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WHEN QUANTIFICATION MAKES A DIFFERENCE: A PRELIMINARY ATTEMPT TO ARRANGE EARLY *VICTORIATI* BY EXTENSIVE DIE STUDIES

Abstract

In this paper we present the results of ten years of die studies on the Roman silver coinage of the Second Punic War. For the first time a correspondence between coinage production and War costs is attempted. A special focus is placed on the victoriatus. In fact the preliminary results of the ongoing Victoriatus Project point to a much larger size of this denomination than believed so far. This has a direct impact also on the way this coinage has to be regarded and its role during the War, which will be discussed with some detail in the paper.

Keywords

Die-studies, Statistical estimates, Victoriatus, relations Coinage-to-War costs, Second Punic War

INTRODUCTION

"*Victoriatus*" is the name of the drachma produced by Rome during the II Punic War, with some sporadic issues tailing into the beginning of the II Cent. The name derives from its type: Jupiter's head on the obverse; Victory crowning a trophy on the reverse. This type never changed; variations are just in the style and in the addition of symbols/letters, almost always on the reverse. In that respect, it behaves as the quadrigatus and the early denarius coinage with Roma/Dioscuri. This detail alone points to a short life for this denomination.

Discussions about this coinage have been continuing, seemingly forever,[1] but a clear and final picture has not yet been achieved. Michael Crawford, following Rudi Thomsen,[2] reached the conclusion that the victoriatus was in full parallel with the denarius' birth. In fact, he lists the first two largest issues, *RRC* 44/1 and *RRC* 53/1, as part of the earliest denarial series with the types of head of goddess Roma/ Dioscuri galloping right. That seems about right, but still some problems are not solved. In fact, the great novelty of the denarial system of having the signs of values specified on all its denominations and related to the unit of account, the *as*, does not show up on the victoriate. In that respect, it behaves like the previous quadrigatus system. Thomsen rejects this view, because quadrigati have their halves[3] and there are several victoriatus issues that bare the same symbols appearing on the denarii, e.g. *RRC* 57, 58, 72, 83, 89, 97, 98, 101, 102, 103, 112, 119, 120, 121, 122, 124, 132, 133, 158, 162, 166 and 168. However, this is not the whole story: *quantification makes the difference*.

In fact, all of that long list of victoriati with symbols is a minor fraction of the overall victoriatus coinage, as we will see in the following. The main and first body of this coinage is separated from the denarius, either by control marks not appearing on the denarius system, or because it is arbitrarily merged with denarial emissions, like *RRC* 44 and 53. In fact, there is no way of linking with certainty the early anonymous denarii and victoriati, either by style (being the types completely different) or by hoards. The two denominations are rarely found together, and, when so, in a way that does not allow any final statement. Therefore, the actual *RRC* arrangement is simply a hypothesis.

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[1] To list just some papers on the subject, from past to present: Mattingly 1957, Marra 2001, Parisot-Sillon 2018.

[2] Crawford 1974, Thomsen 1961.

[3] This is true for incuse-legend quadrigati, which the halves belong to; however, no halves are known for the later quadrigati, with legends in relief.

Another complication to the actual arrangement is the debasement of the victoriatus,[4] with a fineness ranging from about 60% to 80%.

In this paper we try a quantification approach, based on die studies,[5] that possibly shines some new light on this complex topic. Weight and fineness statistics will complement the investigation.

THE MATERIAL

The Victoriatus Project is an ongoing endeavor, started in 2010, which has recently reached its first step, i.e. finishing the die study of the coin images gathered in the first seven years of collection.

In this paper we present the preliminary results based on a sample of about 6150 pieces, which corresponds to the corpus status as of mid-2017. In the meanwhile another 500 coins have become available and ready to enter the corpus. This makes clear the ongoing feature of such projects.

Among the investigated 6,150 pieces, only 930 were possibly produced after the Second Punic War (hereafter, the "War"). Of the approximately 5,220 pieces of Wartime issues, about 3,700 belong to the above-discussed category which cannot be directly related to denarial series. All these details are reported in Tab.1, whose content is the core of this section.

This large sample, the largest ever collected and investigated, comprises all the victoriati available to the authors from public sales and other printed catalogs,[6] private/public collections and hoards, either published or studied in person.[7]

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4 Mancini 1984, Ager *et alii* 2013, Debernardi et al. 2017, Parisot-Sillon 2018.

5 Debernardi would like to thank Giovanni Gorini for putting him on the right path of die studies as the only way to progress in the field.

6 We thank Richard Schaefer who provided us the scans of the victoriati in his Republican Die Project.

7 P. Debernardi heartily thanks all the collectors, dealers, curators and Institutions who kindly hosted/helped him and therefore made the Victoriatus Project feasible. Hoping this is a complete list (and apologies to anyone omitted): Federico Barello (Bessa hoard and Museo Archeologico di **Torino**), American Numismatic Society (**New York**), Bibliothèque national de France (BnF, **Paris**, Frédérique Duyrat and Dominique Hollard), **Verona** Castelvecchio (Antonella Arzone), Trustee of the British Museum (**London**), Musé Puig (**Perpignan**), Museo Nazionale di **Este** (Caltrano Vicentino hoard), MAN **Napoli** (Canosa, Taranto, Sant'Angelo a Cupolo, Boiano, Cerreto Sannita, Maserà hoards), Museo Archologico P. Orsi (**Siracusa**, Angela Maria Manenti, Serra Orlando, Mandanici, and Morgantina hoards), Museo Archologico Nazionale di **Cividale** (with Giovanni Gorini, Enemonzo hoard), Museo Nazionale **Roma**no (Gabriella Angeli Bufalini, Fano hoard, Patrizia Serafin, Capestrano hoard), MANU **Perugia** (Bevagna hoard), MAP **Paestum** (victoriati hoards form Paestum excavations, Debernardi e Carbone 2018), Michael Thomas (**Poggio Colla** hoard), **Mainz** Museum (Numantia hoard, Jérémie Chameroy), Adriano LaRegina/Simone Boccari (**Pietrabbondante** hoard), Museo

The activity of collecting the material for the project has led to some hoard papers[8] and more will follow.

This work does not address details, which will have to wait for future publications, as the new outcomes related to the die study of this large sample. For the current purposes, the material is divided into seven groups, listed in Tab.1, which also provide a guess for the period of coinage:

1. Sicily: *RRC* 70/1, 67/1 and 71/1.
2. *RRC* 44/1.
3. *RRC* 53/1.
4. South Italy: *RRC* 90, 91, 92, 93, 94, 95 and 96, i.e. all the remaining early series not related to the denarial series.
5. Den.1: the early series related to denarial issues, i.e. *RRC* 72/1, 83/1, 97/1, 98/1, 101/1, 102/1, 103/1, 105/2 and 106/2.
6. Den.2: *RRC* 57/1, 58/1, 89/1, possibly to be dated 209-207BC[9] and *RRC* 112/1. Here ends the list of issues that belong to the War.
7. Den. 3: *RRC* 119/1, 120/1, 121/1, 122/1, 124/1, 132/1, 133/1, 159/1, 162/1, 166/1 and 168/1. These series are spread over some thirty years by Crawford, starting from about the end of the War. However, there is no clear evidence for that arrangement, especially no hoard evidence. *RRC* 166/1 is the only anonymous issue in this group and Crawford did not link it to any denarial series, even if the position near *RRC* 167/1 is clear enough. All these series share the following feature: they are always found together in II Cent. hoards, in some cases as smaller sections of large denarius hoards (like Maserà and Bevagna). Therefore no more precise chronological arrangement is possible on the post war series so far.

