Decoding Chancery Records from the 1240s

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The English records from the 1240s contain many references to the purchase of gold on behalf of the king, Henry III. For example, the *Liberate* Rolls give explicit numerical information about the amounts of gold purchased and the price paid for it. These records also contain implicit information, and this can sometimes be extracted by analysing the arithmetical procedures that were used by the king's officials. We shall see how the arithmetical method can be used to explain how the purity of the gold was assessed, and how the price varied in consequence. The records occasionally mention gold in the form of coins, and in such cases our method can be used to identify the type of coin involved. The task of decoding the records is made considerably more difficult by the use of terms for money, weights, and measures that are longer in current use, and it is only comparatively recently that some clarity on this topic has emerged. Another difficulty is the lack of evidence about the methods used to perform the calculations, and we shall consider the extent to which the Hindu-Arabic methods popularized by Leonard of Pisa (Fibonacci) were being adopted in England in the thirteenth century.

Keywords: arithmetic, algorithms, gold, silver, coins, thirteenth century

1. Introduction

On 7 May 1242 Henry III authorized the payment of 12 pounds 5 shillings and 3 pence for six gold brooches weighing 27 shillings and 3 pence. The published record of the transaction is explicit, insofar as it states the amount of money to be paid and the weight of the gold, but it also contains some implicit information, which can only be discovered by means of arithmetic (C 134).[1]

In some respects the process of analyzing such records resembles modern methods of cryptography. The discussion here will involve a wide range of matters relating to the history of mathematics, metrology, and numismatics, but the basic principle can be stated very simply. The payment quoted above is equivalent to 2943 pence, and the weight of the gold is 327 pennyweights. The key fact is that 2943 is equal to 9 times 327. The unshakeable certainty of arithmetic establishes beyond doubt that Henry's officers calculated the price of the gold brooches by *multiplication*. However, in order to discover that the number 9 is the key it is necessary use the inverse operation of *division*, a much more complex procedure.[2]

The official Rolls for the 1240s contain many similar records. They can be studied from several viewpoints: the focus here is the extent to which the algorithms of Hindu-Arabic arithmetic were being used in England in the middle of the thirteenth century. The approach was suggested by some work of the historian and numismatist Phillip Grierson, who used the detailed numerical information in the records to identify the mysterious objects referred to as *oboli de musc'* (Grierson 1951). Indeed Grierson's work is linked with our main theme more closely than he realised, because the *oboli* are mentioned (under another name) in the *Liber Abbaci* of Fibonacci, the book that sparked the adoption of Hindu-Arabic algorithms throughout Western Europe,

This article is part of the quest to find evidence of Fibonacci's fingerprints in medieval English documents. The use of Roman numerals in official records continued long after the underlying calculations were being done with the Hindu-Arabic numerals and algorithms. The people who did the calculations tended to keep their methods secret, and their expertise was not recognised publicly at the time. It is for such reasons that the word 'decoding' is used in the title of this article.

2. Background to the calculations

2.1 The units of value and weight

The task of decoding the information contained in the Rolls is made considerably more difficult by terminology that is no longer in current use. In 1242 it would have been clearly understood by the people who had to carry out the king's instructions, but the

[1]The record is quoted in the form published in the *Calendar of the Liberate Rolls, Henry III Vol. II, 1240-1245* (Chapman 1930). References to this volume will be cited here in the form (C 000). The original roll used the customary language and notation of the thirteenth century, Latin text and Roman numerals.
[2]Indeed, the system of public-key cryptography that is now used to keep our data secure is based on that same observation.

subsequent efforts of historians to unravel it have only recently achieved a satisfactory conclusion. So it is necessary to begin with a summary of the 'facts', as they are currently understood.

The basic unit of value in England in the 1240s was the coin known as a *penny*, which was stamped on one side with an image of the king's head to show its authenticity. The recording of payments often required larger units, which were simply multiples, such as the *shilling*, which signified 12 pence. It is worth noting that in the middle of the thirteenth century the penny was the only denomination actually represented by a coin — there were no shilling coins or pound coins until much later.

