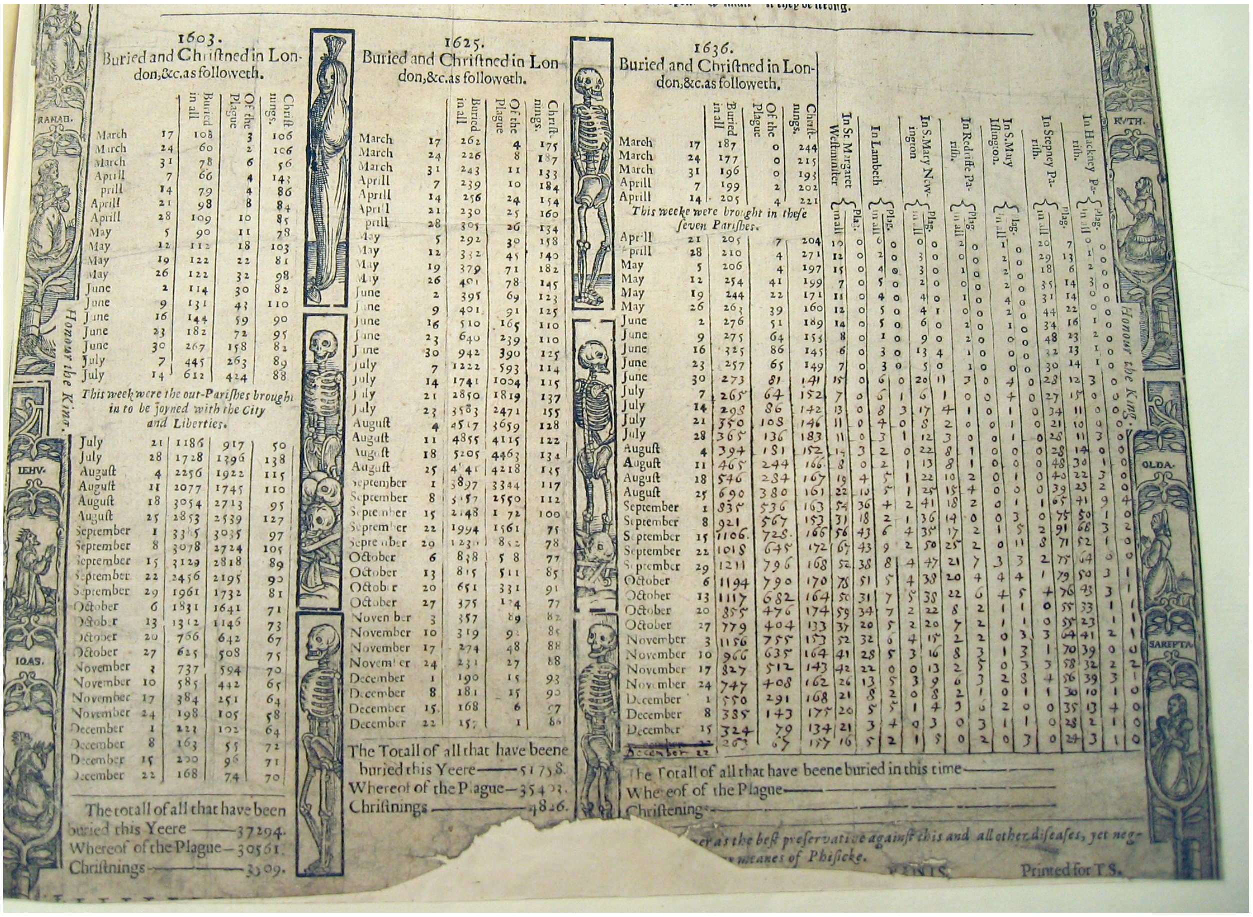
[129] I.D., *Salomons Pest-Hovse, or Tovver-Royall* (London: Henry Holland, 1636), A4v.

[130] LMA, ACC/0262/043, f. 23r, 96r.

[131] A complete archive of early *London Gazette* issues can be found at http://www.london-gazette.co.uk

[132] Many provincial towns instituted their own Bills of Mortality in imitation of the London bills, and by 1665 the London newspapers could confidently report news about the plague in Gosport, Yarmouth, Cambridge, Bristol, and Norwich. Slack, *Impact of Plague*, 239, 245.

[133] While not a factual account of the 1665 epidemic, Defoe's account was written in response to the 1721-2 Marseilles outbreak that caused a major plague scare in England. Daniel Defoe, *A Journal of the Plague Year* (London: The Falcon Press, 1950), 8-10, 18, 56, 111. Text taken from the first edition, London, 1722.



Handwritten Mortality Numbers in a 1636 Plague Broadside[134]

In one of the most famous diaries of the seventeenth century, Samuel Pepys recorded a weekly summary of the Bills of Mortality from June, 1665 until the following May. His diary is invaluable for providing a first-hand account of the passion for and popular discussion of plague numbers during a London epidemic. Even before Pepys began tracking the bills, their numbers were the talk of the city. In a May visit to a coffeehouse, he found "all the news is of the Dutch being gone out – and of the plague

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[134] Anonymous, *Lord Have Mercy Upon Us* (London: R. Young and M. Flesher, 1636). Guildhall Library, 424.9 (Bills of Mortality 1602-1666), 21.

growing upon us in this town and of remedies against it."[135] By August, the plague had grown so dangerous that during a ride through London, Pepys found

> all the way, people, Citizens, walking to and again to enquire how the plague is in the City this week by the Bill – which by chance at Greenwich I had heard was 2010 of the plague, and 3000 of all diseases; but methought it was a sad question to be so often asked me.[136]

A week later, at his office, Pepys and his coworkers were unable to concentrate on work and instead sat around discussing the plague numbers, "in great trouble to see the Bill this week rise so high."[137] Even at the official day of Thanksgiving to celebrate the end of the epidemic, in November of 1666, the numbers in the bills were on peoples' minds: "Lord, how the town doth say that it is hastened before the plague is quite over, there dying some people still."[138] There was thus a general consensus among the population of seventeenth-century London that the Bills of Mortality provided valuable, quantitative information on the severity of a plague epidemic.

Of all the information provided by the Bills of Mortality, increases in the death toll came under the most scrutiny and those people who responded with fear or flight most likely equated increasing death tolls with an increased chance of death. One preacher noted how increases in the bills frightened his parishioners, "made them murmure, and proiect to flee to their Country-houses here or there, and peraduenture to send beforehand their Wiues, Children, and Houshold-stuffe: yea, very carefull they haue

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[135] Samuel Pepys, *The Diary of Samuel Pepys*, ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1972), 6:108.

[136] Pepys, *Diary*, 6:180.

[137] Pepys, *Diary*, 6:187.

[138] Eight people had died of the plague that previous week, and seven more would die in the week to come. Pepys, *Diary*, 7:376-7.

been, & are for this their bodily safegard."[139] Both Pepys' diary entries and Defoe's novel show the same trend. Early in the 1665 epidemic, Pepys noticed plague deaths had risen by fifty percent in one week, hitting "267 – where is about 90 more then the last." He concluded that there was now an unacceptable level of risk for his family and responded by both putting "all my affairs in the world in good order" and "sending of my wife's bedding and things today to Woolwich, in order to her removal thither."[140] Later in the epidemic, when the bill first topped a thousand – and again, when the first plague death occurred in his parish – Pepys similarly interpreted the numbers as indicating an increased chance of his own death. His thoughts turned once more towards "setting some papers in order, the plague growing very raging and my apprehensions of it great."[141] While Defoe's fictional protagonist chose to stay in London and recklessly gallivanted about town, exploring plague pits out of curiosity, his narrator's elder brother swiftly "sent his wife and two children into Bedfordshire, and resolved to follow them" after he had set his business affairs in order. The brother stayed in London for several weeks, hoping to convince the narrator to join them, but eventually the risk of contracting the plague grew too high to allow further delay; "the bills were risen to almost 700 a week, and my brother told me he would venture to stay no longer."[142]

Indeed, people relied so heavily on the Bills of Mortality to evaluate the severity of plague outbreaks that there was real incentive to minimize death tolls by underreporting. At the start of the 1665 epidemic, the aldermen of Norwich attempted to hide the outbreak of plague by restricting local bills and falsifying the numbers reported

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[139] I.D., *Salomons Pest-Hovse,* A4v.

[140] Pepys, *Diary*, 6:142, 145, 147.

[141] Pepys, *Diary*, 6:163, 180.

[142] Defoe, *Journal*, 15-8.

to London papers.[143] Even during the height of the epidemic, when there was no hiding that plague deaths were occurring, not all clerks were completely honest about their numbers. Pepys recorded his concerns over underreporting after a chance meeting in the street with his parish clerk

> who upon my asking how the plague goes, he told me it encreases much, and much in our parish: 'For,' says he, 'there died nine this week, though I have returned but six' – which is a very ill practice, and makes me think it is so in other places, and therefore the plague is much greater then people take it to be.[144]

Pepys was thus concerned that underreporting would cause people to incorrectly evaluate the severity of the epidemic, which would have particularly ill effects for anyone who based their risk-aversion decisions on the bills.

Clerks were not the only ones responsible for underreporting. Before they could add a death into the parish register, an official cause of death had to be determined by the searchers – usually poor women – who inspected dead bodies for "tokens" of plague. John Graunt, in his analysis of plague deaths, calculated that the plague was often underreported by "as many as one to four, there being a fourth part more dead of other casualties that year, then the years preceding or subsequent" and that the fault lay with "the poor Searchers, out of ignorance, respect, love of money, or malice" returning false verdicts. Graunt's solution, however, was simple: look at "the number that died of other diseases, and the casualties the weeks immedately before the Plague begun," and subtract

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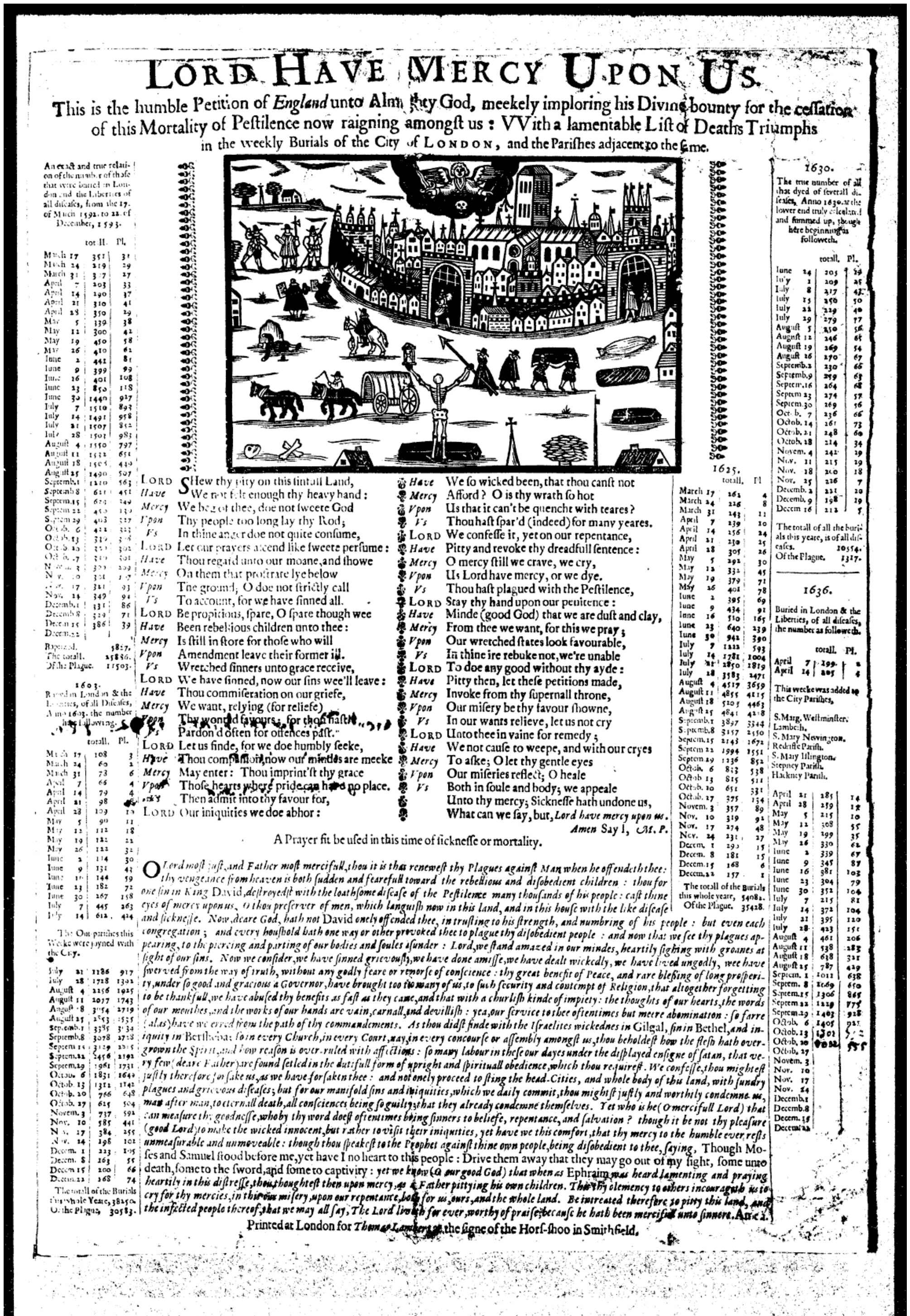
[143] Slack, *Impact of Plague,* 256.