For each group Tab.1 provides the data listed in the table legend. Here we provide some additional information and comments. First of all, the sample is formed *only* by coins documented with an image. Sample size indicates the number of images available and processed. Within this sample, two different sub-samples are singled

Archeologico Nazionale di **Firenze** (Fiorenzo Catalli, Pisa hoard), Museo Civico **Bologna** (Paola Giovetti), Museo di **Murcia** (Luis Miquel, S.Catalina hoard), Steve Brinkman, Alberto Campana, Olivier Legrand, Mark Passehl, Edward Bloume-Poulton, Phillip Davis, Alessandro Calciati, Victor England, Richard Schaefer, Kenneth L. Friedman (with his kind assistance also for improving the English), Scott Rottinghaus, Clive Stannard and Andrew Burnett.

8 Debernardi 2016, Debernardi-Carbone 2018 and Debernardi-Manenti 2018.

9 Debernardi-Brinkman 2018.

out: coins with a recorded weight (col. 3; in many past and present sales, weights were not always specified) and, for coins that the authors have studied in person, with a recorded specific gravity (SG).

Table 1 – Summary of the victoriati sample investigated in this paper. The material is subdivided into different categories (col. 1), as detailed in the text. Cols. 2-7 (in gray) refer to physical parameters: average weight in cg (col. 2) and corresponding sample size (col. 3); col. 4 reports the average weight of the flans before SSE (see text). Similarly, in col. 5-7 the fineness data are provided. Cols. 8 to 20 refer to the die study and its results. In col. 8-9 *RRC* die estimates are reported, in 10-11 the counted dies from the die study, col. 12 shows the size of the sample, 13-14 the counted singletons, 15-16 the characteristic index (sample/dies), 17-18 the Coverage (1-Singletons/Sample Size), and 19-20 the Esty estimates for the obverse dies. Col. 19 represents the minimum value of the interval of confidence, col. 20 the expected value and col. 21 a tentative time-frame.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Type	W (cg)	W sample	Flan weight (cg)	SG g/cm^3	Ag %	Ag% sample	RRC Obv	RRC Rev	Obv. Dies	Rev. Dies	Image sample	Sing. Obv.	Sing. Rev	Char.Ind.O	Char.Ind.R	Cov Obv	Cov Rev	**Minimum Esty**	**Esty Obv. Estimate**	**Date BC**
Sicily	317	416	331	9,61	**76**	90	110	137	290	256	638	162	133	2,20	2,49	75	79	353	414	215-12
44/1	319	1091	335	9,57	**76**	257	200	250	721	751	1148	489	525	1,59	1,53	57	54	1639	1873	214-12
53/1	316	968	333	9,52	**75**	234	500	600	794	771	1043	569	523	1,31	1,35	45	50	2107	2361	214-12
South It.	310	564	333	9,25	**72**	100	148	180	250	321	746	121	164	2,98	2,32	84	78	480	670	215-10
Total		3039				681	958	1167	2122	2157	3711	1382	1369	1,7	1,7	63	63	4648	5404	
Den. 1	304	730	330	9,15	**71**	168	210	262	288	333	1142	91	141	3,97	3,43	92	88	385	497	214-10
Den. 2	295	348	320	9,16	**71**	127	180	225	269	260	386	182	184	1,43	1,48	53	52	361	543	210-06
Den. 3	282	819	307	9,09	**70**	302	430	526	302	295	**933**	312	327	3,09	3,16	67	65	843	1249	205 +
Tot. Den.		1897				597	820	1013	859	888	2461	600	325	2,9	2,8	68	65	1590	2289	
Grand Tot.		4936				1278	**1778**	**2180**	**2974**	**3683**	**6172**	1982	1694	2,1	1,7	65	64	**6238**	**7693**	

FINENESS AND WEIGHT STATISTICS

This topic resulted in a branch of the Victoriatus Project, i.e. a new framework that allows an estimate of the fineness of these debased coins with a confidence interval of ±6%, comparable with other approaches proposed in the literature.[10] For the convenience of the interested reader, the method is briefly described in the Appendix; for all details, refer to Debernardi *et al*. 2017. The SG tool ArchimeDe is versatile, easy to use and portable everywhere, so that it allows extensive measurement campaigns, and Tab. 1 proves. As many as 1278 pieces have been SG measured, mainly from large hoards like Enemonzo,[11] Caltrano Vicentino, Fano,[12] Pisa, Canosa, Taranto, Cerreto Sannita, Boiano and Serra Orlando. By this model the loss of weight due to silver surface enrichment[13] (SSE) is obtained[14] and, therefore, the weight of the flans before the "whitening" process. Such weight is reported in col. 4 and where this is referred to as "flan weight". The main physical data of Tab.1 are shown in Fig.1; on the left the weights and on the right the fineness are shown. A slight weight and fineness decay clearly appears. Fineness starts at 77% in the Sicilian series and decreases to 70% in the latest ones. Overall, this is not such a big change over at least two decades. On the same fineness plot, the fineness of the last quadrigati (215BC, relief quadrigati; 214BC, dot quadrigati)[15] is compared in Fig.1 to that of the victoriati. The relief quadrigati have about the same fineness of 80% of the earliest victoriati, namely *RRC* 70/1, and the dot quadrigati of 214BC[16] are lower. On the same plot the average fineness of the Serra Orlando hoard[17] is displayed, showing a slightly higher fineness than the average over the much larger sample of the corpus.

As for the weights, they also decrease from 3.19 to 2.83g; also in this respect the SG analysis reveals its importance. In fact, by accounting for the weight loss related to

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[10] For an ample comparison of the different approaches, see the table of Figure 1 in Parisot-Sillon 2018, where also the SG method is compared to other methods.

[11] Gorini 2005.

[12] Debernardi 2016.

[13] This nomenclature might be somehow misleading; in fact, it is more like a copper surface bleaching, which leaves a surface of almost pure silver. The latter wording makes clearer that something is lost from the coin, and not gained, as "enrichment" might suggest.

[14] Last formula in the Appendix.

[15] Debernardi-Legrand 2015.

[16] See Debernardi-Brinkman 2018 for P.Cornelius Lentulus, praetor in Sicily from 214, as the moneyer of this series.

[17] Debernardi-Manenti 2018.

