

The markings of the trade: exploring the patterns of olive oil production in Roman Baetica

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Abstract

The aim of this study is to explore economics dynamics in the production and distribution of olive oil trade. Our case of study has been focused on the production processes located in *Baetica* province (currently Andalusia) from 1st to 3rd AD. In particular, we want to detect patterns of olive oil production that link amphora workshops and amphoric stamps. *Baetica* became an important production and distribution centre during the Roman Empire. However, it remains under debate about how this province was organised and whether it could be possible to identify patterns in the olive oil market. Amphoric stamps are used to identify the presence of different groups that might share similar stamps. To achieve this goal, we analyse a set of stamps from two centres: 1) production centres by analysing different workshops in *Baetica* province and 2) two Roman provinces such as *Germania* and *Britannia* as consumption centres. They will be used to detect a connection between the distribution of amphoric stamps and the economic structure in both centres. Here, we use methods borrowed from Ecology that allow us to identify if amphora workshops share similar amphoric stamps depending on the spatial distance.

The analysis explores how the quantitative approach provides a useful tool for the interpretation of the economic processes. Finally, results pretend to

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highlight the organisation of Baetican olive oil production in the Roman Empire linked to the differences observed in the archaeological evidence.

Keywords: Roman Empire; amphora production; Dressel 20; dissimilarity index; Roman provinces

1. Introduction

The role of the Mediterranean sea for the trade had an enormous impact during the Roman Empire. The spread of thousands of different goods along maritime shipping allowed progressive exploitation of communication networks and a major interaction between communities (Remesal, 1998; Temin, 2001; Bevan, 2014). The exchange of different products between regions can be seen in both archaeological and written records as a frequent indicator of Roman trade.

Given this fact, an important mechanism of production control under the Roman government was created spreading by different areas attending to the richness of different places. Roman provinces such as *Baetica* (currently Andalusia, south Spain) became important production centres of olive oil during the Roman Empire. Olive oil was considered the liquid gold since it was used in different aspect of daily life for cooking, hygiene or lighting (Mattingly, 1988). As a consequence of high demand, this product was distributed in a large number of amphorae across the provinces, mostly to supply the Roman Army and Italy (Blázquez, 1980).

The understanding of the olive oil production processes has been widely discussed over many decades (Remesal, 1977-1978; Chic, 1997; Berni, 1998). Despite this topic is still subject to debate: what patterns were followed for the distribution of olive oil to the different provinces? Did each province follow a different pattern for its distribution? Nor the lack of written records has made possible to detect any indication of patterns in the olive oil market.

Advances in the research of the Roman studies have currently led an environment with more diverse commercial dynamics (Duncan-Jones, 1982; Temin,

2006; Bowman and Wilson, 2009). The application of different quantitative approaches combined with the archaeological evidence has allowed us partly to deal with the complexity of the Roman production (Brughmans and Poblome, 2016; Orengo and Livarda, 2016; Rubio-Campillo et al., 2017; Coto-Sarmiento et al., 2018; Rubio-Campillo et al., 2018b).

This paper aims to study the olive oil market connection between provinces by calculating the similarity of stamps. Specifically, our work pretends to detect microeconomic processes focused on a commercial product from a specific province (Isaksen, 2006). We want to understand the pattern of olive oil production linked to amphora workshops and amphoric stamps used to mark them. We focus here on exploring the economic relation between stamps and amphora production and distribution centres.

Two case studies have been studied in order to analyse the relation between production centres (*Baetica*) and consumption centres (*Britannia* and *Germania*). In the case of *Baetica* province, we want to identify the role of the stamps in the organisation of the workshop; in Roman provinces, our aim is detecting groups of stamps concentrated in an area or if some groups have an important role for the exportation of olive oil in those provinces. This economic connection could be identified by different aspects: a) correlation between spatial distance and centres based on the idea that closer workshops concentrate similar amphoric stamps in a specific area than the distant workshops and b) groups of similar stamps were concentrated in a specific province.

In particular, we study the distribution of amphoric stamps to identify a correlation between geographical distance and similarity. Based on this assumption, we proposed three hypotheses: a) we can identify a correlation between spatial distance and the distribution of stamps, b) stamps located in close workshops share similar traits and c) low mobility of amphoric stamps to other regions: stamps always stay in the same region.

To do this, a population approach has been used to analyse the dispersion of stamps between amphora workshops (Rubio-Campillo et al., 2018b). Stamps will be used to identify economic patterns by analysing their similarity. If work-

shops and provinces share stamps with similar traits, then we can identify connections. By contrast, if we do not detect similar stamps between workshops, then workshops worked independently.

The paper addresses these questions as follows: the next section introduces the historical context. Section two displays the dataset and the methods used for the analysis. Section three presents the results and the last section shows the discussion and the main conclusions of this work.

2. The Amphoric production in Baetica province

The high demand of Roman provinces stimulated by the good condition of the *Baetica* lands allowed to develop a massive infrastructure of olive oil production. The production and distribution of olive oil were growing exponentially for almost three centuries (Remesal, 2011). As a result, hundreds of amphora workshops were raised to support this high demand of the Roman Empire. The amphora workshops were situated in different locations in *Baetica* province, along the rivers Guadalquivir and Genil (see Fig.1).

The strategic location of the workshops close to the river allowed the transport of olive oil through river connectivity to the routes of the Mediterranean and the Atlantic (García Vargas, 2010).

The chronology in the workshops is widely diverse from the first to the third centuries AD (Berni, 1998; Remesal, 1998; Chic, 2005). This fact is shown by the archaeological evidence that displays a highly specialised production with a long activity with apparently few changes (Remesal, 2004).