[144] Pepys, *Diary*, 6:187.



LORD HAVE MERCY UPON US.

This is the humble Petition of *England* unto Almighty God, meekely imploring his Divine bounty for the cessation of this Mortality of Pestilence now raigning amongst us: VVith a lamentable List of Deaths Triumphs in the weekly Burials of the City of LONDON, and the Parishes adjacent to the same.

LORD Shew thy pity on this sinfull Land,
Have We not felt enough thy heavy hand:
Mercy We beg of thee, doe not sweete God
Vpon Thy people too long lay thy Rod;
Vs In thine anger doe not quite consume,
LORD Let our prayers ascend like sweete perfume:
Have Thou regard unto our moane, and showe
Mercy On them that prostrate lye below
Vpon The ground; O doe not strictly call
Vs To account, for we have sinned all.
LORD Be propitious, spare, O spare though wee
Have Been rebellious children unto thee:
Mercy Is still in store for those who will
Vpon Amendment leave their former ill.
Vs Wretched sinners unto grace receive,
LORD We have sinned, now our sins wee'll leave:
Have Thou commiseration on our griefe,
Mercy We want, relying (for reliefe)
Vpon Thy wonted favours; for thou hast
Vs Pardon'd often for offences past.
LORD Let us finde, for we doe humbly seeke,
Have Thou compassion, now our mindes are meeke
Mercy May enter: Thou imprint'st thy grace
Vpon Those hearts where pride can have no place.
Vs Then admit into thy favour for,
LORD Our iniquities we doe abhor:
Have We so wicked been, that thou canst not
Mercy Afford? O is thy wrath so hot
Vpon Us that it can't be quencht with teares?
Vs Thou hast spar'd (indeed) for many yeares.
LORD We confesse it, yet on our repentance,
Have Pitty and revoke thy dreadfull sentence:
Mercy O mercy still we crave, we cry,
Vpon Us Lord have mercy, or we dye.
Vs Thou hast plagued with the Pestilence,
LORD Stay thy hand upon our penitence:
Have Minde (good God) that we are dust and clay,
Mercy From thee we want, for this we pray;
Vpon Our wretched states look favourable,
Vs In thine ire rebuke not, we're unable
LORD To doe any good without thy ayde:
Have Pitty then, let these petitions made,
Mercy Invoke from thy supernall throne,
Vpon Our misery be thy favour showne,
Vs In our wants relieve, let us not cry
LORD Unto thee in vaine for remedy;
Have We not cause to weepe, and with our cryes
Mercy To aske; O let thy gentle eyes
Vpon Our miseries reflect; O heale
Vs Both in soule and body; we appeale
Unto thy mercy; Sicknesse hath undone us,
What can we say, but, *Lord have mercy upon us.*
Amen Say I, *M. P.*

A Prayer fit be used in this time of sicknesse or mortality.

Printed at London for Thomas Lambert, at the signe of the Horse-shoo in Smithfield.

Plague Broadside Combining Prayer and Numbers from the Bills of Mortality[145]

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[145] Martin Parker, *Lord Have Mercy Upon Us* (London: Thomas Lambert, 1636).

that number from the current totals. The remainder "are indeed dead of the Plague, though returned under the notion of those other diseases."[146]

While most of London's population used mortality statistics to quantify their risk of plague, some English clergymen who defended God's providential control of epidemic disease used mortality statistics to instead evaluate God's wrath. James Balmford, during the 1603 epidemic, equated God's love with a decreasing number of deaths reported by the bills and exhorted his congregation to "coole not in your deuotion, because the number of the buried in our parish is fallen (blessed by God) fro*m* 305. to 51. in one weeke, and from 57. to 4. buried in one day. Shall our loue coole, whe*n* Gods loue is kindled?"[147] An anonymous preacher, three decades later, complained that his parishioners had not "humbled themselues in Prayer, endeauouring to depart from their sinnes" when God made His wrath apparent via an increasing number of deaths, nor had they "returned to God by the way of thankfulnesse for such his great mercy & forbearance" when He allowed the number of deaths to decrease again.[148]

However, as argued above, these two different worldviews were capable of coexisting in the seventeenth century. During the 1636 epidemic, printed broadsides containing prayers for God's mercy were surrounded by death counts pulled from the Bills of Mortality, quantitatively reinforcing both the extent of God's wrath and the direness of London's situation. In 1665, clergyman Matthew Mead wished "we had Weeklie Bills of such Sins" as brought in the plague and used the language of probability to predict it was "great odds, but the Contagion may shortly reach" the unrepentant

[146] Graunt, *Reflections*, 2.
[147] Balmford, *Plague's Infection*, A4v.
[148] I.D., *Salomons Pest-Hovse,* A4v.

sinner.[149] Regular fast days and days of Thanksgiving were observed throughout all the seventeenth-century epidemics, in hopes that such devotions would have a material effect on the death tolls. As one Interregnum proclamation triumphantly explained, "the two weeks Bills of Mortality, immediately after the Fast upon that occasion, were brought to the half of what they were the week before, and did amount not to more discernably then in the healthiest times."[150] Prayers to appease God's wrath had thus reduced Londoners' chance of death by plague to negligible levels. Proof of God's providence was in the numbers.

Throughout the seventeenth century, ordinary English men and women used quantified chance to interpret risky situations in their daily lives. The increasingly widespread adoption of life and fire insurance reflected popular acceptance of the idea that risk could be assigned odds and monetary values – even if people weren't entirely clear yet on how to calculate those odds. Nor was this idea limited to those who had the resources to pay insurance premiums, as evidenced by the popular interest in mortality statistics, particularly the London Bills of Mortality. During plague years, people used the quantitative information in the bills to evaluate risk and even those who urged people to put their faith in God used the bills of support their arguments. By the end of the century, the idea that chance and risk could be quantified had become a firmly entrenched part of the English worldview.

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[149] Matthew Mead, *Solomon's Prescription For the Removal of the Pestilence: or, The Discovery of the Plague of our Hearts, in order to the Healing of that in our Flesh* (London: 1665), 3, 81.

[150] Oliver Cromwell, *A Declaration of His Highnes the Lord Protector For a Day of Publick Thanksgiving, With An Order of His Highnes Council in Scotland For the Government thereof, For a Day of Publick Thanksgiving in Scotland*, (Edinburgh: Christopher Higgins, 1658), 5.

Conclusions

Over the course of the sixteenth century, widespread familiarity with gaming enabled the development of probabilistic ideas about chance and the creation of a new word, *odds*, to express those ideas. While the more puritan clergymen wrangled with the theological implications of a chance based on natural laws, particularly its relationship to God's providence, others drew upon the doctrine of secondary causes to reconcile chance and providence. Popular familiarity with gaming odds, combined with a belief in the existence of natural laws, led to the idea that the likelihood of all future events – and not just the roll of a die – could be quantified. This quantified chance proved particularly useful for both predicting and thus averting risk in people's daily lives. The popular belief in quantified chance manifested itself in both the widespread adoption of insurance and the popularity of mortality statistics in the seventeenth century.

It is, however, important not to overstate the mathematical facility of the population of seventeenth-century England. At the height of the 1665 plague epidemic, Samuel Pepys heard a sermon preached by the Duke of Albemarle's chaplain, who chastised the bill-readers by proclaiming that "All our physicians can't tell what an ague is, and all our Arithmetique is not able to number the days of man." Only God's providence could determine the future, thus all the work of human physicians or mathematicians had been for naught. Pepys, listening to this sermon, agreed with the chaplain's conclusion, but not with the reasons behind it: "God knows, [it] is not the fault of arithmetique, but that our understandings reach not that thing."[151] Yet even though

[151] Pepys, *Diary*, 6:289.

mathematicians had not yet developed mathematically rigorous theories of probability and statistics, the men and women of seventeenth-century England had already embraced the concept of quantified chance.

Chapter Seven

"Davids Arithmetick"[1]
Quantifying the People

In 1676, Lord Treasurer Danby organized a census of communicants, in order to determine "what proportion or disproportion of number there is betwixt Papists and non Papists, as likewise betwixt other Non-Conformists and Conformists" in England.[2] The Compton Census was conducted through established channels. Information was collected at the parish level by rectors, victors, and churchwardens, then collated and summed at the diocesan and archidiaconal levels.[3] While the local mechanisms of data collection were long established, the questions asked by the census were new and unfamiliar, leading to a fair amount of confusion about who was actually eligible to be counted as a communicant. Approximately 20% of the parish officials who conducted the ground-level census anxiously included detailed information about the categories of people they had chosen to count. The rector of Knowlton provided a typical explanation of his numbers: "If by Persons inhabiting be meant Housholders, the Families are two; but otherwise of grown Persons, & such as be of yeers to come to the Sacraments of the Lords Supper, there may be sixteen."[4] While some returns only contained estimates of the parish population, others went to the opposite extreme and listed all the parish's

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[1] Thomas Grantham, *A Marriage Sermon. A Sermon Called A Wife Mistaken* (London: 1641), 12.

[2] Anne Whiteman, ed., *The Compton Census of 1676*, British Academy Records of Social and Economic History, n.s., 10 (London: 1986), xxiv.

[3] This decentralized model of government was also followed for the collection of taxes such as the subsidies, the organization of musters, and the registration of births, marriages, and deaths. For more on the nature of early modern governments, see Edward Higgs, *The Information State in England* (New York: Palgrave McMillan, 2004), 30-39; Michael J. Braddick, *State Formation in Early Modern England c. 1550-1700* (Cambridge: Cambridge University Press, 2000); Steve Hindle, *The State and Social Change in Early Modern England c. 1550-1640* (New York: St. Martin's Press, 2000).

[4] Whiteman, *Compton Census*, xxiv, xxxvi.

inhabitants – adult or child – by name, rank, and household. Particularly enthusiastic parish officials, such as those in St. Nicholas's Warwick, even compiled "an exact account, in all respects, according to the best information we can get, by going to every house in the parish for our information herein."[5]

The Compton Census was not a neutral attempt to collect demographic data on England's adult population. Rather, it had a specific policy goal of reassuring Charles II there was no truth to the allegations that papists and nonconformists "did very much exceed" the number of English men and women who conformed to the Church of England.[6] This has led some historians, notably Thomas Richards, to argue that the census results were manipulated, "driving up the ratio of Conformists to Dissenters as high as possible." However, Anne Whitman's recent and detailed examination of both the original returns and tabulated data indicates that most discrepancies were arithmetical mistakes, copying slips, or adjustments meant to compensate for inconsistencies in the collection process, such as the failure to include women.[7]

Despite Danby's intentions, popular interest in the Compton Census numbers ended up becoming stronger than the interest of the government that had sponsored it. The census failed to have any substantial impact on monarchical policy, even though its results were presented to Charles II, then presented again to both James II and William III. Instead, interest in the census spread far beyond the government. Its results were cited in religious treatises, calculated and recalculated by political arithmeticians, and

[5] Whiteman, *Compton Census*, xlii-iii.