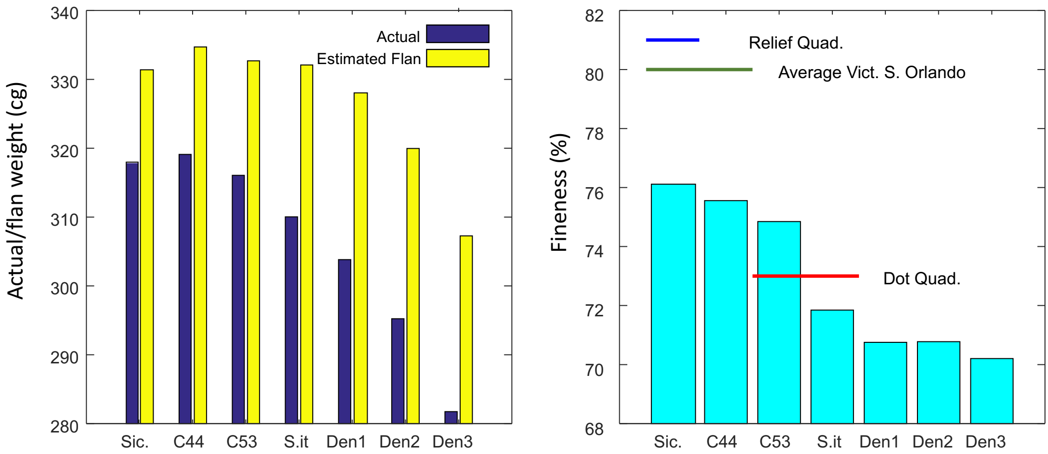

Figure 1 – Visualization of some of the data of Tab. 1 for the seven victoriati groups defined in the text. Left, average actual (blue) and flan (yellow) weights; right fineness. The superimposed lines are not legends, but refer to three fineness values in DEBERNARDI-MANENTI 2018, Fig. 8, where the Serra Orlando hoard Sicilian victoriati are compared to different kinds of quadrigati of Sicilian production, from SG measurements taken in the last decade.

the SSE process steps,[18] things looks much clearer, showing an average weight almost perfectly fitting the 3 scruples (3.35g) of a drachm for all the first five groups. A little decay can be recognized only for the two latest groups, 3.20g for the victoriati of the second denarial group and 3.07g for the ones possibly belonging to the period after the War. These data also allow to comment about the common assumption that the victoriatus experienced the same weight reduction as the denarius. This, ideally starting from four scruples (72 pieced per pound of silver) and arriving gradually to 84 pieces (3.86g, at about 205BC), demonstrates a 15% decay, instead of the 9% experienced by the victoriatus (decay from 3.35 to 3.07g). However, by considering actual numbers, i.e. an average denarius weight around 4.25g for the large investigated sample, it clearly appears that the 4 scruple standard (4.50g) was never applied in practice. With the actual weight figures, the same 9% weight reduction is obtained, moving from the start of the system to 10 years later, at about 205BC. Slightly stronger weight reductions in the actual coin weights instead are related to a certain fineness decrease, limited to a maximum of 10% over their whole production period.

[18] Probably the flans were exposed to several oxidations and the copper oxides eliminated by common chemicals, like vinegar. See DEBERNARDI ET AL. 2017.

DIE COUNT STATISTICS

The second part of the table refers to the die study[19] and reports all the information related to the statistical approach outlined by Warren Esty:[20] Singletons, Counted dies, Sample size. Those quantities, subjected to the Esty formulas, allow us to estimate the number of the actual dies from the subset that appears in the sample.

Even more interesting, from the perspective of this paper, are the histograms of Fig.2, which show how the sample is composed in terms of the defined groups, how the counted dies compare to the *RRC* estimates together with the Esty die estimante and its lower confidence interval. The red bars of Fig.2 make very clear that 80% of all the victoriati were produced before 210BC (up to Den. 1), and, even more importantly, that their dies overwhelmingly exceed *RRC* estimates. To better illustrate this important point, in Fig.2 the important statistical figures for the seven groups are also reported. Since both *RRC* estimates and counted dies by the Victoriatus Project are much lower that the Esty estimates, we think it is more prudent to rely on the lowest Esty estimates.

This topic is very important and it deserves further comments. Some deep investigation has already been carried out on the Esty model,[21] especially regarding its performance for samples highly under-represented like in the present case. To investigate this, it is useful to discuss Fig.3, computed for the Crepvsi surviving sample. In steps of 50, the coins are randomly picked up from the sample and the number of dies of this sub-sample is counted. For a given sub-sample size the experiment is repeated 50 times and every time the dies and singletons are counted and the corresponding *characteristic index (CI)* = number of coins / number of dies is computed together with the estimated number of dies and the corresponding minimum and maximum of the Esty interval of confidence.[22] The estimate lies somewhere in between them and is not shown in the dot-plots of Fig.3[23] because it would cause a too messy plot. As can be seen comparing the left and right plots, the p=2 estimate is closer to the "productive dies", that is those which produced the coinage (continuous black line, the known Crepvsi rev. dies), while p=1 accounts for the whole set of engraved dies, including those that broke immediately (dashed black line, the maximum rev. numeral known).

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19 For the most challenging Groups, comprising around one thousands coins that cannot be split on stylistic ground, the computer-aided die comparison software presented in Debernardi 2014 has been applied.

20 Esty 2011.

21 Debernardi 2014.

22 Esty 2011.

23 Each dot represents a given size sub-sample, with its 50-fold statistical repetition.

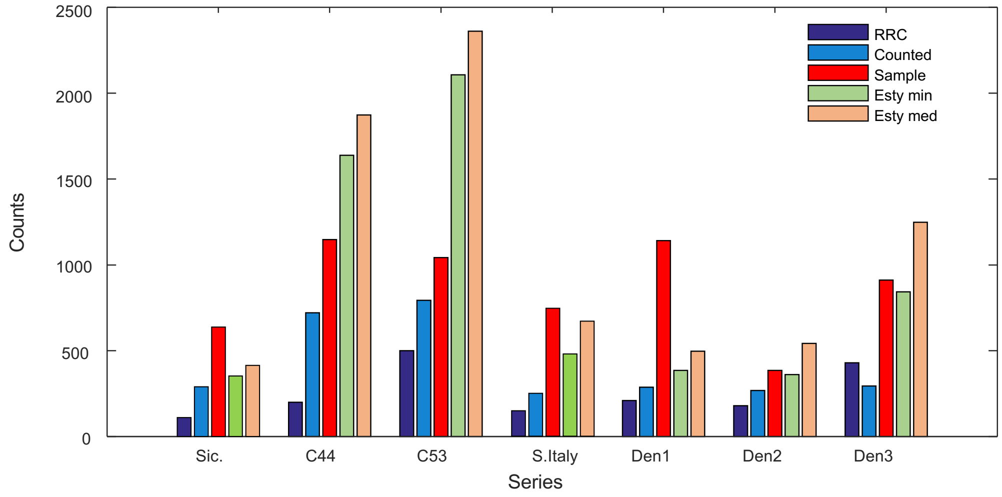

Figure 2 – Visualization of the data of Tab.1 related to the die statistics for the seven victoriati groups defined in the text