The majority of olive oil amphorae produced in this province belong to Dressel 20 type(Dressel, 1878; Berni, 1998). Dressel 20 amphorae were shipped and distributed from *Baetica* throughout western Europe.

Dressel 20 contains much information still unknown. A high percentage of Dressel 20 were marked in stamps, inked in *tituli picti* and incise in *graffiti*. Indeed, most of the inscriptions on the amphora have not enough analysed due to the fragmentation of the material or the shortage of samples (Aguilera, 2007;

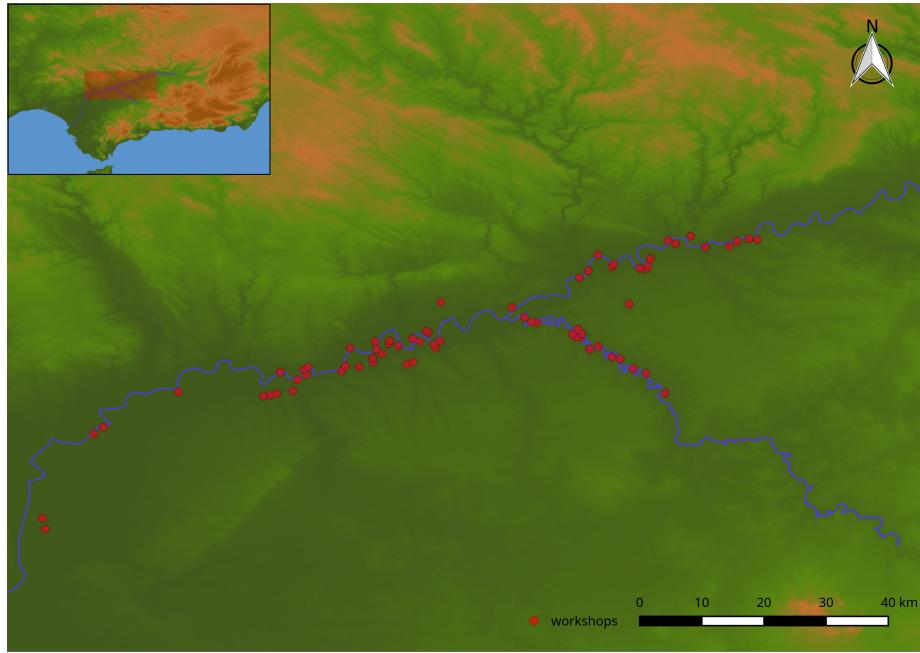


Figure 1: Distribution of the workshops (dots) in Baetica province

Rovira Guardiola, 2007).

3. A potential indicator of Roman economy: Dressel 20 stamps

Dressel 20 was the amphora most stamped during the Roman Empire (Berni, 1998, 18). The usage period is associated with a large amphora production for almost three centuries.

Most stamps display a large activity of production that it can be difficult for specifying an accurate chronology in some cases. They have been frequently dated with the consular dating by studying *tituli picti* found in *Monte Testaccio* (Blázquez Martínez and Remesal Rodríguez, 1999; Berni, 2008). However, the chronology of stamps could be also biased in other sites taking into account that amphorae were deposited after being produced and consumed.

The fascination aroused by stamps has caused it to be one of the inscriptions with the most publications about its origin and meaning. Its endure in time

become an essential element that was used to mark amphorae during almost three centuries (Remesal, 2016) (Fig.2).

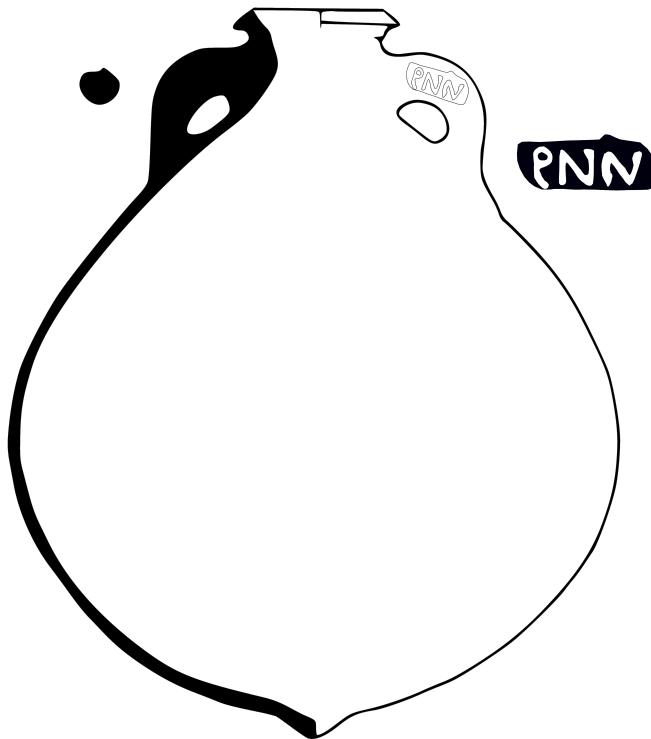


Figure 2: Dressel 20 were mostly marked with stamps of three letters called *tria nomina*

Frequently, they were mainly marked in handles, but seldom in rims and body (Berni, 1998). The information of the stamps is shown in different forms and letter content and it seems that there was not a unique criterion. Stamps are mostly formed by a code of three letters and they can appear in abbreviated form or complete and they are known as *Tria Nomina* (Berni, 1996).

Despite researchers identify stamps as identity marks, there is not a consensus about the meaning of the stamps (Remesal, 1998). Alike a high percentage of Dressel 20 containers were not stamped being difficult to determinate.

