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Small scale beauty, large scale knowledge: how numismatics unravel the past

INAUGURAL SPEECH BY PROF. DR. P. IOSSIF

change perspective
Both in Antiquity and the Middle-Ages, coins have been used primarily for paying for services, with military expenditures covering the essentials of these services. Coins also transmitted messages from the issuing authority to the targeted audiences.

In his lecture Iossif examines coins as proxies for economic transactions and exchanges focusing especially on their role as military payments, on the level of monetization in ancient and medieval societies, on the velocity of coin circulation and comparisons with the euro-currency circulation. Coins will also be addressed as media conveying messages destined to reach particular audiences; as aesthetic objects which impressed their primary end-users and modern collectors, and, of course, as archaeological objects essential to our understanding of macro- and micro-contexts.

Finally, the lecture will address the question of future research programs focusing on the creation of an automated die study software, a major tool for numismatics, one which will transform Radboud University into a major hub in the numismatic world.

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SMALL SCALE BEAUTY, LARGE SCALE KNOWLEDGE: HOW NUMISMATICS UNRAVEL THE PAST
Small scale beauty, large scale knowledge: how numismatics unravel the past

*Inaugural speech delivered at the acceptance of the post of Professor by special appointment of Numismatics at the Radboud University Faculty of Arts, on Thursday 21 June 2018*

*by prof. dr. P. Iossif*
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Dear Rector,
Esteemed colleagues,
Beloved friends and family,

Numismatics is a discipline all its own, a way of accessing and understanding the past through the study of metallic artefacts and their values. From the beginning, I address this strong statement and will try to demonstrate its value and worth in historical sciences by focusing on big data, statistical methods and die studies.

The study of small flans of metal bearing ‘types’ on the obverse and the reverse, symbols, marks and inscriptions allows the numismatist to unravel mechanisms of economy, market transactions or religious and political interactions. Numismatics has a long history which started as an interest in collecting the material. Already from Roman times, emperors showed particular interest in numismatic types and coins of the past (admittedly for political reasons), some of them possessing collections, like Vespasian or his son Titus to name two of the most famous.1 At the end of the Middle Ages and the time of rediscovery of the Classical past, famous humanists like Giovanni de Matociis (last quarter of the 13th c.-1337), author of Historia imperialis, and Petrarch (1304-1374) excelled at collecting coins. John, Duc of Berry (1340-1416), the great artist Lorenzo Ghiberti (1378-1455), Pope Paul II (1417-1471) and Peiresc (1580-1637) collected coins with a rare passion.

Of course, the first golden age of numismatics as a discipline is to be dated to the end of the 18th c. and the 19th c., when, first, Joseph Hilarius Eckhel established the basis of ‘modern numismatics’ with his monumental Doctrina numorum veterum (1792-1798) followed by the works of François Lenormant a century later (La monnaie dans l'Antiquité, Paris, 1878), and, above all, by the Traité des monnaies grecques et romaines by the great Ernest Babelon in 1901 (again published in Paris) and Barclay Vincent Head, one of the leading forces behind the Catalogue of Greek Coins of the British Museum. A very special position in the short gallery of numismatists is reserved for Friedrich Imhoof-Blumer, one of the very first to understand the importance of die studies in numismatics and author of Monnaies grecques in 1883.

There is no doubt that ancient coins were ‘beautiful’ and attracted the attention of collectors and dilettanti. A recent monograph pointed out the reasons behind the aesthetic attraction Greek coins exerted on collection through time and space.2 There is no doubt that collectors were instrumental in building the foundations of what we define as the ‘numismatic discipline.’ Modern numismatics considers coins well beyond their aesthetic value and the trivial iconographic description of types and/or symbols. What follows is a very short survey of the many possibilities the discipline offers for understanding the past; a trip from the mine to the mint, from the mint to the market, from the market to the collector’s cabinet, from the cabinet to university desks, from university desks to economic, statistical models and neural networks in
order to unravel the past. Traditional approaches and modern methods are interwoven so as to get a maximum set of information about coins, their fabrication process and, above all, the people who issued and used them. Numismatics is the discipline of large numbers \textit{par excellence} in historical studies, the field where the \textit{testis unus, testis nullus} finds its perfect application. Therefore, it is impossible to escape playing with large (sometimes very large) numbers and using statistics for addressing questions.