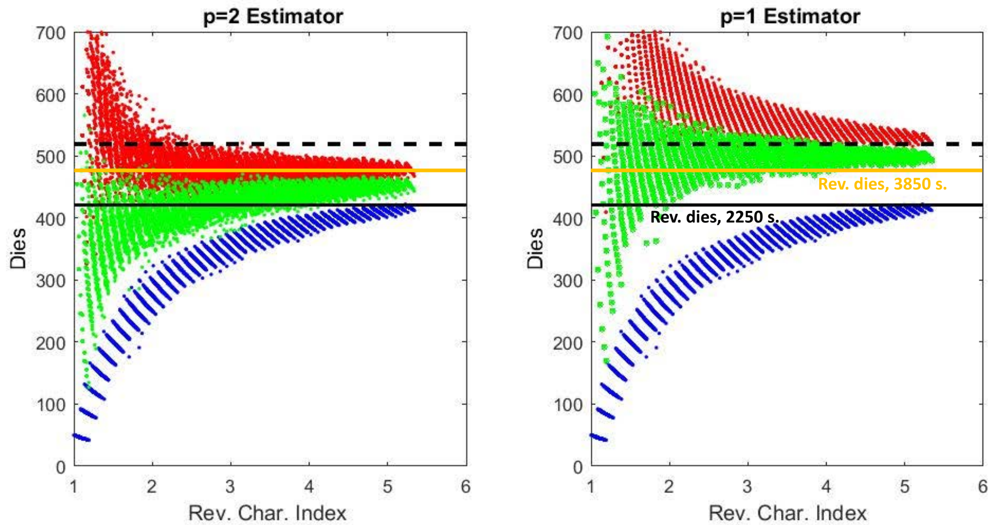

Figure 3 – Monte Carlo approach applied reverse of the Crepvsi sample (see DEBERNARDI 2016) with Esty estimator p=2 (left) and p=1 (right). The graphs show the number of dies vs. the reverse Characteristic Index. Continuous/dashed lines refer to the counted/total number of dies; blue dots to counted dies (corresponding to the maximum numeral 519 engraved on one rev. die), green and red dots to minimum and maximum confidence interval of the Esty model. The orange lines refer to the counted reverse dies in the updated sample by Richard Schaefer (3850 instead of 2250 pieces).

By closer examination of the left plots, one can see that counted dies are not reliable until *CI* is close to 5, which is never achieved[24] for victoriati (see Tab.1 for the *CI* of the different groups). In fact, the largest and uniform issues of *RRC* 44 and 53 display *CI*s at around 1.5 or less, which would result in a die count for the Crepvsi series of about 100 dies, instead of 400. This explains well why the Esty model must be applied to our investigations. The green dots provide an estimate which is fairly good and close enough to the actual values for small or moderate *CI*s. The numerical experiment on Crepvsi also allows us to estimate the maximum error, which from Fig.3 ranges from -20 to +5%. Using the lower confidence extremum is therefore a conservative choice, which should avoid die over-estimates.

By looking at Tab.1 or Fig.2 one can see that not only the die estimates are all higher than *RRC* estimates, but also that the Esty predictions exceed them by a minimum of a factor two, up to a factor of 8 for the series *RRC* 44/1. More importantly, for the first four groups, the ones not related to the denarius and featuring 75% of all the dies, the average underestimate is as large as 4.6. This is the point this paper seeks to underline, investigate and put forward as a stimulus for future research/researchers. In fact, such a large quantitative difference might have an impact on the overall numismatic framework of the War that gave birth to the new silver coinage of the Roman Republic: the denarius.

A NEW FRAMEWORK FOR THE VICTORIATUS

It is not wise to treat a coinage or denomination in an isolated manner, but one must harmonically find it a place in its historical scenario. We can therefore profit from similar projects on the early denarius system and on the quadrigatus, both ongoing.[25]

By an educated guess of the dates of the various groups of quadrigati[26] and denarii, it is possible to estimate their *equivalent denarius dies* per year. The equivalent denarius die concept is essential when dies of different denominations need to be compared on the same graph for quantification purposes. Since the denarius is the star of the Roman Republican Coinage, it is selected as the reference for the conversion. Adopting a denarius of four scruples, which is about correct for the period under analysis, then a quadrigatus is worth 6/4 of a denarius, a victoriatus 3/4,[27] a quinarius 2/4 and a sestertius 1/4.

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[24] In some rare series high *CI* are achieved, but they are statistically insignificant.

[25] Debernardi 2014 and Debernardi-Legrand 2015.

[26] A final work on the quadrigati, with a new catalog, proposal of mints and dates is still in preparation.

[27] Debasement is not taken into account at this preliminary stage of the investigation.

The quadrigati and denarii further split into two large groups: incuse/relief legend quadrigati and early denarii, with splayed/peaked helmet visors. The former denarii were produced up to about 210BC, and the latter, initiated by about 210,[28] produced from then on.

So far we have been dealing with die estimates and how they are temporally distributed in the considered timeframe. To make this exercise relevant, we should relate the die counts to coin production and production to the money needs, in tight connection to the troops fielded during the War. This is a hardly possible task, but we think it is worth trying, at least to access a comparison on the "order of magnitude" level. To attempt this, two other aspects have to be investigated/discussed: die productivity and war costs.

Die productivity

This is a very hot topic, which has been confronted by several researchers; in fact it is a key element in the intersection of numismatics and economics. The problem has been attacked from different sides and perspectives. Ted Buttrey always denied the possibility to infer any useful information from die counts.[29] For those who believe differently two classes of approaches are proposed in the literature:

1. To find special coinages where the need of money, or even better, the quantity of coined silver, is known, or can be reasonably inferred, count the dies, and estimate the productivity[30].
2. To perform archaeo-experiments, trying to reproduce the ancient conditions and to infer the desired information, e.g.: was the striking cold or hot,[31] how long did a die last,[32] what was the production speed,[32] etc.

All the different approaches lead to the range 10,000-20,000, and we therefore chose 15,000 as an educated guess[33] and test this figure in the following on the early coinage of *RRC* 101, produced in winter 211BC by Laevinus in Corcyra.[34] For the present

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[28] See Debernardi-Brinksman 2018 for the first peaked visor denarii of the series *RRC* 53/2.

[29] Buttrey 1993, Buttrey 1994, Buttrey 1997.

[30] *RRC*, Marchetti 1999, Callataÿ 2000, Callataÿ 2006, Callataÿ 2011.

[31] Sellwood 1963, Rottinghaus 2011.

[32] Sellwood 1963, Faucher 2009, Faucher 2016.

[33] Sellwood 1963 p.229 (10-16.000), Marchetti 1999, p.109 (14.350), Callataÿ 2011, p.9 (20.000). An investigation by the authors, based on a mix of the two approaches, is currently underway.

