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Alan Sangster  
THE ROBERT GORDON UNIVERSITY

## THE PRINTING OF PACIOLI'S *SUMMA* IN 1494: HOW MANY COPIES WERE PRINTED?

*Abstract:* This paper considers the printing of Pacioli's *Summa de Arithmetica, Geometria, Proportioni et Proportionalita (Summa)* in 1494. In particular, it attempts to answer the question, how many copies of *Summa* were printed in 1494? It does so through consideration of the printing process, the printer of *Summa*, the size of the book, survival rates of other "serious" books of the period, and the dates it contains revealing when parts of it were completed. It finds that more copies were published than was previously suggested, and that the survival rate of copies has probably as much to do with the manner in which it was treated once acquired as in the number of copies printed.

### INTRODUCTION

In 1494, Luca Pacioli's 615-page compendium *Summa de Arithmetica, Geometria, Proportioni et Proportionalita (Summa)* was published in Venice. It was written primarily for merchants [Strathern, 2001]. However, its influence spread far beyond that audience – it is said to have laid out the program for Renaissance mathematics [Rose, 1976], and it has been credited with having led to the development of probability by Pascal [Strathern, 2001]. The arithmetic part of *Summa* was seen as being of sufficient importance that only 21 years after *Summa* was published, it was translated or, more accurately, used as the basis for a book in Spanish [Andrés de Saragossa, 1515]. The 27-page treatise on bookkeeping contained within *Summa*, the first known published work on that topic, is said to have formed the basis for much of the writing on that subject for the following fifty years [Fogo, 1905] and to have laid the foundation for double-entry bookkeeping (DEB) as it is practiced today.

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Given its importance in the development of accounting, it is upon the bookkeeping treatise that most attention has been focused. Over the last 150 years, it has been translated into English five times [Geijsbeek, 1914; Crivelli, 1924; Brown and Johnston, 1963; Cripps, 1994; Gebattel, 1994] and into at least 13 other languages (Chinese, Czech, Flemish/Dutch, French, German, Italian, Japanese, Polish, Portuguese, Romanian, Russian, Spanish, and Turkish). It has been analyzed, dissected, and critiqued by dozens of researchers from the U.S. and the U.K. and also from most other countries where accounting is a university subject, including Australia, Brazil, France, Germany, Holland, Italy, Japan, Russia, and Spain.

Pacioli's status as the "father of accounting" is such that a 450-page biography of his life was published by Taylor [1942] and reprinted in 1980. A facsimile of *Summa* was printed in Japan in 1989, and the Academy of Accounting Historians produced a 27-minute film documentary on his life in 1990. There are Pacioli societies in Australia, the U.S., and Japan; a Pacioli Institute in Holland; an accounting software package and an academic journal named for him; and an annual tour to his birthplace organized by the Accounting Department of the University of Seattle.

When the 500th anniversary of the publication of *Summa* was celebrated in 1994, many more publications commemorating Pacioli's life and work were produced, including the printing of one thousand facsimile copies of *Summa* in Hungary and another facsimile published in Italy. Two new translations of the bookkeeping treatise appeared in English [Cripps, 1994; Gebattel, 1994] and others in Italian [Conterio, 1994], Spanish [Hernández-Esteve, 1994a], and French [Jouanique, 1995].

It would take weeks to read through all the sites listed by a Google search for "Pacioli" – 345,000 on May 7, 2006. Over one hundred academic articles have been published on Pacioli-related topics including the derivation of his name, whether or not he was a plagiarist, the date of his death, what form an unprinted special character in the bookkeeping treatise was intended to take, and the ambiguities in the text.

It is doubtful if as much has been written in the accounting literature about any other individual; yet, there still remain issues which have only been partially explored. One of these is the subject of this paper – the printing of the 1494 edition of Pacioli's *Summa*, including how often it was reprinted and, in particular, how many copies of that edition were printed. Only one author is known to have written on this topic, Antinori [1980],

who suggested that 300 copies were printed, a quantity for its day that would suggest it was of limited interest and unlikely to have been widely read or influential, none of which is consistent with the evidence presented in this paper.

This paper reopens this debate and is of interest in that it provides additional contextual information on the motivation for the publication of *Summa*. The fact that a book printed in small numbers is clearly intended for a different audience than a larger edition has much to say about whom Pacioli saw as the readers of *Summa*.

The paper starts with an overview of printing in the 15th century, followed by a description of the fledgling copyright system in existence at the time. It then considers the cost of printing, the selling price of books, and the motivations of authors in the late 15th century. There follows considerations of the quality of printing versus handwritten books, proofreading in the 15th century, the language of printing, and the printing process. The printer of *Summa* is then introduced, and the estimate of 300 copies made by Antinori [1980] is considered in the light of the printing process and other factors, including claims that *Summa* was a big seller. The paper concludes with a discussion of findings.