[6] Whiteman, *Compton Census*, xxiv.

[7] Whiteman, *Compton Census*, xlviii-xlix. For a detailed analysis and rebuttal of Richards' arguments, see Appendix C, xcii-c.

even published in a Dutch newspaper.[8] Consequently, people were able to use the census data to discuss important religious and political issues in terms of numbers.

By the early modern period, censuses were a familiar and long-standing government practice that focused primarily on the assessment of wealth for the purposes of taxation and warfare. However, this association of censuses and taxation led to persistent, widespread reluctance to support anything that resembled "numbering" people. The Church of England's parish registers largely avoided this association, which resulted in the registers forming the early seventeenth-century foundation for both mortality statistics. The analysis of mortality statistics in times of plague paved the way for more general attempts to use demographic data for social analysis rather than the extraction of the population's resources.

Over the course of the seventeenth century, people increasingly used the analysis of demographic data to support social and political arguments. This new way of thinking with numbers led to the post-Restoration articulation of a formal practice of "political arithmetic" that was designed to support monarchical policymaking. However, by the end of the century, proponents of political arithmetic had redefined their work as the analysis of neutral demographic data, divorced from any particular political agenda. This led to the eventual transformation of political arithmetic and demographic statistics from a specific tool of government policymaking to a general method for using numbers to understand the population and society of early modern England.

[8] Paul Slack, "Government and Information in Seventeenth-Century England," *Past & Present* 184, (Aug., 2004), 46-7.

Numbering the People

Censuses were not an early modern invention, but rather an ancient practice referenced in classical history and the Bible. Both in antiquity and in the early modern period, censuses were conducted primarily for the purpose of assessing financial or military resources and extracting those resources from the portion of the population best able to provide them. The popular association of censuses and taxation resulted in resistance to the idea of the central government's various attemps to "number" people, with only the locally-controlled and uncollated parish registers escaping this association. As a result, the most accurate and complete source of information on the early modern English population was also the most inclusive, as the registers were supposed to include all the parish's births, marriages, and deaths, regardless of a person's age or social status.

The people of early modern England were familiar with the concept and antiquity of censuses. Those who had attended grammar school encountered the ancient censors of Rome, who were employed to perform "a generall survey and numbring of the people" and whose census results "were reckoned and entred into the Censours bookes of cittizens."[9] Other census-takers could be found in sermons about the Biblical figures of Moses, Saul, and David. Indeed, Moses' censuses were such a prominent component of his Old Testament story that the "third book of Moses is called Numbers, because therein are related two severall numbrings of the people."[10] These censuses were not intended to count the entire population but rather free, adult males "such as could cary armes, from

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[9] Livy, *The Romane Historie Written by T. Livius of Padua... Translated out of Latine into English, by Philemon Holland* (London: Adam Islip, 1600), 655.

[10] Arthur Jackson, *A Help For The Understanding of the Holy Scripture... Containing certain short notes of exposition upon the five books of Moses* (London: Roger Daniel, 1643), 321.

20 yeeres vpward." By Moses' second survey, the Israelites numbered "six hundred twentie foure thousand seuen hundred seuenty three... besides the women, slaues, old men, and youth vnder twentie yeres, which were at the least twice as many" but whose exact numbers were considered unimportant.[11]

Of all the ancient censuses, however, the most familiar was conducted by David, who God punished by sending a deadly plague. Early modern clergymen considered the census one of David's three great sins: "his adulterie, murther, and numbering of the people."[12] David's affair with Bathsheba and murder of her husband, Uriah, were sins that needed little explanation, but the problems inherent in David's census were not so obvious. Attempts to explain David's sin ranged from his trespassing on the prerogatives of the Roman Empire to forgetting to "leuie the summe of halfe a sickle vpon euery one" counted. Some even argued – conveniently ignoring the precedents of Moses and Saul – that it was completely unlawful to number the people since God had promised they would "be *innumerable* as the starres of the skie, and the sand of the Sea: and therefore it belonged vnto God onely to number that, which was innumerable."[13]

However most clergymen agreed that the fault lay not in the census itself but rather in David's sinful reasons for conducing the census – a combination of pride, vanity, and curiosity. Hugh Latimer, the Bishop of Worcester, preached a sermon to Edward VI in which he explained that "it was not the numbrynge of the people that offended God, for a king may number his people, but he dyd it of a pride, of an elacion of mynde, not

[11] Jean Bodin, *The Six Bookes of A Common-Weale... Out of the French and Latine Copies, done into English by Richard Knolles* (London: G. Bishop, 1606), 639.

[12] William Perkins, *A Commentarie, or Exposition, vpon the fiue first Chapters of the Epistle to the Galatians* (Cambridge: John Legat, 1604), 503.

[13] Andrew Willet, *An Harmonie Vpon the Second Booke of Samvuel* (Cambridge: Cantrell Legge, 1614), 139.

accordyng to Gods ordinaunce, but as hauing a truste in the numbre of hys men, thys offended God."[14] Sixty years later, Andrew Willet, the rector of Barley in Hertfordshire, was only slightly less harsh, arguing David's sin lay in "entring into a needlesse action, wherof there was no cause, but onely Dauids curiositie."[15] Shortly before the Restoration, the nonconformist Anthony Burgess argued that David's sin was in seeking to conduct a census "out of vain and ambitious ends," while William Guild, a Church of Scotland minister, placed the blame on all three motivations: "curiosity, vain confidence and pride, which makes the action vicious and sinfull."[16]

Although David's census may have been unlawful, the ability to conduct a census was still one of his rights as a monarch. James Howell argued that the "*Census*, the numbring of the people" was one of the "six *Praerogatives* which belong to a *Souvrain Prince*," alongside powers such as control of the army and the ability to increase or decrease the value of coin.[17] Howell's prerogatives were intended to advance the military and economic welfare of a prince's kingdom, and the census had the ability to do both. The census would prove particularly useful in times of war or expansion, as

> [t]he benefits which redounded to the publike by this numbring of the people, were infinite: for first they knew the number, age and qualitie of the persons, and what numbers they could draw foorth, either to go to the warres, or to remaine at home; either to bee sent abroad in colonies, or to bee imployed in publike workes of reparations, and fortifications.[18]

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[14] Hugh Latimer, *The seconde Sermon of Maister Hughe Latimer, whych he preached before the Kynges maiestie, w[ith]in his graces Palayce at Westminster* (London: Ihon Day, 1549), S5v.

[15] Willet, *Harmonie*, 139.

[16] Anthony Burgess, *A Treatise of Original Sin* (London: 1658), 238. William Guild, *The Throne of David, or An Exposition of the Second of Samuell* (Oxford: W. Hall, 1659), 325.

[17] James Howell, *Proedria Vasilike, A Discourse Concerning the Precedency of Kings* (London: James Cottrel, 1664), 84.

[18] Bodin, *Six Bookes*, 640.

A prince's population was thus one of his most important resources, and only a census would enable him to utilize his people for endeavors ranging from fighting battles and colonization abroad to repairing fortifications at home.

The census was thus an essential tool of good government, however the only valid reasons to conduct one were the advancement of military or economic goals. As Andrew Willet explained, censuses were only lawful

> upon two necessarie occasions: as when either a publike collection is to be made of tribute, or subsidie money, unlesse account should be taken, the burthen should lye upon a few, and others should escape. Again, when any great warres are taken in hand, it is fit that the people should be mustered, that choice may be made of such as are fit for warre.[19]

It was legitimate to conduct a census to assess people's fair share of either a subsidy or tribute payment. A census could also be used to determine the number of men available to fight in a present or expected war, and to choose the most able of them. Under such circumstances, David could have freely conducted a census, however at the time of his actual census, "Warre he had now none in hand... Neither intended he to make any collection."[20] David's census was thus an abuse of his royal prerogative because he numbered the people for his own vanity, curiosity, and pride, as opposed to the public good.

In practice, censuses for taxation and military levies had a long history within England, ranging from the infamous Domesday book to the 1334 assessment that set perpetual tax rates for the "fifteenth and tenth."[21] These English censuses were more

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[19] Andrew Willet, *Hexapla in Genesin & Exodum: That is, A sixfold commentary upon the two first Bookes of Moses, being Genesis and Exodvs* (London: John Haviland, 1633), 570.

[20] Willet, *Harmonie*, 139.

[21] The fifteenth and tenth was a direct tax in which each parish and township was assigned a quota based on the amount of tax they had paid in 1334, minus poverty deductions. The parish or town leadership was then allowed to decide amongst themselves how they wanted to distribute their quota among the

associated with taxation than mustering troops and the very word *census* had financial connotations in both its Latin and English usage. In 1538, Sir Thomas Elyot defined a census as "yerely reuenues. Also valuation of goodes. Also a subsidie, the numbring of the people."[22] Other authors variously defined a census as the "valuation of euery mans goods," "poll mony," "tribute or taxe," and "*revenues*, which a man is esteemed to have, and accordingly is rated and pays Subsidies."[23] While some seventeenth-century authors might define a census as simply "Numbering the Citizens," it was generally understood that the census was conducted with an eye towards assessing the financial resources of the population.[24] This assessment would then be used to determine the amount each taxpayer would be liable for whenever Parliament granted the monarch a subsidy.

The granting of subsidies was a familiar occurrence during the sixteenth and seventeenth centuries. Although there had been at least ten attempts at directly-assessed taxes prior to the reign of Henry VIII, they were largely failures. The subsidy only acquired its early modern form during the war years of the 1510s, under the direction of Cardinal Wolsey. Subsidy commissioners were appointed to assess the wealth of the population, including both annual income and the value of moveable goods. The taxpayer would swear under oath to the value of their assets, then pay a proportional –

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population. R.W. Hoyle, "Crown, Parliament and Taxation in Sixteenth-Century England," *The English Historical Review* 109, no. 434 (Nov. 1994), 1175.

[22] Thomas Elyot, *The Dictionary of syr Thomas Eliot knyght* (London: Thomae Bertheleti, 1538), C5v.

[23] Bodin, *Six Bookes*, 637. Willet, *Hexapla*, 587. William Howell, *An Institution of General History from the beginning of the World to the Monarchy of Constantine the Great* (London: Henry Herringman, 1661), 167. Simon Patrick, *A Paraphrase Upon the Books of Ecclesiastes and the Song of Solomon with arguments to each chapter and annotations thereupon* (London: W.H., 1700), 81.

[24] Thomas Hearne, *Ductor Historicus: Or, A Short System of Universal History and an Introduction to the Study of that Science Containing a Chronology of the most Celebrated Persons and Actions from the Creation to this Time* (London: Tim Childe, 1698), 376.

rather than fixed – amount of taxes.[25] These subsidy valuations were a thorough census of potential taxpayers as they certified "the names and surnames of euery parsone man and woman of thage of .xv. yeres or aboue" who was not on charity, as well those under fifteen with "landes. tenement rentes, fees, annuytes, offyces, or Corodyes, of the yerely value of .xx.s. or aboue, or hauyng goodes or Catalles, mouable, coyne, plate, Stocke or marchandyse on thyssyde the see, or beyonde the see, to the value of .xl.s. or aboue."[26] Subsidy valuations proved so useful that they often formed the basis for assigning a host of other taxes, such as church rates, scavenger rates, poor rates, militia rates, and plague rates.[27]

While subsidy valuations were fairly accurate during the first half of the century, the 1563 elimination of the taxpayer oath was followed by rampant underreporting and tax evasion. In the wealthy London wards of Cordwainer and Broad Streets, the percentage of taxpayers assessed at £50 or more dropped from 30% in 1563 to a mere 5.5% in 1598. At the same time, the percentage of taxpayers assessed at £3 in goods – at that time the lowest assessment level – rose from 20% to 40%.[28] By the 1580s, underreporting was such a well-known problem with the subsidy valuations that the government attempted to divorce them from military rates. In 1584, the earl of Huntingdon ordered his militia commissioners "to have regarde not to the favorable and easie taxacion sett downe in the subsydie booke but what there levings are inded by reasonable construction." Two years later, Yorkshire justices of the peace who proved

[25] Hoyle, "Crown," 1175-1177. Ian W. Archer, "The Burden of Taxation on Sixteenth-Century London," *The Historical Journal* 44, no. 3 (Sept. 2001), 605.

