29. The EPNet Project

Production and distribution of food during the Roman Empire: Economics and Political Dynamics

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Abstract
The EPNet project aims to examine the framework of the Roman economic organisation and its networks by analysing epigraphical data from amphorae. This aim is to be realised through complex network analysis, model building and computer simulation. The objective is to create an experimental laboratory for the exploration, validation and refutation of historical theories, and the formulation of new ones.

Keywords
Amphora, epigraphy, big data, network, computer simulation, Roman economy, Roman policy.

29.1. Setting the focus

The EPNet project, which recently started (March 2014), aims to apply an innovative framework and groundbreaking vision to shed new light on the ongoing debate over the political and economic implications of the Roman trade system, its organization and dynamics. The Roman Empire trade system is generally considered to be the first complex European trade network. It formed an integrated network of interactions and interdependences between the Mediterranean basin and northern Europe. Over the last couple of centuries, several scholars have developed a variety of theories to explain the organization of the Roman Empire trade system. In this context, the study of food management still represents one of the main debates among the field specialists. However, due to the lack of suitable sources, these theories continue to be speculative and difficult to falsify [Garnsey et al. 1983, Lo Cascio 2000] especially due to the lack of a formal framework for the analysis of the available data.

The project intends to re-examine the framework of the economic organisation and its networks by re-analysing existing empirical data through complex network analysis, model building and computer simulation. The objective is to create an experimental laboratory for the exploration, validation and falsification of existing theories, and the formulation of new ones. This approach is made possible by (among other) a large dataset of Roman amphorae and their associated inscriptions [Fig. 29.1 - 29.3] created by the CEIPAC (Centro para el Estudio de la Interdependencia Provincial en la Antiguedad Clásica) in the last 22 years [Remesal Rodríguez et al. 2008] as well as by front line theoretical research done by José Remesal and his group in the political and economic aspects of the Roman trade system. The current version of the CEIPAC database is available at http://ceipac.ub.edu/.

The EPNet project team includes specialists from Social Sciences and Humanities and from Physical and Computer Sciences. These groups are all characterized by their transdisciplinary perspective and have a long experience at collaborating with specialists from different domains.

29.2. An ongoing debate: the economy of Roman Empire

A crucial aspect of any society is the production, supply and re-distribution of food. This topic has long been, and still remains, one of the open problems for sustainable decision policies in a world scale perspective. The food distribution during the Roman Empire is commonly associ-ated with the control of the army. It is argued that the emperor and his circle managed the relationship between food and army in order to supervise and control the whole Roman territory and to strengthen and maintain their own political power.

Two approaches are particularly evident in the current debate over scales and modalities of the Roman economics system:

a the Roman Empire trade system as a specific model not connected with modern global economies

b the Roman Empire trade system as a sort of predecessor of modern global economies perfectly explainable through modern economic theories.

Assuming or not an analogy between past and present or vice versa, the scientific debate has focused mostly on the influence of the Empire

in long distance trade and it has not considered the role played by periphery and regional distribution.

Fig. 29.1. The result of searching for the stamp ACIRGI in the current version of the CEIPAC database. The first 10 occurrences of the stamp are shown (out of 140)

This said, the ongoing debate remains exclusively speculative and often based on rhetoric. Even recognizing the important role played by dialectic speculation and rhetoric argumentation in ancient history, we consider a different approach to be mandatory to move forward.

29.3. A groundbreaking vision

We propose to study the Roman economy by analysing food production and trade using a formal approach, focusing on the role played by regional distribution and periphery. We are not here defending a specific hypothesis against another, but we aim to contrast the several existing in a more experimental way.

Roman archaeology provides us with an incredible source of data and information about economic productions and transactions around modern Europe and the Mediterranean basin. However, a formal study of the mechanisms that have characterised these economic and political relations is still missing. The main reason is the lack of formal approaches in historical and archaeological contexts. Specialists from these disciplines often do not even consider the possibility that their research can be expressed using a formal language (a codified non-ambiguous grammar capable of generating models that can be solved,

by analytical or computational methods) such as that often used in the so-called "hard sciences". On the contrary, ancient societies provide a great opportunity to evaluate diachronic real-world data with a virtual laboratory in which formal models can be built and different hypothesis and theories about the past explored [Epstein 2008].