[34] Marcus Valerius Laevinus, praetor of Apulia in 215BC (Livy, XXIII, 32) was assigned to Greece in 214BC (Livy, XXIV, 10-11) with a reduced *legio* on 50 *quinqueremes* based in *Brundisium*.

purposes, his military force and costs have to be estimated. That was a sea force and the typical complement of a *quinquereme* was: 20/25 sailors, 200/300 rowers[35] and a number of soldiers in the range of 50-75[36]. A standard crew was composed mainly by *aerarii* (Polybius VI, 19.2) and *socii* as sailors and rowers, while the soldiers were mostly Romans. The rowers got about half pay compared to the sailors,[37] and, when all is included, one reaches a salary ratio between Romans and non-Romans of about 1/3 and 2/3 as a rough estimate.

At that time the Roman year used to be split into 3 periods of 4 months: Spring, Summer and Winter. Correspondingly, the salary was paid in three tranches: in May, September and January.

P. Marchetti[38] computes as 8,000 denarii/year the cost of a standard *quinquereme* crew, which means a cost of 8,000 x 50 ships = 400,000 denarii/year, or 134,000 per four months. The latter should be related to the production of *RRC* 101, overall and approximately, which should correspond to 134,000/15,000 = **8.9 dies**.

RRC 101 is a tiny, very rare coinage, whose die study provided us with the following results:

1) Quinarii: Sample of 15 specimens, 4/3 O/R dies, 1/0 singletons. Esty estimate: 5/4 dies

2) Victoriati: Sample of 9 specimens, 4/6 O/R dies, 1/5 singletons. Esty estimate: 5/19 dies.

The dies for quinarii look reliable, while for victoriati, especially for reverse, the *CI* is very low (1.5). Moreover, the strong unbalance 1 to 4 between obverses and reverses, indicates some anomaly. 8 effective dies for victoriati is therefore used in what follows, by making an average between obverse estimate and the minimum of the confidence interval (11), as discussed previously for low CI statistics.

In terms of denarii, this is equivalent to 2.5 dies for the quinarii and 6 for the victoriati, i.e. 8.5 dies. This figure compares well with the previously computed 8.9 dies to produce the pay of the maritime *legio* at Corcyra in winter 211 and confirms that a productivity of 15,000 pieces per die might not be too far from reality.

Laevinus retained that command until the end of 211BC. It's to the last months of this command, on Corcyra (Livy, XXVI, 24.), that Crawford correctly attributes the production of *RRC* 101, because it features the monogram KOP in Greek letters.

35 Marchetti 1978, p.135 and Polybius I, 26.7.

36 Marchetti 1978, pp.126-128; the range depends on the kind of ship deployment.

37 Marchetti 1978, p.253.

38 Marchetti 1978, pp.250-253.

War costs

As regards the salary of the Roman legion, we also refer to Patrick Marchetti,[39] who computed 54 denarii as the net pay per year of a Roman regular soldier, 108 for a centurion and 162 for a knight. Starting from these data, a total of 250,000 denarii/year for a legion can be estimated.[40] In winter 211-210BC about 50% of the force was dismissed and from that time a different balance of Romans/Allies was implemented.[41] The Roman infantry increased from 4,000 to 5,000 men and the knights from 200 to 300.[42] Instead, the Allies were diminished; the *ala* was decreased to 7000 infantry and 300 knights. This results in an increase from 250,000 to 325,000 denarii/year for the Roman part, and in a decrease to 425,000 for the Allies, for the same total as before, i.e. 750,000 denarii/year. Therefore, for all the period under analysis, the number of denarii/year per legion is set at 50 dies in our simulation. For the Allies Rome paid for their food and equipment, while their mother-cities for their salary.[43]

Considering that no coinage is known in such a quantity that might have served for the Allies' salaries, it has been proposed that those coins are the victoriati.[44] It seems reasonable, also from a logistical/political/psychological perspective, that Rome would have taken charge of the production of an uniform coinage, whose silver was provided by the Allies.

It can be estimated that the Allies contributed on a 2/3 basis from 218 until 211BC.[45] Therefore, every legion needed 750,000/15,000 = 50 dies/year for the period 218-210BC.[46] For 219 the data are mostly unsure; we guess 2 consular legions and 100 ships.

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39 Marchetti 1978 pp.246-254.

40 This is a net amount, to be paid to the soldiers, after having subtracted the costs of food and equipment, estimated by Marchetti to amount at 40% of the total pay of 90 denarii/year.

41 This action might be related to the refusal, on the part of the Latin colonies, to provide men and silver (Livy XXVII, 9), which implied higher costs on the Roman side. Those facts were possibly one of the reasons that resulted in an empty treasury in 210BC, with the consequent resorting to voluntary loans (Livy XXVI, 3) and to the deployment of the *aurum vicesimarium* (Livy XXVII, 10).

42 Livy, XXVI, 28.

43 Livy, XXVII, 9.7 and 9.13

44 Marchetti 1978, also reported by Marra 2001, pp.131-134. Even though not long-lasting, that might have indeed been the original aim of the victoriati.

45 Livy XXI, 17, confirmed by the analysis of the losses at *Cannae*, and also from the simple logical fact that altogether the Allies were more numerous than the Romans alone.

46 In the computed need of coinage, only the net salaries were accounted for; if also Allies' food costs are included, then an extra 25% of coinage need would occur. Of course there could have been other costs/overhead (e.g. more general equipment for the legion), but those are not included in the

It also is not completely easy to estimate the fielded Roman force per year. To that end, we rely on DeSanctis, with the following modifications. For the years 214-11, the Laevinus legion accounted for by DeSanctis is subtracted, because it is already included in the navy. Another subtraction accounts for the losses suffered by the Volones[47] in 212 and by the Scipiones[48] in 211.

Regarding the ships, for the years 218, 216, 215, 210 and 206 we have the accounts of Livy; for the remaining years we extrapolated the values.

All the die studies performed so far are assembled in Table 2, where also the details of the costs are given per year. Regarding the distribution of the dies per year, this is in part arbitrary. In fact, for example, incuse quadrigati are difficult to assign to specific years, and that topic is still under investigation.[49] Similar comments holds true for the anonymous victoriati, and refinements could be possible in future. In any case, the subdivisions have been kept in reasonable agreement with the numismatic material. It is quite surprising that the total need, estimated in about 12,800 equivalent dies, compares extremely well with the 13,100 estimated dies, which stems from die counts and statistical projections.

The money need and production of Table 2 are plotted in Fig.4. This is the final and main result of this preliminary/provocative work, which gives us a better visual overview of more than 10 year research and die-counts. As for the coinage need, two estimates are provided: just salaries (Romans + Allies), and salaries +25% overhead for the Allies food cost paid by Rome. In the production, two drops can be noticed in 210 and 206BC. The drop in 210BC is related to the Treasure crisis of that year, while that of 206BC marks the edge of the performed work in the die counting of the denarial series, which will be continued in the next years. Therefore, the only real drop is that of 210BC. It has to be stressed that of Fig.4 only the silver coinage is included; it makes for sure the core value of the War coinage, but also gold (possibly spent on the trade for goods) and bronze (before the denarius, possibly part of the pay for the Romans) could require small revisions in Fig.4. While gold could be easily accounted for, to include bronze is out of reach at the moment. No die study is available so far, and would be in any case much more difficult to perform, due to an overall worse preservation of bronze compared to silver. Moreover, bronze die productivity data are even harder to access than for silver.

present estimate. Overall, those additional costs must be related to the number of deployed legions, and can be accounted as an increased percentage of the need computed here.