[26] Corporation of London, *Commyssioners for our soueraygne lorde kynge* (London: 1515), A1r.

[27] Archer, "Burden," 601.

[28] Archer, "Burden," 610.

reluctant to meet their military obligations were even threatened with the accurate assessment of their subsidy valuations: "yt maye happen that the observacion of other lawes will be required of them which will touche their purses more deeplie then this thinge doth."[29] Despite almost yearly subsidies granted from 1581 until the end of Elizabeth I's reign in 1603, the combined total of these post-oath subsidies was still less than the subsidy revenues of the 1540s and 1550s.[30]

During the seventeenth century, the decline of subsidy revenues encouraged Stuart monarchs to invent new ways to assess and directly tax the wealth of the English population. Customs duties and the excise proved the most durable of these taxes, while quota taxes, such as the ship tax, proved the most reliable method for raising a specific sum of money. However, both the method of assigning quotas was often perceived to be grossly unfair, particularly after the 1640s, when Royalists could claim that their quotas had been artificially inflated as punishment for their politics.[31] The financial demands of mid-century warfare also led to the levying of income-graduated poll taxes in 1641 and 1660, as well as the creation of an entirely new form of census-based taxation, the hearth tax.[32] Since the hearth tax was based on a combination of property values, income, and number of hearths in each household, it proved a far more reliable indicator of household

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[29]Braddick, *State Formation*, 237-8.

[30] Parliamentary subsidies totaled £105,643 in the 1540s and £77,883 in the 1550s. After the oath was dropped, revenues dramatically decreased to £33,417 in the 1560s and £27,821 in the 1570s. Even with near-yearly-subsidies, it only rose again to £38,607 in the 1580s and £57,383 in the 1590s. Archer, "Burden," 608-9.

[31] Braddick, *State Formation*, 254.

[32] Beginning in 1663, the hearth tax included lists of both those "chargeable" and exempt from the tax. From 1684 onwards, assessors were also required to include a list of household residents and the names of those responsible for empty houses. Paul Seaman, ed., *Norfolk Hearth Tax Exemption Certificates 1670-1674: Norwich, Great Yarmouth, King's Lynn and Thetford* Norfolk Record Society 65 (London: British Record Society, 2001), xxvi, xxxiii-iv. Paul Slack, "Measuring the National Wealth in Seventeenth-Century England," *The Economic History Review*, n.s., 57, no. 4 (Nov., 2004), 612.

wealth than taxpayers' monetary self-reports alone. However, it also created a source of general discontent, as it required people to let strangers into their homes to count their hearths, which led to its 1696 replacement by a window tax that could be assessed from the outside.[33]

Not all early modern censuses were explicitly related to taxation, though most had potential financial applications. A 1522 survey of England's military capacity formed the basis for the loans of 1522-3 and would have been used to assess the 1525 Amicable Grant had it not fallen through.[34] The 1535 *Valor Ecclesiasticus* assessed the values of Church properties with an eye towards confiscation, rather than taxation, as did the Chantry Commissions of the 1540s.[35] Even the muster rolls maintained throughout the early modern period had a financial, as well as military, component. They included both the names of men who could be called out for the militia and the names of taxpayers who were required to furnish them with uniforms, arms, and other equipment. A set of 1580 Privy Council muster instructions required "a collection made of mony, indifferentlye and without chardge of the poore, to supplye as well that parte [of armor] that shalbe founde unserviceable, as for the increase nowe at this tyme allotted in the scedule."[36] Sir John Smythe's instructions for militia officers likewise discussed the possibility of "imperfections" in a soldier or horseman's equipment and suggested the officer

> giue order vpon some conuenient penaltie according to the default or imperfection to be imposed vpon the partie that doth set forth the horse

[33] Braddick, *State Formation*, 256.

[34] Hoyle, "Crown," 1178.

[35] Slack, "Government," 38.

[36] The muster books for Hertfordshire include several lists of those required to pay towards the muster, supply equipment, or maintain a watch on the local beacon. Ann J. King, ed., *Muster Books for North and East Hertfordshire, 1580-1605*, Hertfordshire Record Publications 12, (Hitchin: Hertfordshire Record Society, 1996), 5, 146-7, 170, 175-207.

> and horseman, that the same with al speede by a certen prefixed day be supplied or amended.[37]

Thus supplying men for the militia led to the ancillary costs of equipping those men – the so-called "coat money." By the end of the sixteenth century, the rising costs of clothing and equipment led the crown to reassign the responsibility of provisioning the troops; they instead required a tax of 70*s* per man to be paid to the Exchequer, which would then contract out the provisioning to independent suppliers.[38]

The association of censuses and taxation continued throughout the seventeenth century, making financial self-interest the primary barrier to more frequent and reliable censuses. The government as a whole recognized the need for accurate information on its population. As early as 1619, the Virginia colonial assembly passed a registration bill requiring annual quantitative reports of demographic data.[39] Between 1623 and 1700, the English government conducted twenty-one censuses of its various colonies in the West Indies and North America, while between 1671 and 1702, every colonial governor in England's growing empire was required to collect demographic statistics on their colony.[40] At the same time, however, the members of England's Parliament were reluctant to enact measures that would significantly impact their own wealth and resisted efforts to conduct thorough and accurate censuses of the population of England itself.[41]

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[37] John Smythe, *Certen Instructions, Obseruations and Orders Militarie, Requisit for all Chieftaines, Captaines, and Higher and Lower Men of Charge, and Officers, to Vnderstand, Knowe and Obserue* (London: Richard Iohnes, 1594).

[38] Archer, "Burden," 615.

[39] James H. Cassedy, *Demography in Early America: Beginnings of the Statistical Mind, 1600-1800* (Cambridge: Harvard University Press, 1969), 18-19.

[40] Robert V. Wells, ed., *The Population of the British Colonies in America Before 1776: A Survey of Census Data* (Princeton: Princeton University Press, 1979), 5, 7, 13. For a complete list of the 124 censuses conducted between 1623 and 1775, see pp. 8-11.

[41] England only began conducting regular censuses of its own population in 1801, Wells, *Population*, 7. Slack, "Government," 47.

During a 1657 debate over the need to make "equal and equitable" assessments, members of Parliament stonewalled a new census, noting "that the chief magistrate should know men's estates was always avoided." They also implied that any attempt to conduct a census might bring the fate of David down upon England by claiming the "court-project" looked "something like the numbering of the people."[42] Numbering colonists was an acceptable process and yielded valuable information for their home government, but numbering taxpayers – particularly taxpayers who also happened to be MPs – was best avoided.

Conversely, the one type of census that had the least financial implications was also the least contentious of the early modern censuses: the parish registers. Established in 1538, the parish registers recorded every birth, marriage, and death that occurred within the Church of England and only became a source for taxation with the passage of the Birth, Marriages, and Burials Duty Act of 1695.[43] While a register could not provide an account of the parish's population at any one moment in time, it did provide an accurate and thorough census of people as they passed through critical moments in their lives. The registers were particularly significant in that they were not limited to the rich, taxpaying part of the population, nor the part consisting of able-bodied males fit for military service, but rather sought to collect information on the entire population. This inclusiveness would prove to be vital for the work of early demographers in the seventeenth century.

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[42] Slack, "Government," 50.

[43] The act required a payment of 2*s* for a birth, 2*s*6*p* for a marriage, and 4*s* for a burial. There were additional payments required of the rich, gentlemen, bachelors, and widowers, while those receiving poor relief were exempt. Colin Brooks, "Projecting, Political Arithmetic and the Act of 1695," *The English Historical Review* 97, no. 382 (Jan., 1982), 32.

Most censuses in early modern England were geared towards meeting the financial and military needs of the English central government. The popular association of government censuses and taxation made it difficult to accurately assess the population's size, due to the censuses' limited focus, or its wealth, due to rampant tax evasion. Only the parish registers – which recorded births, marriages, and deaths for the entire population at the local, parish level – avoided the limitations of the fiscal-military censuses. As such, the information recorded in parish registers would form the basis of seventeenth-century attempts not only to number the people, but also analyze those numbers and draw conclusions about the state of the English population.

Thinking With Numbers

During the sixteenth century, both central and local governments collected information on the population, but rarely numerically analyzed that information. The main – but not only – exception to this trend were the Bills of Mortality, produced by aggregating the number of burials in London and other cities. Over the course of the seventeenth century, people increasingly attempted to analyze demographic data, particularly the Bills of Mortality, as evidence to support their political arguments. By the end of the seventeenth century, the work of these demographers made it possible to consider numbering the people not for an immediate financial or military purpose, but rather for analyzing long-term trends in the English population, for its own sake.

Although both central and local governments collected information on the population in order to facilitate taxation and military campaigns, this information was seldom summed or aggregated during the sixteenth century. Other than plague death tolls, there were only a few isolated instances where information was summed, such as the 1570 Norwich Census of the Poor, which produced an accurate tally of the Norwich poor.[44] For the most part, information on the population remained in list form and linked to individuals. Censuses of the dead, particularly those related to plague epidemics, were the most likely to be stripped of names and reduced to quantified – and numerically manipulable – form.

As discussed in Chapter Six, plague death tolls were probably first compiled some time in the 1520s, with surviving references dating back to at least 1528.[45] After the institution of parish registers, these numbers were aggregated from the plague deaths listed in the registers at the instigation of city governments or, in the case of London, a combination of city and central government. During the second half of the sixteenth century and on into the seventeenth century, plague death tolls were compiled in London, Bristol, Norwich, Exeter, Chester, York, Newcastle, Oxford, and other major cities.[46] These figures were used to inform governments' decision-making, such as quarantining travelers and goods from other cities, closing the city gates against outsiders altogether, or instituting plague rates to support those shut up in infected houses.

Intriguingly, despite the close association of David's census with plague, there seems to be no indication that people saw a causal relationship between cities numbering

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[44] The Norwich Census followed in the wake of an attempted uprising in the city, which led the city government to fear that the poor might join and strengthen any future rebellions. It was therefore necessary to enumerate the poor and suppress vagrancy to maintain social order. John F. Pound, ed., *The Norwich Census of the Poor, 1570*, Norfolk Record Society 40 ([Norfolk]: Norfolk Record Society, 1971), 8-9. Slack, "Government," 40n24.

[45] Stephen Greenberg, "Plague, Printing, and Public Health," *Huntington Library Quarterly* 67, no. 4 (Dec. 2004): 513.

[46] Paul Slack, *The Impact of Plague in Tudor and Stuart England* (Oxford: Clarendon Press, 1990), 111, 113, 120, 239.

their dead and the outbreak of plague. Even J.D.'s *Salomon's Pest-House*, which bewailed human sins and chastised people for putting their faith in numbers instead of God, failed to draw any general conclusions about censuses and plagues. Instead, J.D. discusses David's plague solely in terms of magisterial flight, noting "that plague [was] caused by his sinne, the numbring of the people, which caused such a sorrow in *Dauid*, that he was ready by his owne death to redeem the publike calamitie." J.D. then entreated magistrates to emulate David in staying to work for the good of their plague-stricken cities: "let not Magistrate forsake his Citie, nor the Minister his flocke" during an epidemic.[47] Yet nowhere did J.D. imply that these same magistrates were responsible for their plague outbreaks, in the same sense that David had been. Compiled mortality statistics were an effect, not a cause, of plague.

By the turn of the seventeenth century, as mortality statistics were becoming increasingly available to the general population, people began to see the possibilities inherent in analyzing demographic numbers. In 1603, Gerard Malynes – a Dutch Stranger and prominent London merchant – wrote a treatise on the balance of trade, arguing that a favorable balance of trade was the only way to increase the wealth, and thus the prosperity, of the realm.[48] To determine this balance of trade, Malynes claimed to "haue made a commparison of country and countries vnder the dominion of the Princes in Europe: so it is not very difficult for me to make a comparison of the wealth thereof." While he begged off doing many explicit calculations in his treatise, "fearing the

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[47] I.D., *Salomons Pest-Hovse, or Tovver-Royall* (London: Henry Holland, 1636), 8-9.

