The Poverty (and Wealth) of the Pre-industrial World

Inquiry on long-run economic development from 1st BC to 18th AD

Luigi Oddo

Department of Economics
University of Genoa

Supervised by Corrado Lagazio, University of Genoa
Andrea Zanini, University of Genoa
May 24, 2022

In partial fulfillment of the requirements for the degree of PhD in Economics and Political Economy

Abstract

The aim of this thesis is to investigate structural determinants of economic performance from Classical Age to the dawn of the Industrial Revolution with an inter-disciplinary approach. To this end, I adopted an inter-temporal comparison covering around two thousands years, putting together Economics, History, and quantitative analysis. What emerges from my studies is that every period of pre-industrial history shows different way to lead economic performance that not always reflects the Malthusian model prediction. The ability of economy to positively respond to the fixity of land and to the diminishing returns of labor made the difference between societies that was trapped in the Malthusian stagnation and which do not. However, these dynamics emerge only when a long-run approach is adopted, allowing comparison between technologies, market structures and institutions in different periods. This thesis aims to show the potential emerging from exchanges and collaboration between economists, economic historians, and ancient historians in explaining the economic development in a more comprehensive manner.

Acknowledgements

In the course of my PhD, I have incurred more debts than I can possibly acknowledge, and the gratitude I feel towards the professors, colleagues, institutions, friends and family whose support allowed me to write this thesis far outstrips my ability to express it. The project was generously supported by the PhD program of the University of Genoa. Special thanks are due to the PhD coordinators Anna Bottasso and Claudio Piga that have always encouraged me. A warm thank you to my advisors Corrado Lagazio and Andrea Zanini for their precious supervision and for patience that they had with me along the way. I am also grateful to several professors that helped me with their comments and suggestions to improve and enrich my work, including Mile Bosnjak, Maurizio Conti, Kirsten Enflo, Paul Erdkamp, Alister Filippini, Paolo Malanima, Giovanni Battista Pittaluga, Elena Seghezza, Riccardo Soliani, Bruno Soro, Silvio Traverso and Koenraad Verboven. A special mention to the two anonymous referees for their precious advice. Thanks also to all my colleagues and friends that shared with me PhD experience, especially Gianluca Cerruti, Antonio Iodice, Alessando Le Donne and Andrea Sbarile. Finally, to my girlfriend Alessia and my whole family, thank for your love, sacrifice and support. Any remaining errors or omissions are my responsibility.

Contents

1 Introduction

The history of humankind and its development from the dawn of civilization until the advent of the Industrial Revolution has always fascinated and intrigued a multitude of scholars from any part of the world, regardless of their disciplines. Starting from the pioneering works of Karl Marx and Max Weber, studies on long-run economic development aim to explain because are humans wealthier and healthier than they were in the past and because the whole world is not developed at the same pace following the Industrial Revolution (Figure 1).

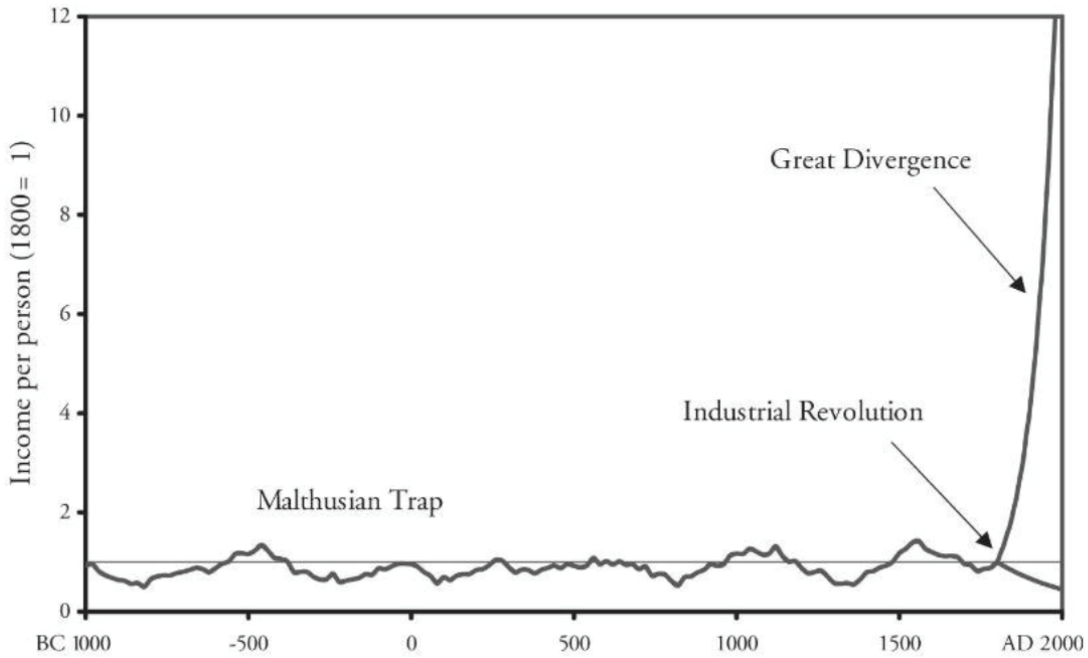

Figure 1. World economic history in one picture. Incomes rose sharply in many countries after 1800 but decline in others. Source: Clark (2007).

The classic writings of Marx and Weber argued that the impressive path of the European economic development from the mid-18th century emerged from exceptional “structural” conditions. In other words, Europe was fundamentally different from the most advanced regions of China and India, and it was these structural differences that gave Europeans a comparative economic advantage able to shift the continent on a different growth trajectory[1]. For Karl Marx, the difference between Europe and elsewhere was the emergence of capitalism; a dynamic and innovative new economic order which rested on private property and wage labor. Whereas China and India remained trapped in an Asiatic mode of production[2]. On the other hand, Max Weber stressed cultural differences to explain the happening of the Industrial Revolution. In his most famous book, *The Protestant*

[1] Cf. Parthasarathi and Pomeranz (2019), pp. 19-37.
[2] Marx (1978[1853]).

Ethic and the Spirit of Capitalism, Weber suggests that the Reformation led to modern economic rationality in those countries that embrace it[3]. However, more recent studies bring to light some weaknesses behind these classical theories. As suggested by Allen (2009), Weber's evidence was limited to a transitory correlation between Protestantism and high levels of income, in addition, this evidence is not robust either for the sixteenth century or nowadays. Whereas Clark (2007) stressed as already medieval institutions showed features suitable for development; capitalism might not be the only way forward economic take-off. The debate is still on.

Fast-forwarding through the history of thought of long-run economic development, most of the recent literature converges on the conclusions claimed by the Malthusian model hypothesis[4]. Following this point of view, humankind was trapped to the subsistence level from the dawn of the Neolithic Revolution until the advent of the Industrial Revolution. Although a large part of the literature agrees on this long-run economic trend, there is a strong debate about the capacity of this model for describing economic performance of all societies that have followed in the past two millennia. Moreover, there is no consensus on the causes of the Malthusian stagnation and on the factors triggering the transition to sustained economic growth for some countries started in the middle of the 18th century. The growth of the markets, the technological changes, the demographic, institutional, and geographical features are just some of the main interpretations adopted by the literature to explain the poverty and wealth experienced by humankind in the last 13,000 years.

All these schools of thought fall within the also known as "macro approach" or the "grand narrative" of the Global Economic History[5]. The term "Global" added to economic history other perceptions, questions, and approaches, implying long chronologies stretching back over millennia, and analyzing global connections across oceans, geographies, and frontiers with an interest in economic changes.

This long narrative starts in the mists of time, from 10,000 to 13,000 years ago, with the Neolithic Revolution, also known as the (First) Agricultural Revolution. This innovation is considered together with the Industrial Revolution of the late 18th century one of the most important changes in Human History. Diamond (2005) argues that the emergence of the Neolithic Revolution in the Fertile Crescent millennia before than in other regions explains the starting point of the economic advantage of Western countries on the rest of the world. The advent of domesticated crops and animals that progressively replaced foraging and hunting activities allowed small groups of hunter-gathers to pass from nomadism to a sedentary lifestyle changing the course of history. For the first 200,000 years of human existence, humans survived by foraging and hunting. This passage to sedentary lifestyle was not convenient for all individuals, since the number of working hours drastically increased and the quantity and the quality of calories extracted by agriculture activities was less respect to a hunter gathers' one, implying a general deterioration of material standard living. Likely, the Fall from the Eden Garden into a world of hard work mentioned in the Bible is a sad metaphor of this process, the latent memory of which was passed through millennia. However, this revolution has a great advantage, allowing more

[3]Weber (1930).