## PRINTING IN THE 15TH CENTURY

The first known example of printing using movable type in Europe was published in Mainz, Germany in 1454. The first book, commonly referred to as the "Gutenberg Bible," was printed the following year. Approximately 150 copies of this two-volume, 42-line-per-page, 1,282-page work were printed on paper and 30 on vellum (parchment). Forty-eight copies are known to exist ([www.mainz.de/gutenberg/english/bibel.htm](http://www.mainz.de/gutenberg/english/bibel.htm)). Germany dominated printing in the years immediately thereafter, and it was German printers who spread the use of the printing press throughout Europe in the 15th century.

The first Italian printing press was established in 1464 by two Germans, Sweynheym and Pannartz, who installed their operation at the behest of the local abbot in a monastery at Subiaco, 45 miles from Rome. In 1469, Johann and Windelin of Speyer founded the first press in Venice. There were at least 150 printers in Venice by 1500. By that year, at least nine million printed books were in circulation [Carter, 1995]. Some estimates put the figure much higher. For example, Jones [1997] wrote that by 1501, there were "1,000 printing shops in Europe, which

had produced 35,000 titles and 20 million copies.”

Febvre and Martin [1984, pp. 186, 215, 248] identified 236 towns in Europe that had printing presses pre-1500 and arrived at the same volume figure as Jones based on average print-runs of 500 copies. However, this is likely an underestimate given that the average print-run between 1480 and 1490 was 400 to 500 copies, rising to an average between 1,000 and 1,500 by the early 16th century. Richardson [1999, p. 21] suggests that 1,000 copies was the norm in Venice at the end of 15th century, as does Bernstein [2001, p. 11]. Harris [2006b] estimates that for books not expected to be big-sellers, 1,000 to 1,500 was the limit. Others dispute these figures. For example, it has been suggested that the number of copies printed up to 1501 rarely exceeded 300 [Cachey et al., 1993]. However, the weight of opinion is on the side of the figures derived by Febvre and Martin.

Partly because of the quality of low-priced paper and the ease with which it could be obtained [Brown, 1891, p. 24], by 1482 Venice had become the printing capital of Europe, a position it retained until a least 1530 [Febvre and Martin, 1984, pp. 183-184]. Richardson [1999, p. 6] presents data suggesting 5,000 editions (different books) were published in Venice before 1501. Such was its dominance of the printing market that between 1495 and 1497, almost one-quarter of all books in print were published in Venice [Febvre and Martin, 1984, p. 186].

The *Incunabula*<sup>1</sup> Collection of the Bancroft Library, University of California at Berkeley (<http://sunsite.berkeley.edu/incunabula/>) includes 142 books that were published in Venice before 1501, the earliest dated 1471, 23 years before the printing of *Summa*. Thus, while printing may have been in its infancy in 1494, Pacioli's *Summa* was by no means, as suggested by Weis and Tinius [1991], one of the earliest books to be published in Venice. Rather, it was actually one of hundreds of different books printed in Venice by that date, many of which have survived to this day, albeit often no more than in the form of a single copy.

## COPYRIGHT

In the 1490s, Italian copyright laws were in their infancy. Where they existed, they extended protection across a very limited geographical area. Pacioli's *Summa*, for example, had a ten-year copyright when published in 1494, which was effec-

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<sup>1</sup>books printed before 1501

tive only in the area under the Venetian Republic's control. This meant that other Venetian printers were prohibited from publishing their own versions of *Summa*, but that printers located outside the area, such as in Tuscany, could freely publish pirated versions of the book.

In addition, the copyright granted did not prohibit copying a printed text by hand. Hand copying by scribes had been the norm since books were first written and continued to be commonplace after the coming of the printing press since scribes were in plentiful supply well into the 16th century. In fact, some 15th century bibliophiles so resisted printed texts that it was quite common for a printed book to be copied by hand so that the owner could have a unique, handwritten manuscript rather than a mass-produced book [Richardson, 1999, p. 9].

However, despite these practices being fairly common, no pirated copy of *Summa* or any scribal copy is known to have existed. The first known reproductions of *Summa* were facsimiles published in the late 20th century in Japan (1989), Italy (1993), and Hungary (1994). There are currently at least three websites at which scanned copies of *Summa* can be viewed and printed, one of which also sells electronic copies of the book for €12.

The lack of pirated copies of *Summa* can be explained, at least in part, by its great length. However, the book's greatest defense against pirating is that it is replete with diagrams and marginal notations which would make copying a relatively unattractive proposition compared to a text without such embellishments.