The names of the units and their relationships had evolved over several centuries (Biggs 2013). The units known as the pound, mark, ounce, and shilling appear in the Rolls of Henry III, and were related as shown in Figure 1. Pounds, shillings, and pence were denoted by the abbreviations *l*, *s*, *d*; for example, 12*l* 5*s* 3*d* was the usual way of writing 2943*d*.

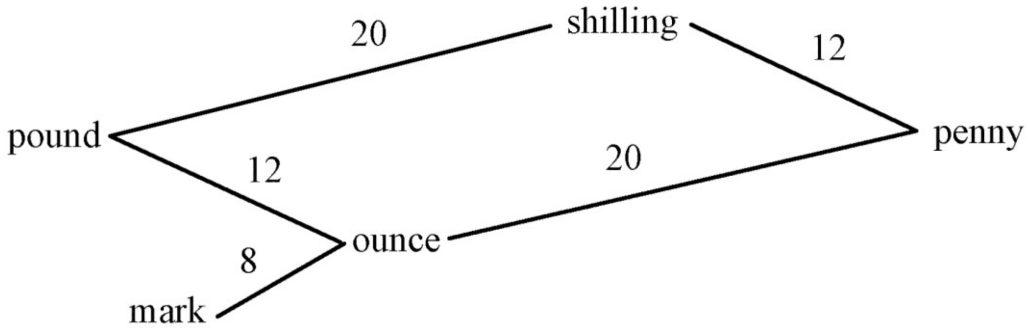

Figure 1. The multiple units that appear in thirteenth century English documents.

An eminently reasonable hypothesis is that the unit of weight was simply the weight of the king's penny coin. This would imply that the officers of the king's mints kept a standard object, a pound-weight, and they ensured that 240 of the penny coins they produced balanced it exactly. But this hypothesis cannot be accepted unreservedly, for several reasons. In particular, it is quite clear that the weight of the English penny was altered frequently throughout the entire medieval period. The period from 1180 until 1247 was a relatively stable one, known to numismatists as the era of the *short-cross penny*, and current research shows that the reasonable hypothesis is 'almost' correct for that period (Brand 1994, Allen 2012). We can state with some confidence that *about* 240 pennies were made to balance the weight of a 'Tower pound', which in modern terms was *about* 350 grams. If the figures were exact that would imply that the average penny weighed 1.46 grams, but in fact the figure obtained from actual specimens is slightly less, around 1.41 grams. Later the weight of the penny coin and the pennyweight gradually diverged, until eventually the silver penny weighed about 0.5 grams, while the pennyweight stabilized at just over 1.5 grams. (The modern English 1p coin, which is not silver, weighs about 3.5 grams.)

Further confusion arises because the names used for recording multiples were the same for weights as for values, and the abbreviations overlapped in an alarming way. For example, the weight of the six brooches mentioned in the Introduction was recorded 27*s* 3*d*, and the value as 12*l* 5*s* 3*d*. A penny*weight* could be denoted by either *d* or *dwt,* seemingly at random, whereas the shilling of 12 pennyweights and the pound of 240 pennyweights were always denoted by *s* and *l*.

2.2 The precious metals and their value

On 24 April 1242, two weeks before the purchase of the six gold brooches mentioned in the Introduction, the king authorized the purchase of several small lots of gold (C 120). The first lot weighed 1½*dwt*, and 16½*d* was paid for it. Here it is easy to spot that 11 is the multiplier, and the fact that it is greater than the 9 allowed for the brooches indicates that the gold was of higher quality,

Nowadays the *fineness* (purity) of gold can be measured very accurately by scientific means, and is often reported in the millesimal system. For example, 789 denotes an alloy that has 789 parts of pure gold in a thousand. This system allows for measurements of high precision, but it was not available in the thirteenth century.[3] At that time a gold object was tested by making a mark on a touchstone, and comparing it with the marks made by a set of standard 'touch-needles'. This method used only a discrete scale of numbers, such as the 9 and 11 mentioned above. corresponding to the known fineness of the needles. The appropriate number/needle was the multiplier used to calculate the value of the item, and thus provided a secret 'key' to the record. In Section 3 we shall examine some examples from the *Liberate* Rolls of 1241-42 in detail.