[4]Among others see Voigtländer and Voth (2013, 2009), Galor (2012), Crafts and Mills (2009), and Clark (2007).

[5]Cf. Riello and Tirthankar (2019), pp. 1-19.

numerous communities and the early embryos of labor specialization. Warriors, religious personnel, and the ruling classes started to develop from the Neolithic Revolution, creating societies able to improve the first forms of non-agricultural sectors, as manufacturing, trading, and cultural activities. However, large communities implying also increasing needs for lands and resources. Farming indeed helped the first generation but cursed the following generations with greater work effort to get inferior result. The best guess is that early farm settlements faced a one-way Malthusian Trap[6].
The Industrial Revolution represents the second most important breakpoint in the "grand narrative" of Global Economic History. Most of the literature converges that this event represents a watershed in the history of humankind. However, the debate on causes behind triggering Industrial Revolution in England in the mid-18th century is an open discussion also nowadays. In the long story of studies on this issue, three main approaches stand out. In the second half of the 20th century, Neo-institutional historians showed the key role played by English democratic institutions that emerged after the Glorious Revolution in the arising of the Industrial Revolution. North et al. (2009) and Acemoglu and Robinson (2012) asserted that the Glorious Revolution was a crucial event for the limitation of the absolute rule of the monarch and the development of secured private property in English society. This was fundamental for the advent of an economic environment suitable for development. At the dawn of the third millennium, Joel Mokyr added another piece to this puzzle, bringing light on the relevant role played by the Scientific Revolution on the emergence of the Industrial Revolution in England[7]. He stressed how the Enlightenment connected the Scientific Revolution to the Industrial one. Enlightenment has played a key role in the development of the knowledge necessary for the emergence of the Scientific Revolution and the technological change that fueled the Industrial Revolution. He coined the term 'Industrial Enlightenment' to describe these essential features. The new vision on the nature of the world that matured during the Enlighten period drastically changed the development of the technological progress through a scientific and experimental method, which until then had advanced through a trial-and-error process[8]. The discovery of the steam engine was probably not possible without the occurrence of the scientific method. Finally, the most likely hypothesis concerning the emergence of the Industrial Revolution in England was formulated by Allen (2003, 2011). This author stressed the role of relative prices of work and capital as key factors to explain adoption of mechanized production earlier in England than in other countries. During the 14th century, a terrible plague hit Europe. In the period 1347-51, it peaked, and according to estimates, it killed from 30 to 60 percent of the European population, including Great Britain. This had two important consequences. Firstly, Black Death acted as a positive check, and as a consequence of high mortality, wealth came to be distributed in fewer hands, and thus survivors found themselves in a better condition than before. Secondly, scarcity of labor has weakened the feudal system, leading gradually to the disappearance of serfdom and the emergence of the free labor market. These factors had a natural consequence: abnormally high level of wages in England. Conversely, England was characterized by a relatively low cost of

[6]Cf. For studies on the Neolithic Revolution see Sachs (2020), Matranga (2016), Machintosh, Pinhasi, Stock (2016), and Sahlins (1972).

[7]Mokyr (2002, 2009).

[8]Cf. Lin (1995).

capital by virtue of the abundance of energy sources within its borders useful to fuel the mechanization of the production process. The combination of high wages and relatively low cost of capital determined an incentive to substitute labor with capital in the production process before than in other countries. This led to mechanizing the production process in advance with respect to other European countries. In the following centuries, the new machinery introduced during the early phase of the Industrial Revolution improving their efficiency were gradually introduced in the rest of Western Europe. From this point of view, this theory explains both the causes behind triggering the Industrial Revolution in England, how it was widespread in Western Europe, and the reason for the poverty of non-European countries, the so-called Great Divergence phenomenon.

In the first decade of the twenty-first century, a new theory emerged to explain the long stagnation experienced by humankind for millennia, the following "escaping" the Malthusian Trap for the West and the contemporaneous failure for other countries to take the road to sustained economic growth, the well-known Unified Growth Theory (UGT)[9]. This theory, citing its developer Oded Galor, "provides a fundamental framework of analysis for the evolution of individuals, societies, and economies over the entire course of human history" (Galor 2012, p. 9). The Unified Growth Theory is being carried out in opposition to the prevalent theories of economic growth, since these last, called by Galor the "nonunified theories"[10], did not capture the transition between Malthusian stagnation to modern growth regime and have shown limited ability to shed light in the vast global disparity in living standards emerged after the Industrial Revolution. Specifically, he refers to Exogenous growth models (e.g., Solow 1956) that have focused primarily on the role of exogenous technological progress as determinants of economic performances, and to the Endogenous growth models (e.g., Kaldor 1957, Romer 1990, Grossman and Helpman 1991, and Aghion and Howitt 1992), developed as the counterpart of the exogenous ones, which have devoted their attention to explaining how technological progress was endogenously determined in the development process. These models, are, citing Galor, "inconsistent with the pattern of development that had characterized economies over most of human existence. They do not account for the Malthusian epoch the economic factors that brought about the take-off from the Malthusian regime into the Post-Malthusian Regime, and the forces that brought about the demographic transition and ultimately the state of sustained economic growth." (Galor 2005, p. 44). However, Galor's theory never denies the advance in economics discipline brought out by nonunified theories. In fact, he seems to argue implicitly, but often explicitly, that all theories explain a part of the economic growth process, but are unable to capture the growth process entirely, specifically the transition process from the Malthusian stagnation to sustained economic growth and the Great Divergence phenomenon in per capita incomes experienced in rich and poor countries since the end of 19th century. Therefore, interpreting Galor's thought, all theories on growth are valid; however, they are incomplete, both for understanding the past and for forecasting the future. The cornerstone of the Unified Growth theory is the assumption on the persistence of the Malthusian model for most of the history of humankind until the dawn of the Industrial Revolution in the 18th century when a gradual process of transition started leading to modern growth regime at the end of the

[9] Galor and Mountford (2008), Galor (2005), Galor and Moav (2002), Galor and Weil (1999).

[10] Galor (2012), p. 7.

19th century. The transition between a world mired in the Malthusian Trap to (for some countries) a heavenly place fueled by sustained economic growth is explained by the interaction between the rate of technological progress and the size and composition of the population. This interaction started in the Malthusian Era, gradually triggered an acceleration of the pace of technological progress, which has raised the importance of education in coping with the rapidly changing technological environment. To some extent, it is a sort of a Darwin selection where millennia of Malthusian Trap shaped a new kind of "human being", always more technologically advanced and less prone to high fertility rate. In fact, the Malthusian regime, characterized by scarce resources (land in particular), low technological progress, low productivity, and high mortality, imposed the rule of "large family" in order to overcome the need for manpower for agriculture and the high mortality rate. However, this "law of survival" is, in turn, the same cause of the Malthusian Trap. According to UGT, in the pre-industrial world was latent the gradual process that led the women to reduce the fertility rate, implying less numerous families and the development of an implicit preference for the "quality" than for the number of children. In millennia, this slow process led to a new generation always more resourceful and enterprising, as also pointed out by Clark (2007). This demographic and cultural transition, in turn, has liberated productivity gains, which enabled technological progress and human capital formation to take the road of sustained economic growth.

However, the literature assuming all societies trapped in the Malthusian Trap from the Neolithic Revolution to the emergence of the Industrial Revolution raised some dramatic critiques: Has all of human history been mired in the Malthusian trap for millennia? Were all countries united by the same unfortunate fate? Is there only one kind of economic growth: that powered by machines?