## THE COST OF PRINTING IN THE LATE 15TH CENTURY

Printing in the late 15th century was a production process notable for its separation of tasks. It was organized around the printing press and, in all but the smallest enterprise, was undertaken by a team typically comprising two compositors, two pressmen, an apprentice, and a proof-reader (often the master printer, although sometimes the author). Printers were also frequently book publishers<sup>2</sup> and booksellers. [Eisenstein, 2005]

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<sup>2</sup>The word "publisher" had a different meaning during the late 15th century from that which it has today. Publishers were, effectively, investors in printing, providing the funds to finance printing [Richardson, 1999, p. 29]. Sometimes the printer was also the publisher; sometimes a bookseller was the publisher; sometimes it was someone unconnected with the book trade. In the case of the 1494 edition of *Summa*, the sponsor of the book, Marco Sanuto, a wealthy Venetian

The printer had his own stock of inks, metal founts, and the wooden blocks used, for example, for the initial capital letter at the start of chapters and sections. Wooden blocks would often be prepared for specific books, as was the case with *Summa*, and, occasionally, special founts would be created to fit requirements stipulated by the author. Woodcuts or, alternatively, metal [copper] plates would be prepared for page bordering, diagrams, and pictures, including maps. Pacioli's work featured all of these. All these items were the responsibility of the printer, and it would be assumed included in the amount a sponsor or a publisher<sup>3</sup> was willing to pay the printer to produce a book. Paper cost as much as printing. Printers did not pay for paper unless they were funding the publication. Paper costs were usually paid by the publisher, sometimes by the author.

During the period up to the publication of the Gutenberg Bible, the "age of scribes" [Eisenstein, 2005], all published books were copied by hand, mainly by monks or nuns for whom performing scribal duties was part of their normal day. The cost of using scribes was far greater than the cost of printing, one reason why so many printers set-up business in the last 30 years of the 15th century.

Comparing the cost of printing with the cost of using scribes, Febvre and Martin [1984, p. 112] present an example from 1483 where one Florentine printer, the Ripoli Press, was paid 3 florins per quinterno. (A quinterno was a bundle of four sheets of paper folded once giving 16 pages if printed double-sided or eight single-sided.) By comparison, a scribe at that time would expect to receive 1 florin<sup>4</sup> per quinterno [Eisenstein,

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and professor of mathematics who paid for it to be printed, was the publisher. The printer was the publisher of the second edition in 1523.

<sup>3</sup>Sponsors sometimes only contributed a proportion of the costs. Others, such as the author or a bookseller, could be the major investor in a book's publication.

<sup>4</sup>This paper mentions two different currencies, Florentine gold florins and Venetian gold ducats. They had virtually the same gold content and, therefore, typically exchanged at a ratio of 1:1. However, they were seldom used in every day transactions, which were usually in a coin of lower value called a soldo. The Florentine and Venetian soldi were not identical, either in their silver content or in the number of them that equaled a florin/ducat. In addition, exchange rates fluctuated considerably in the 15th century depending upon such events as fairs, harvests, sailings, changes in government expenditure, and the time of year [Lopez and Raymond, 1955, p. 150]. They also varied over time as a consequence of debasement/enforcement in the silver content of the currency involved. In 1464, there were 106 Florentine silver soldi per florin; in 1494, 130 [Munro, 2006]; in 1499, 137. Throughout that period, there were 124 Venetian silver soldi per ducat [Mueller, 1997, p. 656]. Mueller also provides the silver content of these coins in 1464 and 1499. On the basis of these data, and assuming the 1494 silver content



2005, p. 15]. At first glance, the printer would seem the more expensive, but the Ripoli Press printed 1,025 copies of the book compared to the single copy that a scribe would have produced. There were 30 quinternos in the book, so the total cost of printing 1,025 copies was 90 florins, equivalent to the cost of three scribal copies.

The scribes could not compete, especially with that particular printer, for the Ripoli employees were nuns for whom wages were considerably less than the “going rate” [Richardson, 1999, p. 160, fn. 53]. The printer could produce so many more copies than a scriptorium<sup>5</sup> in the same time, and of a more consistent standard, that the cost of using scribes was uneconomical when publishing more than a few copies. Consequently, while scribes continued to be in demand for another 150 years or so, those who continued to work at the trade found the amount of work diminishing as the years passed.

As an indication of how much a “serious” book (i.e., bibles; textbooks; Latin, Greek, and Hebrew classic texts) cost to print in the 15th century, Richardson [1999, p. 25] describes the production costs of printing 930 copies of a bible, comprising 228 sheets of paper, printed in Venice in 1478. Paper and wage costs would have been about 500 ducats. Brown [1891, p. 26] states that the wage cost in this example was the equivalent of £500, approximately £36,400<sup>6</sup> or \$65,500 in modern money (\$70 per bible). On the basis of Richardson's view that the paper cost would have been about the same as the printing cost, each of the bibles would cost approximately \$140 at today's prices.