For testing silver, a chemical process known as the 'fire-assay' had been used at the Exchequer, possibly since the time of the Domesday Book. The ultimate intention was that all the silver in England, including that used for ornament and plate, should be at least as fine as the coins. To that end, in 1238 an ordinance was recorded in the Close Rolls, instructing that no silver was to be worked by the craftsmen of London if it was worse than the king's money (Maxwell-Lyte 1911, 85). A minimum standard for gold was also specified, but it cannot be assumed that the policy was entirely successful, and there remains some doubt as to what the standard of the money really was (Brand 1994, Allen 2012).

2.3 Arithmetic in practice

The thirteenth century saw great changes in the practice of arithmetic, comparable to the advent of the electronic computer in the twentieth. The old methods of calculation had involved reckoning on the fingers, or moving counters on a board (abacus), but these methods were being replaced by the algorithms of Hindu-Arabic arithmetic. The new methods had been known in Western Europe since the end of the tenth century, but the chronology of their use in the affairs of government remains obscure; indeed, a leading historian of the later medieval period has referred to 'the lack of surviving documentation from the thirteenth century' (Spufford 2002, 29).

In the context of the English administration there are two documents that focus attention firmly on the period considered in this article. The *Dialogus de Scaccario* was

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[3]For the history of assaying gold, see (Oddy 1983). In the early 1600s Thomas Harriot began using hydrostatic methods to check the fineness of English gold coins (Biggs 2019).

written in the late 1170s, and contains many details of the procedures used when taxes were received at the Exchequer. It also contains the assertion that accounting was done by the customary procedures of the Exchequer (meaning the counters and board) not by arithmetic (*consuetum cursum scaccari non legibis arismeticis*) (Amt and Church 2007, 52). On the other hand, the *Tractatus de Nova Moneta* (Johnson 1956), written in the 1280s contains very strong circumstantial evidence that calculations were being done in the algorithmic manner at that time (Biggs 2020). The changes implied by these documents suggests that it is worth looking for clues in the intervening years, such as the 1240s. The conclusions obtained for this period may well throw some light on the events of the following decade, when gold began to play a more important part in English financial affairs (Carpenter 1986, Carpenter 1987).

3. Clues from the *Liberate* Rolls 1241-42

The king's purchases of gold and other items were authorized by means of writs of *liberate* (meaning 'let it be released'). These writs were produced in the Chancery and sent to the Exchequer, where the cash was kept (Carpenter 2004). The officers of the Exchequer then made the payment and recorded the 'issue'. The present article is based on information contained in the *Liberate* Rolls, the records that remained in the Chancery.[4]

In Section 2.2 we noted that on 24 April 1242 the price of 'pure gold' was 11 pence per pennyweight. This is one of many payments recorded on that day. The first one is simple, but informative (C 120):

7*s* 1*d* for 7*s* 1*d* weight of silver for enlarging a censer . . . .

Here is support for the claim that our hypothesis about the unit of weight is 'almost correct'. The only credible interpretation is that 85 of the king's silver pennies were to be paid for an approximately equal weight of silver bullion. It seems that the Chancery assumed that the ordinance of 1238 was in being observed, so that the bullion and the pennies were of equal fineness.

The next item in the list is less helpful (C120):

10*s* for 10*dwt* of pure gold and for quicksilver to gild it [the censer].

Although the multiplier (12) is easy to spot, the fact that the quicksilver is included means that we cannot conclude that the gold itself was pure in the strict sense (100%). We have already noted that the multiplier 11 was used for 1½*dwt* of 'pure gold' with no mention of quicksilver, and in the same list (C 120) there are other purchases of 'pure gold', including 22*d* paid for 2*dwt* and 45*d* paid for 4½*dwt.* In these cases the multipliers are 11 and 10 respectively, suggesting that the words 'pure gold' appearing in the *Calendar* are just a convenient translation of a term that signified gold of a good grade, but not necessarily 100% fine. There are other purchases in which the multiplier 10 is used, although the adjective 'pure' does not appear: they include 25 marks 5*s* paid

[4]Most of the numbers quoted in this article can be checked independently, because the issue rolls corresponding to writs of *liberate* for 1241-42 have also been printed (Stacey 1992).

for 33*s* 10*d* weight ('gold for a brooch') and 10 marks 10*s* paid for 14*s* 4*d* weight ('gold for making a girdle').