47 Livy XXV, 19-20.

48 Livy XXV, 32-36.

49 Legrand-Debernardi, in preparation.

Table 2 – First attempt to quantify the money needed in terms of equivalent denarius dies (col. 4) and the corresponding available coinage, in its various denominations. Meaning of the columns: 1, year BC; 2-3, number of legions-ships according to DeSanctis; 4, equivalent denarius die need; 5-7, incuse quadrigati (proposed dies/year, and total in col. 7); 8-10, 11-13, 14-15 and 16-17 similarly for relief quadrigati,[50] victoriati, early denarii with splayed visors and latest ones with peaked visors.[51] The columns pertaining to different coinages are marked by different colors.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Year BC	Leg.	Ships	Dies	1,50	Quadrigati incuse equivalent		1,50	Quadrigati relief equivalent		0,75	Victoriati equivalent		DEN splayed	1	DEN peaked	1	8000	15000	
													from 214	50	from 210	50	Period Need	Period Prod.	Period
219	2	100	120	120	180			0											
218	6	220	317	200	300			0											
217	11	220	484	300	450	720		0				2475							
																	921	930	220-217
216	11	200	657	100	150		330	495						splayed Den. 1					
215	14	200	807				160	240	1005	1000	750						1463	1635	216-215
214	19	200	1057			incuse QDG	180	270		1100	825	anon. Vict.	150						Den. Start
213	21	200	1157							1200	900		350				2213	2495	214- 213
212	23	200	1257							800	600		700	2300		peaked Den. 2			
211	23	200	1257						rel. QDG Sic.	500	375		800						
210	20	180	1096							350	263	1485	300		400		3609	3438	213-210
209	21	180	1146							250	188				1100				
208	21	170	1141							80	60				1200				
207	23	160	1235							120	90				1300	4700			
206	20	150	1080												700				
																	4602	4638	209-206
Tot	235	2580		720			670			5400		anon. Vict. + Sym							
					1080			1005			4050		2300		4700				
Tot. need			12809												13135		12809	13135	

[50] Refer for quadrigati die counts and estimates to DEBERNARDI-LEGRAND 2015

[51] Refer for denarius die counts and estimates to DEBERNARDI 2014

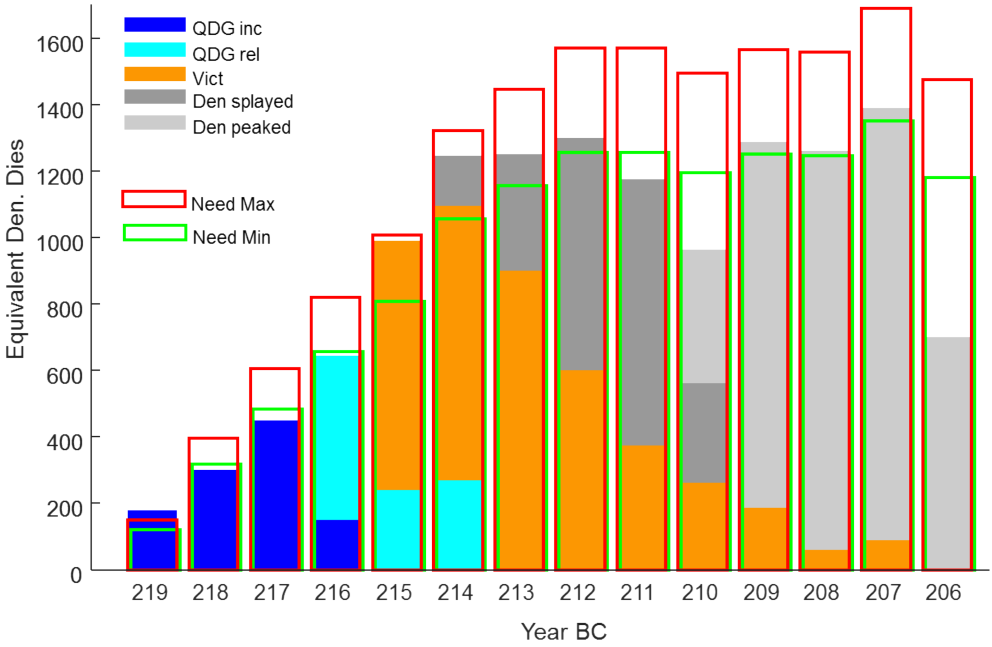

Figure 4 – Histogram of the estimated equivalent *denarius dies* including all the silver denomination produced during the War: quadrigati, victoriati and denarii. These productions are compared to the War costs (including or not the cost of food and equipment for the Allies, indicated with green and red lines respectively), converted into dies as discussed in the text.

CONCLUSIONS AND OUTLOOK

Several comments arise from the overall results reported in Fig.4:

- The quadrigatus seems to have been correctly placed, in the preliminary publication, even though the victoriati dies had not been counted at that time.[52]
- The early denarius system cannot be exactly as described in *RRC*.[53] A start in 211BC strictly together with the victoriatus would leave a four year gap (215-212) for the payment of the army on one side; on the other it would tie together, in one year or so, all the coinage of five years. There are several indications that the peaked visor denarii started in about 210.[54]

[52] Debernardi-Legrand 2015.

[53] See also McCabe 2013, who arrives at similar conclusions starting from the bronze side.

[54] Debernardi-Brinkman 2018. The arrangement of the early denarius stages (splayed visor helmets) is in preparation.

- The victoriatus seems to find its natural place as a *trait d'union* between the quadrigatus and the denarius system. Its production was huge, much larger than any previous coinage that far, quadrigatus included. Only its quantification allows us to regard it in a correct perspective, i.e. not as a complementary coinage to the denarius, but as the main coinage during the first stages of the denarius. This is also confirmed by comparing the fineness of the last quadrigati with the earliest victoriati.
- As the denarius becomes more and more popular, the victoriatus fades and becomes a subsidiary coinage from about 210 onwards; production continued possibly because of the success of this denomination, sought after in several areas/ situations.

Previous researchers already have proposed a similar role for the victoriatus, like Marchetti and Coarelli;[55] however here, for the first time, a solid foundation for this idea is provided.

More work and refinement certainly are still needed and they will be the topic of future research and papers. All the involved die studies will be updated due to the continuous increase of the *Corpora*. In combination with an augmented hoard table, larger by 17 hoards compared to the 19 known to RRC, the detailed inner features of the large series *RRC* 44/1 and 53/1 will also be discussed in future, together with the publication of small victoriati series and other features not treated in *RRC*.

[55] Coarelli 2013.

