The ecology of Roman trade. Reconstructing provincial connectivity with similarity measures

Xavier Rubio-Campillo [a, *], Jean-Marc Montanier [b], Guillem Rull [c], Juan Manuel Bermúdez Lorenzo [d], Juan Moros Díaz [d], Jordi Pérez González [d], José Remesal Rodríguez [d]

[a] *School of History, Classics and Archaeology, University of Edinburgh, UK*
[b] *Barcelona Supercomputing Centre, Spain*
[c] *SIRIS Lab, Research Division of SIRIS Academic, Spain*
[d] *CEIPAC, Universitat de Barcelona, Spain*

ARTICLE INFO

ABSTRACT

The creation of the Roman Empire promoted the connectivity of a vast area around the Mediterranean sea. Mobility and trade flourished over the Roman provinces as massive amounts of goods were shipped over thousands of kilometres through sea, rivers and road networks. Several works have explored these dynamics of interaction in specific case studies but there is still no consensus on the intensity of this connectivity beyond local trade.

We argue here that the debate on the degree of large-scale connectivity across the empire is caused by a lack of appropriate methods and proxies of economic activity. The last years have seen an improvement on the availability of evidence as a growing amount of datasets is collected and published. However, data does not equal knowledge and the methods used to analyse this evidence have not advanced at the same pace.

A new framework of connectivity analysis has been applied here to reveal the existence of distinctive trade routes through the provinces of the Western region of Rome. The amphora stamps collected over more than a thousand sites have been analysed using quantitative measures of similarity. The patterns that emerge from the analysis highlight the intense connectivity derived from factors such as the spatial closeness, presence of military units and the relevance of the Atlantic sea as a main shipping route.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

The intensity of provincial connectivity is one of the most debated aspects of the Roman economy. Hypotheses oscillate between a unified market defined by a constant flow of goods through long-range trade to isolationist approaches based on autonomous regions with little contact, with some exceptions (Temin, 2001; Bang, 2007). Both archaeological and written sources indicate that there was a large diversity of scenarios as connectivity was not homogeneous and some regions were much more integrated than others. A key player of this integration was the Roman army as its supply required the import of vast quantities of products (Scheidel et al., 2007, 591). They were mostly produced in specialised

provinces and required large-scale trade. A good example of this connectivity is the shipping of massive amounts of olive oil from the Baetican province to Britannia after its conquest (Remesal Rodríguez, 2011, 60). These basic goods were distributed amongst military garrisons but it seems probable that the trade network rapidly expanded to supply civilian settlements (Williams and Peacock, 1983). Other goods such as exotic foods were widely shipped to distant urban centres using non-military redistribution networks (Livarda and Orengo, 2015; Orengo and Livarda, 2016). However, the general question remains unanswered: how frequent and intense were these economical contacts beyond specific case studies?.

The topic has a renewed interest as an increasing corpus of datasets including archaeological, epigraphical and written sources is becoming available. One example of this exciting explosion of evidence is the Orbis project which is focused on exploring the cost

---

of mobility along the entire Roman Empire (Scheidel, 2015). Other initiatives such as the Pelagios project aims at aggregating tens of different databases to generate a multifaceted view of the classical world (Barker et al., 2016). This collection of evidence is a critical step towards understanding the Roman economy but its use also presents several challenges (Bowman and Wilson, 2009, 3–87). As other authors have pointed out this data is riddled with biases and uncertainty up to the point where it is difficult to find patterns beyond the noise (Bevan, 2014; Wilson, 2009). The datasets being merged often have diverse temporal and spatial dimensions and were collected by different formats and methods while the projects creating them use different theoretical approaches to the past (Bevan, 2015; Calvanese et al., 2016).

The aim of integrating datasets should be combined with the creation of methods able to tackle the complexities of the existing evidence (Brughmans and Poblome, 2016). Roman studies typically use descriptive statistics and linear regressions to analyse relations between variables (Wilson, 2009) but these generic approaches were not designed to face the uncertainty of archaeological data. First, our sample sizes are usually very low as they consist of tens or hundreds of data points for a vast region that did not remain stable over time. Second, the data points have a large degree of uncertainty which is badly captured by exploratory methods and require the use of probabilistic approaches to the past (Yubero-Gómez et al., 2016; Crema, 2015; Bevan et al., 2013a, b). Finally, the multiple biases generated by the archaeological process should be taken into account while analysing the existing evidence (Bevan, 2012; Rubio-Campillo et al., 2012).