### THE SELLING PRICE OF BOOKS IN THE 15TH CENTURY

Not surprisingly, given the difference in the relative cost of producing such a book compared to a printed text, the purchase price of a “serious” scribal text in the late 15th century was many times that of a printed book. In cost-of-living terms, a manuscript copied by hand would cost the buyer the mod-

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was the same as in 1499, the silver-based exchange rate in 1464 was 1 ducat = 0.98 florins; in 1494, it was 1 ducat = 1.13 florins; and, in 1499, it was 1 ducat = 1.17 florins. While the values were close, they were not the same as the 1:1 exchange rate for gold florins and gold ducats.

<sup>5</sup>A scriptorium was the name given to a group of scribes working simultaneously from a single dictation.

<sup>6</sup>conversion undertaken at [www.measuringworth.com/calculators/ukcompare/](http://www.measuringworth.com/calculators/ukcompare/) using the Retail Price Index



ern equivalent in U.S. dollars of \$2,000-\$10,000. The price of a printed book was equivalent to only a few hundred [Mack, 2005].

Printed short stories and early short novels were far cheaper and cost little more in real terms than they cost today. *Aesop's Fables*, for example, was selling in Parma in 1484 for 2 soldi ( $\approx$ \$2.12), and, in 1491, also in Parma, eight popular books were selling for an average of 2 soldi, 4 dinari ( $\approx$ \$2.47) [Richardson, 1999, p. 115].

*Summa* was a "serious" book. It was also an extremely large book and sold for 119 soldi [Dunlop, 1985, p.153], making it considerably more expensive to buy than most printed books at that time, the equivalent of over \$120 at today's prices using Brown's [1891] conversion rate.

To put these examples into the context of income rather than shifts in general price levels, the modal salary of a university teacher in Italy in the late 15th century was approximately 40-60 ducats a year (4,960-7,440 soldi). Even Pacioli, despite his prominence and reputation, was only paid one hundred florins a year, approximately 85 ducats at 1 ducat = 1.17 florins<sup>7</sup> to teach Euclid at the University of Florence between 1499 and 1507 [Taylor, 1942, p. 295]. He never earned a university salary greater than 200 ducats a year.<sup>8</sup>

Thus, despite the cost of producing books in the late 15th century being many times cheaper than in the age of scribes and with the selling price of printed books being significantly less than scribal texts, prices of "serious" books remained high in relation to wages. It would have taken a week's income for a university teacher to purchase *Summa*. As a result, while printing significantly reduced production costs and the selling price of such books similarly fell, *Summa* was still beyond the pocket of the average person.

## AUTHORS AND THEIR MOTIVATION

Book authorship in the late 15th century was, at times, similar to what is now referred to as "vanity publishing" [Richardson, 1999, p. 59]. When authors presented their manuscript to a printer, they were neither paid nor did they receive royalties [Febvre and Martin, 1984, pp. 159-61]. They often had to agree to buy a quantity of copies, sometimes as much as half or even

<sup>7</sup>See Footnote 4.

<sup>8</sup>the salary he was paid in Milan between 1496 and 1499 [Grendler, 2002]

more of the print-run. Sometimes they had to agree to meet all costs. In this way, the printer covered all his costs; any copies subsequently sold by him were virtually 100% profit.

When the printer believed there was a ready market for a book, the author would sometimes receive some free copies. In all cases, the rights to the work were assumed to have passed to the printer once the manuscript was submitted by the author. Possibly because it made the printer's life easier and may have helped create a good relationship between author and printer, as was the case with *Summa*, copyright applications were typically made on behalf of the printer by the author, rather than by the printer.

Authors earned money from publication of their books by giving signed, dedicated copies to the wealthy and influential who, in order to preserve their own reputations, would repay the author with financial grants or privileges [see, for example, Richardson, 1999, pp. 52-56]. In addition, like printers, authors acted as their own booksellers, selling their copies to bookshops and individuals.

Authors with little money who felt they had a ready market for their work were not only motivated by personal gratification but also by the financial incentive to seek a sponsor who would pay for the printing of their books. This was a major difference between the age of scribes and the age of printing, as there was between the qualitative aspects of books in the two eras.

#### BOOK QUALITY: THE AGE OF SCRIBES AND THE AGE OF PRINTING

In the age of scribes, no two copies of a manuscript contained precisely the same text; neither was a copy identical to the original. Such corruption of text was rife and a serious problem with the copying of manuscripts. In scriptoria, scribes worked from dictation and errors abounded, even though the head of each scriptorium was charged with ensuring that all scribes performed their work accurately. Even scribes working alone copying a manuscript could not avoid errors and omissions unless they took so long in completing the task that it became uneconomical for them. Scribes other than monks were paid on a piecework basis; the faster they worked, the more they could earn. Monks, who comprised the majority of scribes, were not generally paid, but speed was of the essence as volume of output was the driving force. Although there are some notable exceptions, most errors were not normally corrected, even when

identified, since to do so would have spoiled the look of the book. The concept of an errata list was an innovation of the age of printing that did not exist in the age of scribes.