\textbf{COINS AND THE NUMISMATIST}

The definition of a coin is relatively simple: a small blank of metal whose alloy and weight are guaranteed by the impression of an official stamp and a seal. Coinage first appeared in Asia Minor, in Lydia and Ionia more precisely, sometime in the 7\textsuperscript{th} c. BC, in a process which can easily be qualified as a revolution.\textsuperscript{3} An issuing authority, the Mermnad dynasty, was powerful enough to impose a currency of standardized stamped lumps of metal priced well above their intrinsic value. For the first time in human history, money was no longer weighed but counted, implying the trust of users expressed toward an issuing authority imposing its own seal on the lump of metal. These were the famous ‘electrum’ coins, the first coins in human history (Fig. 1).

Recent research on these coins shows that the percentage of gold in the alloy is often well below a minimum of 65 percent found in its natural state and copper and lead are always added in relatively high percentages. This can only mean that for the first coins in human history an artificial alloy has been used and the issuing authority was able to manipulate the intrinsic (metallic) value of the final product as opposed to its nominal one.\textsuperscript{4}

These electrum coins were massively produced and in relatively large numbers of denominations varying between five and seven; hence, a high level of monetization of the Lydian economy is to be observed already at the earliest stage of the phenomenon, since denominations are often used as proxies for the level of monetization of an economy (to be compared, e.g. with the 12 denominations in the coinage of Ptolemy II). In addition to these facts, electrum denominations, even the smallest among them,
represent high values ranging from one month’s salary for the larger denomination (the stater) to one week’s expenditures for the smallest (1/96th of a stater). Hence, their use as a means of exchange for everyday transactions is not a convincing one; these first issues were far more likely adapted to large state expenditures with soldiers being the obvious end-users of these issues since the army represented the most important expenditure until very recently in modern economies.⁵

Two important notions can already be stressed from this very brief introduction: the notion of ‘trust’ users are asked to invest in the issuing authority and the close relationship between coinage and military pay. The former is a key element in economic sciences from Antiquity to the present. Ancient Greeks and Romans personified these notions on their coins, pointing out that no economic transaction can take place without this pistis in Greek (Fig. 2) or fides (Fig. 3) in Latin.

The close connection between issuing coins and paying the army is in no doubt today and the works of François de Callataj⁶ (following a groundbreaking article by Colin M. Kraay) were instrumental in that respect. In fact, nearly all coins were struck for military purposes; which does not, of course, imply that all military expenditures were paid with coins.
With these historically unprecedented electrum coins, massively produced and distributed exclusively within the limits of the Lydian kingdom, all questions are raised that a numismatist is called upon to face with every single coinage he or she will have to deal with from Greek and Roman antiquity, the Western Middle Ages or the Byzantine and Arabic world: how were coins produced? Who was the issuer and the end-user of the coinage, i.e. what was the purpose of issuing coins? How many coins were produced? How did these coins penetrate the economy and the market? Where did they circulate? What was the level of monetization of a given society or which were the distribution patterns of coinages? How fast did coins circulate within an economy, i.e. what was the velocity of circulation? How did authority choose to be represented on these issuances?

These are the questions a modern numismatist should be able to address; we are far from the artificial dichotomy proposed by the great Théodore Reinach (1860-1928) between 'pure numismatics' and 'applied numismatics.' A numismatist is not only someone capable of preparing a corpus on a given coinage but also someone who can interpret the data by combining them with other types of historical evidence. Some of these questions will be addressed below from a purely methodological point of view by focusing on a few Seleucid examples (but the methodological approach remains the same for all coinages in Antiquity and the Middle Ages): I will stress the need for creating reliable databases for statistical analyses, and demonstrate the potential of these databases when addressing complicated iconographic and political issues or when asking modern questions such as that concerning the velocity of coin circulation.

**BIG DATA AND STATISTICS**

Recent research in different scientific fields, including the humanities in the broader sense, has been obsessed with 'big data,' a quest to accumulate as many data as possible in a given field. The analysis of these big data is the real challenge for the generations to come, since new tools and statistical models are becoming available every day. Hal R. Varian, chief economist at Google, stressed the importance of statistics in analysing big data and went so far as to state: ‘I keep saying that the sexy job in the next 10 years will be statisticians, and I’m not kidding.’