[48] Gerard Malynes, *Englands View, in the Vnmasking of Two Paradoxes* (London: Richard Field, 1603), A2v-A3r, 6.

reprehension of some *Apelles* (this being a matter of State)," he did venture to give one example of his work:[49]

> Yet to giue some glaunce of comparison betweene *England* & *France* the greatest kingdome of Europe: let vs take notice of the obseruation of *Polititians,* which affirme *England* properly to be devided into 52 thousand villages or hamlets... and to containe (as they say) 2800 thousand families, euery family 6 persons, is 6800 thousand persons: *England* containing by our computation but 34 millions 438 thousand measures of land square: whereas *Fraunce* containing 91 millions 350 thousand measures of land, is but esteemed to haue 4400 thousand families, and fiue persons to euery family: which is but 22000 thousand persons.[50]

Malynes thus considered it a matter of state to be able to calculate the size of the English population, as well as the size of the country, and compare it to other European countries. For the population, he did this by multiplying the size of an average family by the number of families in England. While it is unclear where he found the number of families – though his reference to the "obseruation of *Polititians"* implies he derived the number from government sources – or how he determined the average family size, Malynes' work represents an attempt to numerically analyze population information.

There were other early attempts to analyze demographic data for political purposes in the first half of the seventeenth century. In 1607, a Privy Council paper used subsidy and muster rolls to calculate the wealth and population size of Somerset and Northamptonshire. The paper then attempted to justify the enclosure of pasture lands by pointing out the greater wealth and population of enclosed Somerset, as opposed to unenclosed Northamptonshire. In 1613, Francis Bacon – a strong proponent of quantification – pointed out the analytic potential in the information that the government already gathered: "the greatness of a state in bulk or territory doth fall under measure; and

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[49] Malynes, *Englands View,* 134.

[50] Malynes, *Englands View,* 135-6.

the greatness of finances and revenue doth fall under computation. The population may appear by musters, and the number of cities and towns by charts and maps."[51] Others collected and analyzed information from new sources, such as Andrew Willet's 1614 analysis of livery company and prerogative court records that demonstrated charitable bequests had increased since the Reformation.[52]

The wide availability of the printed London Bills of Mortality made them a particularly useful source of demographic data and, during the relatively plague-free years between 1636 and 1665, people began to analyze the bills to support an increasing variety of arguments. An anonymous 1644 petition of "some hundreds of retaylers" argued that the abolition of the farthing as a coin of the realm had led to an increase in starvation among the poor. This increase in starvation could easily be seen by those "who observe the weekly Bills of Mortality; That many already departs this life by a new kind of Plague, for not having the old Tokens about them."[53] Later that decade, London draper Rice Bush's treatise on caring for the poor advocated for the establishment of a "*Generall store-house*... to receive such food as might be frugally saved, and prudently ordered, multiplied and disposed in such sort" as to feed the poor. The proof of the effectiveness of these storehouses would be seen in the decrease in deaths by starvation as, ideally, the storehouses would altogether "prevent the mention of that sad disease in the weekly bills of mortality."[54] During the 1650s, James Howell took up the familiar

[51] Slack, "Government," 42.

[52] Slack, "Government," 66.

[53] Anonymous, *The Humble Petition and Remonstrance of Some Hundreds of Retaylers... For the Restoring of Farthing Token* (London: 1644), A3v.

[54] Rice Bush, *The Poor Mans Friend, or A Narrative of what progresse many worthy Citi- [sic] of London have made in that Godly Work of providing for the Poor. With An Ordinance of Parliament for the better carrying on of the Work* (London: A.M., 1649), 18.

task of comparing the size of London and Amsterdam's populations. He used the Bills of Mortality to compare mortality rates, reasoning that they would be proportional to the size of the respective cities' populations. Amsterdam's Bills of Mortality "at the utmost, come but to about threescore a week; whence may be inferred, that *London* is five times more populous; for the number that dies in Her every week, comes commonly, to near upon three hundred."[55]

By the middle of the century, the acknowledged utility of analyzing the Bills of Mortality even led some people to lament their inability to use the bills in support of their arguments. Richard Whitlock wished "the Country [would] keep its *Bills* of *Mortality*, as the City doth" and mysogynistically added that both should include a new cause of death among those listed, so that numbers could prove female medical practitioners were "a Disease, as surely killing as *Surfet, Stone*, &c. or any other in the Bill."[56] A year later, the physician Thomas Culpepper complained that the threat of overindulgence in food and drink was not widely recognized; "surely, our Bills of Mortality acquaint us not, how many digge their Graves with their teeth, who, I fear, are more in number, then those that fall by Sword, Famine, and Pestilence."[57]

While people were beginning to see the analysis of demographic data as a useful tool for advancing their arguments, only rudimentary arithmetical knowledge was needed to think with numbers and thus demographic analyses remained accessible to the majority of the population. Shortly before plague reemerged, the physician Marchamont Nedham

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[55] James Howell, *Londinopolis; An Historicall Discourse or Perlustration Of the City of London* (London: J. Streater, 1657), 389.

[56] Richard Whitlock, *Zootomia, or Observations on the Present Manners of the English* (London: Tho. Roycroft, 1654), 60.

[57] Thomas Culpeper, *Morall Discourses and Essayes, Upon Severall Select Subjects* (London: S.G. for Charles Adam, 1655), 281.

used just addition and subtraction to analyze the change in disease over time to prove that "the Diseases of this present Age are of another nature than they were in former times" and argue that physicians should no longer rely on ancient writers, regardless of what established authorities such as the Royal College of Physicians advocated.[58] To prove his point he chose to examine a small subset of diseases presented in the Bills of Mortality, "and leave you to observe and reason out the rest in others" using the same methods.[59] After examining the historical symptoms of scurvy, he turned to the bills to provide evidence of the disease's increase.

> [I]f you look back on former dayes about 30 yeares agoe, the number reckoned to dye of that Disease was but small, and year after year ever since it hath encreased gradually. In the year 1630. the number was but 5. In 1631. 7 --- 1632. 9. --- 1636. 25. Afterward, in the year 1647. the Account came up to 32. --- In the year 1652. to 43. --- In 1655. to 44. --- In 1656. to 103... which signifieth, that the Disease is very much alter'd, being grown to a higher pitch of Malignity and Mortality than in former time.[60]

Nedham similarly analyzed rickets, consumption, "Stopping of the Stomach," "Rising of the Lights," convulsion, smallpox, measles, gout, and rheumatism, using only the increase or decrease of annual mortality statistics to prove his points.[61]

In 1662, John Graunt took the analysis of demographic data to a new level by expanding the scale of his analysis and devoting an entire treatise to the Bills of Mortality. His *Natural and Political Observations* was derived from the bills with only "the *Mathematiques* of my Shop-Arithmetique," including addition, subtraction,

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[58] This book was licensed on Sept. 2, 1664, indicating that it was written and published prior to the 1665 plague epidemic. Marchamont Nedham, *Medela Medicinae. A Plea For the Free Profession, and a Renovation of the Art of Physick, Out of the Noblest and most Authentick Writers* (London: Richard Lownds, 1665), A1v-2r, 1.

[59] Nedham, *Medela Medicinae*, 29.

[60] Nedham, *Medela Medicinae*, 42-3.

[61] Nedham, *Medela Medicinae*, A8r, 44-55.

multiplication, and ratios. With this, he "reduced several great confused *Volumes* [of bills] into a few perspicuous *Tables*, and abridged such *Observations* as naturally flowed from them."[62] These observations were demographic and political in nature, ranging from "not above one in four thousand are *Starved*" and "there are about six Millions, and an half of people in *England* and *Wales*" to "The City removes *Westwards*" and "the most *healthfull* years are also the most *fruitfull*."[63]

In his treatise, Graunt also explained to potential critics "to what purpose tends all this laborious buzzling, and groping" with numbers.[64] He argued that the purpose of "the Art of Governing, and the true *Politiques*, is how to preserve the Subject in *Peace*, and *Plenty*" and the foundation of this

> is to understand the Land, and the hands of the Territory to be governed, according to all their intrinsick, and accidental differences: as for example; It were good to know the *Geometrical* Content, Figure, and Scituation of all the Lands of the Kingdom... It is no less necessary to know how many People there be of each Sex, State, Age, Religion, Trade, Rank, or Degree.[65]

This would enable the government to estimate the needs of human consumption and make trade more regular, to the profit of the country as a whole. Furthermore, knowing "how small a part of the People work upon necessary Labours, and Callings, *viz.* how many Women, and Children do just nothing, onely learning to spend what others get" as well as the distribution of other trades "is necessary in order to good, certain, and easie Government, and even to balance Parties, and factions both in *Church* and *State*." Indeed, this information was of such importance for government, that Graunt concluded

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[62] John Graunt, *Natural and Political Observations Mentioned in a following Index, and made upon the Bills of Mortality* (London: Thomas Roycroft, 1662), 2-3.

[63] Graunt, *Natural and Political Observations*, a1r-a4v.

[64] Graunt, *Natural and Political Observations*, 71.

[65] Graunt, *Natural and Political Observations*, 72-3.

his treatise by wondering if he had done the right thing in publishing his demographic analysis: "whether the knowledge thereof be necessary to many, or fit for others, then the Sovereign, and his chief Ministers, I leave to consideration."[66] His readers were less ambivalent about the need to make this information publicly available, resulting in the treatise being republished three times in under three years.[67]

By the end of the seventeenth century, while the original meaning of David's census was not forgotten, interest in demographic data had grown strong enough that the judge Sir Matthew Hale could analyze David's census in a wholly demographic context:

> [I]n the latter end of the Reign of *David*, about the Year of the World 2925, which was 435 Years after the Numbring of the People by *Moses* and *Eleazar*, *David* again Numbers the People, and then the Account of the People... [was] in all 1300000 fighting Men: and if we should take in Women, Children, and Aged, it is probable they were above five Millions. So that in the space of 435 Years, notwithstanding all these Decrements they were increased about three Millions.[68]

For Hale, the significance of David's census was not David's sin and the plague that followed. Instead, Hale focused on the numbers that resulted from each of the Biblical censuses and compared them to one another in order to argue that, plagues and hardships notwithstanding, the overall population of Israelites had dramatically increased between the exodus from Egypt and the reign of David. Numbering the people was no longer an act of pride, it was good government.

With the exception of mortality statistics, demographic data were seldom aggregated and analyzed beyond what was necessary for taxation during the sixteenth

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[66] Graunt, *Natural and Political Observations*, 74.

[67] There were two editions of Graunt's *Natural and Political Observations* published in 1662, two further editions published in 1665, and a fifth edition published in 1676.

[68] Matthew Hale, *The Primitive Origination of Mankind, Considered and Examined According to the Light of Nature* (London: William Godbid, 1677), 232.

century. However, over the course the seventeenth century, people increasingly acknowledged the possibilities inherent in thinking with numbers and analyzing demographic data to support their political arguments. As the London Bills of Mortality were widely available in print, they formed a particularly accessible and well-known source of demographic data, and writers lamented when the subjects they were interested in failed to be encompassed within the bills. By the end of the seventeenth century, the growing association of demographic data analysis and good government led to the invention of so-called "political arithmetic."

Political Arithmetic

At the end of the seventeenth century, ideas about the analysis of demographic data culminated in the newly formalized practice of political arithmetic. William Petty, the first self-identified practitioner of political arithmetic, was unapologetic in his manipulation of demographic data to advance the policies of the current monarch. After his death, later political arithmeticians reimagined their work as the presentation of demographic data whose power to influence politics lay in its avowed neutrality. In doing so, numbering the people was expanded from a specific extension of government policymaking to become, more generally, another method for using numbers to understand the world.