They could be identified based on three premises: content (olive oil), context

(amphora workshop) and subject (individuals involved). On the one hand, it seems that stamps could have been identified as the landowner of the olive groves (Remesal, 1977-1978). On the other, they could belong to the owner of the making amphorae workshops or even a group of amphora workers (Berni, 2008). In any case, the use of these stamps became in a good proxy to define somehow the system of working in the workshops.

Nevertheless, some challenges remain under discussion such as how this production was organised and whether it is possible to distinguish production patterns in the olive oil trade. Our questions will be focused on the distribution of amphoric stamps. Did they follow a distribution pattern? Did stamps share the same workshop?

Neither the use of written records have allowed providing enough information that can explain the economic role of *Baetica* province in the Roman organisation.

4. Case study: consumption centres

The conquest of new provinces allowed the Roman Empire the arrival of resources through Mediterranean and Atlantic routes. This lead to a progressive change in the economic and social structure creating new trade networks for supplying Roman conquest. As a result, Augusto's administration created the figure of the *praefectura annonae* for the supply of wheat. The role of the *praefectura annonae* was mainly to provide though *frumentationes* a quantity per month of wheat to Roman citizens (Remesal, 1986, 2011).

Annona could have also included other goods for the supply of Roman legions such as olive oil according for some hypotheses (Remesal, 1986, 1990)

The importance of olive oil production could be explained by the fact that we detected a massive amphora distribution in different Roman provinces. This amphora has been commonly associated with the transportation of Baetican olive oil for supplying military camps and civil settlements (Berni, 2008).

The military consumption of olive oil in Roman provinces may be related to

two aspects: a) cultural consumption whose product is consumed by cultural reasons such as to identity or habit and b) economical reasons where olive oil distribution is based on the transport costs, unlike other products (Carreras Monfort and Funari, 1998, 69-70).

Olive oil supply had a special impact in militarised provinces such as *Britannia* and *Germania*. The concentration of amphorae in eminently militarised areas suggests the existence of a broad supply mechanism, being accurate to imagine a possible organisation in charge of its distribution from military camps to civil settlements(Remesal, 1986; Carreras Monfort and Funari, 1998).

4.1. *Britannia*

The consumption of olive oil in *Britannia* was residual until starting the Roman conquest (Funari, 1996; Carreras Monfort and Funari, 2003). It is well known that this product was not frequently consumed by indigenous population (Carreras Monfort, 1998, 161). The absence of olive oil importation before the conquest can be reflected by the shortage of this product until the arrival of a high percentage of Dressel 20 amphorae to *Britannia* (Carreras Monfort and Funari, 1998, 1). Additionally, the land of *Britannia* showed inadequate for the olive oil production due to low environmental conditions. This issue was necessary for creating an important export apparatus from *Baetica* to supply Roman army.

At this moment, we detect an increase of the olive oil exportation concurring with the displacement of legions during the military campaigns (Carreras Monfort, 1998, 161). This fact will have a spatial incidence in sites close at Hadrian Wall. Olive oil production in *Baetica* would cross the Atlantic until they reached the province and redistribute throughout the area from a series of strategic points (Carreras and Morais, 2012). The increase of the exportation of Dressel 20 amphorae created an important commercial network for exchanges. Thus, the network was mainly focused on the support of soldiers during military campaigns.

The presence of Dressel 20 stamps in military camps in *Britannia* have been

widely studied in Roman archaeology (Carreras Monfort and Funari, 1998). This fact also indicates a possible governmental organisation allocate to reinforce and supply of olive oil in military camps, such as *Germania* (Remesal Rodríguez, 1986). However, it is unknown the type of economical system when managing or control the redistribution of olive oil in different sites in *Britannia* but it seems that it could have been in the main cities (Funari, 2005, 45).

Finally, the increase in olive oil exports would experience a progressive slowdown from the third century A.D., coinciding with the change in market strategy in the Empire. As a result, a progressive decrease of Dressel 20 is documented being gradually replaced for Dressel 23 amphorae (Remesal, 1991; Berni, 1998).

4.2. *Germania*

The Roman conquest in *Germania* dates from the end of the 1st century BC, during Caesar campaign and subsequently continued by Augusto. The advance of the Roman legions toward *Gallia* opened a path through the Atlantic Ocean to *Germania* (Remesal, 1986, 2002). It is thought that this route would have been initiated previously through terrestrial transport, although recent studies question this position giving an important role to the Atlantic route for both the conquests of *Germania* and those of *Britannia* (Remesal, 2010; Rubio-Campillo et al., 2018b).

The Roman studies about the presence of Dressel 20 amphorae in *Germania* has not had the same repercussion as the rest of the province. This could be explained due to the lack of archaeological sources (González Cesteros, 2010).

As a consequence, we do not the role that commerce agents in the participation of the distribution and exportation of olive oil in *Germania* or, on the contrary, the Roman army was the responsible to supply the product in the own province (Remesal, 2010, 156).

As the case of *Britannia*, the consumption of olive oil in *Germania* was not detected before the conquest. This is evidenced by the presence of Dressel 20 amphora in different sites close to *limes*.

The presence of the Roman army encouraged the exchange in the province

showed by the arrival of this product both civil settlement and military sites with a mayor concentration at German *limes*. It seems that some Baetican centres would be assigned to the support of olive oil. However, this hypothesis can not be proven by the lack of archaeological sources (Remesal, 2011, 125).

5. Material and Methods

The goal of this study is exploring the effect of the production patterns between different centres. We are especially interested in identifying links between production and consumption centres by using amphoric stamps. To do that, we use the CEIPAC database to collect stamps from different places. The CEIPAC dataset contains over 50.000 of epigraphy records found in amphorae, mostly from *Monte Testaccio*.