Despite the greater consistency in the text they contained, early printed books had, if anything, a greater variety of errors than scribal texts; for example, errors in folio numbering and in running headers were fairly common. Neither device was used in the age of scribes. While individual copies of a printed book may have had a number of errors, these were not simply to be found in one copy, as in the age of scribes, but in as many copies as it took for someone to notice the error. Even then, an error would only be corrected if it was decided it would be worthwhile to halt the press to do so.

Nowadays, anyone who has written a book is well aware of the perils of typesetting. Correcting proofs is an essential part of the publication process. It is not uncommon for four or more people, including the author, to proofread a modern text concurrently, and for each of them to identify and prepare a different list of corrections.

Yet, despite this effort, modern books are seldom error-free and textbooks, in particular, frequently contain dozens of errors. Nobes [1995] draws attention to this ongoing problem by pointing out that just as there were typographical errors in Pacioli's bookkeeping treatise, so also were there in its 1994 translation by Gebattel. However, the incidence of printing errors was much worse in the 15th century than it is today. The principal reason was the approach to proofreading that existed at that time.

#### PROOFREADING IN THE LATE 15TH CENTURY

Type was set into a forme.<sup>9</sup> Once a forme was typeset, it could be proofread before printing. If so, one person read from the mirror-image type while another checked what was read out against the text of the manuscript; clearly, a far more difficult process than proofreading printed text. Yet, this was often the only proofreading that took place [Richardson, 1999, p. 15]. Alternatively, one sheet could be printed and the press halted until it had been proofread. Either way, it would delay the printing so that proofreading was done quickly and inadequately, if done at all.

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<sup>9</sup>A forme was comprised of type set for pages that would be printed together. The forme was held in place by a rectangular wooden or iron frame.

Sometimes, proofreading took place during printing, the press only being halted if a major error or omission was found. Typically, pages printed before the press was stopped and the typesetting corrected were not destroyed but included in the completed batch as if no errors existed. Evidence that this approach was used in *Summa* can be seen by comparing copies of the 1494 edition where, for example, folio<sup>10</sup> numbers missing from or incorrect in one copy are in place and correct in another [Dunlop, 1985].

There was also the apprentice problem. While the compositor was a skilled tradesman, as in any trade, the apprentice was not. The apprentices had to learn and were given the “simple” tasks, such as typesetting the running headers and folio numbers. *Summa* is replete with errors in folio numbering and contains a number of incorrect or misspelt running headers, both distinctly easy items to check in the proofreading process, suggesting that the proofreading of the book was cursory at best.

There is a very clear example in *Summa* of the difference between 15th and 21st century proofreading. Nowadays, it is normal practice for the author to be involved. This was not the case 500 years ago. The examples at the end of the bookkeeping treatise contain a fundamental error which would be sufficient to confuse and undermine the confidence of those who thought they had understood everything to that point – the credit side of a journal entry contains the instruction to debit an item when it should have been a credit [Hernández-Esteve, 1994b]. It was never corrected in any of the known printings of either edition of *Summa*, which suggests that not only was the proofreading careless, but that Pacioli himself never read that part of the printed bookkeeping treatise, either while it was being printed or after it was published. This view is reinforced by an error in another of the journal entries, where the amount stated in the narrative differs from the amount shown in the money columns, an error perpetuated in the second edition.

It is inconceivable that the printer/publisher of *Summa* would have ignored a list of corrections compiled by Pacioli when it came to reprinting the book. To have ignored Pacioli in this way would have jeopardized their working relationship

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<sup>10</sup>Page numbering as we know it did not become the norm until well after *Summa* was printed. In 1494, the practice of numbering each folio, each double-sided page, was becoming common although not universal, by any means. Pages in *Summa* are identified by their folio number, and the term recto (facing) and verso (back). Folio 144r in *Summa* is page 287 and 144v is page 288. The folio number is only shown on the recto side of the folio.

– the same printers published other work by Pacioli in 1509, for which Pacioli petitioned a 20-year Venetian copyright on behalf of the publisher (a 15-year copyright was granted).

This also raises another issue relating to the first bookkeeping error highlighted by Hernández-Esteve – could it have been in the original manuscript? If so, the manuscript was certainly derived from another document for nobody who knows DEB would have made the mistake in question, although a scribe copying an original manuscript could have done so.

### THE LANGUAGE OF PRINTING IN LATE 15TH CENTURY VENICE

For a long time after printing was invented, most of the published bibles, classics, and textbooks were printed in Latin.<sup>11</sup> Among the educated, Latin was a second language common across much of Europe. However, the majority of people spoke only their local vernacular well, and what Latin they knew was sufficient solely for attending church. The vernacular varied from state to state within what was to become Italy. However, there was great commonality among the various dialects. With minimal exposure, citizens from other Italian states could understand and be understood in Venice as if they were themselves Venetians.