EPNet aims to use computer simulation as a virtual laboratory in which different techniques are exploited to encourage the formalization and falsification of scientific hypotheses about economic and political mechanisms of the Roman Empire trade network. Many practitioners of social and historical sciences continue to consider that it is not possible to reproduce "inside a computer" what past societies did and believed, because of the perceived complexity of the social, economic and political structures. Human behaviour is complex, however it is not the only complex system studied in sciences and many other systems have similar properties and behaviours to those of social structures [Epstein et al. 1996]. Furthermore, complexity science and artificial intelligence have shown how the appropriate interconnection of very simple computational mechanisms is able to show extraordinary complex patterns, and now that access to distributed supercomputing (grid technologies) has become affordable, it is no longer possible to justify not applying these methods to the perceived complexity of the humanities and social sciences.

Computer simulation was first pioneered as a scientific tool in meteorology and nuclear physics just after World War II. Computer modelling and complex systems simulation have thereafter dominated the scientific debate, providing important outcomes in other sciences such as biology, environmental and life sciences. The humanities, and especially archaeology, have been lagging behind this trend and only few research groups worldwide have developed or are currently developing research programs in this direction [Lake 2000, Kohler et al. 2007]. However, the results are extremely promising and we think that simulation technologies have the potential to become an essential tool in the field.

In archaeology, computer simulation has been applied to study mainly prehistoric societies and rarely to explore ancient history and more recent societies. EPNet aims to fill this gap: we aim to model and simulate Roman trade networks, the paradigm of past complex trade networks. Most of the actual social simulations define a basic society through a so-called "toy" model, where a simple set of rules

Fig. 29.2. Stamp over Dressel 20 amphora that belonged to Septimius Severus and his sons

is defined in order to explore the interaction between the different possible behaviours of the agents. We aim at expanding this approach to virtual societies with complex interactions in order to explore the role and weight assumed by different aspects (parameters) and mechanisms (behaviours), which different theories have proposed or are proposing as fundamental and explanatory. Existing datasets and new data gathered during the project provide the opportunity to validate the simulation experiments with empirical data. Correlation between simulation experiments (driven by existing theories) and empirical data allows a more critical evaluation of the existing explanations as well as the possible discovery of the role played by underestimated values. In addition, computer simulation of social phenomena allows the researcher to detect important relations between parameters and behaviour that can be hidden if the system is studied by classical approaches.

29.4. Innovation

The project is articulated through three main innovative aspects. None is "new" by itself, but the combination of them represents an unexplored aspect, determining the originality and also the risk of this research.

Fig. 29.3. Titulus pictus in delta position over Dressel 20 amphora. [R A]stigis arca p(endo) ccxl / [act]us agatephori · p(ensit) · atimetion / [d(omino)] n(ostro) antonino iii et comazonte co(n)s(ulibus) [222 A.D.]

29.4.1. To explore our dataset using an exhaustive semantic approach

Semantic approaches can account for discrete data in addition to qualitative influences, so as to answer broader questions about motives and patterns of behaviour. In that perspective, a semantic model consists of a network of concepts and the relationships between those concepts. The concepts and relationships together are often known as ontology. Semantic models enable users to ask questions about the information in a natural way and help identifying patterns and trends in this information and discover relationships between disparate pieces of it. The extensive data provided by the CEIPAC database is to be connected and subsequently interpreted in a variety of levels that will give new insight to the complexity of exchange relations in the Roman Empire by moving beyond the limitations of a simple relational database. We consider this aspect essential for the generation of new knowledge about the object of study and for the definition of values and parameters that will be integrated in the simulation experiments.

In the current initial phase of the project, we are exploring and adapting existing ontologies from the domain of epigraphy with the aim to develop such a semantic model for the CEIPAC database. In this direction, the work done by the EAGLE project [Orlandi et al. 2014] is being very helpful. We intend to reuse as much of the EAGLE's ontology as possible, not just because it is already based on solid standards such as CIDOC-CRM [Crofts et al. 2011] and Epidoc [Elliott et al. 2007], but also to leave open the possibility of a future incorporation to the Eagle federation of epigraphy databases.