Therefore, this study proposes a robust baseline to explore the distribution of Baetican olive oil production by computing the spatial correlation between stamps. A way to analyse is to use a quantitative framework to measure the similarity between amphoric stamps. Here we use an ecological approach based on three steps: a) to detect similarities between stamp codes, b) to explore a potential spatial correlation and c) to establish a correlation between similarity of stamps and spatial distance.

5.1. Production centres: *Baetica* province

We studied a dataset of 3798 stamps collected from different Dressel 20 amphora workshops in *Baetica* province. For the analysis, we used a database compiled by CEIPAC group (Remesal et al., 2015) (see CEIPAC database here <http://romanopendata.eu>). CEIPAC database contains over 50.000 epigraphy records found on different types of amphorae. From the database, we collected the site where stamps were found, the stamp code and the geographical coordinates.

The stamps with incomplete information were discarded and not integrated into our dataset. We finally filtered a total sample of 987 stamps composed of 130 different stamps from 81 workshops.

We also created a new column with the area of the stamps. These areas, known as *conventus*, were administrative centres for territorial organisation in the Roman Empire (Ozcáriz Gil, 2013, 58). Dressel 20 stamps were found in three different *conventus*: *Hispalensis* (currently Seville, hereafter Hispalis), *Cordubensis* (currently Córdoba, hereafter Corduba) and *Astigi* (currently Écija, Sevilla, hereafter Astigi) (Remesal, 1977-1978; Chic, 2001; Berni, 2008).

It is important to mention that some workshops exhibited the same coordinates but they were catalogued as different workshops in Roman Studies (i.e. Tesorillo de Doña Mencia and Doña Mencia). The analysis took into account this particularity but some biases can occur due to the archaeological dataset.

We calculated the frequency of distribution in amphora stamps with the purpose of implementing an exploratory analysis (EDA) to detect the distribution and the number of stamps per each centre.

The frequency of stamps per workshop can be seen in Fig. 3. Most workshops contained only one stamp whereas one workshop (La Catria) concentrated a high frequency of amphoric stamps with a total number of 228 stamps. The type of distribution is also frequent in amphora production where we observed a self-organised complex system pattern with a major concentration of the number of stamps in a few workshops (Rubio-Campillo et al., 2017; Coto-Sarmiento et al., 2018).

The distribution of amphora stamps in different *conventus* can be seen in Fig. 4. The majority of stamps are concentrated in *Hispalis* with 574 stamps while *Corduba* and *Astigi* with 267 and 146 stamps, respectively. Mostly, workshops show a homogeneity on the frequency of stamps except for both La Catria and Arva that exhibit a big amount of stamps with 29 different code stamps. According to previous studies, those workshops became in most important centres of amphora production although they could have more intensely prospected than others. (Remesal et al., 1997).

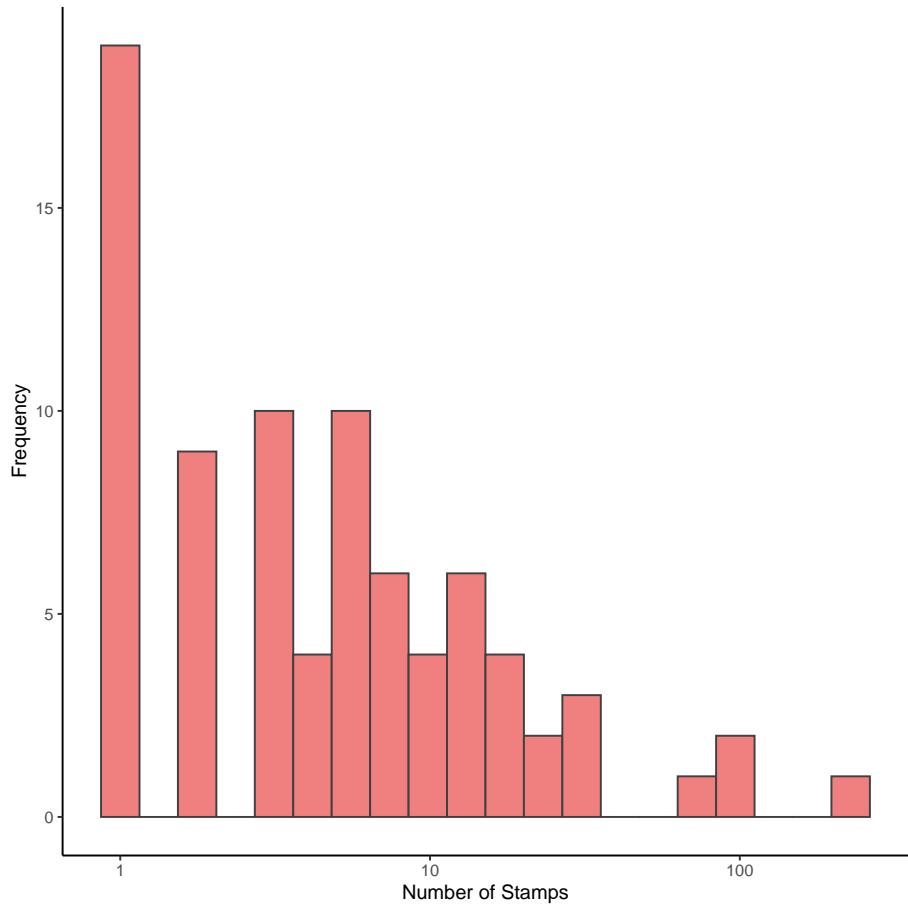


Figure 3: Histogram on a log scale with base 10. X axis is represented by the number of stamps and Y axis is the frequency of workshop. The distribution is widely diverse with most workshops have only one stamp