In the field of numismatics, statistics were already introduced relatively early in the 1960s following trends in the 'New Archaeology' and the 'New Economic History'. The nature of coinage produced in large and continuous series of which most types are preserved offered a perfect field for statistical applications. These analyses were based on the creation of large data sets, mostly of important corpora covering a given coinage, reign, mint or area. Very early on (already in the beginning of the 1830s) numismatists realized the quantitative possibilities offered by the material they collected focusing first on the date, obverse and reverse types of coins before considering more complex questions such as metrology, axes or numbers of dies.
The recent development of computer-based and linked open data extended the size of databases from some thousands (but generally less than 10,000 coins from the Greek world) to some hundreds of thousands or even millions if all numismatic databases are considered together. These powerful online databases offer invaluable tools for quantification and statistical analyses of the material but their reliability still needs to be proved. It is worth mentioning the coinhoards.org database with material from the Inventory of Greek Coin Hoards (IGCH) created and hosted by the American Numismatic Society (ANS), the Hellenistic Royal Coinages project with its constituent components, Pella (for the Argeads including Alexander III’s coinage), the SCO (for Seleucid coins) and the PCO (for the coinage of the Ptolemies), again under the direction of the ANS. The collections of the most important museums and coin cabinets are also online and offer invaluable tools for all types of quantitative and statistical analyses as I will demonstrate below.

Creating Databases for Statistical Analyses: Testing Reliabilities

The idea of quantifying data in Greek numismatics passes through die studies which are considered to represent the most reliable source for quantification. Unfortunately, this type of study is missing major parts of Greek coinages, even if an optimistic view estimated that there will be a die study for all Greek coinages before...2093. There is certainly a lack of die studies for Seleucid coin production and this is the reality the numismatist and historian of the dynasty must face. Because of this absence of sufficient quantifiable data, alternative methods must be explored for estimating the total sizes of issues based on the output of different individual mints, reigns, types and denominations, calculating the level of monetization or the percentage of monetized metal as opposed to non-monetized; and this is what I have done in my recent research.

Roman numismatics lacks a complete record of die studies because of the size and volume of issuances. Therefore, numismatists working with the Republican and Imperial coinages created methods which offer an alternative to Greek numismatics: the extrapolation from hoards or from a ‘master hoard’ as developed by Michael Crawford. The idea behind the ‘master hoard’ is simple: gather those hoards which are representative of coin production and/or circulation in the Roman Empire; therefore, create a reliable sample from Roman hoards in order to extrapolate general conclusions. It should be stressed that the method met with strong criticism from Ted Buttery, especially the size and the normalcy of the sample, but most of these criticisms were convincingly answered by François de Callataÿ. Needless to say de Callataÿ was also quite dubious about the extensive use of this method, since he stated that this method ‘should be a last resort’ for Greek numismatics. He explained that two reasons permit the use of this method for the Roman world: first, and most importantly, the considerable sizes of Roman issuance make extended die studies impracticable, and second, Roman history presents a continuum with few changes and many hoards.
Interestingly enough, these conditions are met in the case of the Seleucids as well: large issuances and relatively unified history.

In the Seleucid case under consideration, the challenge is to create a reliable database whose recorded numbers of Seleucid coins would be representative of the total original volume issued or represent satisfying results in terms of coin circulation, local or kingdom-wide. This resulted in two databases: the Seleucid Hoards Database (hereafter: SHD) and the Seleucid Excavations Database (hereafter: SED). As the names indicate, the former contains all hoards with Seleucid coins, while the latter gathers material from more than 80 archaeological sites extending from modern day Bulgaria to eastern Pakistan (Fig. 4).

<table>
<thead>
<tr>
<th>Database</th>
<th>Hoards/Sites</th>
<th>No. of parameters</th>
<th>4drs</th>
<th>AR fractions</th>
<th>AEs</th>
<th>Total coins</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHD</td>
<td>253</td>
<td>41</td>
<td>10,203</td>
<td>826</td>
<td>1,549</td>
<td>12,605</td>
</tr>
<tr>
<td>SED</td>
<td>80</td>
<td>38</td>
<td>24</td>
<td>29</td>
<td>8,273</td>
<td>8,334</td>
</tr>
</tbody>
</table>

Fig. 4: Numerical data from SHD and SED (source: Iossif)

The question of the representativeness of a sample as compared to its ‘population’ is of course an essential one. In statistics, in a general way, the ‘law of large numbers’ is often invoked, according to which the larger a sample is, the higher the probability that it is representative of the total population from which it is taken. But only invoking this law to prove the representativeness of SHD and SED would not be convincing and any assumption based on this law without additional controls is incorrect from a methodological point of view. Hence, additional formal indications of the representativeness of the sample need to be explored and considered.