A few days later, on 2 May 1242, several more items of gold were bought, and (exceptionally) the multipliers are stated explicitly in the record (C 126).[5] The numbers used are 8 and 8½, suggesting that the gold was of good quality, but not the best.

So we have examples of gold for which the price was calculated with the multipliers 8, 8 ½, 9, 10, and 11. These examples, and several others, suggest that in 1242 the fineness of gold was being assessed on a scale in which the numbers were integers or half-integers, and the maximum was either 11 or 12. For our purposes it is convenient to use the term *fineness factor* to refer to these numbers. Such a system allowed for up to 24 grades of fineness, and would have required a set of 24 touch needles. The *Liberate* Rolls thus provide what may be the earliest evidence of the *carat* system in England, where it is still used today in the retail jewellery trade. It is thought to have originated in the Islamic world in the early medieval period, the name being derived from the *quirat*, a weight-unit equal to one twenty-fourth of the Islamic ounce. There is an Arabic document of the early thirteenth century which describes the construction of a set of 24 touch-needles for the Cairo Mint using the Islamic units (Oddy 1983). The Latin form of the word 'carat' appears in Roger Bacon's *Opus Minus* of 1267, but without numerical details (Brewer 1859, 375), and it is clearly defined in a Mint document of Edward III (Johnson 1956, 83). By the sixteenth century the English word was in common use, and it appears, for example, on the trial plates used at the Mint (Watson 1962).[6]

The carat system (to be pedantic, the system based on what we have called the fineness factor) was easily adapted for practical purposes, and the calculated price could be adjusted if the circumstances required. For example, in 1246 the king bought gold weighing 17*s* 4*d* (208 pennyweights) in order to decorate a crystal box (Chapman 1937, 58). According to the *Calendar* the cost was '7*l* 8*s* (*corrected from 10s*)' and the gold had been 'assayed (*combusto*) and tested'. This translation is very doubtful, especially the meaning assigned to the word *combusto.* A more likely interpretation is that this was a parcel of 'scrap' gold, which had been melted into a single ingot and then tested by the touch. If the fineness factor was 8½, it would have been worth 7*l* 7*s* 4*d*, but the price seems to have been subject to negotiation, before being finally settled at 7*l* 8*s*. Another transaction recorded on the same day was the purchase of a mark (160 pennyweights) of gold-dust (*auri in pallera*), for which 103*s* 4*d* (1240*d*) was paid. Here it is stated explicitly in the record that the 'dust' was cast into 'ingots', which would have facilitated the use of the touchstone. The 'fineness factor' is 7¾ exactly, suggesting a settlement agreed after negotiation. (This transaction also provides a useful clue to another mystery, to be investigated in Section 5.)

We must also be aware of the possibility that a few of the numbers in the Rolls are plain and simple mistakes. For example, it is recorded that on 12 October 1241 the king

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[5]The *Calendar* has a footnote remarking on this feature, but it is misleading. There was no such thing as a 'gold penny' in 1242. See Section 6.

[6]According to the *Tractatus* (Johnson 1956) the number 24 was also important in the assay of silver. Since there were 24 grains in a pennyweight, the sample to be assayed should weigh exactly 10 pennyweights, so that (in money terms) each grain represented one penny in a pound.

paid 53*l* 10*s* (12840 pence) for 8 marks 40*d* (1320 pennyweights) of 'pure gold' (C 83). If indeed 12840 pence was paid for 1320 pennyweights, the fineness factor would be $\frac{107}{11}$, an unlovely and highly suspicious fraction. The problem disappears if the weight were actually 8 marks 4*d* (that is, 4*d* not 40*d*), when the number of pennyweights would be 1284 and the price could be obtained by multiplying by the fineness factor 10 in the normal way.

4. The arithmetical basis of the records

The procedure for valuing gold, as described in the previous section, determined the type of calculation needed to produce the figures stated in the official records. The weight of an item of gold would be found by the scales, and expressed in appropriate weight-units. Then it would be tested by the touchstone and assigned a number, which we called the fineness factor. The weight was then multiplied by the number, and the result was expressed as a monetary value in pounds, shillings and pence. In the middle of the thirteenth century very few people knew how to do such calculations.