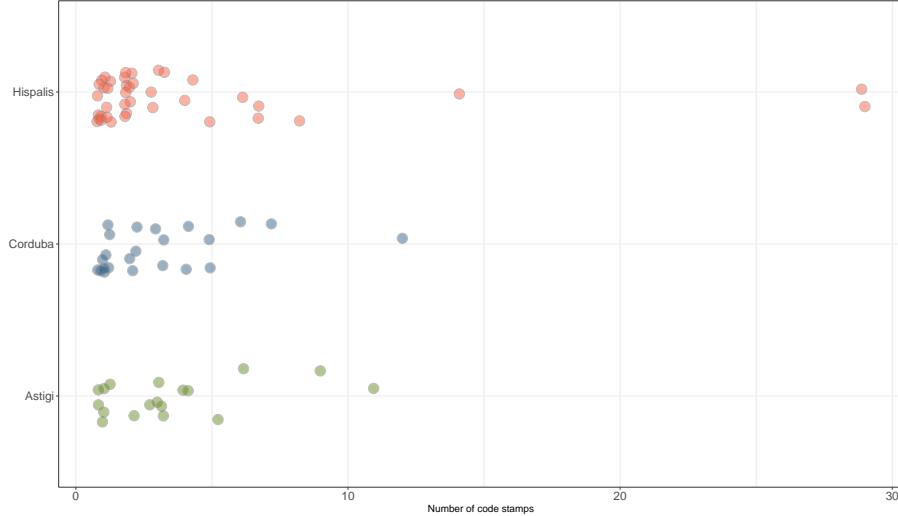


Figure 4: Distribution of the number of different code stamps (X axis) for each *conventus* (Y axis). Each dot corresponds to a workshop sorted by different areas. Colours are represented by areas divided into Hispalis (red), Astigi (green) and Corduba (blue)

5.2. Consumption centres: *Britannia* and *Germania*

We analysed a dataset of 4271 stamps from different centres in *Britannia* (2219 stamps) and *Germania* (2052 stamps). Both *Germania* and *Britannia* were analysed as regions and not as Roman provinces. This means that we selected centres beyond the borders of the provinces. We analyse the two provinces (Ulterior and Citerior) close to *limes* in *Germania* while the analysis for *Britannia* was extended to *Caledonia*.

We used the same CEIPAC database as previous before to select amphora stamps, centres and coordinates. The database contained anomalies that were eliminated using the same criteria cited above. We selected the centres with more or equal than five stamps.

In *Britannia*, we studied a total sample of 1765 stamps composed of 968 different stamps from 46 centres. The centres located in *Britannia* can be seen in Fig.5.

In *Germania*, we finally collected a total of 1621 stamps consisted of 850

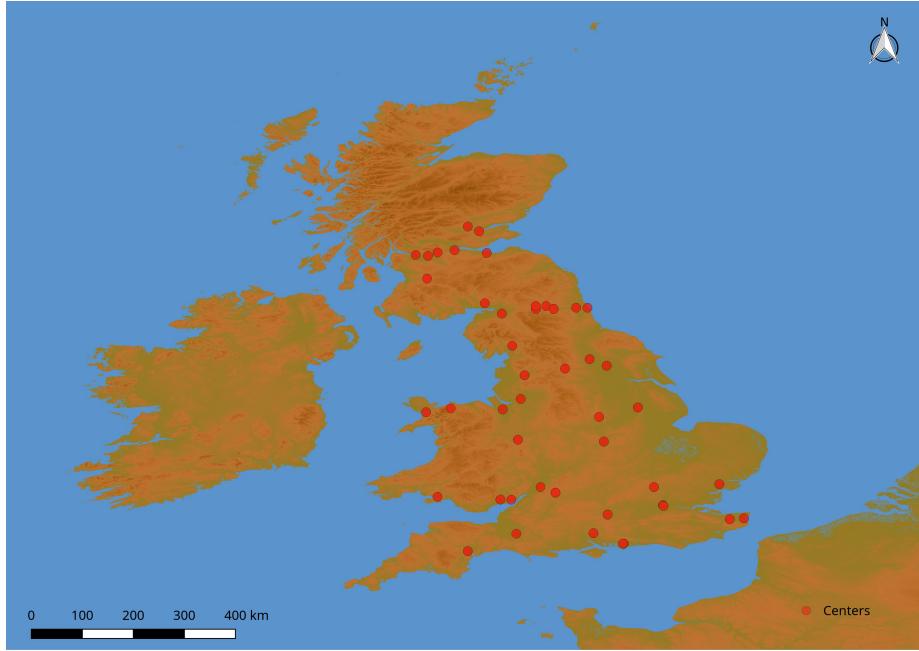


Figure 5: Distribution of centres in *Britannia*

different stamps from 46 sites (see Fig. 6).

5.3. Measuring the dissimilarity

The approach proposed here is based on the idea of measuring the similarity between amphora workshops by quantifying similar stamps. A measure of dissimilarity has been chosen to analyse the dataset. We use the statistical technique Morisita-Horn index (Morisita, 1959; Horn, 1966). This method was performed to measure the dissimilarity between different samples of sets. Generally, it describes the dissimilarity between the system of two communities based on the idea of inverse correlation between diversity and species (Magurran, 1988).

