Heads & Tails: A study of the informational value of Greek coinage (650 BCE – 336 BCE)

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1. Introduction: Ancient Greek coinage

Shortly after the invention of coinage in Asia Minor, the practice of minting bits of precious metal to guarantee their weight diffused rapidly and widely in the ancient Greek world. One of the most prominent features of coins is their design, the image in relief pressed usually on both sides of the metal disc. Images can be found on the earliest coined money, the electrum coins of Asia Minor. The image identified the issuing authority and served as a guarantee of standard weight and metal purity (Kraay, 1976). Ancient Greek cities adopted coinage very early, c. 600. BC. Greek coins usually depict people (gods, heroes and kings), as well as natural motifs (plants, animals and fantastic creatures) and objects, referring to the patron deity or famous myth associated with the city issuing the coin. Sometimes the image has little to do with deities, but instead depicts a personification of local geographical feature, most famous local product, or simply refers to the city name (similar to "canting puns"). Some cities never changed the coin design they adopted (e.g. Athens), whereas some cities changed the design completely with each following issue (e.g. Lesbos, Phocaea).

Greek coinage appeared in a period of intensive communication: trade networks connected Greeks with the rest of the Mediterranean, and by that time the networks of Greek cities inside and outside the mainland Greece were well established. Even though coinage did not completely transform the economy of archaic Greece, it provided a manner to facilitate transactions inside a city and between cities, and enhance the already high level of exchange and prosperity (Osborne, 2009: 245).

The earliest coinage consisted of electrum tokens of determined weight but varying gold and silver content in the alloy. It was used mainly for paying the individuals (e.g. mercenary soldiers) who would then have to exchange the coins for other goods in the same city, which helped the local economy. Silver coinage followed quickly afterwards (c. 550 BC), and its value was based on the coin's weight as well as high silver content guaranteed by the issuing authority. Although the weight standards still varied between the cities, silver coins were exchanged more easily across the Greek world thanks to their bullion value. The influence of the weight standard and coin design of a particular city seems to be influenced mainly by politics and trade (Osborne, 2009: 242-4).

2. Coin motifs: Information and cultural diffusion

Emblems and identifiers are characterised by a peculiar trade-off between two cultural dynamics. In theory, any emblem that serves to distinguish items in a population — names for individuals, coats of arms for families,

flags for countries, etc. — best performs its informative function when one unique identifier designates each item. Cultural diffusion prevents this. First names get imitated on a massive scale (Lieberson and Bell, 1992; Bentley et al., 2004), which necessarily diminishes their informational value (increasing the risks of confusion). The heraldic coats of arms that served to identify European lineages in the Middle Ages and Renaissance got copied, either as entire designs or on a component-by-component basis (Morin and Miton, submitted). Even though makers of arms had efficient ways of mitigating this risk, it resulted in many families sharing the exact same arms, once more reducing their informative value. The national flags of the world, although each is at least slightly different, are not as distinctive from one another as they could be, were it not for the widespread diffusion of some basic designs (e.g. the 3-bands basic plan, the pan-African or pan-Arab colours). This is a relatively rare and interesting family of cases where cultural diffusion directly hinders the efficiency of a cultural practice.

Greek coins developed inside a culture (Archaic Greece) whose members already shared a substantial graphic repertoire. Coinage motifs (the images that were impressed upon the coins by minters) were first adapted from this repertoire. In subsequent centuries, this cultural unity increased markedly. Greek culture expanded and consolidated during the classical period. The cultural unification went along with substantial commercial integration between city-states (poleis) (Ober, 2016). As time went by, minters were increasingly exposed to graphic creations from other poleis, multiplying opportunities for imitation. Their coins were more likely to travel to remote markets, where they would be exchanged with coins from other mints. Their metal weight then needed to be compared against that of other coins, possibly issued by different poleis. This comparison could concern both the coin's actual weight (coins were occasionally weighted, especially for strong denominations) and the denomination advertised by the coin's mint (i.e. whether the coin was a drachma, an obol, a tetradrachm, etc., each of these denomination corresponding to a theoretical weight in silver). Importantly, several poleis would typically mint coins of similar denominations: the issue of drachmas, obols, etc. was not the preserve of one city alone (just like several European countries would later mint silver thalers). Denominations were not necessarily (or even customarily) inscribed on the coins, but the reputation of certain currencies, like the Athenian drachma, made them reliable. Denomination marks as such were usually absent from the coins, although there is some reason to assume the incuse squares of reverse of earliest coins denoted denomination (number or pattern of squares), and Italian colonies sometimes put pellets on the reverse of their bronze coins, or inscribed the name of the denomination. But outside of assaying, the weight, size and aspect were usually most salient way of determining the coin’s metal content (Rutter, 1983; Rutter, 2000; Velde, 2013).