Not all empirical literature and historiography agree that the whole pre-industrial world was mired in the Malthusian Trap. This dispute opens another Pandora's box. The same literature of Maddison, used as the main proof of the Malthusian stagnation, gives results for some periods that do not match with the alleged poor standard of living in pre-modern history. In fact, the income per capita estimation proposed by Maddison (2007) for the Roman Empire is far from to the subsistence level, as instead is supposed by the Malthusian model. Allen (2003) wrote that Europe took its firs step in escaping the Malthusian Trap from 1500 onwards, therefore at least more than two century before the Industrial Revolution. Similarly, De Pleijt and Van Zanden (2016) highlight that the Netherlands and England had already escaped Malthusian constraints long before 1800 due to skilled human capital and institutional changes. While Grantham (2008) has questioned the causal relationship embedded in the Malthusian model. He pointed out that in pre-industrial Europe population growth was more linked to falling real wages in countries that had the lowest population density. This can be attributed to the fact that agriculture acted as a residual employer in pre-industrial world, meaning that all labour not finding employment elsewhere was employed on the land. Economic growth in England started with lowering of labour input in agriculture and the effective use of labour in other sectors. An excessive input of labour caused low agricultural labour productivity. Therefore, agriculture did not need large families, but was rather held back by large families. Another skeptical point of view is presented by Karl Gunnar Persson when he stated that for England in the period 1400-1800, the reliability of the Malthusian model has not yet been confirmed[11]. In addition, Persson has raised some criticalities about the explanatory power of per capita income measures to identify effective well-being independent of income distribution in pre-industrial societies. Similarly, Dutta et al. (2018) states that only measure material living standard with food consumption is misleading: Industrial Revolution boosted non-food consumption, while food consumption remained quite flat. This observation implies that increase in non-food consumption coupled with stagnation food-consumption still leads to a rise in material standard living, situation which cannot be captured through standard Malthusian model based only on food production and consumption. Naturally, this latter situation was perhaps not common in ancient times - but not non-existent. Therefore, models of historical growth should therefore be designed to accommodate this possibility.

Even among ancient historians, differing opinions are more and more numerous. In his masterpiece, *The Ancient Economy*, Moses Finley (1973) captures the complex economic and social dynamics of the ancient world, clarifying how the uncritical application of modern economic theory could become misleading in a world pervaded by social ties, religious beliefs and where the concept of status was more important than economic rationality. In the light of this valid argument, ancient economy has often been interpreted, whether rightly or wrongly, through the lens of economic irrationality. The strict application of this approach has implicitly relegated the role of innovation and commercial and mercantile activities to exceptional cases or phenomena of little importance. However, this "primitivist" interpretation of the ancient economies – introduced by K. Polanyi (1957, 1968) and developed with the main contribution of M. Finley (1973) – was almost totally dropped in the last thirty years[12]. In this regard, it is worthwhile to quote the historian Peter Sarris extensivily: "It is becoming increasingly evident that primitivist approaches to the ancient, late antiquity and early Byzantine economies ultimately rest upon a misunderstanding or lack of appreciation of the evidence" (Sarris 2011, pp. 260-1).

As pointed out by Erdkamp et al (2020), actually the concept of expenditure for "status" was intrinsically correlated to economic expenditure; in ancient times the best way to obtain wealth was to have "status" and vice-versa. The evergetism practices and the consequently apparent non-economistic mindset were part of elite social culture and a condition to becoming part of the elite social networks of the time in order to have advantageous marriages and access to lucrative business; i.e., the most common and effective way to obtain wealth in the pre-industrial world. Status-oriented strategies and income-oriented ones were not mutually exclusive[13]. From this perspective, Erdkamp (2016) attributes the ability of the Roman Empire to generate economies of scale to population growth, which, combined with market efficiency, is capable of avoiding the Malthusian Trap. Geoffrey Kron (2014) is even more optimistic; he argues that living standards in classical antiquity were among the highest in world history, close to the level of Europe in the eighteenth and nineteenth centuries. To some extent, based on archeological evidence, Dark (2001) posits the existence of an advanced manufacturing sector, classifying the Roman economy as "proto-capitalist". Similar arguments are also given by Bresson (2016), for Greek economy in Classical times, and by Bintliff (2014), which through an intensive field-by-field

[11] Persson (2008).

[12] Economou et al (2021), Economou and Kyriazis (2021).

[13] Veyne, P. (1976), pp. 118-28. See also in this sense D'Arms (1981) and Verboven (2004).

survey surface supports the theory of a precocious appearance of "proto-capitalism" in ancient Rome. Even the conclusions about the take-off from the Malthusian stagnation triggered by the Glorious Revolution proved by the Neo-institutional school start to be questioned. It speaks about the importance of the "rule of the game" such determinants of economic success. Property rights, norms to safeguard commerce, and a democratic regime are all factors that improve economic growth. These were fundamental for the advent of an economic environment suitable for development. This interpretation, however, shows some weaknesses and in addition, many societies before the early modern age showed good and stable institutions. Studies on available interest rate time series fail to detect any structural break after the Glorious Revolution able to demonstrate improved investment climate[14]. In addition, secured property rights were not exclusive of England; France showed at least the same level of secureness at that time[15]. Whereas Clark (2007) stressed as already medieval institutions showed features suitable for development, ; capitalism might not be the only way forward economic take-off. Harper (2017) also pointed out that that the Roman world showed, like other classical Mediterranean societies, citizenship-based political experiments, norms of government, by which even the masters of the empire might to held to account, and for the first time in history, remaining a unique case for a long period yet, sea routes without the danger of pirates, a common currency and a language shared by the whole Empire population[16].

In light of this impressive and fascinating literature, in this thesis, one wonders about the "structural" causes of poverty and wealth in the pre-industrial world, through an inter-temporal analysis that range from the Classic Age to the dawn of the Industrial Revolution. Long-run approach allows to identify "effective" determinants of development, minimizing the risk of misleading interpretation due to focusing on specific epoch. What emerges from my studies is that every period of pre-industrial history shows different forms to express economic performance that not always reflects the Malthusian model prediction. The ability of economy to positively respond to the fixity of land and to the diminishing returns of labor made the difference between societies that was trapped in the Malthusian stagnation and which do not. These results suggest that aggregate models which describe whole human history as a progressive escaping by Malthusian Trap are a long way from reality[17].

The thesis explores economic development in three different places and periods of the pre-industrial world. Specifically, the first chapter explores the possibility that the Early Roman Empire thanks to the high level of markets extension and integration experienced a Smithian Growth Model rather than Malthusian stagnation. The second chapter analyses the consequences on economic development of the first pandemic in human history experienced by Roman Egypt in the late second century, the Antonine Plague. Finally, the third chapter studies the relationships between demographic trends, urbanization levels, and economic growth in the Republic of Genoa between the late Middle Ages and the late Early Modern period.

[14] Goldstone (2003).

[15] Allen (2009).

[16] Cf. Lagerlöf (2014), Temin (2006).

[17] For a deeper critique analysis on the adoption of aggregate models in the field of economic development see Valli (2022).

References

Acemoglu D., Robinson J.A. (2012). *Why nations fail: The Origins of Power, Prosperity, and Poverty.* London: Crown Business.

Aghion, P., Howitt, P. (1992). A Model of Growth through Creative Destruction, *Econometrica* 60: 323-351.

Allen, R. (2003). Progress and Poverty in Early Modern Europe. *The Economic History Review*, 56, no. 3, 403-43. http://www.jstor.org/stable/3698570.

Allen, R. (2009). The Industrial Revolution and the Pre-Industrial Economy, in Robert Allen (eds) *The British Industrial Revolution in Global Perspective*, Cambridge: Cambridge University Press, pp. 1–22. doi:10.1017/CBO9780511816680.001

Allen, R. (2011). *Global Economic History: A Very Short Introduction.* Oxford: Oxford University Press.

Bintliff, J. (2014). Settlement patterns. In: Horden, P., Kinoshita, S. (Eds.), *A Companion to Mediterranean History.* Wiley-Blackwell, Malden.

Bresson, A. (2016). *The Making of the Ancient Greek Economy: Institutions, Markets, and Growth in the City-States*, Princeton, NJ: Princeton University Press.

Clark, G. (2007). *A Farewell to Alms. A Brief Economic History of the World.* Princeton, NJ: Princeton University Press.

Crafts, N., Mills, T. C. (2009). From Malthus to Solow: How did the Malthusian Economy Really Evolve? *Journal of Macroeconomics* 31(1), pp. 68–93, https://doi.org/10.1016/j.jmacro.2007.08.007

D'Arms, J. H. (1981). *Commerce and Social Standing in Ancient Rome.* Cambridge, Mass., and London: Harvard University Press.