The formula can be described as follows (Magurran, 2004):

$$D(MH) = 1 - \frac{2 \sum(a_i \cdot b_i)}{(d_a + d_b) \cdot (N_a \cdot N_b)} \quad (1)$$

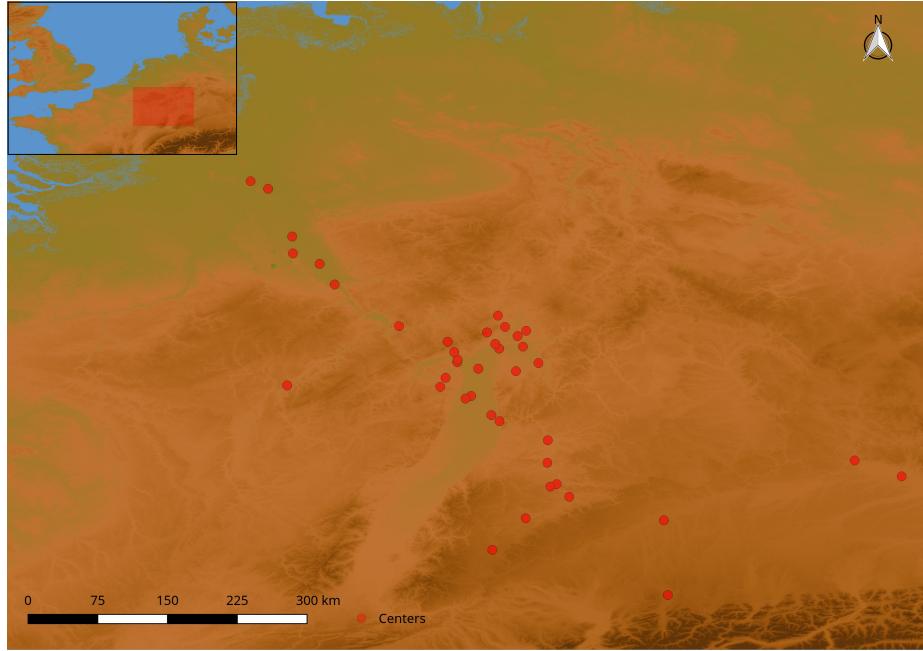


Figure 6: Distribution of the sites in *Germania*. Most sites were located in German *limes*

d_a and d_b are given by the following equation:

$$d_a = \frac{\sum a_i^2}{N_a^2} \quad (2)$$

where N_a is the total number of stamps in workshop A; N_b is the total number of stamps in workshop B; a_i is the number of different stamps for workshop A and b_i is the number of different stamps for workshop B.

Considering our dataset as a non-uniform sample, this method provides a useful tool to handle large samples with different sizes and diversity (Wolda, 1981). Morisita-Horn index can be expressed considering 0 as the total presence of similarity of stamps and 1 a total dissimilarity between stamps. In our case,

it will be calculated the number of times that one stamp appears in an amphora workshop. This method allows to bear in mind a similar number of times for each repeated stamp per workshop. If two workshops have similar stamp codes, then the probability would be 0 whereas stamps codes are totally different when the results would be 1.

5.4. Hierarchical clustering

Morisita-Horn index resulted in a numeric matrix of dissimilarities containing the distance value between the sites and the code stamps. The method was used to group sites with similar stamps codes. The matrix was then computed using hierarchical clustering. The algorithm was selected to cluster similar groups in order to analyse the relationship between groups of sites and the distribution of similar stamp codes. The results were visualised using a dendrogram to detect groups of sites sharing similar stamp codes.

6. Results

6.1. Production centres: *Baetica Province*

The analysis shows that the similarity of amphoric stamps could be correlated with spatial distance. The dendrogram in Fig. 7 was obtained with Morisita-Horn index. The dendrogram suggests that amphora workshops used different stamps for their production system. Nearby workshops show similarity on the stamps while most workshops seem to display different stamps. Groups of workshops sharing similar stamps were not found in the dendrogram: the majority of stamp grouping was composed of no more than three workshops. Additionally, workshops that shared more similar amphoric stamps belonged to the same *conventus* area, such as Picachos, Cerro de los Pesebres and El Castillejo.

6.2. Consumption centres: *Britannia and Germania*

The results show a similarity with the results obtained in *Baetica* province. However, the similarity is less pronounced as we observed in the dendrogram in

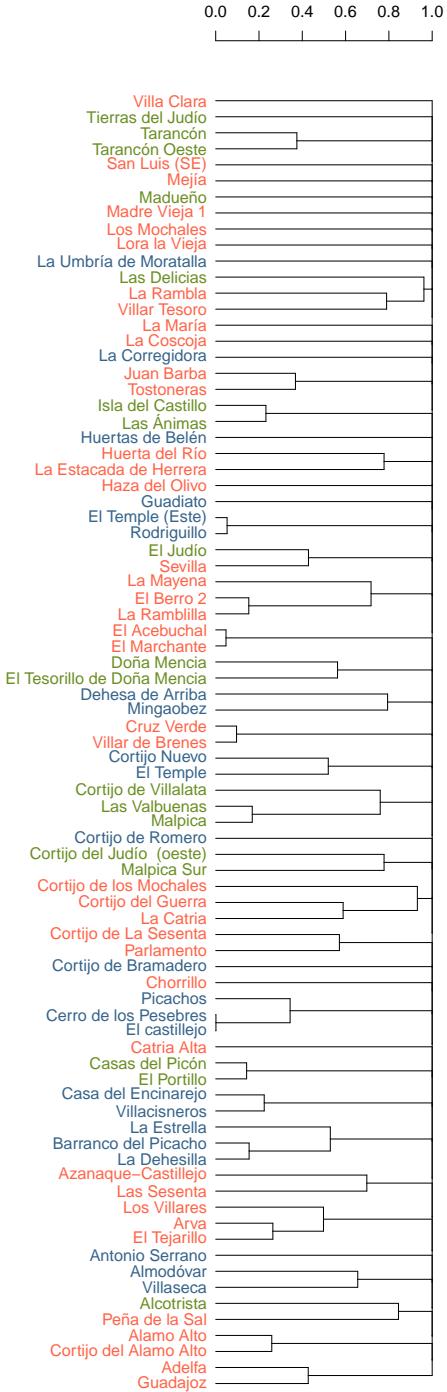


Figure 7: Dendrogram obtained by Morisita-Horn algorithm of different amphora workshops in Baetica area. Colours are represented by areas divided into *Hispanis* (red), *Astigia* (green) and *Corduba* (blue)

Fig. 8

A minor correlation can be explained by the fact that *Britannia* spatial area is much wider than *Baetica* where the centres were more concentrated.