2.1. Predictions

This study aims to test two hypotheses regarding the consequences of this dynamic upon the meaning and informative value of coinage motifs. A single motif, by itself (a laurel branch, a bull, an owl, Apollo, etc.) would

seldom define a coin by itself (except in the very beginning of coinage, when only the obverse was marked). A typical coin would bear several motifs, supplemented by other marks such as monograms, whole words, mint marks, etc. Yet, motifs being the most salient and recognisable components of Greek coins, we would expect them to carry some information regarding the coin they figured on—both the polis that issued it and the coin's denomination.

As Hart (2005) remarks, coinage usually carries two very different kinds of information, symbolized on today's coins by the "Heads" and "Tails" sides. The Heads side typically carries the symbols of the state that issued the coins, while the Tails side carries information concerning the coin's denomination. The separation is particularly clear when a several distinct states issue the same currency (e.g., the Euro), or when different currencies are issued in the name of one single head of state (e.g. the currencies of the Commonwealth). Greek coins usually lacked this differentiation: no side was particularly reserved for state imagery while the other would have been kept for denomination-relevant information. In spite of this, the point of this project is to find traces of the tension between Heads-type imagery (state symbols) and Tails-type imagery (denomination symbols) in Ancient Greek coins.

We plan to test three predictions derived from the two hypotheses, one concerning the motifs representing the issuing authority and informing us about a coin's provenance, and two about the motifs symbolizing the value of the coin (denomination).

(1) Motifs become less informative about a coin's provenance.

Cultural unification should cause the use of individual motifs to spread from one polis's mint to another, reducing the amount of information that motifs carry about their provenance. In addition to the normal flow of ideas and symbols permitted by the circulation of art objects, coins among them, there is evidence that mint masters themselves travelled from city to city (de Callataÿ, 2012). Whenever a polis' minters borrow a motif in use by another mint, this reduces the informational value of that motif: it becomes less distinctive than it used to be, as far as the provenance of the coins bearing it is concerned. The more motifs get borrowed, the lower the informational value of motifs in general.

(2) Motifs become more informative about a coin's denomination.

Economic integration would have increased the pressure for coins to be exchangeable at their face value, leading to important demands for coins (like the Athenian drachma) whose metal content was faithfully indicated by their denomination, advertised on the coin by the image symbolizing the silver weight standard the denomination was based on. In highly integrated markets where coins from many poleis would be traded together, this information may have become more relevant than knowing which particular polis issued a coin. The cultural diffusion of motifs from mint to mint would not have affected their informational value as far as denominations were concerned, since several mints could have used the same weight standard (Kraay,

1976: Appendix I).

Our second prediction is more speculative than the first, since the literature does not echo the view that mints might have attempted to signal denomination with coin motifs, whereas everyone agrees that poleis tended to put their identifying emblems on their coins. There is some evidence, however, that very successful types were copied abroad, for instance the Athenian owl design by the kingdom of Judah (Schaps, 2014). The second prediction will only be worth testing if the degree of information carried by motifs about the denominations they figure on is not trivially low. This also applies to our third prediction below:

(3) Motifs are more informative about lower denominations than about higher ones.

Bresson (2006) shows that coinage was more costly, more difficult to produce for smaller denominations. This was for two reasons. First, minting a given amount of silver into smaller denominations requires a greater quantity of labour than minting the same amount of silver into higher denominations (the amount of work being a multiplicative function of the denomination). Second, smaller denominations are more sensitive to imprecision and weighing errors. A margin of error of 1 milligram of silver would have almost no impact on a sum of silver minted in high denominations, but a much bigger impact on the same amount of silver, denominated in smaller currency. Bresson cites evidence that Greek minters compensated for this substantial cost by minting small denominations below their face value. Small denominations were thus less reliable than bigger ones, and the cost of this unreliability could be important. We speculate that minters would attempt to compensate for this by borrowing the motifs found on more trustworthy small denominations. Their motivation to do so should be greater for smaller denominations than for bigger ones.