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APPENDIX

ESTIMATING THE FINENESS OF A DEBASED COIN FROM THE BUOYANCY METHOD

In the following, for the convenience of the reader, the main results of the paper Debernardi *et al*. 2017 will be summarized, by focusing on the effect of the blanching process applied to debased coins during the flan production and how that can be accounted for to obtain an estimate of the core fineness of a debased coin. The specific gravity (SG) of a silver coin obviously depends on its metallic composition, consisting of, besides silver itself, copper, but also many other metals, such as tin, zinc, lead, iron, gold, etc., whose inclusion was not intentional but resulted from the limits of ancient metallurgy. However, the sum of these other metals is generally lower than 2%. Hence, for numismatic purposes, it is generally accepted for a silver coin to be treated as composed of a binary silver/copper alloy, at least for freshly prepared flans. During their lifetime, coins get corroded, acquire dirt, etc., which might influence their SG. However, for some coin issues, flans were intentionally treated in order to make them appear to be made of better silver than they actually were; this treatment consisted of different steps. First the flans were allowed to oxidize (copper oxides), then washed with an acid, which attacked the copper (oxides) in the surface, but left the silver unharmed. This washing yielded a layer with a higher, almost pure, silver content, with a thickness ranging from a few μm (micro-meters) up to several hundreds μm, depending on the degree to which the oxidation step was pushed, possibly applied several times.

The so-processed flans were then ready for the striking, which made more compact the copper-depleted layer and sealed the copper-rich core below. The above described process is called surface silver enrichment (SSE[1], Beck 2004). In Fig.A1 an example from a cut coin is reported, which clearly shows the effect of copper depletion in the SSE outer layer and, most importantly, that the surface layer is composed of a quite pure silver phase and voids, corresponding to where the copper grains resided before they had been oxidized and removed.

[1] Beck 2004 = L. Beck, Bosonnet, S., Réveillon, S., Eliot, D. and Pilon, F. (2004) Silver surface enrichment of silver–copper alloys: a limitation for the analysis of ancient silver coins by surface techniques. Nuclear Instruments and Methods in Physics Research B, **226**, 153–162.

To be more quantitative, the SSE layers range around 200-300 µm, the silver increases and the copper decreases close to the surface. This phenomenon is a serious problem for the conventional buoyancy method, which works with the assumption of an AgCu binary alloy. In fact, the voids in the SSE layer strongly lower its SG, even below the copper value.[2] This is the origin of the bad reputation of SG in the numismatic field, where frequently debased silver coins are encountered.

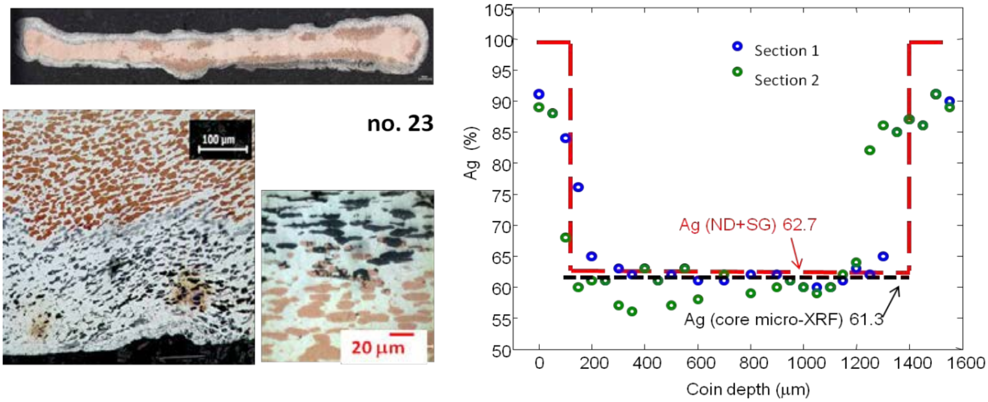


Figure A1 – Left: images of the sectioned victoriatus no. 23 from Corsi 2015.[3] Right: Ag profiles at two positions (blue and green dots) vs. depth of the coin (sample N10 in Ager 2013 and Moreno 2015[4]). The red-dashed line shows the complete depletion model proposed here, while the black line the estimated average from the micro-XRF data

[2] See Angelini 2013 (I. Angelini, F. Barello, E. Barzagli, J. Corsi, P. Debernardi, A. Lo Giudice, Monetazione preromana dell'Italia settentrionale e vittoriati: Analisi per diffrazione neutronica, Quaderni della Soprintendenza archeologica del Piemonte, 28, p. 331-333) and, for example, two victoriati RRC 121/1 at ANS: 1944.100.79317 (SG=8.73) and 1968.116.6 (SG=8.98). They are marked as "plated" in the museum trays, as many others. Lower SG values displays some selected quadrigati at The British Museum: BM 1843,0116.82, SG=8.49; R6350, SG=7.05; BM 2002,0102.161, SG=5.54. P.D. would like to thank Mr. D. Hook for providing these data.

[3] Corsi et al. 2015 = J. Corsi, B. Maróti, A. Re, Zs. Kasztovszky, L. Szentmiklósi, M. Torbágyi, A. Agostino, D. Angelicia and S. Allegrettia, Compositional analysis of a historical collection of Cisalpine Gaul's coins kept at the Hungarian National Museum, J. Anal. At. Spectrom., 30, 730.

[4] Ager 2013: F.J. Ager, A.I. Moreno-Suárez, S. Scrivano, I. Ortega-Feliu, B. Gómez-Tubío, M.A. Respaldiza, Silver surface enrichment in ancient coins studied by micro-pixe, Nuclear Instruments and Methods in Physics Research B 306, p. 241-244, 2013. Moreno 2015: A.I. Moreno-Suárez, F.J. Ager, S. Scrivano, I. Ortega-Feliu, B. Gómez-Tubío, M.A. Respaldiza, First attempt to obtain the bulk composition of ancient silver–copper coins by using XRF and GRT, Nuclear Instruments and Methods in Physics Research B 358, p. 93–97, 2015.

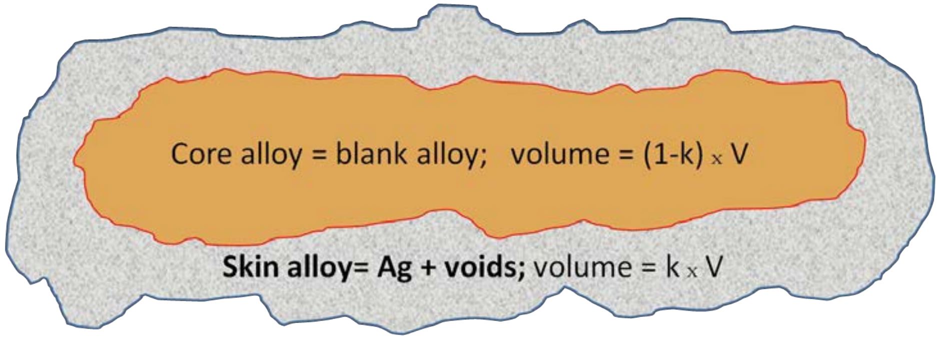


Figure A2[5] **–** Sketch of a debased coin of volume V with SSE volume kxV, emulating the actual coin section in Fig. A1. The image illustrates the adopted "complete depletion" model, meaning that it is assumed that the core is composed of the original flan alloy and the SSE layer by pure silver and voids, whose SG can be taken as being 0. The measured SG is a weighted average of the inner original SG and the outer SG, much lower because it includes the voids