In order to maximize sales, books aimed at the general reading public rather than at the scholar or churchman were printed in the vernacular rather than in Latin, even if the target market was outside the state in which that vernacular was the dominant language. *Summa* was intended mainly for merchants, artists, engineers, and architects. Thus, apart from the bookkeeping treatise which is mainly in the Venetian dialect, the *Summa* is in the Tuscan dialect of 1494, with some occasional use of Venetian and a small amount of Latin [see Yamey, 1994, pp. 18, 22; Field, 1999, p. 301].

### THE PRINTING PROCESS IN THE LATE 15TH CENTURY

The printing process in the late 15th century has been described many times [e.g., Febvre and Martin, 1984; Richardson, 1999; Eisenstein, 2005]. *Summa's* pages are folio-size, approximately 11.5 inches by 8 inches (30 by 20 centimeters). In

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<sup>11</sup>The only consistent exceptions are classic Greek texts which were published in Greek and Hebrew texts published in Hebrew. In both cases, these were for audiences who understood the language of the text.

folio printing, two pages were printed on each side of a sheet of paper. First, two pages were typeset, placed into a single forme, and the front ("recto") side of a sheet of paper was printed. The type was then removed from the forme and used with other type for the next forme which was then used to print the back ("verso") of the same sheet of paper. The printing on the back of the sheet could only be done when the paper was completely dried from the first side printing, usually the following day.

After printing had been completed on both sides, the sheets were typically grouped with three other sheets to make a quintero ("quire") of 16 pages of printed text which was then bound (sewn). This is confirmed as having been the typical grouping for the binding of *Summa* by the printer's signatures [Dunlop, 1961], although there are occasional instances in *Summa* of five (20 pages) and seven (28 pages) folios being bundled together in binding.

Although typesetting was a major task, standard-width characters were used, the equivalent of the fixed-space letter spacing to be found in the Courier font of Microsoft Word, making the switching of wrongly placed letters a relatively straightforward process. Since the formes were broken down as soon as the sheets had been printed, if a book was reprinted, the type had to be set from scratch which, given that type wore out and was often replaced with differently spaced characters, could play havoc with pagination [Dunlop, 1985]. As a result, reprinting was not something done without full consideration of the likely costs, the unsatisfied demand, and the potential revenue. Furthermore, anyone wanting one copy after none remained would find it cheaper to rent the book and pay scribes to copy it than pay the high premium for one printed copy. Consequently, reprints of even a few sheets were not generally undertaken to satisfy the demands of a single customer; rather, print-runs were of a significant quantity.

According to Febvre and Martin [1984], one hundred years after *Summa* was printed, in the late 16th century, a compositor would have been expected to create one to three formes per day and pressmen to print at least 2,500 sheets. When *Summa* was printed in 1494, techniques were less well-developed and typesetting and printing were slower. Typically, two compositors and two pressmen worked on each press. In the case of *Summa*, on the basis of the font used, the number of lines printed per page, and the complexity of the marginal annotations, a realistic expectation was that two compositors could typeset two formes per day, which could then have been printed on a single press at

the rate of 1,000 sheets printed on both sides per day [Harris, 2006b].

#### THE PRINTER OF *SUMMA*: PAGANINO DE' PAGANINI

The printer of *Summa* in 1494 was Paganino de' Paganini. He and his son Alessandro were the printers of all Pacioli's books known to have been printed between 1494 and 1523. Paganino de' Paganini was from a wealthy family and a relative newcomer to running his own printing firm when he printed *Summa* in 1494. Work known to have been completed by Paganini indicates that his press was a small operation in 1494, although the business grew when Alessandro took it over in the mid-1510s. At 615 pages, *Summa* would have been a huge book for its day, and it would certainly have been the firm's largest venture since its inception.

The last known work undertaken by Paganino de' Paganini before *Summa* was completed on December 9, 1493, virtually a year before he finished printing *Summa*. While it was commonplace for jobbing workers to be employed short-term by printers in the late 15th century, for a job of the size of *Summa* a more permanent team would have been involved. However, as the firm was small and in its infancy, it is likely that the same employees were used as on previous work – one or two compositors, two pressmen, an apprentice, and Paganini, the master printer, working a single press.

It is Paganini who would have done any proofreading. Despite Pacioli's being present during 1493 and 1494 to oversee the printing of the book and saying so in *Summa* [Taylor, 1942], it is clear he was not proofreading text. There are simply too many errors that he, the author and mathematician, would have identified had he been proofreading pages as they came off the press. If he checked anything, it is likely to have been the woodcuts used in the marginal notes to ensure that they were accurate representations of his artwork and that they were correctly positioned in the margin.

#### HOW MANY COPIES OF *SUMMA* WERE PRINTED IN 1494?

No records exist of how many copies of *Summa* were printed, either of the first (1494) or second (1523) edition. On the basis of a highly detailed analysis of differences between various copies of the 1494 edition, Antinori [1980, p. 40] hypothesized that there were 300 copies printed. However, in arriving at that figure, he does not consider the norms in the late 15th century



for the size of print-runs. As will be shown later, his estimate appears to have been a significant underestimate.