3. Methods

We will be considering only coin types, not coin tokens. Numismatics defines coin types as designs on the obverse side and the reverse side of the coin. We extend this definition to a unique coin (with a unique obverse and reverse design combination). In other words, all duplicate coins — tokens of the same type — will be removed from our dataset. We should not be doing this if our dataset were a faithful reflection of the prevalence of the coins issued by the different polis—if, for instance, its composition reflected the overwhelming popularity of Athenian coins. But we strongly suspect that such isn't the case: the compilers understandably tried to constitute a representative sample with a great diversity of coin types and issuing polis, not a faithful record of their respective prevalence on ancient Greek markets. The dataset contains quite a few coins from obscure cities, and comparatively not a huge number from Athens or Corinth. The question, how many coins were minted for a particular issue, certainly influences the informational value of motifs and is a valid one, but exploring it would need a much bigger dataset that would reflect the preponderance of some coin types over others, while still including a great variety of types.

3.1. The data

We assembled a dataset based on the online database of *Sylloge Nummorum Graecorum* (SNG) project of the British Academy (Carradice, n.d.). The purpose of the SNG project is publishing illustrated catalogues of Greek coins in public and private collections of the British Isles, and it is a part of worldwide initiative whose published corpus now exceeds 120 volumes and is considered to be a reliable source of information on Greek coins. The online database displays c. 25 000 coins from 13 SNG volumes in the form of a searchable catalogue.

We searched the database for coins dated before 323 BCE, and the search returned 3584 coin tokens from the Archaic and Classical periods. We limited our time frame to the conventional end of Classical period because the coins in the Hellenistic period changed a lot in comparison to earlier periods: the obverse started bearing the portrait of a ruler, the types became more standardised and the coins were mass produced and distributed thorough the Hellenistic world (Thonemann, 2016). Since our project is focused on relationships between motifs on coins and the provenance or denomination, we chose the periods known for many diverse coin types minted at many different places.

Numismatists date the start of Hellenistic coinage in 336 BCE, the year Philip II of Macedon was succeeded by his son Alexander. The reason we extended our search for the coins struck prior to 323 BCE is because the SNG coins are dated in unequal time intervals (from coins dated inside a 200 years interval to ones dated in a single year), and we wanted to avoid losing data points. We subsequently narrowed our date limit to the year 336 BCE (see section 3.1.).

After obtaining 3584 data points from SNG database search, we proceeded to tailor this dataset to the

hypotheses we are planning to test. First, because we are interested in coin types (unique combinations of obverse and reverse designs), not coin tokens (examples of same coin type), we searched our dataset for unique coins, taking in account obverse and reverse design, issuing authority, denomination and date. This resulted in 2561 unique coin types. We noticed that 11 of those are not coins in the usual sense of the word, but cast bronze objects used as currency in Eastern Greek colonies (Mielczarek, 2005), so we had to exclude them. We also identified 3 coin types whose entries in SNG were inconsistent (possible mistakes in data entry) so we had to exclude them too. It left us with 2547 unique coin types. Next, we had to reformat the dataset following the restriction criteria regarding time frame, motif inventory and information on denominations and issuing authority. The criteria are discussed below.

3.2. Dataset criteria

3.2.1. Time frame and time periods

As mentioned before, we decided to follow the numismatics in setting the lower border of our time frame to 336 BCE. The earliest date we have is an interval between 700 and 550 BCE, but since the earliest electrum coins were made in mid-7th century BCE (Schaps, 2014; Rutter, 1983), we decided to start with the year 650 BCE. To deal with the more or less imprecise time intervals, we calculated the "mid-point" (the average of first and last year of the time interval given by SNG) and we used that year as the general orientation point while limiting our dataset of unique coin types to temporal borders of 650 – 336 BCE. This limited the original dataset to 2540 unique coin types.

We chose to divide our time line in three time periods which seem to guarantee that we will possess a sufficient sample, while covering the maximum amount of time. Our first time slice will cover the 6th century BCE, the second the 5th century BCE, the third the 4th century BCE (until 336 BCE, the beginning of rule of Alexander of Macedon, conventionally used for the beginning of Hellenistic coinage). Because the coins are dated to the time intervals of different length, we had to decide how to deal with the cases dated in between two centuries (e.g. 425-375 or 450-325). Of our 2540 unique coin types, 1483 can be dated within a century, whereas 1057 cannot. For those 1057 cases which span two centuries, we will determine the time in a following way:

a) In 212 out of 1057 cases the time interval the coin type was dated to is symmetrical, i.e. covered the same amount of time in two centuries (e.g. 425-375). For cases like this, we decided to assign them to the century the "mid-point" falls into. In our example, the first year of the interval, 425 BCE falls into 5th century BCE, whereas the last year, 375 BCE, belongs to the 4th century BCE. The "mid-point" between those two years is 400 BCE, which is the first year of 4th century BCE. Therefore, we will assign the coin type to the 4th century BCE.

b) In 845 out of 1057 cases the time interval the coin type was dated to is asymmetrical, i.e. it covers more time in one century than the other (e.g. 450-375). The coin types with this kind of time intervals will be ascribed to the century most of the interval falls into. In our example it would be 5th century BCE.