The term *political arithmetic* originated no later than the 1670s, in the writings of a doctor and government official named William Petty.[69] In both his privately circulated

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[69] *OED*, s.v. "political, *adj.* and *n.*" William Petty, *Political Arithmetick, or A Discourse Concerning The Extent and Value of Lands, People, Buildings*... (London: Robert Clavel, 1690), A2v-A3r.

treatises and his printed works, Petty advanced a method of quantitative data analysis similar to that of John Graunt's *Natural and Political Observations*. Indeed, Petty probably helped Graunt with his research and *Natural and Political Observations* bore such a striking resemblance to Petty's later work on Dublin's Bills of Mortality that some of their successors mistakenly attributed Graunt's work to Petty.[70] Like Graunt, Petty was aware of the newness of his methodology, it being "not yet very usual," and deliberately contrasted "using only Comparative and Superlative words and Intellectual Arguments" with "the course (as a Specimen of the Political Arithmetick I have long aimed at) to express my self in Number, Weight, and Measure."[71]

Unlike earlier demographers whose analyses could be used to support a variety of political positions, Petty's political arithmetic was explicitly harnessed to the needs of England's government. Petty's son, editing and reprinting *Political Arithmetick* in 1690, explained that his father's political arithmetic was "in as much as things of *Government*, and of no less concern and extent, than the *Glory* of the *Prince*, and the *happiness* and *greatness* of the *People*, [which] are by the *Ordinary* Rules of *Arithmetick*, brought into a sort of Demonstration."[72] For Petty, political arithmetic's true purpose was the advancement of the current monarch's policies – whatever they might be – and thus quantitative analysis of demographic data was only a means to that end.

Petty's political arithmetic transformed political problems into demographic ones and reframed the work of the government as the manipulation of populations, particularly

[70] Graunt compared London mortality statistics with those of Romsey, the country parish where Petty was born and whose statistics were probably supplied by Petty. Slack, "Government," 64. Ted McCormick, *William Petty and the Ambitions of Political Arithmetic* (Oxford: Oxford University Press, 2009), 119, 131.

[71] William Petty, *England's Guide to Industry: or, Improvement of Trade for the good of all People in general* (London: R. Holt, 1683) bound with Edward Chamberlayne, *The Present State of England* (London: William Whitwood, 1683), Aa4v-Aa5r.

[72] Petty, *Political Arithmetick*, A2v-A3r.

the ratio of one subgroup to another.[73] In 1670, Petty had calculated ratios for the population of lands he held in Ireland, where "the right numbering of the People [demonstrated] that there were living about then, upwards of 500 Papists for one of these Protestants."[74] The 1676 Compton Census similarly reduced the religious populations of England to such ratios by determining that only one person out of 22 was nonconformist and one out of 178 a Catholic.[75] To manipulate such ratios, Petty advocated for the transplantation of large numbers of people. One of Petty's plans involved exchanging 200,000 Irish men, women, and children with a like number of English ones; the former would form less than 2% of the new population of England, while the latter would definitively shift the balance of Protestants to Catholics in Ireland. Other, similar proposals included the exchange of Irish for English women, or even the replacement of Irish Catholic priests with English ones, thus getting rid of troublesome English Catholics while simultaneously destroying Catholicism's relationship to Irish nationalism.[76]

Petty's manipulation of ratios, while essentially quantitative and mathematical, did not require extensive mathematical education to understand.[77] During a presentation to the Royal Society, Petty attempted "to explain the Intricate Notions, or *Philosophia Prima* of Place, Time, Motion, Elasticity, &c." and "to excite the World to the study of a little Mathematicks, by shewing the use of *Duplicate Proportions* in some of the most weighty of Humane affairs." However, he reassured his listeners that the mathematics of

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[73] McCormick, *William Petty*, 206-7.

[74] Richard Orpen, *An Exact Relation of the Persecutions, Robberies, and Losses, sustained by the Protestants of Killmare, in Ireland* (London: Thomas Bennet, 1689), 2.

[75] Slack, "Government," 47n46.

[76] McCormick, *William Petty*, 193-4.

[77] By contrast, Graunt's earlier manipulation of statistics in his *Observations* was far more complicated than anything Petty produced in either his unpublished or published works. McCormick, *William Petty*, 131.

proportion should be simple enough that "the meanest Member of adult Mankind is capable of understanding" and "a Child of 12 years old may learn in an hour."[78] The presentation went over well among the members of the Royal Society, but Petty overestimated the mathematical learning of some of his fellow government officials; the Solicitor-General of Ireland was particularly "angry with [Petty], for saying a Child of 12 yeares old might do in one houre what he found he could not do in many."[79]

In keeping with his political focus, Petty was less interested in the precision of mathematical calculations than in the potential benefits of thinking numerically. He was particularly interested in the kinds of questions that could be asked and policies that could be advocated by using demographic proportions. He defended the use of numbers even in situations where he could not acquire exact information, noting that even those "that ayme at so much cleernes & certainty are forced sometimes to fly to estimate & opinion." Whenever possible, he advocated the political arithmetician "stick to Number Weight & Measure," but allowed that there were situations in which "the Estimate bona fide made by those of greatest practise & Experience must bee made use of."[80] The important thing was to make certain that

> the Observation or Positions expressed by *Number, Weight,* and *Measure*, upon which I bottom the ensuing Discourses, are either true, or not apparently false... and if they are false, not so false as to destroy the Argument they are brought for; but at worst are sufficient as Suppositions to shew the way to that Knowledge I aim at.[81]

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[78] McCormick, *William Petty*, 217-8.

[79] McCormick, *William Petty*, 233.

[80] BL, MS Additional 72865, ff. 7-8 as cited in McCormick, *William Petty*, 178.

[81] Petty, *Political Aritmetick*, A4v.

Thus, the absolute truth or falsity of his demographic data was unimportant as long as the numbers – and the immediate conclusions drawn from those numbers – were not so obviously false as to destroy the political arguments they were intended to support.

Although political utility was more important than numerical precision, Petty preferred to use the most correct demographic data. In his second set of observations on the Dublin Bills of Mortality and related demographic data, Petty noted an improbably large increase in the number of Dublin houses: "the Houses which *Anno*. 1671, were but 3850 are *Anno* 1682, 6025; but whether this difference is caused by the real encrease of Housing, or by fraud and defect in the former Accompts," was unclear.[82] Petty went on to compare the alleged numbers of houses, hearths, and burials, and concluded it was most "likely there hath been some errour in the said Account of the Housing, unless the new Housing be very small, and have but one Chimney apiece, and that 1/4 part of them are untenanted."[83] He then fell back on experience, rather than mathematics, to claim "there is no ground from experience to think that in 11 year, the Houses in *Dublin* have encreased from 3850 to 6025. Moreover, I rather think that the number of 6025 is yet short" however it was "the best estimate I can make of that matter, which I hope Authority will ere long rectifie, by direct and exact Enquiries."[84] Indeed, Petty repeatedly called for more thorough and exact surveys of the English and Irish populations, and English lands, in order to support government policymaking and the practice of political arithmetic.[85]

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[82] William Petty, *Further Observation Upon the Dublin-Bills: Or, Accompts of the Houses, Hearths, Baptisms, And Burials in that City* (London: Mark Pardoe, 1686), 2.

[83] Petty, *Dublin-Bills*, 3.

[84] Petty, *Dublin-Bills*, 4.

[85] Petty, *Dublin-Bills*, 6. McCormick, *William Petty*, 146.

By the time of Petty's death in 1687, other political arithmeticians had begun to disassociate their discipline from Petty's policy-centered version of political arithmetic. While they acknowledged Petty's founding role in political arithmetic – noting Petty "first gave it that Name, and brought it into Rules and Method" – they self-identified more strongly as demographers, studying populations only as quantifiable objects of knowledge, subject to natural laws.[86] One anonymous contributor to the 1686 *Philosophical Translations of the Royal Society* praised only Petty's demographic work, noting that political arithmetic "made it appear that Mathematical Reasoning, is not only applicable to Lines and Numbers, but affords the best means of Judging in all concerns of humane life."[87] Another Royal Society member, John Houghton, similarly linked political arithmetic with demography when he proposed a treatise that would include "an account of the several Parts of the *Bills of Mortality* of *London*," which he expected to be "for the benefit of *Physicians, Apothecaries*, and... also for the *Political Arithmeticians* that desire to know the *Increase* and *Decrease* of Places."[88]

During the 1690s, political arithmeticians Gregory King and Charles Davenant reimagined political arithmetic as a neutral method of thinking numerically that could be applied to political ends. King argued that it was the job of the political arithmetician to draw conclusions from the numbers, not manipulate the numbers to support a predetermined conclusion or government policy. He agreed that "to be well apprized of the true state, and condition of a nation, especially in the two main articles, of its people,

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[86] Charles Davenant, *Discourses On the Public Revenues, and On the Trade of England* (London: James Knapton, 1698), 2. McCormick, *William Petty*, 288.

[87] "An Extract of two Essays in Political Arithmetick concerning the comparative Magnitudes &c. of London and Paris by Sir William Petty Knight, R.S.S.," *Philosophical Transactions of the Royal Society* 16 (1686), 152, as cited in Peter Buck, "Seventeenth-Century Political Arithmetic: Civil Strife and Vital Statistics," *Isis* 68, no. 1 (Mar., 1977), 81.

[88] John Houghton, *A Proposal for the Improvement of Husbandry and Trade* (London, 1691), 1.

and wealth, [was] a piece of political knowledge" however he castigated the exaggeration of "all former calculations" of English demographic data, whose untruths had the potential to lead government decision-makers astray.[89] While King was also forced to make educated guesses over the course of his calculations, he insisted that his numbers "come very near the truth." Any errors were not a deliberate manipulation meant to advance a specific political agenda but rather a natural result of the limitations of his original data.[90]

Like King, Davenant also argued for the neutrality of political arithmetic, casting it as a methodology with no inherent political agenda. He defined the discipline as "the Art of Reasoning, by Figures, upon things relating to Government" and noted the "Foundation of this Art is to be laid in some competent Knowledge of the Numbers of the People"[91] For Davenant, political arithmetic was not a method of government, per se, but rather a method of reasoning about government-related matters whose foundations lay in numbers and demography. This method of reasoning provided quantitative evidence that might influence policy, but the evidence itself was politically neutral.

> A great Statesman, by consulting all sort of Men, and by contemplating the universal Posture of the Nation, its Power, Strength, Trade, Wealth and Revenues, in any Council he is to offer, by summing up the Difficulties on either Side, and by computing upon the whole, shall be able to form a sound Judgment, and to give a right Advice: And this is what we mean by Political Arithmetick.[92]

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[89] Gregory King, *Natural and Political Observations on the State of England* (London, 1802) as cited in McCormick, *William Petty*, 294.

[90] For an analysis of how King came by one of his population estimates, see D.V. Glass, "Gregory King's Estimate of the Population of England and Wales, 1695" *Population Studies* 3, no. 4 (Mar., 1950): 338-374. Slack, "Measuring," 623-4. McCormick, *William Petty*, 294.

[91] Davenant, *Discourses*, 2.

[92] Davenant, *Discourses*, 13-4.

The political arithmetician calculated the difficulties of all possible courses of action and only then used this data to decide which course of action to advocate. Even then, this was no more than a judgment, "Political Arithmetick being a good Guide in these Matters; though it gives not demonstrative Proofs." At the end of the day, the primary purpose of political arithmetic's calculations was "[s]o that the Parliament would not be quite in the Dark" when making policy decisions, not to make the policy decisions for them.[93]

While the work of early seventeenth-century demographers could be applied to a wide variety of ends, the first formal theories of political arithmetic were explicitly harnessed to the needs of England's government. William Petty, the first self-identified practitioner of political arithmetic, imagined the work of government to be the manipulation of demographic ratios to solve political problems. While Petty attempted to make as accurate demographic calculations as possible, he also subordinated numerical accuracy to political utility. By contrast, his successors reframed political arithmetic as a method of reasoning on demographics that could be applied to political matters but was inherently neutral and divorced from any specific policy goals. They thus expanded political arithmetic from a method of governing by numbers to a more general method of reasoning by numbers, which could be applied to a whole host of political, economic, and social questions.

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[93] Charles Davenant, *An Essay Upon the Ways and Means of Supplying the War* (London: Jacob Tonson, 1695), 134-5.

Conclusions

Censuses were an ancient practice of collecting information about a population, usually for the purpose of taxation or war. Because census data were generally applied towards immediate fiscal and military goals, there was little need to aggregate or analyze census data, which were generally left in a form that was as much qualitative as quantitative. During the sixteenth century, the institution of parish registers formed a new type of census with less of a perceived connection to taxation and impositions. The demographic data within these registers, particularly information about mortality, were often stripped of personal identifiers and quantitatively aggregated. This enabled people to think numerically about demographic and social problems, particularly those associated with plague epidemics.