In the case of the SHD we have at least one reference point, which are the results from the die study by Georges Le Rider for Antioch, the major mint of the kingdom. On the graph (Fig. 5), I gathered and illustrated the Antiochene tetradrachms as they appear in SHD by reign, and the ‘estimated’ number of dies as they were calculated for the same mint based on the data in Le Rider’s seminal work.
The similarity which can be visually observed between the estimated numbers of dies on the one hand, and the numbers of coins in SHD on the other, is confirmed by the value of the correlation coefficient $r^2$ between these two values, which is about 93 percent. We can therefore conclude that this database constitutes a sample that is highly representative of the actual population; in other words of coin production, at least as far as coins struck at Antioch are concerned.

In order to test the representativeness of the SED, as also in the case of the SHD, we should ideally need a complete record of Seleucid dies for bronze coins, and then compare the set of dies identified in the SED to this record. But since such a complete record has not yet been found, the question is if there is any other type of data that could be used to test the representativeness of the SED? The answer to this question turned out to be a crucial one and might sound surprising: major museum collections. In a recent article, Andrei Gândila argued that instead of biases introduced into the collection because of the preferences of curators, large collections present common patterns when compared with site finds and hoards. Hence, and following the arguments by Gândila, it would be logical to assume that if there is a correlation to be observed between major collections and the SED, then the representativeness of the SED should not be questioned. If the patterns to be observed were common between the SED and museum collections, this would have a reciprocal importance: not only would
the SED have been a representative sample for statistical analyses, but museum collections would have offered reliable samples as well.

Before testing the reliability of the dataset per se, it is necessary to say a few words on how numismatists deal with museum collections as statistical samples. It is a topos to read that these collections suffer from a series of flaws mostly in the line of what I qualify as the ‘Grierson complex’. So-called ‘collector’s behaviour’ might, indeed, affect choices and introduce biases into the collection in terms of the original volume of coins produced. Gândilă offers a series of arguments showing that ‘the fact that a collector’s/curator’s choice, although inherently present, does not have a dramatic effect on the type of material selected for this analysis’ (Gândilă 2009, 158-160). Among these arguments, the fact that the SED deals with petty coinage, i.e. bronze and copper respectively, softens the effect of selectivity which can indeed be expected when it comes to silver and more especially gold (but even in that case, there are no serious flows as can be demonstrated for the SHD; see Iossif 2015). In many large museum collections, bronzes of the exact same type (duplicates) are present in large numbers, thus pointing to randomness in the way the collection was assembled. Furthermore, since most of the larger collections were created by accumulating partial donations, it is legitimate to assume that the original collectors applied different selection criteria, thus globally limiting the possible effect of individual bias, and that the museum curator did not refuse to accept duplicates.

Which collections? The choice is rather obvious for a numismatist: the ‘Big Four’ (the American Numismatic Society, the Bibliothèque nationale de France, the British museum, and Berlin) and in addition the large private collection created by the late Arnold Spaer in Jerusalem. In total, 9,533 bronzes were identified from these online and open-access databases and the visual comparison between the SED and these five collections is illustrated on the graph (Fig. 6).

One cannot escape the striking resemblance between these five major collections in terms of structure. This visual impression is confirmed by the correlation coefficients \( r^2 \) between on the one hand the composition of each individual collection (in terms of percent of coins per reign), and on the other, the weighted average of the five collections: these correlation coefficients vary between 88 percent (for the Spear collection) and 94 percent (for the collection of the BnF), which shows that – if indeed there has been a bias in the way these collections were assembled – this must have been very similar, so probably close to non-existent. In other words, it seems reasonable to assume that these collections are indeed representative samples (i.e. chosen at random) of the total circulation.

Having established this randomness in the five reference collections, it is necessary to verify if the same or at least a similar pattern can be observed in the SED. We did correlation and dependence analysis, as well as a linear regression, on the different datasets under consideration. The results in the table (Fig. 7) show a strong statistical
relationship between the different sets. From a statistical point of view, the SED presents a very positive correlation with all other datasets varying from 68 percent to 82 percent, while the r² of the linear regression is a very high positive (0.859). The average correlation between the SED and the collections is estimated to be 75.2 percent, a level of correlation proving that excavation material is a reliable dataset for different kinds of statistical analyses.