Most military sites that showed a high similarity in the results were geographically close. We identified two factors: 1) nearby sites tend to share similar stamps and 2) most sites have different stamps. By contrast, most sites did not show a strong similarity in stamp correlation. Neither we found a grouping of similar stamps in a specific place. In general, the dendrogram did not observe any production pattern that indicates a clear organisation between production centres and consumption centres. In other words, our results did not indicate the presence of a specific production centre from *Baetica* in *Britannia* province. Rather, it would imply that olive oil production was distributed by non-specific production centres.

In *Germania*, the similarity of stamps shows results less significant than *Britannia* province as it can be seen in the dendrogram (Fig. 9).

A higher concentration of sites sharing similar stamps were found in areas eminently militarised and close to German *limes*, even if most sites mostly showed different stamps. The interpretation of the results suggests that there is still no possibility to determine the existence of a defined pattern that reflects in more detail the route of this production in the area of the German limes.

7. Discussion

In this work, we aimed to analyse the distribution of the amphoric stamps in the organisation of the olive oil market both in the production and consumption areas. For this reason, an index of dissimilarity was used to detect differences between the distribution of the amphoric stamps and the spatial distance of producers and consumption centres. The general purpose was to explore if such differences found in the stamp codes could play an important role in the Roman market.

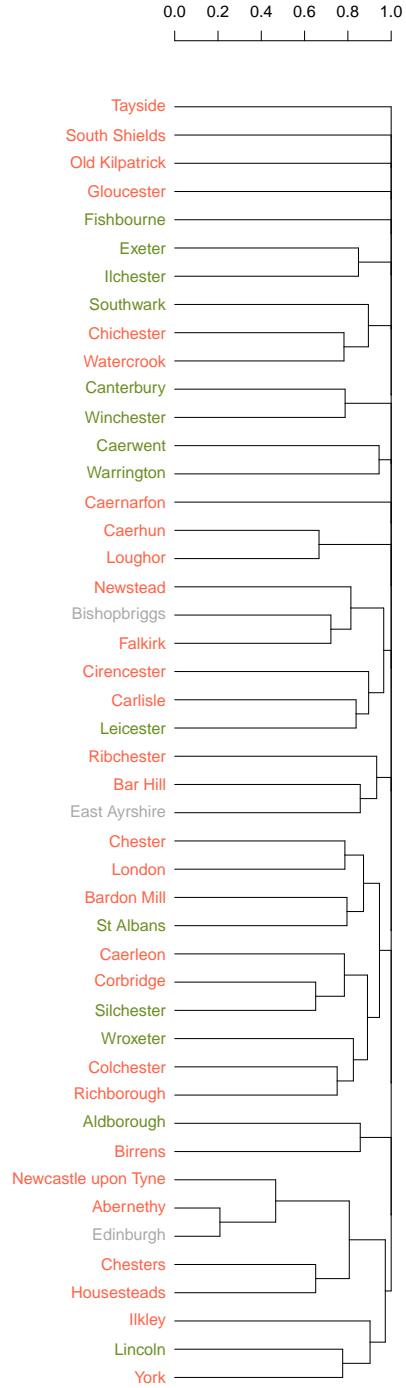


Figure 8: Dendrogram obtained by Morisita-Horn algorithm of different sites in *Britannia*. Colours are represented by type of sites divided into military sites (red), civil sites (green) and no specific (grey)

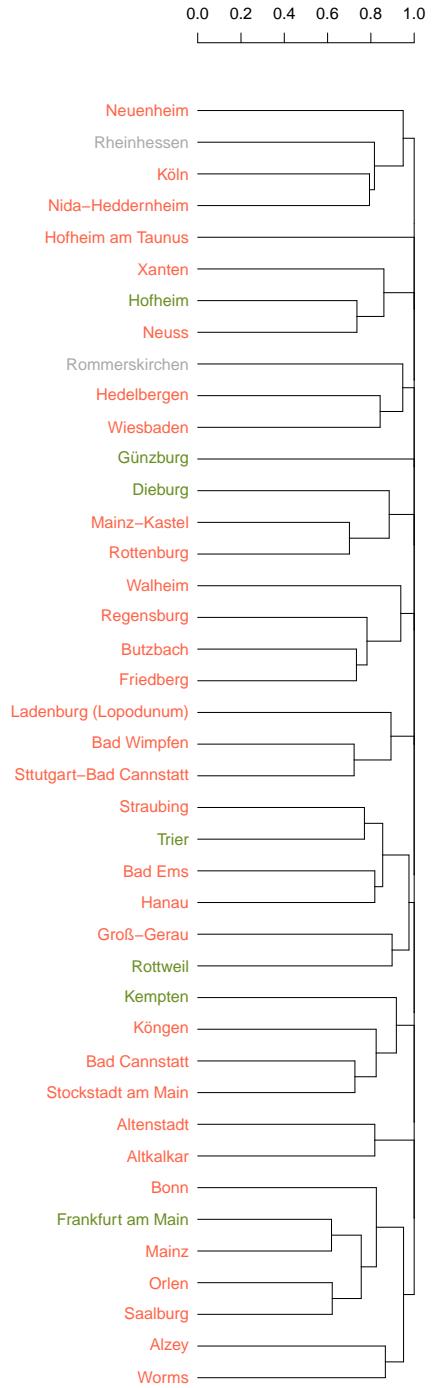


Figure 9: Dendrogram obtained by Morisita-Horn algorithm of different sites in *Germania*. Colours are represented by types of sites divided into military sites (red), civil sites (green) and no specific (grey)

7.1. Production centres

The analysis of the amphora workshops in *Baetica* province resulted in a significant correlation between spatial distance and the similarity of the amphoric stamps.