Over the first half of the seventeenth century, people increasingly analyzed demographic data and used the results to form one strand of a larger argument about politics and English society. This culminated in the systematic demographic work of John Graunt's *Natural and Political Observations* and led to a formal theory of political arithmetic. Although William Petty used political arithmetic to lend support to whatever policies his current monarch wished to pursue, later political arithmeticians recast their discipline as a neutral method of analyzing demographic data. This led to its separation from specific government policy goals and its recreation as a politically neutral method of demographic data analysis. Political arithmetic was no longer a method of government, rather it had become a method of thinking numerically in order to understand both the people and the world that they governed.

Conclusion

In 1599, the playwright Thomas Dekker composed a comedy for the Lord Admiral's Men to perform before Queen Elizabeth and her Court during that year's Christmas season. In the epilogue, an old man beseeched the audience to pray to God for the long continuation of Elizabeth's reign and framed his own prayer in numerical terms:

> And that heau'ns great Arithmetician,
> (Who in the Scales of Nomber weyes the world)
> May still to fortie two, and one yeere more,
> And stil adde one to one, that went before,
> And multiply fowre tennes by many a ten:
> To this I crie Amen.[1]

As this prayer shows, ideas about numbers were inextricably bound up with ideas about God in the early modern period. God was the "great Arithmetician" who created the world in number, weight, and measure. Afterwards, God continued to use "the Scales of Nomber" to weigh the world and reckon the days of every man and woman's life. One of the many ways God showed His favor towards Elizabeth was through acts of arithmetic, adding still more years to a reign that had already lasted forty-two years. In Dekker's enthusiasm, he even suggested God might multiply the decades and allow her to live as long as the prophets and kings of the Old Testament. God's love was in the numbers.

Throughout this dissertation we have seen how a numerical worldview existed within a framework defined by Christianity. The people of early modern England believed the world functioned according to numerical laws because God had made it so, and that people could learn these laws because God had given humans the ability to

[1] Dekker, Thomas, *The Pleasant Comedie of Old Fortunatus* (London: S.S. for William Aspley, 1600), L3v.

comprehend numbers when he raised them above all other creatures. Early modern attempts to quantify abstract phenomena like time and chance reflect this view. Calendar reform and concerns over the relativity of time were inspired by the need to celebrate religious festivals at specific chronological moments, while the impulse to quantify chance led to debates over the mechanisms of God's providence and how He directed earthly events through quantifiable laws. Even a proposal to conduct a national census was interpreted within the context of Biblical censuses and God's directives to His chosen people. Early modern numbers were therefore not value-neutral conveyors of quantitative information but rather the building blocks of Creation.

The religious nature of early modern numbers is a good example of the fact that, by contextualizing numbers and numeracy in a specific historical culture, we can make surprising discoveries about the way people apprehended their world. Instead of treating numbers as transcendent phenomena, we need to acknowledge their historicity. We need to recognize that ideas about numbers and numeracy are culturally determined, and thus can vary significantly over time and place.

This study reveals two vital characteristics of early modern numbers that have repercussions for the study of numeracy more generally. The first concerns the power of numbers to shape modes of thought. As much as possible, I have reconstructed what is essentially a cognitive element of English culture by looking at not just how people used numbers, but how people thought about numbers and how they used them to think about events in their day-to-day lives. In analyzing numbers this way, I give ordinary people a stake in philosophies and technologies of knowledge and reconnect some of the revolutionary changes in early modern science with the changes occurring in vernacular

English numeracy. The early modern period did not just see the mathematization of elite natural philosophy. It also saw ordinary English men and women increasingly use numbers to interpret the world around them. Many later eighteenth-century developments in economics, politics, and navigation, among other fields, had antecedents in early modern ways of thinking about numbers. The men and women of seventeenth-century England understood the potential of numbers as a technology of knowledge, even if they had not yet developed the mathematics to completely explain the world via numbers.

The importance of thinking with numbers cannot be overstated. The "literate turn" in the closing decades of the twentieth century encouraged historians to examine the power of language to shape thoughts and actions. However, we have largely ignored the similar – or perhaps greater – power of numbers. Indeed numbers, especially Arabic numerals, are so embedded into our twenty-first-century worldview – from our methods of scientific knowledge production to our daily lives – that we take them for granted. But numbers, as a type of knowledge, need to be put through the same rigorous analysis as words and literacy. This is especially critical because numbers form an integral part of modern ways of understanding the world.

When we describe our world as inherently mathematical, we mean both the mathematics of advanced scientific disciplines and the use of numbers in ordinary men and women's everyday lives. In the twenty-first century United States, most of the population is not highly skilled in mathematics by the standards of modern mathematicians. If asked, many people will self-depreciatingly refer to themselves as "bad at math" or "unable to balance a checkbook." Yet at the same time they rely heavily on numbers in their everyday lives, using numbers to explain such diverse subjects as time, the location of their homes, or how well they did in school. It is this essentially numerical way the general population views the world, as much as the equations that send people into space, that defines a mathematical worldview – both now and in seventeenth-century England.

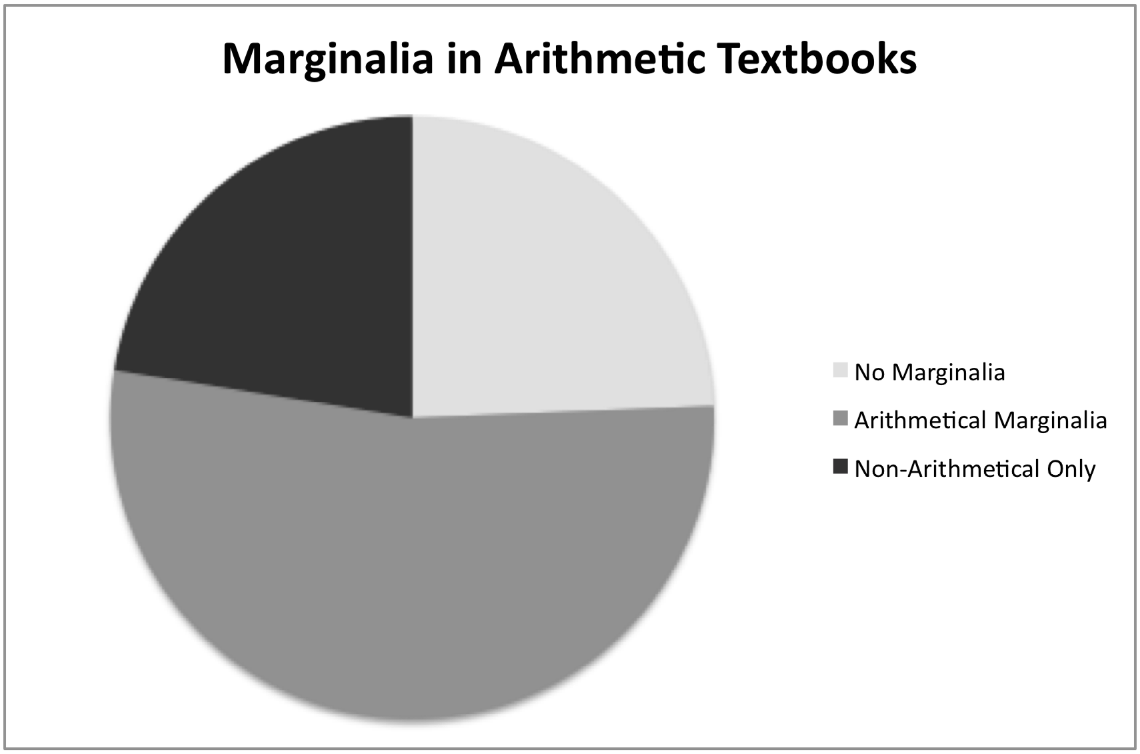
This leads us to the second point, which is that numbers were a socially pervasive technology of knowledge in early modern England. Indeed, numeracy was far more pervasive than literacy, as barely half the people in England were able to sign their names even at the end of the seventeenth century. It is thus critical that we understand numeracy better than we have, for it was the most clear and widespread way that people attempted to impose order on the world around them. By looking at a diverse array of both material and textual sources, we see that the multiplicity of early modern symbolic systems ensured that people across the socioeconomic and educational spectrums could perform simple arithmetical calculations and create permanent numerical records. During the sixteenth century, the combination of tally sticks, jetons, and Roman numerals served the needs of the entire population, from the illiterate to highly educated political officeholders. Only at the turn of the seventeenth century did the literate subsection of the population begin to prefer the use of Arabic numerals. Even then, this preference never operated to the complete exclusion of other systems.

The adoption of Arabic numerals is particularly significant for modern historians because Arabic numerals linked the previously separate functions of permanent recording and calculation. This link was established via the act of writing. Through examining patterns of change in the use of numerical symbols and in education in the seventeenth century, we see the increasing conceptual connection between writing and arithmetic in the rise of arithmetic textbooks and writing-cum-arithmetic schools. By the eighteenth century, the dominant form of English numeracy was a self-consciously literary form of numeracy – the same numeracy we still use today.[2] But in combination with the historian's usual emphasis on written sources, this literary form of numeracy can blind us to the vitality of different types of numeracy in both the early modern and other periods. It is therefore crucial that we examine the full range of historical numeracies and not underestimate the pervasiveness of numerical concepts in the past.

By looking at numbers through the lens of early modern English culture, my ultimate goal has been to defamiliarize the Arabic numerals we historians so often take for granted and instead bring to light the full range of numeracies in the early modern period. Recovering these numeracies has enabled us to analyze the major transformation in the way people used numbers during the early modern period. Changes in symbolic systems and educational practices encouraged new ways of experiencing the natural world, as people began to consider numbers as a tool for interpreting the world around them. By the end of the seventeenth century, numbers had been transformed into the building blocks of God's Creation and the foundation of English men and women's efforts to understand their world.

[2] For more on the everyday mathematics of the eighteenth century, see Benjamin Wardhaugh, *Poor Robin's Prophecies: A Curious Almanac, and the Everyday Mathematics of Georgian Britain* (Oxford: Oxford University Press, 2012).