This work presents a method to study provincial connectivity through the estimation of similarity indexes. The premise of this analysis is that regions that share trade routes should exhibit more similar cultural traits between them than with the rest of the empire. We reconstruct here the dynamics of provincial trade based on a well-tested proxy of long-range trade: the stamps found in amphorae containers found over the entire Roman Empire (Scheidel et al., 2007, 690). By applying a Null-Hypothesis Significance Testing Framework based on ecological methods we explore two specific research questions: a) was large-scale trade related to the provincial structure? and b) can we find patterns of connectivity between provinces beyond spatial closeness?

The next two sections define the dataset and the methods we used for this large-scale analysis. The fourth section presents the results of the analysis which are discussed and interpreted in section five. The text finishes with a summary of the method and its potential contribution within the current debates on the discipline.

2. Patterns of trade in the Roman empire

Clay amphorae are arguably the archaeological artefacts that best represent trade dynamics in the classic world (Bevan, 2014). These standardised containers were used to transport large quantities of liquids and other goods through a dense network of sea and river routes. Maritime shipping was the fastest and cheapest transport system so amphorae were massively distributed over the entire Roman empire. At the same time amphorae were functional and robust because they were designed to be transported aboard ships that may be crossing hazardous waters. This robustness and widespread use has allowed amphorae to survive in higher quantities and frequencies than containers serving a similar purpose such as wooden barrels (Tchernia, 1986).

The study of these containers plays a key role in our understanding of the Roman economy thanks to their visibility in the archaeological record (Greene, 1986, 162). The production of an amphora type is typically linked to a specific area and product so a trade link can be suggested between the production place of a type

and the sites where the amphorae of this type are found. The aggregation of large volumes of findings reveals the degree of specialisation of certain provinces that shipped thousands of amphorae filled with a single product to distant consumption places; this dynamic can be seen in Baetica for olive oil (Remesal Rodríguez, 1998; Funari, 1996) and some areas of Italia for wine (Paterson, 1982; Loughton, 2003).

The use of this archaeological proxy also presents some challenges. Elsewhere has been argued that the information provided by amphorae findings can be potentially biased by reuse activities (Peña, 2007, pp. 61–208). These biases could affect distribution patterns at least in two different aspects: a) transportation to a new destination and b) refill with a different substance than the original.

The first scenario would see an empty amphora refilled and shipped to a different location. The archaeological record does not allow us to track the route of the amphora which will always be found in the last location it was shipped. This bias would not heavily affect large-scale analysis such as the one we present here because the evidence for long-range reuse is very scarce (Peña, 2007, p. 72). If short-range reuse was frequent then the amphorae found on nearby sites would be more homogeneous but it would not affect the role of the dataset as proxy of long-range trade.

The second scenario would break univocal ties between specific amphora types and their contents. While this bias does not affect the current work given our focus on stamps it is certainly a relevant barrier to improve our understanding of Roman trade and requires further exploration (probably through residue analysis techniques, see Pecci et al., 2017).

A significant percentage of these amphorae were stamped on one of their handles with a code of letters and symbols. Most of these codes are *tria nomina* identifying an individual linked to trade activities, albeit it is difficult to know if this person was involved in the production of the container or its contents (Remesal Rodríguez, 1998; Funari, 1996). In any case these codes highlight the dynamics of trade because they were not unique: amphorae found in distant sites were stamped with the same code while containers found in the same place often exhibit a diversity of them. The study of the frequencies of codes has found interesting patterns on their spatiotemporal distribution, and for this reason they seem a good proxy for long-range trade in the classic world (Remesal Rodríguez, 1998; Berni Millet, 2008; Broekaert, 2015; Rubio-Campillo et al., 2017).

This long tradition of amphora stamps analysis has been mostly focused on single sites or provinces. Here we use this proxy to identify links within the Western part of the Roman empire by comparing the similarity of stamp codes found across thousands of Roman sites. The hypothesis to test can be defined as follows: sites receiving goods through different trade networks would be supplied by distinct producers, so we should find differences in the stamps found on these sites. In a majority of sites only a small number of stamps has been found, but if this hypothesis is correct then a large dataset should exhibit a pattern significantly distinctive from a random distribution of code stamps. In addition, if a group of provinces were more intensely connected because they shared trade routes then some code stamps should be more present in these provinces than in the rest of the areas.

The database used to test our working hypotheses is the Corpus of amphorae with Latin epigraphy compiled by the CEIPAC group over 30 years (Remesal Rodríguez et al., 2015). For each record in the dataset the following information was compiled: a) *id* of site where it was found, b) *province* where the archaeological site was located and c) stamp *code*. At present the Corpus contains 32.375 amphora stamps from which the amphorae collected in the city of Rome were removed for two reasons. First, the economic activities of the capital's supply were unique given its size and political role.