Fig. 6: Comparison of ratios between major numismatic collections and SED coins (Iossif 2016, 274, fig. 3)
Dear Rector,

Esteemed colleagues,

Beloved friends and family,

FROM RELIABLE DATABASES TO HISTORICAL CONCLUSIONS: AN ICONOGRAPHIC DEMONSTRATION

Once the reliability of large numismatic samples is proved, we can move forward to the next and essential step: asking historical questions. The number of questions to be addressed in a numismatic dataset is only limited by the scope of a given research problem. As a study case for the numerous possibilities offered by reliable big datasets, I will focus on the so-called 'divine coins,' i.e. coins depicting Seleucid kings associated with one or more divine attributes.

The kings as issuing authorities used different ways to approach the divine or to create an association with a particular deity. The most obvious choice is the use of divine attributes of an ambiguous character (at least, to us). These attributes belong to the divine sphere and are generally associated with one or more deities. Attributes were powerful instruments of communication, because they transmitted significant cognitive information by means of visual, non-verbal signs.¹⁷

Attributes (as well as epikleses) are used as strong markers for the 'divinization' of the kings in modern scholarship.¹⁸ Nevertheless, as usual in historical disciplines,
nuances are important. Modern scholarship considers and identifies divine attributes on royal portraits in different ways, but the most likely explanation, as I argued recently, is to understand divine attributes and their use on royal portraits as gifts offered by the gods to the kings and therefore as expressions of divine favour attributed to the king.\textsuperscript{19} At the same time, in a reciprocal way of reading the evidence, these attributes were expressions of the piety of the king toward the divine. It is important to keep in mind that reciprocity is a key notion of the established relation between the divine and the human in Greek religion (and indeed in any religion).

From the numismatic evidence, it becomes obvious that the Seleucids made extensive use of divine attributes. The first Seleucid king known to have systematically attributed divine attributes to his image was Antiochos IV. The king used three different divine attributes: the radiate crown (Fig. 8), stars (Fig. 9) and the elephant headdress (Fig. 10). The first two clearly involve the notion of \textit{Epiphaneia} serving as visual markers of his first epithet: \textit{Epiphanes}. These types are by far the most significant of all Seleucid types in terms of quantity, and they also found much popularity among the king’s successors. The elephant headdress appeared on bronzes from Susa showing that this mint followed a local pattern using a higher than usual number of divine attributes.

Fig. 8: Antiochos IV, Antioch, Bronze B coin, 173/2-169 BC. Radiate head of Antiochos IV/Zeus standing (SC 1408)

Fig. 9: Antiochos IV, Ptolemais-Ake, Bronze B coin, 170-168 BC. Head of Antiochos IV with star above forehead/ Apollo seating omphalos (SC 1472)

Fig. 10: Antiochos IV, Susa, Bronze C coin. Head of Antiochos IV wearing elephant headdress/Goddess seated holding Nike (SC 1533)
In the previous section, I tested the reliability of the two numismatic databases for the Seleucids. It is time to put them to a stress test in order to quantify the relative percentages of each iconographic type. First of all, it is possible to question our databases on the relative percentage of divine coins in the production of the Seleucids. We arrive at different percentages following the metal and the denomination of coins. The following chart (Fig. 11) summarises the evidence from the SHD. Fewer than 7 percent of Seleucid tetradrachms carry a divine type; the percentage drops to less than 3 percent when we are dealing with silver fractions and rises to 34 percent with bronze coins.

![Fig. 11: Percentage of divine coins in SHD](image)

In order to propose an additional test of reliability of the database and see if quantifications of types are reliable, we compared our results with the SED. The table (Fig. 12) records this evidence. The percentage of these divine portraits from excavation coins is 29 percent, a number very close to what we observed above for SHD.

<table>
<thead>
<tr>
<th># of tetradrachms</th>
<th># of silver fractions</th>
<th># of bronzes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>Divine types</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Percentage of divine types</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

![Fig. 12: Percentage of divine coins in SED](image)
It is possible to test the evidence even further by comparing the number of divine coins of the Seleucids between the databases and the five large numismatic collections in order to examine their correlation to this particular aspect. In fact, as can be seen on the following graph (Fig. 13), the variation of divine coins of the Seleucids in all databases under consideration turns out to be around 30 percent. This is an additional proof of the reliability of the two databases and their correlation to large numismatic collections.