The analysis suggests a connection between the same stamp code and nearby amphora workshops, excluding certain exceptions. Consequently, the majority of stamps are located in different amphora workshops and only similar stamps between closer amphora workshops were found. Indeed, our results show that most similar stamps were detected in the same *conventus* area. This results may indicate a grouping of stamps with similar codes in the same *conventus*. Despite these stamps tend to share the same area of production, we do not identify groups of any more than three workshops sharing the same amphoric stamps as the dendrogram showed. In general, the majority of stamps were located in different amphora workshops.

Our results indicate that the hypothesis about groups of amphora workshops sharing the same stamps seems do not match with the results of the analysis, even though there are similar stamps in closer workshops. Rather, it seems that each workshop was organised independently with different stamps. Those stamps detected in closer workshops do not move from other distant workshops. In other words, the stamps tend to remain in the same area and different stamps were located in a same amphora workshop.

This could be defined by several factors. First, each workshop had a different organisation involved in the use of stamps and they were not used in other workshops. Second, stamp similarity in closer workshops could be linked to a spatial pattern. It is more probably than closer workshops tend to share more traits than distant workshops. While the role of the river was significant for the distribution of amphorae, river connection amongst workshops does not seem to show relevancy for the distribution of stamps. Finally, the distribution of stamps could have shown some research bias. In some cases, workshops have been catalogued with different names in spite of belonging to the same workshops or being closer between each other. Additionally, most of the workshops were not

widely excavated.

7.2. Consumption centres

Both consumption centres showed a correlation between spatial distance and similarity in the amphoric stamps. In the case of *Britannia*, the correlation was higher than *Germania*.

In *Britannia*, the majority of similarity stamps were mainly found in military centres. This could be also interpreted by a intense bias where military centres have been mostly excavated than civil centres.

It should be noted that centres with a similarity correlation were located close to the Atlantic coast around the North Sea and the Celtic Sea. This may indicate that the Atlantic route could have played an essential role in transporting olive oil to the area of *Britannia*, since in the places where there is greater similarity they are found in different strategic points near the sea.

This fact seems to concur with the latest research that suggests the idea of a more important Atlantic route that would connect the militarised provinces (Remesal, 1986, 2008; Carreras and Morais, 2012; Morillo et al., 2016; Rubio-Campillo et al., 2018a).

Therefore, most part of the centres where similar stamps are shared can correspond to eminently military areas, which may mean that the transport could reach the military areas from the beginning and then be distributed by land routes along with other civil areas (Carreras Monfort and Funari, 1998; Ayllón-Martín et al., 2018).

In *Germania*, the results followed the same pattern as *Britannia* but with a minor correlation as we can observe in the dendrogram. The areas mostly militarised share similar stamps than civil areas. However, we do not detect a concrete pattern regarding the distribution of the stamps in the German limes (Remesal, 2018).

It is worth to mention that it was not detected a robust model of organisation in both cases with regard to the distribution of stamps in consumption centres. This evidence means that it is unknown whether some production centres went

to one province or another or, at least, that they can be clearly reflected in the data with a greater similarity in the amphoric stamps. Thus, production centres could have distributed randomly olive oil both *Britannia* and *Germania*. Neither we do not detect production centres dedicated to the distribution of olive oil in a certain province.

Judging by the results obtained, there does not seem to be a specific pattern in terms of geographical distribution. Nor it was detected consumption areas where stamps are specified from an amphora workshop.

8. Concluding remarks

The results of this work can be interpreted for several reasons. On the one hand, the use of amphoric stamps could have been exclusively running by the owner or owners of the workshop to distinguish the amphora workshop. This hypothesis would explain the fact that we do not find similar stamps in different workshops; however, different code stamps have been detected in the same workshops that they would be barely difficult to assign to different owners.

On the other hand, the presence of different stamps in the same workshop could imply some kind of organisation from within the workshop affecting the closest centres (Moros, 2018). The marked amphorae could have allowed to potters organise the production with a batch stamping for the posterior commercialisation.

This could be explained such as batch systematic organisation between potters (Moros, 2018). This method allowed to potters organises the production with the batch stamping for the posterior commercialisation.

Considering that Dressel 20 was not marked in most cases, some researchers point out that potters marked the amphorae to prepare and distribute the product in order to be shipped (Berni, 2008). This method would be used as an identifier to count the number of amphorae of a branch (Moros, 2018). This organisation could also have served to identify different groups of potters working in the same amphora workshop. Potters could have marked the amphorae

to distinguish different groups working in parallel (Li et al., 2014). This fact would explain wherefore why we detect different stamps in the same workshop. In any case, we do not have enough archaeological evidence that can validate the interpretations presented here and our results are only certainly valid with the context of our case study.

As a summary, this method presented here provides a potential tool to understand the mechanisms of production based on the similarity of artefacts. This work has identified differences in the case of the amphoric production within the Roman Empire. The combination of archaeological data and quantitative methods have finally highlighted for the interpretation of the complex economic processes connected with the archaeological evidence.

9. Acknowledgements

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