For many centuries calculations had been done with a simple 'analogue computer', that is, with counters or pebbles (*calculi*) arranged on a board (*abacus*). Such devices have been found in ancient Greek and Roman contexts, but they are rare. Documentary evidence of the procedures used is almost non-existent, and remained so throughout the middle ages. The *Dialogus* (Amt and Church 2007) tells us that in the twelfth century the Exchequer was using an abacus to check the payment of taxes, but the arithmetic involved was quite simple, as it required only the addition of amounts of money. On the other hand, by the middle of the thirteenth century, it is clear from the *Liberate* Rolls that another branch of the government was relying on calculations that required some form of multiplication. A simple abacus could certainly be used for such calculations, but the details of the procedures were known only to a select few, and it is likely that they were passed on by word of mouth. This situation changed dramatically in the sixteenth century, when printed textbooks of Arithmetic became widely available. These books contained detailed descriptions of how the abacus could be used for all kinds of arithmetical procedures, and a convenient summary is available in the classic work of F.P. Barnard. He refers to the kind of calculation required to establish the value of gold as 'mixed multiplication' and in several cases (but not all) he finds that the method was to express the given amount in terms of the smallest unit, multiply the numbers, and convert the result back to the required form (Barnard 1917; 287, 299, 309). For example, in order to multiply the weight of 27*s* 3*d* by 9, the weight would be expressed as 327 (pennyweights), multiplied by 9 to get 2943, and finally reduced to 12 pounds 5 shillings and 3 pence.

It is quite possible that some form of abacus was used to calculate the king's payments for gold in the 1240s. A significant improvement on the simple abacus had certainly been in use since the twelfth century, and is now known as 'Gerbert's abacus'.[7] The main innovations were that the counters were inscribed with Hindu-

[7]An account of Gerbert's abacus can be found in the document known as Manuscript 17, from St John's College, Oxford, available online at digital.library.mcgill.calms-17. The Bodleian Library has several manuscripts with relevant information; see for example Ms.Bodleian.Auct.F.1.9.f65v.

Arabic numerals, and the board was divided into labelled columns, corresponding to the 'places' in decimal notation. However, by the 1240s another method was available. The *Liber Abbaci*, Fibonacci's seminal work on Hindu-Arabic arithmetic, first appeared in 1202, and was revised in 1228.[8] In the prologue, Fibonacci specifically asserts the superiority of Hindu-Arabic algorithms over older methods, including 'Pythagorean arcs', which seems to be a reference to the columns of Gerbert's abacus (Sigler 2002, 16). His calculations are clearly intended to be done by writing down the numerals, rather than using counters; for example he refers to the use of 'the chalk table' (Sigler 2002, 24)

Fibonacci began by describing algorithms for adding, subtracting, multiplying and dividing ordinary numbers, but the main thrust of his work was the application of these methods to commercial arithmetic. In Chapter 8 he expounded a 'universal rule' for dealing with the valuation of goods, which was destined to be taught (by rote) to reluctant children for many centuries, under the name of the Rule of Three. One of his first examples was (essentially) this: if 100 items cost 13*l*, what is the cost of 27 items? The method, according to the Rule of Three, is to multiply 13 by 27 and divide by 100, so the answer (in pounds) is 351 divided by 100. For practical reasons it is necessary to convert this into *l s d*, leading to the answer 3*l* 10*s* 2 2/5*d.*[9]

The *Liber* contains many similar calculations, and readers of the book would surely have learned several ways of calculating with money using the Hindu-Arabic system. For us, the question is: when did the king's officers acquire this knowledge? Several other manuscripts dealing with the new methods were available by the middle of the thirteenth century, and may well have reached England by that time. For example, in the Bodleian Library there are no less than eleven copies of the *Carmen de algorismo* of Alexander Ville Dieu, who died in 1240, as well as a copy of the *Algorismo* of Johannes Sacrobosco, who died around the same time (Stedall 2002, 25-27). So, although we cannot give a firm answer to our question, the evidence presented here puts the focus clearly on the period considered in the present article. A terminal date of 1279 can be stated with some confidence, because by then the king was importing experts on financial matters from Italy, and some of them would surely have been adept in the methods described by Fibonacci.[10]