Setting aside Antinori's estimate, in the absence of any information other than the average print-runs at that time, it would be reasonable to infer that the print-run of *Summa* in 1494 was at least 500 copies. However, other factors indicate it may have been higher. Among these is evidence of some sheets being reprinted, the analysis of which goes beyond that conducted by Antinori; the number of extant copies of *Summa*; print output quantity limits and the time taken to print the last eight folios; and three estimates made over the last 90 years of the book's popularity.

*Page Reprints circa 1502 and 1509:* It is known that parts of the 1494 edition were reprinted at least twice [Business Historical Society, 1926], once after 1502, possibly to avoid expiration of the 10-year copyright, and the other after 1509 [Clarke, 1974], presumably taking advantage of a 15-year copyright granted to Pacioli in 1508. The later reprinted pages are noticeably different from the first printing, making it easy to demonstrate that the book had been reprinted.

Based on at least three definite printing dates/periods for the first edition, assuming a modern perspective that print-runs of the same book are typically of the same size, as many as 1,500 first edition copies of *Summa* may have been printed between 1494 and 1523. However, while some sheets were clearly re-typeset, the majority in both cases are as in the 1494 printing, which could only have occurred if the printer had a stock of pages left over from that printing.<sup>12</sup> It seems likely, therefore, that the total number of copies printed of the first edition was the number printed in 1494, bringing us back to the initial estimate of at least 500 copies. Support for a print run higher than 500 is provided by the number of extant copies.

*Extant Copies:* Boncompagni [1862-63] identified 72 extant copies of the 1494 printing, 19 of the post-1502 printing, and eight of the post-1509 printing. This suggests a pattern of sales indicative of a seldom-used reference text sold slowly over a long period, as might be expected of a book written mainly as

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<sup>12</sup>It is inconceivable that the typesetter in 1502 or 1509 could have copied the layout of the 1494 typesetter on all but the few obviously amended pages. Wooden blocks used at the start of paragraphs and sections wear out and simply could not be reproduced identically.

a reference text for merchants [Harris, 2006b]. Boncompagni [1862-63] also counted 36 copies of the 1523 edition, suggesting that the print-run of that edition was approximately one-third of the 1494 edition.

Very little is known of incunabula print-runs versus extant copies. A quarter of known incunabula are represented by a single extant copy [Harris, 2006a]. In addition, Harris [2006c] estimates that only 1% of all copies of incunabula have survived and that as many as 40% of editions may have been lost. Two examples show the difference that may exist, possibly depending upon how much a book was actually read once acquired. It is thought that only 200 copies of the first edition of Neumeister's *Comedy* were printed, of which only about 20 (10%) are extant [Cachey et al., 1993]. Gingerich [2004] reports 277 extant copies (18%) of a print-run he estimates at 1,500 of *De Revolutionibus* by Copernicus, "the book nobody read," according to Gingerich. A survival rate somewhere between 10-20% may be normal for "serious" books from the period of *Summa*, depending to a large extent on whether they were read once acquired.

Taking a 10-20% survival rate of unread incunabula as a starting point, Boncompagni's count of 99 extant copies of the 1494 edition of *Summa* in 1862 suggests a print-run of 500 to 1,000 copies. The Incunabula Short Title Catalogue at the British Library currently shows 160 extant copies of the 1494 edition of *Summa*. It also distinguishes two more from the 1523 edition. However, the attribution of copies to dates has not been accurate; some 1523 copies being misclassified as from the 1494 edition. Taking these 162 copies and splitting them in proportion to those identified by Boncompagni, approximately three-quarters, or 120, are likely to be the 1494 edition.

The incunabula survival rates would suggest that the 1494 print-run of *Summa*, a "serious" book read and referenced to with care, was between 600 and 1,200 copies. However, there were other uses for a book of this type, such as classroom teaching, where the survival rates are even lower [Harris, 2006b], so a print-run higher than 1,200 is quite possible. Other evidence points to the actual print-run in 1494 being far larger – the print output quantity limits of the period and the time taken to print the last eight folios.

*Print Output Quantity Limits and the Printing of the Last Eight Folios: Summa* was printed in two volumes. Volume 1 contains 448 pages of text plus 16 pages of introduction; Volume 2, *Geometry*, has 151 pages of text. No record exists showing ex-

actly when printing started. However, Volume 2 was completed on November 10, 1494, and the introduction to Volume 1 was completed on November 20, 1494. The first quinterno in Volume 1 comprised the 16-page introduction and, following the practice of the time, would have been the last part of the book to have been printed. It, therefore, appears that the period from November 10-20 was required to print those pages.