Dark, K. (2001). Proto-industrialization and the Economy of the Roman Empire. *Montignac.*

De Pleijt, A. M., Van Zanden, J. L. (2016). Accounting for the "Little Divergence": What drove economic growth in pre-industrial Europe, 1300–1800?, *European Review of Economic History*, 20: 387–409, https://doi.org/10.1093/ereh/hew013.

Diamond, J. (2005). *Guns, Germs, and Steel: the Fates of Human Societies.* New York: Norton.

Dutta, R., Levine, D.K., Papageorge, N.W. and Wu, L. (2018), Entertaining Malthus: Bread, Circuses and Economic Growth. *Economic Inquiry*, 56: 358-380. https://doi.org/10.1111/ecin.12479

Economou, E. M., Kyriazis, N. A. (2021). Achieving Sustainable Financial Transactions under Regimes without a Central Bank—An Intertemporal Comparison, *Sustainability*, 13(3), 1071.

Economou, E. M., Kyriazis, N. C., Kyriazis, N. A. (2021), Money Decentralization under Direct Democracy Procedures. The Case of Classical Athens, *Journal of Risk and Financial Management*, 14(1), 30; https://doi.org/10.3390/jrfm14010030.

Erdkamp, P. (2016). Economic growth in the Roman Mediterranean world: An early good-bye to Malthus? *Explorations in Economic History* 60: 1-20, https://doi.org/10.1016/j.eeh.2015.11.004.

Erdkamp, P., Verboven, K., Zuiderhoek, A. (2020). *Capital, Investment and Innovation in the Roman World.* Oxford: Oxford University Press.

Finley, M. I. (1973). *The Ancient economy.* University of California Press, Berkley.
Galor, O. (2005). *From Stagnation to Growth: United Growth Theory*, Handbook of Economic Growth, vol. IA, Elsevier North-Holland, Amsterdam.
Galor, O. (2012). Unified Growth Theory and Comparative Development. In: Chiarini B., Malanima P. (eds) *From Malthus' Stagnation to Sustained Growth.* Central Issues in Contemporary Economic Theory and Policy. Palgrave Macmillan, London.
Galor, O., Moav, O. (2002). Natural Selection and the Origin of Economic Growth, *Quarterly Journal of Economics*, no. 117(4), pp. 1133-1191.
Galor, O., Mountfortd, A. (2008). Trading Population for Productivity: Theory and Evidence, *Review of Economic Studies*, no. 75(4), pp. 1143-1179.
Galor, O., Weil, D.N. (1999) From Malthusian Stagnation to Modern Growth. *American Economic Review*, no. 89(2), pp. 150-154.
Goldstone, J. A. (2003). Europe's Peculiar Path: Would the World Be Modern If William III's Invention of England in 1688 Had Failed?, in N. Lebow, G. Parker and P. Tetlock (eds.), *Counterfactual History*, New York.
Grantham, G. (2008). Explaining the industrial transition. A non-Malthusian perspective, *European Review of Economic History* 12: 155-65.
Grossman, G. M., Helpman, E. (1991). Trade, knowledge spillovers, and growth, *European Economic Review*, Volume 35, Issues 2–3, pp. 517-526,
https://doi.org/10.1016/0014-2921(91)90153-A.
Hansen, G. D., Prescott, E. C. (2002). Malthus to Solow. *American Economic Review* 92(4), pp. 1205–1217, https://doi.org/0.1257/00028280260344731
Harper, K. (2017). *The Fate of Rome: Climate, Disease, and the End of an Empire.* Princeton; Oxford: Princeton University Press. doi:10.2307/j.ctv9b2txr.
Kaldor, N. (1957). A Model of Economic Growth, *Economic Journal*, 67, pp. 591-624.
Kron, G. (2014). Comparative evidence and the reconstruction of the ancient economy: Greco–Roman housing and the level and distribution of wealth and income. In: de Callataÿ, F. (Ed.), *Quantifying the Greco–Roman Economy and Beyond.* Edipuglia, Bari, pp. 123–146.
Lagerlöf, N. P. (2014). Population, technology and fragmentation. The European mircale revisited, *Journal of Development Economics* 108:87-105. Lin, J. Y. (1995). The Needham Puzzle: Why the Industrial Revolution Did Not Originate in China, *Economic Development and Cultural Change*, 43(2), 269–292.
http://www.jstor.org/stable/1154499.
Machintosh, A. A., Pinhasi, R., Stock, J. T. (2016). Early Life Condition and Physiological Stress Following the Transition to Farming in Central/Souteast Europe: Skeletal Growth Impairment and 6000 Years of Gradual Recovery, *PlosOne*, 11, n. 2, eo148468.
Maddison, A. (2007). *Contours of the World Economy 1-2030 A.D.* Oxford University Press, Oxford.
Marx, K. (1978 [1853]). The future results of British Rule in India, in R. C. Tucker (ed.), *The Marx-Engels Reader.* New York: Norton, 659.
Matranga, A. (2016). The Ant and the Grasshopper: Seasonality and the Invention of Agriculture. Working Paper, New Economic School.
Mokyr, J. (2002). *The Gifts of Athena: Historical Origins of the Knowledge Economy.* Princeton; Oxford: Princeton University Press, 2002.

Mokyr, J. (2009). *The Enlightened Economy: An Economic History of Britain 1700–1850.* London: Penguin Press.

North, D. (1991). *Institutions, Institutional Change and Economic Performance.* Cambridge University Press, Cambridge.

North, D. (1994). Economic Performance Through Time. *American Economic Review*, 84(3): 359-368.

North, D. (2005). Understanding the Process of Economic Change. Princeton University Press, Princeton, N.J.

North, D., Wallis, J., Weingast, B. (2009). *Violence and Social Orders: A Conceptual Framework for Interpreting Recorded Human History.* Cambridge: Cambridge University Press. doi:10.1017/CBO9780511575839

Parthasarathi, P., Pomeranz, K. (2019). The Great Divergence Debate, in Giorgio Riello and Tirthankar Roy (eds), *Global Economic History.* Bloomsbury Academic, London and New York.

Polanyi, K. (1957). *Trade and Markets in the Early Empires.* Free Press and Falcon's Wing Press.

Polanyi, K. (1968). *Primitive, archaic, and modern economies: Essays of Karl Polanyi* (G. Dalton, Ed.). Garden City, NY: Anchor Press.

Persson, K. G. (2008). The Malthus Delusion. *European Review of Economic History*, XII (II), pp. 165-173.

Riello, G., Tirthankar, R. (2019). *Global Economic History.* London and New York: Bloomsbury Academic.

Romer, P. (1990). Endogenous Technological Change. *Journal of Political Economy*, 98(5), S71-S102. http://www.jstor.org/stable/2937632

Sachs, J. D. (2020). *Terra, popoli, macchine. Settantamila anni di globalizzazione.* Luiss University Press.

Sahlins, M. (1972). *Stone Age Economics.* Chicago: Aldine-Atherton, Print.

Sarris, P. (2011). The early Byzantine economy in context. Aristocratic property and economic growth reconsidered, *Early Medieval Europe* 19:255-84.

Solow, R. M. (1956). A Contribution to the Theory of Economic Growth, *The Quarterly Journal of Economics*, Oxford University Press, pp. 65-94.

Temin, P. (2006). The Economy of the Early Roman Empire. *Journal of Economic Perspectives*, Vol. 20, Number 1, p. 133-151, DOI: 10.1257/089533006776526148.

Veyne, P. (1976). *Le pain et le cirque. Sociologie historique d'un pluralisme politique.* (Coll. l'Univers historique). Paris: Le Seuil.

Verboven, K. (2004). Mentalité et commerce: le cas des "negotiators" et de ceux "qui negotia habent", in J. Andreau, J. France, and S. Pittia (eds). *Mentalités et choix économiques des Romains (Scripta antiqua 7).* Bordeaux, 179-97.

Valli, A. (2021), *Riflessioni sull'economia. Per uno sviluppo inclusivo e sostenibile*, Moneta e Credito, 74 (296): 301-332.

Voigtländer, N., Voth, H. J. (2009). Malthusian Dynamism and the Rise of Europe: Make War, Not Love. *American Economic Review* 99 (2), pp. 248–254, https://doi.org/10.1257/aer.99.2.248

Voigtländer, N., Voth, H. J. (2013). The three horsemen of riches. Plague, war, and urbanization in early modern Europe. *Review of Economic Studies* 80(2), pp. 774–781,

https://doi.org/10.1093/restud/rds034
Weber, M. (1930). *The Protestant Ethic and the Spirit of Capitalism*, trans. Talcott Parsons. New York: Scribner.