This c. 30 percent of divine coins for the Seleucids can also be observed in a broader Hellenistic perspective, when considering evidence surrounding the Greek kings of Bactria and the ‘Indo-Greek’ kings (for the moment, we still don’t have a quantitative and quantifiable basis for the Ptolemies). For the Greek kings in Bactria, a different method has been attempted since there are no reliable data coming either from Bactrian hoards or excavations. For these kings, I compared the relative percentages of divine portraits in the four major collections as they appear in recent works. For additional testing of the reliability of the samples, I also counted coins from other collections and provenances (excavations, hoards, auction catalogues). The results for the divine portraits of the Greek kings of Bactria are those on the following graph (Fig. 14). It can be observed that the percentage of divine types among the Greek kings of
Bactria is c. 30 percent.

Fig. 14: Percentage of divine coins in Greco-Bactrian coinage

A general pattern seems to exist for these types of coins, one that can only be observed when we proceed to the quantification of large numismatic datasets. This quantification is a decisive clue in favour of an expression I coined in the past on the ‘discreet’ divinization of the Seleucid king.\textsuperscript{20} The king, the noble issuer par excellence of his times, is only sometimes depicted bearing divine attributes; in most cases he is represented on bronzes, the humble metal of the trimetallic system, and even in that petty metal, divine coins represent less than 33 percent. The noble issuers of the Hellenistic period remained discreet when they enriched their portraits with divine attributes. Interestingly enough, the very few times they did, they mostly preferred to use bronze coins, the humble metal, mostly used either in everyday transactions or, very likely, as the everyday payment of soldiers. This is an important historical conclusion, one which would have totally escaped our attention if large quantifications based on reliable databases had not been used.

\textbf{FROM RELIABLE DATABASES TO CIRCULATION PATTERNS: AN UNEXPECTED COMPARISON}

The above example offered a demonstration of the usefulness of big and reliable datasets. One of many questions that can be asked of the databases concerns the velocity of money, and a rather intriguing comparison can be made between the Seleucid economy...
and the present-day Eurozone. In a recent study we calculated the share of German euros in Germany (as the central region within the EMU) and the rest of the Eurozone and compared their velocity of circulation with that of silver and bronze coins within the Seleucid kingdom.  

Calculating the speed of diffusion of EU coinage to and from Germany is straightforward since we have direct monthly observations concerning the share of domestic coins in Germany between January 2002 and the present. The general trend can be seen on the graph (Fig. 15). The share of euro coins issued by the five German mints bearing the types of the Federal Republic of Germany started out at 100 percent when the euro coins were introduced, but dropped quickly to 92 percent already during the first month of circulation, implying a considerable coin exchange among EMU countries. The diffusion process seems to follow an exponential trend, with the share of German coins decreasing by 0.24 percent per month, 2.8 percent after the first year, and 25 percent by the end of the tenth year.

![Graph showing the diffusion of German coins in Germany](source: www.eurodiffusie.nl; van Leeuwen, Iossif & Foldvari 2018, 156, fig. 7.1)

To estimate the diffusion of silver Seleucid coins (divided by larger regions within the kingdom), we can use the SHD, and for bronze coins of the dynasty, we can refer to the SED. The patterns of estimates for the share of domestic coins for the two types of coins are visualised in two graphs.

In the case of bronzes (Fig. 16) the overall pattern indicates a gradual but limited diffusion process. The results for silver coins (Fig. 17) suggest a quicker diffusion in the first years followed by a gradual reduction, converging between 20 and 30 percent. This
is much lower than what we found for bronze coins, which end up with a c. 50 percent share of domestic coins.

Fig. 16: Estimated share of domestic bronze coins in circulation (percent) as function of time difference between minting and burial (SED) (van Leeuwen, Iossif & Foldvari 2018, 159, fig. 7.2)

![Graph showing estimated share of domestic bronze coins in circulation](image1)

\[ y = 0.6432e^{-0.003x} \]
\[ R^2 = 0.1122 \]

Fig. 17: Estimated share of domestic tetradrachms in circulation (percent) as function of time difference between minting and burial (SHD) (van Leeuwen, Iossif & Foldvari 2018, 160, fig. 7.3)

![Graph showing estimated share of domestic tetradrachms in circulation](image2)

\[ y = 0.5457e^{-0.02x} \]
\[ R^2 = 0.5821 \]

But how fast was coin diffusion? We can make a rough estimate by plotting the exponential function, suggesting that silver tetradrachms circulated by 2 percent per year versus 0.5 percent per year for bronze coins. We can calculate that after 10 years the share of domestic bronze coins would be reduced by only 6 percent while the share of
domestic silver coins declined by 22 percent. This result is about equal to the spread of coin diffusion in Germany, which was, after one year, 2.8 percent with a decline of 25 percent after 10 years.