Harris [2006b] estimates that compositors working on *Summa* could have averaged one forme each per day. This immediately makes a print-run of under 1,000 copies unlikely, since 1,000 impressions of two formes a day was the accepted pace of the pressmen, and a lower print-run would have idled the pressmen while the compositors were setting the next formes to be printed.<sup>13</sup>

At an average of 1,000 sheets a day, double-sided, printing the last 16 pages would have taken four days had the print-run been 1,000 copies. Assuming that the introduction was all that was printed during the nine working days between completions of the two volumes, the print-run for *Summa* could have been as large as 2,000 copies.

However, had the print-run been that large, the two compositors would have had to work on other jobs 50% of the time during those last nine days. They could set two formes per day, but the pressmen could only use one of those if printing 2,000 copies. Most printers always had work waiting to be done, especially as one project came to an end, and it is unlikely that the compositors would have been idle [Harris, 2006b]. Alternatively, compositors were generally paid on a piece-rate basis and may have worked at the pace of the press during this final phase of the printing of *Summa* if no other jobs were available. This mismatch between compositor and press speed was not a major problem during the last phase of a late 15th century printing project. However, it would have been had it existed throughout the project.

If the print-run of *Summa* was 2,000 copies, two compositors could only have worked concurrently if the printer used two presses and four pressmen. This is not unlikely as many printers had more than one press, but there is no evidence that Paganino de' Paganini was of sufficient size. Compared with other

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<sup>13</sup>While this would not have been unusual as printers always had other work on hand such as pamphlets and leaflets to do, comments made concerning the popularity of the book support the hypothesis that a print-run as low as 1,000 copies was unlikely.

Venetian printers of the day, very little incunabula printed by Paganino de' Paganini has survived, perhaps indicating that his operation did not print very much during that period.

Had 1,000 copies been printed, two compositors would have been used, and the job would have taken approximately 154 days to print. At six working days a week, this is the equivalent of 26 weeks or six months. However, it is inconceivable that the last four double-sided sheets took nine days unless more than 1,000 copies were printed. If 1,500 copies was the number, it would have taken nine months, but both the pressmen and the two compositors would have been working at only 75% capacity.

On balance, based on print output quantity limits, it seems likely that 2,000 copies were printed, which would have meant it took approximately eight days to print the final 16 pages. If this was the size of the print-run, one compositor, not two, and two pressmen would have been required throughout the project.

Printing 2,000 copies would have taken approximately one year, the time available if the last job known to have preceded *Summa* had actually done so. The compositor would have set one forme each day, and the pressmen would then have spent the next day printing 2,000 copies. While this was being done, the compositor would have typeset the next forme. Further support for a print-run closer to 2,000 copies is provided by claims regarding *Summa*'s volume of sales.

*Claims that Summa was a "Big Seller":* A "big seller" in the late 15th century can be defined as any book that sold over 1,500 copies [Harris, 2006b]. Evidence of this estimate comes entirely from secondary sources, but three scholars have delved deeply into the subject. Olschki [1918] wrote that, for fifty years after its publication, *Summa* was the most widely read mathematics work in Italy. Taylor [1942, p. 198] claimed that the second edition of *Summa* was even more popularly received than the first, justifying the publisher's decision to finance the second edition personally. Finally, Favier [1998, pp. 261, 276], then president of the French Bibliothèque Nationale and author of many books on the Middle Ages, averred that *Summa* was "an instant success and [was] for many years used by the business world" and that "merchants from every country rushed to buy this guide to accountancy." Secondary or not, these three testimonies support the view that the print-run of *Summa* was greater than the norm which, for "serious" books in the late 15th century was 1,000-1,500 copies [Harris, 2006b].

## CONCLUSION

*Summa* was not a curiosity piece, published with a view to a limited market. It was intended to be sold in large quantities for its day, but sales were slow yet steady as evidenced by the 1502 and 1509 sheet reprints [Harris, 2006b]. The fact that Pacioli himself petitioned for a 20-year copyright in 1508 on any reprint of his 1494 book indicates that it continued to sell at a level that justified reprinting missing or damaged folios. The fact that the printers themselves acted as publishers and financed the printing of the second edition also supports the view that *Summa* continued to sell in significant quantities for many years following its original publication.

Available evidence – the reprinting of some sheets of *Summa*; the number of extant copies of *Summa* and the survival rate of other incunabula; print output quantity limits of the late 15th century; the time taken to print the last eight folios; and the apparent success of the book – makes it appear likely that the print-run of *Summa* was at least 1,000 copies, and probably, on the basis of the time taken to print the last eight folios, closer to 2,000 copies.

However, this conclusion must be treated with caution. It is one interpretation of a series of facts and information relating to a process that transpired 500 years ago. Unless the printer's records are discovered, there is no possibility of anyone ever stating with certainty what the print-run was of *Summa* in 1494. However, it can be said with certainty that the number of copies printed was significantly higher than the previously reported estimate.

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