5. Gold coins in England: Grierson revisited

For many years, up to and including the 1240s, no gold coins had been minted in England, although some foreign gold coins had entered the country, brought in by merchants engaged in international trade. For example, coins referred to as *bezants* appear regularly in the official records from the middle of the twelfth century onwards. Some authorities, including Carpenter (1987) and Cook (1999), interpret all the

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[8]A printed edition of Fibonacci's Latin manuscript was published by Boncompagni (1857) and an English translation is now available (Sigler 2002). It must be noted that, although Fibonacci used the decimal place-value system of representing numbers, his methods of calculating with them were not the same as the ones (such as 'long division') that were taught to children in the nineteenth and twentieth centuries.

[9]The pounds, shillings, and pence were the Pisan kind, which were related in the same way as the English kind, but differed in value (Sigler 2002, 129). Some care is needed in interpreting Sigler's translation.

[10]Edward I had several reasons for employing the Italians, including the fact that they represented his bankers (Biggs 2020).

occurrences of ‘bezant’ in the English records as referring to the gold hyperpyron of Byzantium, as the name suggests. However, there is evidence that the word ‘bezant’ eventually came to be used as a generic term for any gold coin, in particular the Islamic dinar. Indeed the *Handbook of Medieval Exchange* contains many references to these Islamic ‘bezants’ being exchanged throughout Western Europe (Spufford 1986, 286-308). It is possible that arithmetical methods would throw some light on this point, but that is not the object of the present paper.

By the 1240s the old dinar was no longer the only gold coin of Islam. Grierson (1951) studied the *Liberate* Rolls with the aim of identifying the objects referred to therein as *oboli de musc'*. These words appear often among purchases of gold and other expensive items, but earlier writers had failed to uncover their meaning. One authority had stated dogmatically that the entries did not refer to gold at all, but musk (a spice). With hindsight, it is clear that the *oboli* were indeed gold coins. The word `obol’ is a general term meaning ‘half’, which here is used to distinguish the coins from similar but larger ones, which also appear in the Rolls, as *denari de musc'*. Grierson identified these *oboli* and *denari* as gold coins from the parts of North Africa and Spain that were ruled by the Almohad caliphate for over a hundred years from the middle of the twelfth century (Figure 2). The words *de musc'* in the English records may have been a fudged reference to Murcia, the main city of the Almohads in Spain. The coins were minted in large numbers and circulated widely, not only in the Islamic world, but also in continental Europe, where they were referred to as *mazmudina* or *massamutini* (Grierson 1951, 77, 80; 1974, 387). Fibonacci would have been familiar with them from his youth, when he travelled with his father on business in North Africa; indeed, the *massamutini* occur in the *Liber Abbaci* in a problem illustrating the Rule of Three (Sigler 2002, 132).

Figure 2. Left: a gold dinar *de musc'* of the type minted by the Almohads in North Africa during the period when Fibonacci travelled in that area with his father. Right: an obol *de musc'* found in Suffolk. Wikimedia Commons: (1) Classical Numismatic Group Inc., www.cngcoins.com; (2) The Portable Antiquities Scheme / The Trustees of the British Museum.

Grierson relied for his identification mainly on two entries in the *Liberate* Rolls, dated 4 November 1244 (C 273-4) and 21 April 1245 (C 296-7). There are similar entries from the years 1241 and 1242, contemporary with the material on purchases of gold already discussed in Section 3. In fact just two records from 1242 are enough to confirm Grierson’s conclusions — as well as showing the usefulness of the arithmetical approach.

The relevant entries are dated 17 March 1242 (C 113) and 24 April 1242 (C 121). They involve two alternative methods of valuing coins. The first method is simply to treat the coins as bullion, so that they must be weighed and tested by the touchstone.