Hence, silver coins within the Seleucid kingdom diffused at about the same speed as euro coins because of their nature and use for military pay and large transactions, while bronzes travelled 4-5 times slower and were mostly limited to the issuing regions. Euro coins are not used to pay the army, at least not the coins, but the movements of the army in antiquity were replaced by the movements of...tourists, another type of invasion.

THE IDEAL SCENARIO: DIE STUDIES FOR EVERY COINAGE
All that has been developed and discussed above involves a series of assumptions which need to be made in order to compensate for missing data and to establish proxies. Of course, as Charles Babbage formulated it in 1852, ‘errors using inadequate data are much less than those using no data at all.’

The ideal case scenario would have been to have die studies available for every single coinage in the Greek and Roman world. Nevertheless, such a scenario sounds like the quest for the Holy Grail of ancient (even Medieval) numismatics in the actual state of research. Performing die studies for the larger issues, like those of Athens, the Alexander’s or the coinages of most of the Roman emperors bears the characteristics of an academic utopia.

It is generally agreed that one of the most urgent projects for the field of numismatics is the development of digital recognition for performing automated and reliable die studies. Die studies, i.e. determining the common dies used to produce coins and therefore getting statistical and historical results, is a major tool for ancient numismatists, but they are very long, time consuming and eye-destroying methods. Therefore, in the next couple of years, we are planning to work toward the development of an algorithm capable of performing fast and reliable die studies. There are certain difficulties that need to be considered when addressing this issue, such as the variable quality of images of coins or the criteria required to teach the system through a ‘deep learning’ process. In the actual state of research, we think that a neural network is the ideal way to proceed. A neural network is defined as a series of algorithms capable of identifying underlying relationships in a set of data by using a process imitating the way in which the human brain operates (hence the term ‘neural’). Neural networks have the ability to adapt to changing input so the network produces the best possible result without the need to redesign the output criteria. Once the criteria of the neural network are in place, the difficult part will be to feed the system with images of coins either by scanning coin files from older auction catalogues or training the algorithm to identify and insert images of coins automatically when it comes to newer catalogues and open-access databases like those already discussed. The
number of coins available is to be counted in many millions when it comes to Greek
coins, to dozens of millions in the case of Roman coins or to a few hundred thousand
for medieval and Byzantine issues.

A test case based on one of the die studies I did in the past²⁴ is actually taking
place; the first results are quite promising and we hope to have more positive results to
report in the very near future.²⁵ In case of a positive outcome, a huge set of quantitative
data from Greek and Roman antiquity or the Middle Ages will be available for further
research, and questions about the monetary mass in circulation or of deep monetisa-
tion could be backed by reliable numbers.

We are far from the preoccupations and methodologies of our predecessors; today
numismatics has all the hallmarks of the hard sciences, offering a quantifiable snap-
shot of human history. The era of digital numismatics is open and, to use the motto of
our university, 'changing perspective' is what we have to do in order to remain at the
cutting edge of research.

A WORD OF THANKS
With this optimistic, for some probably too optimistic note, it is time to address the last
and probably most complicated part of this lecture: thanking all and not forgetting
anyone.

It goes without saying that the first to be thanked are my parents who are actually
in front of their computer screen listening to my words. They not only provided me
with a great childhood but they stimulated my mind in every possible way. Sometimes,
it might be difficult to express my love and gratitude to them, but this is certainly the
right moment and occasion.

Cathy Lorber is my closest colleague, a member of my family; a beloved friend who
supported me in every way in the past, who is still supporting me as if I were her second
son with her love and kindness. She’s always there for me when I ask for help and sup-
port; I might ask too much of her and I’m not sure if I have always been there for her.

It is my great joy to thank Martin Bloemendal, the President of the KNGMP, for
all his support and kindness. It is one of those rare occasions in life when you know
someone for a short period of time but with deep appreciation. The idea of creating a
chair of Ancient and Medieval numismatics in the Netherlands, the first after the one
occupied by Enno van Gelder, was partly his idea.