The dataset is clearly skewed towards later periods: there are only 32 coin types in the 6th century BCE, most of the coin types (1547) fall into 5th century BCE, and 961 coin types belong to the 4th century BCE.

3.2.2. Individuating motifs

As in some of our previous studies (Morin et al., 2017), we are confronted with the problem of classifying and individuating motifs. We decided to stick to our sources' classification of motifs as much as possible. The SNG dataset contains the classical description of obverse and reverse coin design, which is very detailed and idiosyncratic. For the purpose of our study, we needed to extract individual motifs from each such description. In defining the motifs, we were focused on individual people, animals, plants, objects, symbols or inscriptions – not the coin legends (name of the issuing authority), but the monograms and short inscriptions which are part of the coin design. In creating our motif list, we did not include features such as posture of a depicted person or animal, sex, age, clothing or hairstyle (cf. Caltabiano et al., 2013: 414, fig. 1). We did not retain motifs which rarely appear independently and are either more likely to appear as attributes with a particular character (e.g. Heracles' lion skin, Dionysus's thyrsus staff, Hermes' caduceus), or are a part of the character's clothing (e.g. headband, jewellery, military dress, hats, staffs, Persian pants etc.). The terms used for the motifs (including personal names) vary across the SNG data set, so we had to normalise them. The motifs which are variants of the same, e.g. different kinds of helmets, stars, wheat, or incuse squares will all be treated as a same motif (a helmet, a star, wheat, an incuse square). All writing (monograms, inscriptions, names) will be marked as "inscription" and subsequently disregarded as a relevant motif, as we are interested in images, not in writing. We will only take into account the presence of a motif on a coin, irrespective of how many times that motif is instantiated on that coin: a coin with 3 boars and a coin with 1 boar each count as one instantiation of the “boar” motif.

We append to this registration a complete list of all the images we will consider as motifs (N = 364).

3.2.3. Denominations and issuing authorities

The SNG dataset includes the information on coin's provenance (issuing authority) and value (denomination). We will use the SNG information on denomination of a coin type as it stands in the SNG data set, but we will merge the information on issuing state, mint and ruler into "authority" variable in the following way: if a coin type has information of a state which issued them, we take that information; if not, we take the name of the

mint; if both state and mint are missing, we will use the name of the ruler.

We have information on issuing authority for all 2540 unique coin types in our data set, but we lack denomination information for 583 coin types.

4. Computation of informational value and detailed predictions

Informational value. A motif's informational value concerning its denomination or issuing polis will be formalised as conditional entropy. Conditional entropy is a standard measure of the informational value of symbols (Reali and Griffiths, 2009, Sproat and Hall, 2014, Winters et al., 2015). It will be computed in the following way.

$$H(C|M) = -\sum_{m \epsilon M} P(m) \sum_{c \epsilon C} P(c|m) \ log P(m|c)$$

C stands for "class" the category that a coin belongs to: Denominations are a kind of category, and so are issuing authorities. We will compute the motifs' informational value for these two categories in the same way. The class C may thus be a set of authorities or a set of denominations, while each item c will be a particular class, i.e., a particular authority or denomination depending on the category we consider. M stands for the set of individual motifs m.

Chronological analysis (Predictions 1 & 2). The conditional entropy of class given motif will be computed separately for each of our three centuries of interest, once for each category (Authority and Denomination).

Testing Prediction 3. Prediction 3 will only be tested if the conditional entropy of denomination given motif is not trivially low, that is, if we can establish that some motifs reliably track some denominations. If that is the case, we will split the dataset into two, with coins of the “median denomination” as our cut-off point. The “median denomination” is the denomination such that roughly one half of the coin types (not the denominations) are higher and the other half is lower in denomination. The informational value of motifs (conditional entropy of denomination given motif) will then be calculated separately for each half. We predict lower entropy for the low-denominations half.

Appendices:

- Complete list of motifs considered in the study (2017-11-20_Coin_Images_Motifs.csv)
- Complete list of coin types considered in the study (2017-11-20_Coin_Images_Dataset.csv)

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