2 Did long-distance trade trigger Smithian growth in the Roman world? An extension of Maddison's estimates

Abstract

Did long-distance trade in the Roman world operate on a scale sufficient to increase the overall size of markets, enabling specialization and division of labor and thus Smithian growth? Economic theory suggests that Smithian growth could be triggered through the division and coordination of labor generated by the increase in the size of domestic markets and the amount of trade. This paper explores the connections between long-distance trade and Smithian growth in the Roman world. Beginning with the work of Maddison, we used archeological data and comparative evidence to quantitatively evaluate the economic impact of long-distance trade activity on the Roman economy. The results show that long-distance trade was a widespread economic activity, where elite groups were deeply involved in these businesses, showing the existence of a high capacity for division of labor in the Roman world. However, this analysis highlights that long-distance trade activities led to increasing inequality within Roman Empire.

Keywords: Roman world, Economic growth, Long-distance trade, Smithian growth, Roman GDP, Inequalities.

JEL: D31, N70, O10, O47.

Introduction

Almost fifty years have passed since Moses Israel Finley (1973) revolutionized economic historians' scientific approach to the ancient economy and its models of growth. An incessant debate between modernists and primitivists[1] has been ongoing ever since and continues to the present day. This debate has been highly contested and has sometimes gone dormant, only to reappear under other names. It is often misunderstood or trivialized, but always remains a central issue for economic historians. This debate strongly affected the perception of the role and size of economic activity in ancient economies, conditioning, to some extent, the views about the texture and nature of economic growth experienced in the Roman world. In fact, even if in the last thirty years the primitivist approach was almost totally dropped[2], the same cannot be said for the Malthusian's interpretation of economic growth in the pre-industrial world, which assumes that in the long

[1]Ancient "primitivist" historians such as M. Finley have described ancient history through the framework of Polanyi, and modernists such as Rostovtzeff (1957) have applied Marx's interpretation. Historians today usually reject this categorization, although they are often indirectly affected by this distinction.

[2]Economou et al (2021), Economou and Kyriazis (2021).

run, economic growth will be halted by population growth (see among others Galor and Weil 2000, Clark 2007, Ashraf and Galor 2011). According to the Malthusian model, any progress in agricultural productivity and income per head is undermined by population growth as a result of the existence of fixed factors of production, land in particular. However, in the period coinciding with the late Republic and the Princedom, various evidence appears to contradict the Malthusian pattern, such as the rate of population growth, the rate of urbanization, the volume of trade, the level of real wages, the rate of fertility, and the level of pollution[3].

In the literature, we find different conclusions about the Malthusian model during the Roman era. The development model of Roman cities proposed by Hopkins (1978)[4] attributes the considerable Roman economic growth that occurred between the late Republic and the Princedom to military expansion, implying the return of the Malthusian trap once the expansion was arrested. Likewise, Scheidel (2009) considers the Roman Era as an exception to the recurrent "low equilibrium trap" in ancient times. The military power of the Empire, through the collection of tributes and spoils of war from the conquered provinces, allowed for an extractive power sufficient to escape the Malthusian constraint. However, according to the author, this was a temporary and exceptional period that would be exhausted with the end of the Empire's expansionary capacity. Goldstone (2002) also included the Roman world between societies that experienced "efflorescence", meaning approximately per capita income growth; however, he supposed that per capita income growth would taper down after two or three generations, implicitly supposing that the Roman Empire would fall into the Malthusian trap in the long run. By comparing the per capita income of the Roman Empire to that of the Middle Ages and Early Modern age, Lo Cascio and Malanima (2014) conclude that the differences are marginal. However, they specified that some periods, such as the Roman Era, could show cycles of economic growth, even though in a long-term perspective—from the ancient to the early modern age—this trend remained substantially stable, fluctuating around its long-term average. In line with the neo-institutional approach, Temin (2013) pointed out that the modernization of Roman institutions and the presence of market economies probably enabled an increase in the level of incomes, but in the long term, the population and resources would return to the same Malthusian equilibrium. In contrast, Paul Erdkamp (2016) attributes the ability to generate economies of scale to population growth, which, combined with market efficiency, is capable of avoiding the Malthusian trap. Geoffrey Kron (2014) is even more optimistic; he argues that living standards in classical antiquity were among the highest in world history, close to the level of Europe in the eighteenth and nineteenth centuries. To some extent, based on archeological evidence, Dark (2001) posits the existence of an advanced manufacturing sector, classifying the Roman economy as "proto-capitalist". Similar arguments are also given by Bresson (2016), for Greek economy in Classical times, and by Bintliff (2014), which through an intensive field-by-field survey surface supports the theory of a precocious appearance of "proto-capitalism" in ancient Rome. From a financial point of view, Homer and Sylla (1963) showed that Roman interest rates were tendentially lowest in the ancient era, demonstrating the high level of development reached in Roman times; however, they pointed out that at that time,

[3]Erdkamp (2016).
[4]Cf. Erdkamp (2001).

interest rates were determined by customs rather than the laws of supply and demand, stressing a deep difference between the ancient economy and the economy of the modern age in the capital markets.

This paper questions the reliability of the Malthusian model in properly describing the Roman economy. To answer this question, we adopt, as was done by Erdkamp (2016), an alternative growth model based on Adam Smith's thought. However, previous papers about economic growth in the Roman world generally lack a quantitative basis to estimate to what extent the Smithian model was embedded in the Roman economy. This work aims to contribute to filling this gap.

The Smithian growth model has been quite neglected by economists until now, treated as "a poor relative among theories of economic growth" (Kelly 1997, 939). However, Smith's thought has been recently reassessed, not only for historians of economic thought but also in the field of economic history (Schumacher 2016; Lampe and Sharp 2019)[5]. The cornerstones of Smith's view are the division and specialization of labor, which are in turn stimulated by an increase in competition. The concept of competitive markets is strictly connected with the extension of the markets and to their level of integration. Following Karl Gunnar Persson and Sharp (2015), we can summarize the core of Smithian growth as follows: population growth and market integration leading to the division of labor and technological development. Therefore, the essence of Smithian growth is to increase the total production and productivity levels of land, labor, and, no doubt, capital by changing the conditions of economic activities without requiring any significant innovation. Although it must be stressed that when we speak about Smithian growth in pre-industrial economies, we are well aware that economic growth triggered by labor specialization is possible only within certain limits. Although the specialization of labor is able to endogenously increase the productivity level, per capita income is limited by the available energy sources; therefore a very high level of labor specialization in an agrarian society could not imply an increase in productivity comparable with societies that experienced Industrial Revolution which was fueled by new energy sources (i.e., carbon and later oil, and natural gas)[6]. Since the only energy sources available to agrarian societies are animal, human, wind, or water-powered[7], they cannot compete with societies that can use steam or internal combustion engines[8]. In any case, this does not prevent some pre-industrial societies, such as the Roman world, from being capable of overcoming the Malthusian trap thanks to labor specialization and Smithian growth.

Market extension and integration are features that we can also observe in the Roman world. Economic theory suggests that the large geographical extent of the Roman world, the high level of population density and urbanization[9], the presence of a suitable environment for trade allowed by *Pax Romana*, and the spread of efficient transport infrastructures, such as roads and harbors, are prerequisites for Smithian growth. Specifically, our paper focuses on the connections between long-distance trade and economic growth.

[5] However, since 2010 there are other papers concerning market integration within the meaning of Smith's thought, among the others are Bateman (2011) and Chilosi et al (2013).

[6] Cfr. Lo Cascio and Malanima (2014) and Sachs (2020), p. 46.

[7] For further references about the role of technology, wind and sea power in the Roman world see, among others, Lo Cascio (2003), Wilson (2020), Ronin (2020), and Lewit (2020).

[8] For example, see Smil (2010).

[9] Cfr. Persson (2010) and Sachs (2020) pp. 27-29.

High levels of trade activities, particularly long-distance trade, are usually a reliable approximation of the existence of extended and integrated markets. Exploiting archeological evidence and historical comparative data, we will implement a theoretical model to try to estimate the impact of long-distance trade on the Roman economy.
The first paragraph of the article introduces the differences and the main results of the Malthusian model of growth in comparison with the Smithian model. In the second paragraph, we offer a large overview of the role of long-distance trade in the Roman world. The third paragraph illustrates some quantitative studies concerning Roman GDP. The fourth paragraph shows the methodology used to quantitatively estimate the hypothetical income share of the merchant activity in Roman times.