The SG of a debased silver coin may be below that of pure copper (8.95) simply because a debased coin is not made of a homogeneous AgCu alloy. That is true for good silver, while when SSE is employed, it transforms the binary alloy to a more complicated object, as previously discussed. In Fig. A1 a typical silver fineness profile[6] is shown in better detail together with a piece-wise linear approximation (red dashed line).[7] That will be referred as a "complete copper depletion" model, i.e. it is assumed that the coin is composed just by two homogeneous parts:

- the bulk, in the core, whose Ag wt.% content is denoted by x, the fineness of the original blanks
- the fraction k x V of the SSE layer, which is assumed as an alloy of pure silver and voids, i.e. the spaces freed from copper.

The density ϱ=W/V (Weight/Volume, also referred to as "SG") of a coin is a come bination of the internal (ϱ_i, the original alloy now present in the core) and external densities (ϱ_e, the Ag-void alloy at the periphery of the coin):

[5] We thank Jan Moens for suggestion such a simplified sketch and for his suggestion that we write this appendix.

[6] See n. 20; we thank Ana Isabel Moreno-Suárez for providing the Ag profile of sample no 2.

[7] Beck et al. 2004; see also fig. 2, left.

$$\boldsymbol{\rho} = (1 - k)\rho_i + k\rho_e$$

where k indicates the volume fraction where copper has fully leached out, in the assumed "complete depletion" hypothesis.

For the internal part, the well known binary alloy equation holds for the inverse of the density:

$$\frac{1}{\rho_i} = x(\sigma_1 - \sigma_2) + \sigma_2$$

where x is the Ag weight fraction of the inner alloy, σ_1 and σ_2 refer to Ag and Cu respectively (1/10.5 and 1/8.95), while it can be shown that:

$$\rho_e = \rho_i x$$

In this way the SG of a debased coin has been written in terms of the core alloy and the depletion parameter k. The problem of course is, that this model contains now two unknown parameters, while the buoyancy method only yields one value, i.e. the SG of the whole coin, core and SSE layer. This problem can be overcome if there is another measurement, such as neutron diffraction. Such technique is known to provide reliable values for the average silver content, which can be easily computed within the complete depletion model previously described. In this way the problem can be uniquely solved, because it is a simple system of two equations, SG and average fineness, with two unknowns, x and k. This is what has been carried out in Debernardi 2017. By applying this model to three different silver coin issues, *viz*. a sample of 43 coins, composed of drachms, victoriati and denarii, a relationship between x and k valid for victoriati (the majority of the sample) was found.

The experimental results and their mathematical modelling are represented in figure A3. As can be seen in Fig. A3(a) there is a clear relation between coin SGs and k. This, therefore, suggests the use a mathematical fit of the experimental data (black solid curve), to compute k from only the SG measurement, and allows an estimate of the coin's core fineness x from the simple SG measure.

The outcomes of such procedure are shown in Fig.A3 (b) and (c), where the results of the SG + neutron measurements (open circles) are compared to those obtained by only the SG measurement, complemented by the k-fit of Fig. A3(a). The reliability of the method obviously depends on the 'goodness of fit' between the observed values and the ones resulting from the fit. For the given sample of 43

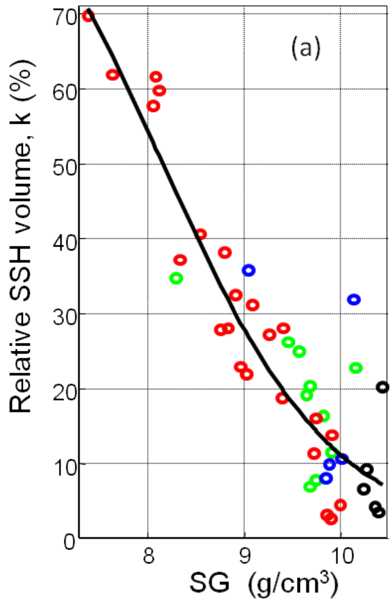
Figure A3 – Model derived data (*k* and core fineness) from experimental ND and SG of a sample of drachms, victoriati (red circles) and five denarii (black circles, from Debernardi 2017):

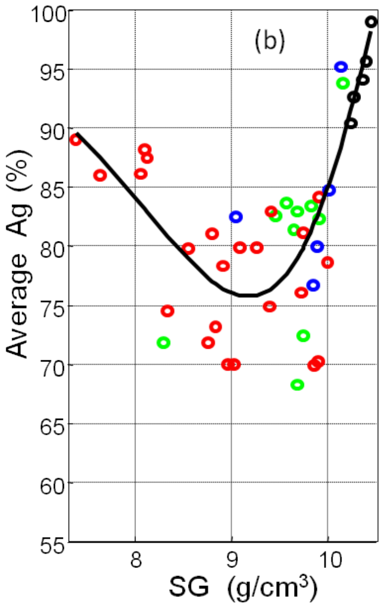
(a) the estimated volume fraction *k* of SSE vs. SG;

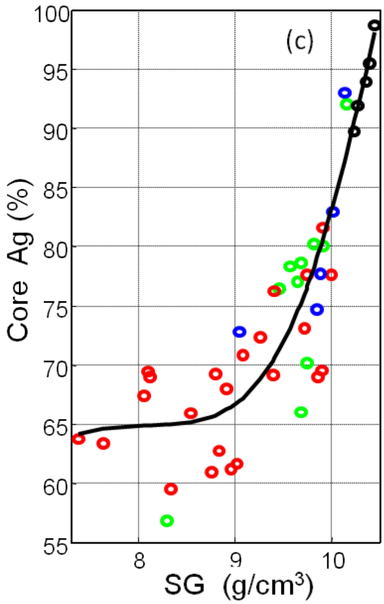
(b) the measure d fine average vs. SG;

(c) the corresponding extrapolated values for the original alloy.

The lines refer to values resulting from fitting *k* vs. SG (see Debernardi 2017).







coins, covering a wide range of SG values, the standard deviation amounts to 5%, with 39 of the 43 specimens laying between ± 6% difference, mostly attributable to the approximation of full depletion and to different oxidation processes that locally modified the density.

It has to be repeated and emphasized that the procedure previously described is valid for any debased coinage, but the direct estimate of the core fineness from only the SG measurement can be safely applied only to victoriati, because the *k*-fitting has been obtained specifically from a large set of those coins.

The presented model also allows an estimate of the weight loss of the cons. This is given by:

$$\frac{\Delta W}{W} = k\ \frac{V}{W}\rho_{Cu}(1 - x) = k\ \frac{\rho_{Cu}}{\rho}(1 - x)$$