29.4.2. To apply network theory to the analysis of existing data

Complex networks have become a very active field of research in the last decade, providing a common language, which tools can have a wide range of applications. A clear example of this is the application of complex networks in economy in general, and trade in particular. Examples of trade between companies or banks, and even between countries have been the subject of intense research in the last years. We aim to extend this characterization of trade networks for current economic data to the ancient trade network of some of the most basic products of Mediterranean diet (wine, oil and salsamenta). Historically, wine and oil network distributions were complementary. On the one hand, oil was a strongly controlled good and produced in a single region (first in the Bética and later on in the Roman province of Africa) to be then transported to the most distant corners of the Empire. On the other hand, wine production escaped from state control and was hence distributed from many different sources all across the empire. The complementarity of these two networks, together with new techniques developed in the complex network community to infer real networks from empirical data, is to be exploited to obtain a global image of food distribution throughout the whole Empire.

29.4.3. To use agent-based simulation to analyze the structures and dynamics of the Roman Empire trade network

The project aims to implement computer simulation as a tool to explore research hypotheses. Complex network analysis can generate several ideas about the dynamics of the system, but we need additional techniques to understand complex social spatiotemporal patterns such as those involved in Roman trade. Agent-Based Modelling is a particular type of computer simulation specialised in exploring problems which entities are capable of executing decision-making processes. These entities, the agents, interact both with other entities and with the virtual world where they live (the environment). The different processes are executed in a sequential series of regular time steps in order to check the evolution of the model over time. This mechanism can produce a chain of events capable of modifying the system and enabling new behavioural patterns to emerge from a bottom-up perspective, portraying complex qualities (the system as a whole exhibits traits that were not defined in the individual parts). By modifying and improving the

simulation we can produce data suitable to be compared with our empirical one, in such a way that this shows us the most probable historical situation. Moreover, this way we can improve the understanding of the interaction between local and large-scale trade interactions.

Bibliography

"Definition of the CIDOC conceptual reference model" (2011). In: ed. by N. Crofts, M. Doerr, T. Gill, S. Stead, and M. Stiff, pp. 21–05 (cit. on p. 460).

Elliott, T., G. Bodard, E. Milonas, S. Stoyanova, C. Tupman, and S. Vanderbilt (2007). "EpiDoc Guidelines: Ancient documents in TEI XML". In: url: http://www.stoa.org/epidoc/gl/latest/ (cit. on p. 460).

Epstein, J. M. (2008). "Why model?" In: *Journal of Artificial Societies and Social Simulation* 11.4, p. 12. url: http://jasss.soc.surrey.ac.uk/11/4/12.html (visited on 07/29/2014) (cit. on p. 458).

Epstein, J. M. and R. Axtell (1996). *Growing Artificial Societies: Social Science from the Bottom Up*. en. Brookings Institution Press. isbn: 0262050536 (cit. on p. 458).

Garnsey, P. and C. R. Whittaker (1983). *Trade and famine in classical antiquity*. Cambr. University Press (cit. on p. 455).

Kohler, T. A. and S. E. Van der Leeuw (2007). *The model-based archaeology of socionatural systems*. School for Advanced Research Press (cit. on p. 458).

Lake, M. W. (2000). "MAGICAL computer simulation of Mesolithic foraging". In: *Dynamics in human and primate societies: agent-based modelling of social and spatial processes*, pp. 107–143 (cit. on p. 458).

Lo Cascio, E. (2000). *Roma imperiale. Una metropolis antica*. Roma (cit. on p. 455).

Orlandi, S., L. M. C. Giberti, and R. Santucci (2014). "EAGLE: Europeana Network of Ancient Greek and Latin Epigraphy. Making the Ancient Inscriptions Accessible". In: *Lexicon Philosophicum: International Journal for the History of Texts and Ideas* 2. url: http://lexicon.cnr.it/index.php/LP/article/view/408 (visited on 07/29/2014) (cit. on p. 460).

Remesal Rodríguez, J., P. Berni Millet, and A. Aguilera Martín (2008). "Amphoreninscchriften und hire elektronische Bearbeitung". In: *In-*

strumenta Inscripta Latina II. Ed. by M. Hainzmann and R. Wedenig. Klagenfurt, pp. 247–264 (cit. on p. 456).