Malthus vs Smith: different perspectives for long-term economic growth

The "primitivist" interpretation of the Roman economy—introduced by K. Polanyi (1957, 1968) and developed with the main contribution of M. Finley (1973)—assumed that the Roman economy was characterized by sad lifestyle conditions, stagnant technology, low productivity levels, and the absence of an economic mindset[10]. Despite numerous variants (in some cases real contrasts between the positions of Polanyi and Finley), this approach generally agrees with the prominence of the agricultural sector over other economic activities, pointing out the limited importance of the manufacturing and trade sectors and the general role of markets in ancient Rome[11].

"We must therefore rest content with the vague but sure proposition that most people in the ancient world lived off the land, in one fashion or another, and that they recognized the land to be the fountainhead of all that was good, material, and moral[12]"

Though not perfectly overlapping, the primitivist view is strictly connected with the dominant theory currently adopted concerning economic growth in pre-industrial societies: the well-known Malthusian model. On the one hand, a Malthusian model does not indicate a primitivist view is being taken, on the other hand, a primitivist view implies the Malthusian model is being used.
The first appearance of the Malthusian model appears naturally in the well-known manuscript *An Essay on population* (1798) by Thomas Malthus, which uses a geometric progression to illustrate the impossibility of sustaining population growth through an increase in food production, which instead follows an arithmetic progression. The Malthusian growth model is based on the assumption that the supply of land is rigid, meaning that once all the fertile land has been farmed, the only way to improve food production is to increase the productivity of the land already cultivated or to cultivate the less fertile land that is still free. This assumption leads to a natural consequence: any increase in population triggered by agricultural improvement will lead to a less than proportional increase in food production according to the law of "diminishing returns", since, assuming no technological

[10] For further references on the role of agriculture in the Roman economy see White (1970), Foxhall (1990), Lo Cascio (2009), Scheidel, Morris and Saller (2007), Bowman and Wilson (2013).
[11] Cf. Temin (2006a).
[12] Finley (1973), p. 97.

progress, both the rise in productivity of land already cultivated and the cultivation of new less fertile land will produce a lower marginal rural productivity. Therefore, an increase in population, or decreasing labor productivity, will lead to an increase in the number of workers and a decrease in nominal wages; in addition, a greater number of mouths to feed combined with a reduction in labor productivity will lead to increased food prices that will further reduce real wages. In an attempt to restore agricultural output per capita to previous levels, farmers will be induced to increase the use of the labor factor to compensate for the drop in production related to the growth in population. The increase in the labor factor presupposes an extensive rise in production rather than an intensive rise based on the capital factor. Extensive production growth does not necessarily imply the absence of innovation and productivity gains; however, the presence of diminishing returns will always lead labor productivity to equal, at most, the population growth rate. Labor productivity will never exceed the population growth rate, except for short periods, implying stagnation of per capita income in the long run. There is no unanimity regarding the direction of causality between population growth and agricultural production. Boserup (1965), for example, stresses that population growth stimulates agricultural development and not the other way around. However, both the "classic" Malthusian model and the version of Boserup come to the same conclusion: the pressure of the population pushes farmers to cultivate less fertile lands through intensification of the labor factor to increase production, implying diminishing returns.

Since Malthus' publication in 1798, many other scholars have studied and deepened his theory, stylizing the three main relationships that characterize the Malthusian model. Following Pedersen et al. (2021), the three relationships become:

(1) The preventive check: whereby fertility increases with per capita income (i.e., people married earlier when wages were above the equilibrium level and married later when they were below); (2) the positive check: mortality is inversely proportional with per-capita income; (3) diminishing returns to labor: when the population increases, per-capita income in both the short and long term tends to fall, due to the existence of fixed factors of production, particularly land.

The simultaneous action of these three main dynamics leads to Malthusian long-run equilibrium, since any increase in productivity, or income, implies a rise in population and, consequently, due to diminishing returns, a fall in income until the previous equilibrium level is reached. As pointed out by Erdkamp (2020), the application of the Malthusian model of growth by many scholars has implicitly tied any possible interpretation of Roman economic growth to stagnation, namely, in the off chance of the latter experiencing simultaneous increases in population and per capita income over the long run[13]. Moreover, an increase in average consumption, when it happened, could be eroded by the increase in inequalities. Therefore, the agricultural surplus remained low, preventing the development of non-agricultural sectors and thus stifling innovation. Many other scholars have analyzed the Malthusian dynamic, despite there being no lack of skeptical positions regarding its reliability. For example, Hansen and Prescott (2002) interpreted the development of real wages in England from 1250 to 1800 as a confirmation of the Malthusian model, emphasizing the role of the 14th century Black Plague in increasing real wages. Similarly, Allen (2003) states that Europe came out of the Malthusian trap around the

[13] Cfr. Jongman (2006).

16th century. Clark (2007) notes that between the period of hunter-gatherers and the dawn of the Industrial Revolution, the standard of living remained almost unchanged. Ashraf and Galor (2011) state that technological progress in the long term has increased only the population density but not it's standard of living. However, Voightländer and Voth (2013) show that TFP in Europe between 1500 and 1700 moves in the same direction as the mortality rate, invalidating the Malthusian model. States became rich, so they increased their military activity, trade, and mobility, all of which increase mortality and disease. Additionally, Persson's analysis (2008) states that for England in the period 1400-1800, the reliability of the Malthusian model has not yet been confirmed. Another central strand of the literature that is useful for identifying the presence of Malthusian dynamics concerns anthropometric analysis. Koepke and Baten (2005) show how there was a substantial increase in average height immediately after the Roman period, both in the Mediterranean and in the northernmost parts of Europe. In the following centuries, stature decreased during early medieval expansion and then surged in the wake of the Black Plague. To the extent that it can be accepted as representative, this model is logically consistent with a Malthusian scenario in which demographic contraction eases the pressure on scarce resources and survivors live temporarily in better conditions. On the other hand, Klein Goldewijk and Jacobs (2013) showed an increase in stature in late Roman Italy, a decline in northern Gaul for much of the Roman Empire period, and long-term stability in Roman Britain. These results make the identification of a linear and consistent Malthusian pattern more nebulous.

However, economic growth can have different meanings and so could be interpreted using many different approaches. Almost at the opposite side of the Malthus framework, we find Adam Smith's "optimistic" view about economic growth patterns, which is illustrated in the well-known book *The Wealth of Nations* (1776). Since there is no specific section of *The Wealth of Nations* that presents a fully developed model of economic growth, in contrast to what Malthus did, the observations and arguments regarding conditions that facilitate increased labor productivity are interspersed through the book[14]. Smith observed that specialization triggered by the division and coordination of labor can generate substantial increases in labor productivity[15] and that specialization is stimulated by increases in the extension of domestic markets (effectively, increases in population size and density) and by strengthening market integration (i.e., the amount of trade)[16]. These phenomena are captured in Smith's famous statement "That the Division of Labor is Limited by the Extent of the Market" (The Wealth of Nations, chapter III, pp. 18). Market extension and integration can be labeled as the starting point for Smithian growth (Grantham 1993; 1999)[17]. An extension of the domestic market (i.e., population growth), lead to an increased density of buyers and sellers, allowing specialists to find a larger market for their particular good or service by stimulating specialization. A strengthening of market integration is possible when trade activities increase between economic agents. Market integration enlarges the extent of the market, channeling a larger number

[14] Ortman and Lobo (2020).

[15] The increase in the division of labor implies an increasing number of operations producing the same or new goods.

[16] See footnote n° 15.

[17] For a different interpretation see Bateman 2011: 466.

of consumers and buyers in a unified economic area. In addition, the connections between remote geographical areas - with different climate conditions and natural resources (i.e., biodiversity, topography, presence of mineral deposits, pathogens, etc.)[18] – further stimulate the regional specialization of labor. However, this latter dynamic should not be confused with a crude version of Ricardo's theory of "absolute advantage" (Schumacher 2012). In fact, Smith did not mean elaborating a static theory based on the idea that "countries are different in autarky" for which they trade; rather, he suggested a dynamic theory. People trade because "Trading is, quite simply, a more efficient means of producing" (Buchanan and Yoon 2002), and this does not require some initial competitive advantages, just the expectation of the availability of gains from trade in general, which emerge as trade is taking place. Consequently, the division of labor triggered by trade activities endogenously leads to an increased productivity level, which in turn encourages more trade and a deeper division of labor, creating a virtuous circle[19].