Thus, on 24 April it was recorded that half a mark's weight of obols was purchased for 5 marks: that is, 800 pence was paid for 80 pennyweights. Here the fineness factor resulting from the assay is clearly 10, although it is not stated explicitly. The number of coins is stated to be 52. It plays no part in the calculation on this occasion but, as we shall see shortly, it does provide useful information. The second method of valuing a coin is to use an accepted value. This assumes that coins of specific type have a standard weight and fineness—which is, of course, the feature that distinguishes a coin from bullion. On 17 March twelve obols worth 15*d* were purchased for 15*s*. On this occasion there is no mention of the weight or fineness, and the payment is calculated by multiplying the accepted value of 15*d* by 12, the number of coins.

The accepted value of a coin was not fixed in time, but varied due to economic factors such as the supply and demand for precious metals. For example, in January 1241, just over a year before the value of an obol was recorded as 15*d*, the sum of 15*l* 14*s* 8*d* was paid for an unstated number of obols (C 22). The price equates to 3776 pence, but this number is not an exact multiple of 15. However, it is an exact multiple of 16, which suggests that the accepted price at this time was 16*d* and the number of obols was 231 (since 3776 = 231 x 16). Fortunately this conclusion can be checked in another way, since the record says that the obols weighed 2 marks 36 (that is, 356 pennyweights). We have already noted that 52 obols weighed 80 pennyweights, so the number of obols that weighed 356 pennyweights should be obtained by dividing 356 by 80/52. The result is just over 231, close enough to confirm our suggestion.

Thus the two records from 1242, together with another from 1241 and the arithmetical imperatives, imply that an obol weighed just over 1½ pennyweights and had a fineness factor of 10 on the exchequer scale. There are several other contemporary records that confirm these figures, and they support the conclusions of Grierson,

A more difficult test for the arithmetical approach is provided by a problem that Grierson discussed, but was unable to solve satisfactorily (Grierson 1974). In the *Liberate* Rolls for October 1241 and April 1242 there are two references to purchases of gold pieces of ten pennyweights. The second one (C 120) records the purchase of 32 of these pieces for 16 marks. Given that each piece weighed 10 pennyweights, the total weight was 320 pennyweights. The price was 2560 pence, so the fineness factor was 8. The first record (C 83) is slightly more complicated, since it concerns a mixture of obols and pieces of 10 pennyweights, but fortunately the arithmetic falls out nicely. The record states that 6*l* 8*s* was paid for 36 obols and 12 of the ten-pennyweight pieces. Assuming that the obols were reckoned as coins valued at the 1241 rate of 16*d*, and the pieces were treated as 120 pennyweights of bullion with fineness 8 (as in the other record), the total cost (in pence) would be

$$(36 \times 16) + (8 \times 120) = 576 + 960 = 1536,$$

which equates to the stated 6*l* 8*s*.

Numismatists have naturally assumed that the ten-pennyweight pieces were coins but, as Grierson himself pointed out, it is hard to find examples of gold coins of that size. Bezants and dinars weighed roughly 3 pennyweights, and the obols just half that. The only possible candidate was a coin produced by the Ghurid dynasty in Afghanistan, and Grierson thought that a few of them may have reached England in the thirteenth century. This possibility was discussed by Morton (1978). There are indeed some specimens in the British Museum that have about the right weight, so there is some support for Grierson's suggestion. However, modern assays showed that the Ghurid coins are almost pure gold. This conflicts with the arithmetical evidence given above, which strongly suggests a fineness factor of 8, far from the maximum.

In that light, further evidence is worth considering, and a clue can be found in an entry in the Rolls for 1246, already mentioned in Section 3 (Chapman 1937, 58). This refers to some gold 'dust' that had been valued and assigned the fineness factor of 7¾, possibly after negotiation. The significant point is that the gold had been cast into 16 'ingots'. Since the total weight was stated to be one mark, each of these 'ingots' would weigh 10 pennyweights. Thus we must take seriously the suggestion that the 'pieces of 10 pennyweights' were not coins at all, but simply pieces of gold bullion. Such items would have been convenient for use by the goldsmiths engaged in the ornamentation of the king's offerings.

6. Conclusion

The evidence presented above is consistent with the view that there were significant links between the practical problems of medieval finance and the introduction of the Hindu-Arabic algorithms in Western Europe. It is only the fickleness of fate that has resulted in Fibonacci being famous for the one chapter (12) of *Liber Abbaci* devoted to artificial arithmetical problems, rather than the four chapters (8 - 11) on monetary matters. His contributions to higher mathematics have likewise been overlooked.