Appendix A: Marginalia in Arithmetic Textbooks

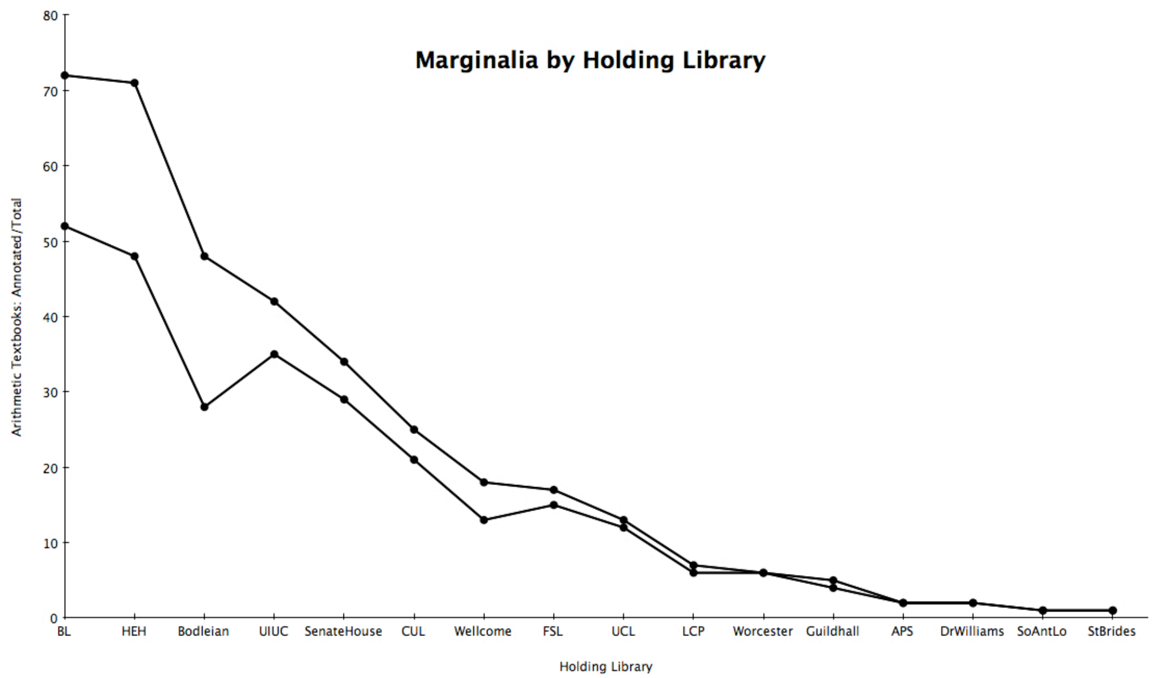


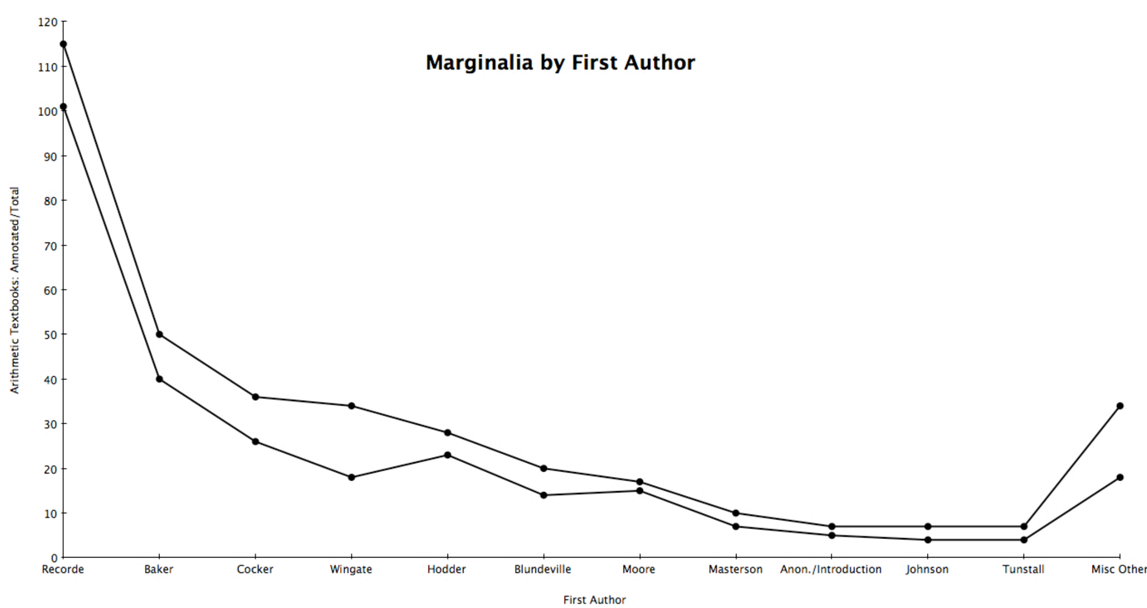
Sample Size: 365

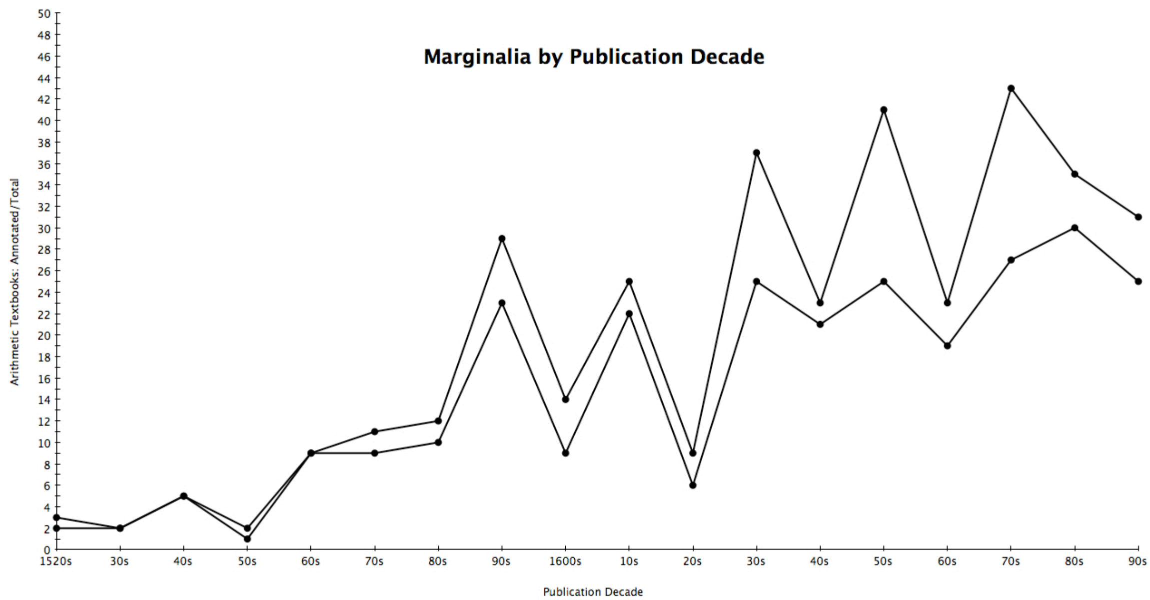
Arithmetics classified as having "No Marginalia" have no markings datable to before 1800. They do have library markings, including notes on acquisition and rebinding, which generally date to the twentieth century. The subset of arithmetic textbooks from the Senate House Library, University of London, were largely acquired in the nineteenth century by Augustus DeMorgan and most contain notes in his hand.

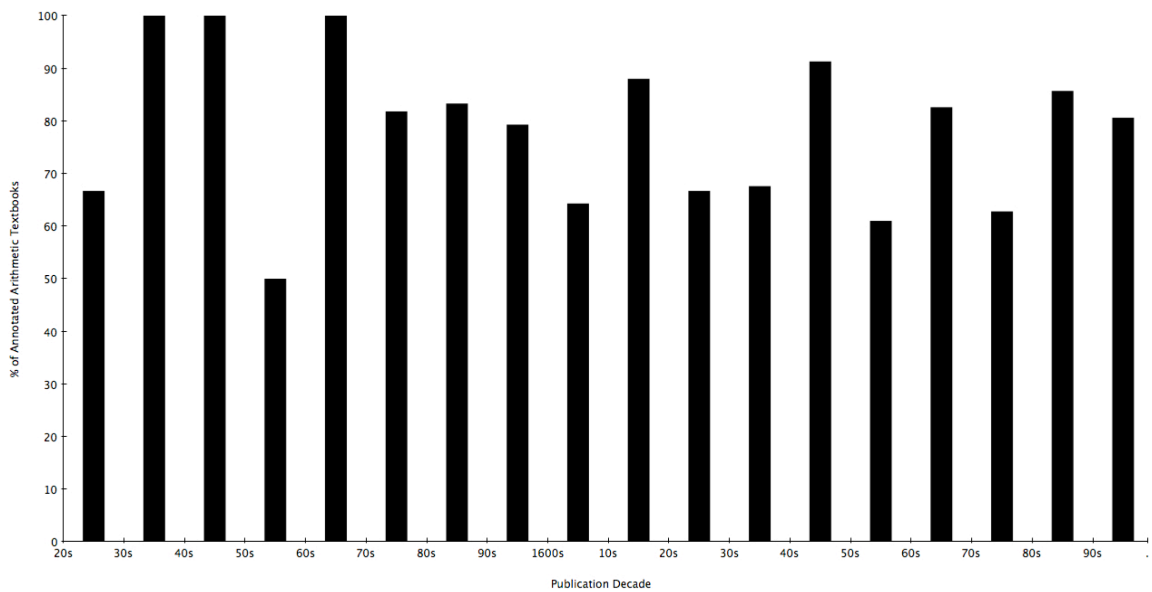
Arithmetical marginalia includes: manicules, underlining, corrections to the text, marginal glosses, accounting, and scratchwork.

Non-arithmetical marginalia includes: owners' names, years of ownership, purchase dates, purchase prices, poems, handwriting practice (exclusive of numbers), and doodles.


Marginalia by Holding Library
Arithmetic Textbooks: Annotated/Total
Holding Library
BL
HEH
Bodleian
UIUC
SenateHouse
CUL
Wellcome
FSL
UCL
LCP
Worcester
Guildhall
APS
DrWilliams
SoAntLo
StBrides


Marginalia by First Author
Arithmetic Textbooks: Annotated/Total
First Author
Recorde
Baker
Cocker
Wingate
Hodder
Blundeville
Moore
Masterson
Anon./Introduction
Johnson
Tunstall
Misc Other





*This does not include arithmetic textbook fragments of uncertain publication date.

Appendix B: Editions of *The Ground of Artes* and *The Welspring of Sciences*[1]

Robert Recorde's *The Ground of Artes*

1542 (?)	1543	1549	1551	1552
1558	1561	1566	1570	1571
1573	1575	1577	1579	1582
1586	1590	1594	1596	1600
1605	1607	1610	1615	1618
1623	1631	1632	1636	1640
1646	1646	1646	1646	1648
1648	1648	1651	1652	1652
1654	1658	1662	1668	1673
1699				

Humfrey Baker's *The Welspring of Sciences*

1562	1564	1568	1570	1574
1576	1580	1582	1583	1590
1591	1598	1602	1607	1612
1617	1618	1631	1646	1650
1655	1659	1670	1687	

[1] Compiled from Worldcat, Early English Books Online, and the ESTC. Despite bearing the same approximate title and claiming the same original authorship, many of these books are radically different from the original, and have been edited, amended, and rewritten by other authors. They have also been printed in a variety of locations, ranging from the elite Saint Paul's Churchyard to the disreputable Smithfield. Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making,* (Chicago: The University of Chicago Press, 1998), 76-9 and 69n24.

Appendix C: Examples of Arithmetic According to Recorde's Methods

Addition:

1670000
743000
2413000

Subtraction:

1670000
743000
927000

Multiplication:

232
59
18

232
59
218
7

232
59
1218
87

232
59
1218
87
10

232
59
1218
87
110
5

232
59
1218
87
1110
05

232
59
1218
87
1110
05
13688

Division (192 divided by 12) :

192
12

~~1~~92 (1
~~1~~2

7
~~19~~2 (1
~~12~~

7
~~19~~2 (1
~~12~~2
1

1
~~7~~
~~19~~2 (16
~~12~~2
~~1~~

~~1~~
~~7~~
~~192~~ (16
~~122~~
~~1~~

Appendix D: Salaries in Sir Humphrey Gilbert's *Scheme of an Academy for Wards*[1]

£10
usher to assist with French
usher to assist with Italian
usher to assist with music

£20
4 ushers to assist with Latin and Greek grammar

£26
French instructor
Italian instructor
Spanish instructor
Dutch instructor
sword instructor
dancing instructor
music instructor
heraldry instructor
librarian

£40
reader in logic & rhetoric
reader in natural philosophy
usher to assist with arithmetic
usher to assist with geometry
mapmaker/drawing instructor

£66.13*s*.4*p*
schoolmaster of Latin and Greek grammar
reader in Hebrew
riding instructor
soldier/military instructor
mathematician teaching cosmography & astronomy
reader of common law
minister/clark

£100
reader in moral philosophy
mathematician teaching arithmetic & geometry
doctor of physic
reader of civil law
reader of divinity
treasurer of the academy
rector of the academy

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[1] BL, MSS/Lansdowne/98, 2r-5v

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MS Arundel 293	Wilboldt Imhoff of Nürmberg's Cyphering Book
MS Lansdowne 98	Scheme of an Academy for Wards
MS Lansdowne 213	Relation of a Short Survey of 26 Counties
MS Lansdowne 1181	Keils Arithmetick
MS Sloane 1428	A Book of Arithmetick

Bodleian Library, Oxford University

MS Aubrey 10	An Idea of Education of Young Gentlemen

Essex Records Office

D/DHe/E8	Fire Insurance Certificates
D/P 94/5/1	Chelmsford Account Book, 1557-1668
D/Q 6/1/1	Papers of the Free Grammar School in Earles Colne

Guildhall Library

MS 25491	St. Paul's Cathedral Account Book, 1678 Rebuilding
Store 424.9	Bills of Mortality, 1602-66

Huntington Library

MS HA Inventories	Inventory of Earl of Huntingdon's Goods, 1596
MS HA School Exercises	Mathematical Commonplace Book, via John Speidell 1623

London Metropolitan Archives

E/PYM/624-31	London Fire Insurance Policies, 1682-9
ACC/0262/043	Letters from Edward Wood to John Pack, 1665
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