Expansion and integration of the markets imply a high degree of regional specialization, which allowed farmers to concentrate on those crops that were best suited to the soil and climate, thus improving the levels of soil and labor productivity in agriculture. This is especially true for the Roman Empire which was located in the "lucky latitudes" (i.e. locations with favorable climates), containing within it several climate zones (i.e. temperate, arid and mountain)[20]. In the Tiber Valley, for example, Goodchild notes a shift in site location to the *Veientanus ager* that may reflect a shift in cultivation strategies away from cereals to olives, vines, or animal grazing. The *Veientanus ager* site was at the heart of Italy, a region that had been intensively cultivated for centuries and where there was limited scope for releasing new land[21]. Therefore, if this shift in cultivation strategies implied an increase in productivity despite a fixed land supply, we can infer the existence of intensive growth based on regional specialization, allowed by extension and integration of the markets[22]. In an essay that provides an extensive and comprehensive overview of the uses and spread of presses in the Roman world, Tamara Lewit[23] shows how this technology was highly varied and perfectly adapted to the geographical, climatic, and morphological characteristics of each region within the Roman Empire[24]. For example, in North Africa and the provinces of Tripolitania and Tunisia - where large estates of wealthy "absentee" landowners were popular - the archeological evidence highlights the diffusion of massive stone presses, often located in huge multi-press complexes, capable of processing large crops. From the perspective of North Africa, the lack of natural resources—in the form of good-quality wood and a tradition in woodworking—in contrast to the abundant wood resources of Roman Gaul seems significant for the development of massive stone lever presses. The ability to adapt the "press technology" to different environmental characteristics, to the increase in demand for a certain product, or the

[18]For a complete overview about the relationship between geography and development see Sachs (2020), pp. 34-46.

[19]Cfr. Lampe and Sharp (2019), p. 665.

[20]Sachs (2020), see the Appendix.

[21]Goodchild (2006, 2009), Goodchild and Witcher (2010).

[22]Cfr. Erdkamp (2015).

[23]Lewit (2020).

[24]For further references on presses in the Roman world see, among others, Frankel (1999), Brun (2004; 2005), Waliszewski (2014).

lack or abundance of a certain raw material (for example, wood or draught animals, etc.) is an indication of a significant degree of regional specialization within the Roman Empire[25]. In the Roman world, a good example of increased competition pushed both by extension and integration of the markets could be represented by *Terra Sigillata*. This good produced from *La Graufesenque* was widely traded in the Roman Empire. They are found in Gaul, Britain, Italy, North Africa, and Danube provinces. Wreck sites on the south coast of France and Spain (such as *Culip IV*) attest the use of shipping to transport the products of this production center (Marichal 1988). As stated by Dark (2001), by the mid-first century, Gaulish and Eastern sigillata had replaced 'Arretine' (or 'Italian-type') ware in broad regions of the Empire. This may suggest the existence of an interregional competitive market, from which a more distant producer could be excluded by the rise of a more readily available and presumably cheaper product. It also shows the ability to move ceramics across entire regions of the Empire to capture these markets. In addition, as Adam Smith pointed out, the division of labor also increased overall productivity and production levels in non-agricultural sectors and was, therefore, an important factor in achieving structural economic growth. The increased availability of nonessential goods has stimulated both agricultural production and the urban economy. In the more recent historical period, the pressure on the agricultural sector generated by the non-agricultural sector could stimulate productivity gains, with a consequent stimulus to technological progress. The case of medieval and premodern Europe shows that the presence or absence of a non-agricultural sector complementary to the agricultural sector implies substantial differences in agricultural productivity. Productivity in agriculture is often lower than the potential capacity of technology; the causes are a combination of low labor specialization, low labor productivity, and high hidden unemployment[26]. In the 18th century in France, the potential productivity of labor, given the technical level of knowledge, allowed the entire population to sustain their livelihoods by employing 40% of the population in the agricultural sector. By contrast, the ratio of the population employed in the agricultural sector was much higher, leading to inefficiencies and low productivity. In England, during that same period, not more than 40% of the population was employed in the agricultural sector, ensuring a lower level of hidden unemployment in agriculture and higher productivity per capita. The differences between these two countries were not so much in the techniques for employing labor but in the development of the non-agricultural sector and the structure of land ownership. In France, the high fragmentation of land and the absence of a developed non-agricultural sector precluded alternative employment opportunities for agricultural workers. In England, excess labor, accentuated by Enclosures acts and the Agricultural Revolution, could be transferred to the non-agricultural sector (Cfr. Erdkamp 2016).

Putting together these suggestions, we tried to consolidate the main features of Smithian growth triggered by expansion and integration of the markets as follows:

1) Enlarging the domestic market following a rise in population size and density strengthens the demand and supply mechanisms, which stimulate the division and specialization of labor; 2) an increase in connections between different economic areas through trade further enlarges the extent of the market, and 3) an expansion in the geographical scope

[25] Oddo and Le Donne (2020).

[26] Sylos Labini (1984, 1986), see also Valli (2005).

of trading, triggering in turn a greater regional specialization.
In fact, as stated in point 3, it is more likely that coming into contact with areas that have different climate conditions and natural resources stimulates a more efficient allocation of resources (for example, shifting in cultivation strategies). The interaction of all these dynamics increases competition within the unified economic area, stimulates technological progress, increases the productivity level, and squeezes production costs and sales prices. Therefore, the Smithian model can trigger endogenous economic growth - within the limits imposed by energy sources available - without needing to use exogenous causes (i.e., wars, depredations, spoils, tributes, etc.). These developments, however, should not be seen as inevitable and did not happen automatically, as several conditions relating to market integration, transport, transaction costs, and the use of labor had to be met. Smith attributes great importance to the role of transportation in allowing for the expansion and integration of markets.

"Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of the country more nearly upon a level with those in the neighborhood of the town. They are upon that account, the greatest of all improvements. They encourage the cultivation of the remote, which must always be the most extensive circle of the country. They are advantageous to the town by breaking down the monopoly of the country in its neighborhood. They are advantageous even to that part of the country. Though they introduce some rival commodities into the old market, they open many new markets to its produce." (The Wealth of Nations, book 1, chapter XI, part I)

Therefore, the improvements in transportation conditions within the Roman Empire (i.e., roads, harbors, bridges, etc.) could stimulate trade activities and market expansion, which in turn enlarged the possibilities for labor specialization. In addition, economic theory suggests that if institutions are able to reduce the risk of transports and uncertainty in profit expectations, the propensity towards trade activities increases[27]. From this point of view, the uncertainty related to trade activities in the Roman world was reduced following the *Pax Romana* and the clearance of the Mediterranean Sea of piracy by *Gnaeus Pompeius Magnus*, creating an environment conducive to business activities.

How important was long-distance trade in the Roman economy? Going into the debate

As stated in the previous paragraph, long-distance trade, specifically water-carriages, transportation networks, and supporting infrastructures are one of the most important variables in triggering Smithian growth due to their capacity to create market integration.

"As by means of water-carriage a more extensive market is opened to every sort of industry than what land-carriage alone can afford it, so it is upon the sea-coast, and along the banks of navigable rivers, that industry of every kind naturally begins to subdivide and improve itself, and it is frequently not till a long time after that those improvements

[27] See North (1991, 1994, 2005) and North and Weingast (1989).

extend themselves to the inland parts of the country." (The Wealth of Nations, book 1, chapter III)

However, trade, especially long-distance trade, its ownership structure, and the scale of investments, have always been at the center of the debate on the structure and performance of the Roman economy. Any answer to the question of whose savings were fueling the Roman shipping industry has consequences for one's approach to the development of trade and its contribution to the Roman economy[28]. In the historical debate between primitivists and modernists, the former sustained their view emphasizing the moralistic ancient literature and stating that elite money never financed shipping and that poor and marginalized traders would never be able to engage in large-scale transactions (Finley 1999), while the latter stresses detailed descriptions of giant freighters, the high tonnages of ships sailing, or the remarkable cargo capacities of some shipwrecks (Casson 1956, 1971 and Wallinga 1964). In this section, we try to put together the main arguments about long-distance trade in the Roman age, putting aside the sterile dispute between primitivists and modernists.
To briefly explore the huge amount of evidence concerning long-distance trade in the Roman world, we divide the whole section into seven subsections: 1) Macroeconomic overview 2) Ancient literary sources 3) Shipwrecks 4) Institutional framework 5) Harbor infrastructures 6) Elite classes' investments 7) Financial capital and credit market 8) Technology.