Although the financial calculations in the *Liber* are mainly concerned with the production and use of the numerous silver coins of the time, gold coins do make an appearance. As has already been noted, the *oboli de musc'* (or *massamutini*) are used in one of the problems in Chapter 8. More significantly, there is a strong suspicion that Fibonacci had a direct connection with the gold coinage of his time. The central character here is Frederick II of Sicily, who became Holy Roman Emperor in 1220, and was a major player in European affairs for the next thirty years. He was a learned man, who employed scholars to translate the scientific works of Greece and Islam into Latin. Some of these scholars were in touch with Fibonacci, and the 1228 edition of the *Liber* is dedicated to one of them, Michael Scotus. Around 1225 Frederick met Fibonacci in Pisa, and presented him with some mathematical problems, including a cubic equation, which he solved numerically with great precision.

Frederick is known in numismatic circles for his efforts to re-establish a coinage of gold in Christian Europe. Although there is no documentary evidence, it is highly likely that he consulted Fibonacci about this project, which required the arithmetical expertise set out in the *Libe*r, as well as the great political power and technical facilities that Frederick could provide. In 1231 Frederick began minting a gold coin, the *augustale*, which was about 20 carats fine and weighed about 5.25 grams (Figure 3). It may have been intended as a sign of his imperial status, rather than as a tool of trade, but a significant number of these coins have survived. By 1244 some of them had reached England and were being acquired by the king (Carpenter 1987, 109).

Figure 3. A gold *augustale* of the type produced by Frederick II from 1231 onwards, after he met Fibonacci in Pisa. Wikimedia Commons: Classical Numismatic Group Inc., www.cngcoins.com.

The success of Frederick's project prompted the production of gold coins elsewhere, and in 1252 the city-states of Genoa and Florence both began minting coins of practically pure gold. The Florentine coin (florin) was soon to become the most important coin in European commerce. In England, the king and council were persuaded that a national coinage of gold was desirable, and some bullion was purchased for that purpose (Carpenter 1986). The project was attempted in 1257, but it was a dismal failure. There are no official records with data that might throw light on the reasons for the failure, and the only near-contemporary account is to be found in the *Chronicle of the Mayors and Sheriffs of London* (Riley 1863). This begins with the assertion that the king declared that his gold pennies were 'two sterlings in weight, of the purest gold, [. . .] and should pass for twenty sterlings'. It seems that he was attempting to fix the accepted value of his gold coins, instead of allowing it to vary in the market as had been the case with foreign coins. Furthermore, the implied price of 10 pence per pennyweight was questionable, if the coins were indeed 'of the purest gold'. The *Chronicle* goes on to tell us that the king summoned the mayor and citizens to the Exchequer in November 1257, where they expressed reasons for their opposition. Their arguments were a now-familiar mixture of populist rhetoric and simplistic economics. First, they said that a poor man would have no use for the gold coins, since his entire wealth did not amount to a single one of them Then they said that the increased supply of gold had led to a fall in the price. They did not mention that (by their own argument) this would only affect rich people, like themselves, or that they had benefitted from the rise in price when the king was buying gold to prepare for his new coinage. In reply, the king said that no one would be compelled to take his gold pennies, and that the Exchequer would exchange them for 19½ pence in silver.

It is difficult to unravel the true facts behind the events of 1257. Certain it is that the new gold coins quickly disappeared, and a few years later the king was buying them back for 24*d*. He had attempted to set a fixed price of 20*d*, rather than allowing them to be exchanged at a value determined by their fineness, as had usually been the case with foreign gold coins. If they were indeed 'of the purest gold', they would have warranted a fineness factor of 11 or even 12, not the 10 which he decreed. However, for practical reasons the fineness and weight of the gold pennies may have been subject to minor adjustments that were not apparent in the king's bald assertions (Carpenter 1986, 1987).

Nearly a century would elapse before a successful English coinage of gold was established. The arithmetical calculations required were difficult, both conceptually and technically, and the official records are rarely explicit about the details. The material presented here suggests that, in some cases, useful information can be extracted from the records by a process akin to 'decoding'.

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