In the person of Martin, I would like to thank all the members of the KNGMP for
trusting me with this heavy but at the same time joyful duty of succeeding van Gelder,
and alongside a number of young colleagues in other Dutch universities, prepare the
next generation of Dutch numismatists and publish, if all goes well, a first volume of
_Sylloge Nummorum Graecorum_, the Netherlands 1.
The same feelings are addressed to my colleague and dear friend Olivier Hekster. With Olivier, we corresponded for years, at least since 2006; I invited him twice to conferences I organized and he always politely declined the invitation. We also were supposed to meet at a series of conferences around Europe but we always missed each other for various reasons. The first time we met in person was last June; we are celebrating an anniversary, when I was here for my interview with the Rector Magnificus. Olivier is one of the kindest persons I’ve ever met in my academic life, always available to help, to share and to provide. And through Olivier, I would like to thank the Executive Board of the University and the Dean of the Faculty for the trust they place in me through this appointment.

A very special position in this list of thanks is to be given to the Belgian School at Athens (EBSA), especially to its director Prof. Dr Jan Driessen and the members of the Comity who allowed me to combine my duties in Athens with this chair.

To this list, three outstanding persons must be added, three of my professors. Professor Robert Laffineur was my first mentor, the person who initiated me into Greek archaeology, made me love the Hellenistic world and helped me to avoid the dire straits of his beloved Aegean Bronze Age. Professor Laffineur, my Doctorvater, never stopped supporting me. He is such an inspiring scholar, such a warm person, such a beloved friend!

Professor Vinciane Pirenne-Delforge is this kind of rare combination of an inspirational academic figure and a protective mater who supports and protects her paides. She played that role perfectly for me, like a Hera protecting her children, throughout my university years and became my... Doctormutter, the one who guided me through the winding path of the PhD labyrinth.

And what can I say about François de Callataÿ?François, even if he has never been officially my professor, is the reason I studied numismatics; he’s the reason I love quantifications, the reason I play with coins instead of doing stylistic studies in Classical and Hellenistic sculpture. He’s the person who influenced me the most in my academic life, the one who showed me the way into coins, the one whose writings and life influenced mine (and keep influencing me). François is much more than a mentor; he is a member of my family.

Last in this list but certainly first in my life and mind is my beautiful wife Maria and my two amazing children, Nefeli-Alexandra and Philippos-Maximos. My English, my French and my Greek are too poor to express what you represent in my life. All starts and ends with you; you are my alpha and omega.

This professorship and chair offer me an ideal opportunity to achieve what I have always dreamed of in numismatics and make proud all those who believed in me. I would have loved to count among these my beloved paternal grandfather, Alexandros Kamilis, who would have been so happy and proud today.

Ik heb gezegd.
ENDNOTES

1 Mattingly, BMC II, xxxviii, xlix; lxxv-lxxviii. For the general policy of (re)using types of the past for legitimizing political authority, see now Elkins 2017 passim.
2 de Callataj 2016.
3 de Callataj 2013, 11-13 reporting on the forthcoming publication of the proceedings of the White Gold conference held in Jerusalem in 2012 proposes the date of c. 630 BC based on evidence of ceramics found in the foundations of the Artemision of Ephesos. On the notion of revolution instead of evolution for the invention of coinage, see Schaps 2004.
4 de Callataj 2013, 8-9.
5 de Callataj 2000.
6 Kraay 1984. See, for a brief summary, de Callataj 2012.
7 Interview in the NY Times, Aug. 5, 2009.
8 de Callataj 2011, 14.
10 Crawford 1974.
11 de Callataj 1995.
12 Le Rider 1999.
13 Iossif 2015, 240, fig. 2.
15 Gândilă 2009.
16 SNG Israel 1.
17 Mylonopoulos 2010, 179.
18 Iossif 2014.
19 Iossif 2018.
20 Iossif 2012.
21 van Leeuwen, Iossif and Foldvari 2018.
22 See de Callataj 2011 for a general introduction to the quantitative issues related to die studies.
23 Priddy & Keller 2005 for a short and comprehensible introduction.
25 In collaboration with the department of Digital Humanities, Radboud University Nijmegen. My warmest thanks are to be addressed to Henk van den Heuvel and Wessel Stoop for their invaluable collaboration and input into this project.
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small scale beauty, large scale knowledge: how numismatics unravel the past