Macroeconomic overview

Starting from a macroeconomic point of view, we have to state, without fear of making a mistake, that the main source of income for the Roman economy was land ownership; however, some wealth could also have originated from trade or other sectors such as manufacturing and construction, but, unquestionably, the Roman economy was primarily agricultural. Another fixed point concerns the fact that the aristocratic elite was the largest group of landowners for a long time in Roman history, undoubtedly until the crisis of the 3rd century.

"Many or most senators would have been similarly placed (landowner), especially those who, like Pliny, were not among the most wealthy and who were not from Rome itself or its environs." (Garnsey and Saller, 2014, p. 91).

However, after a period of underestimation, the role of trade activities began to attract an increasing number of scholars. One of the first to shed light on the Roman trade was Hopkins (1980). In his contribution, the role of trade in Roman times is explained using a theoretical modeling approach. The author associates taxation with the emergence of long-distance trade. Starting from the simple principle that imports of goods into the center of the Roman Empire were balanced by the outflow of liquidity (in the form of taxes) from the provinces; Hopkins provides evidence of consistent merchant activity in Roman times. The empirical evidence shown by Hopkins—findings of coins at various

[28] Broekaert and Zuiderhoek (2020).

sites and wrecks in the Mediterranean Sea—suggests that trade was actually widespread during the period of the High Empire.
In more recent times, much evidence suggests that merchant activity in the Roman world was important and helped to expand business. A geospatial model created by Walter Scheidel and Elijah Meeks, shows very vividly how sea trade was widespread in Mediterranean during the Roman Era[29]. In addition, impressive shipwreck discoveries have stimulated a change in the way we view Roman trade; however, in reality, not all the evidence is convincing, and there is much evidence to the contrary. In any case, archeological data that was recovered and synthesized over approximately the last thirty years has demonstrated that long-distance trade in the Roman world was normal and common and involved not only luxury goods (silks, spices, marble) but also a range of staple foods and other relatively low-cost commodities. The great number of goods and commodities and the context in which much of it is found usually suggest that these goods were moving as trade rather than as personal equipment, gift exchanges, on even imperial shipments (Wilson 2009)[30].

Ancient literary sources

The ancient literary sources usually tend to minimize the role of commerce in the Roman economy and, for this reason, are used by "primitivists" as confirmation of their thesis. In this kind of evidence, the immorality of the merchant activities and those senators involved in these activities is emphasized. In addition, clues concerning elite involvement in shipping activities are rarely found. In the scriptures of *Petronius* on the freedman Trimalchio (*Satyricon* 53, 3), the three most important means to collect wealth in Roman times are listed as land, short-term interest-bearing loans, or a strongbox. In the context of Roman culture, where there was a "non-economistic" preference for land investment with respect to the activity of money lenders, which was historically deplorable[31], we can deduce the importance of land wealth with respect to manufacturing and trade. Of course, we must consider the overstated statements of a satirical figure such as Trimalchio: there was wealth in ships, warehouses, enslaved artisans, and raw materials, but following *Petronoius* it was a secondary source of wealth for elite groups[32]. In contrast, we find that the ancient literary sources used by modernists overestimate the role of trade in the Roman world. Ancient authors frequently marveled at giant ships of over 1,000 tonnages and described these vessels in such extraordinary detail that their existence has some-

[29]ORBIS: The Stanford Geospatial Network Model of the Roman World

[30]For a different view Whittaker (1985, 1987, 1989).

[31]In *De officiis* (1, 150-1) Cicero lists a series of occupations considered "miserable", including money lending. However, despite the ethical admonition, the activity of moneylender was present in ancient Rome.

[32]However, this observation, which seems to minimize the role of commerce, is contradicted by another part of the literary work. *Petronius* itself mentions a certain Lichas as single owner and captain of a large ship in the *Satyricon* (101), but adds that Lichas also owned several estates and many slaves engaged in business, stressing the diverse nature of Lichas' portfolio. If Lichas represents one roman businessmen, the resulting image about shipowners is that these last ones are rich people, with many different economic activities under their control.

times been willingly accepted by modern scholars[33]. Other scholars, however, have shown serious concerns about the reliability of these sources, considering it to be implausible that such large ships ever sailed the Mediterranean in antiquity[34].

Further evidence of the partial overlap between the land ownership and wealth of the Roman elite during the period of the Princedom—from 27 B.C. to 285 A.D.—is the list (table 1) of the 27 richest personalities of ancient Rome, elaborated by the English historian Duncan-Jones (Duncan-Jones, 1982, pp. 343-343) based on ancient literary sources. This ranking shows that out of 27 names, 23 belong to the aristocratic classes, mostly made up of landowners, and that only one, *C. Caecilius Isidorus*, appears to belong to a class comparable to the modern entrepreneurial bourgeoisie. In more detail, 13 belong to the senatorial class or their families, and 4 are imperial freedman (enslaved in service to the emperor, usually they are tutors or educated individuals) rewarded by the emperor with important positions and extensive land estates[35]. The ranking includes an emperor (*Tacitus*); five magnates, namely, personalities with relevant positions such as magistrates or governors; two doctors; and a court poet. One partial exception is *C. Caecilius Isidorus*, a businessman who seems to have made his fortune by his entrepreneurial skills, even though he seems to be mainly a landowner[36]. However, despite the considerable wealth (60 million sestertii), *C. Caecilius Isidorus* is in the second half of the ranking, namely, in seventh place at a relative level and fifteenth at an absolute level.

[33]See for instance Lucian's Isis (*Navigium* 5), Hiero's Syracysia (Athenaeus 5.40-54; Duncan Jones 1977; MacIntosh Turfa and Steinmeayer 1999), or Caligula's obelisk ship (Pliny, *Historia Naturalis* 16.76; see Wirsching 2000 and 2003 for the argument that is actually consisted of three smaller, interconnected ships, a theory which is however considered "wholly unconvincing" by Wilson 2011; 40 at n. 33).

[34]Houston (1988) and Wilson (2011).

[35]The case of *Marcus Aurelius Cleander* (a freedman under the reign of *Commodus*) is perhaps one of the most famous examples of the power that imperial freedmen could achieve.

[36]Upon his death in 8 B.C., *C. Caecilius Isidorus* bequeathed 3,600 pairs of oxen, 257,000 other stocks, and 4,116 slaves, plus 60 million sesterces in cash (HN 33.135).

Position	Name	Wealth (millions of sestertii)	Social class	Period
1	*Cn. Cornelius Lentulus*	400	Senatorial	25 A.D.
1	*Narcissus (freedman of Claudius)*	400	Imperial freedman	54 A.D.
2	*L. Volusius Saturninus*	300	Senatorial	56 A.D.
2	*L. Annaeus Seneca*	300	Senatorial	65 A.D.
2	*Q. Vibius Crispus*	300	Senatorial	83-93 A.D.
2	*M. Antonius Pallas*	300	Imperial freedman	62 A.D.
3	*C. Iulus Licinus*	280	Imperial freedman	14 A.D.
3	*Tacitus*	280	Emperor	275 A.D.
4	*C. Iullus Callistus*	200	Imperial freedman	52 A.D.
4	*T. Clodius Epirus Marcellus*	200	Senatorial	79 A.D.
4	*C. Sallustius Passienus Crispus*	200	Senatorial	46-47 A.D.
5	*M. Gavius Apicius*	110	Senatorial	28 A.D.
6	*Ti. Claudius Hipparchus of Athens*	100	Magnate	81 A.D.
6	*L. Tarius Rufus*	100	Senatorial	31 B.C.–1 4 A.D.
7	*C. Caecilius Isidorus*	60	Imperial freedman	8 B.C.
7	*M. Aquillius Regulus*	60	Senatorial	105 A.D.
8	*Lollia Paulina*	40	Senatorial	49 A.D.
9	*C. Stertinius Xenophon*	30	Doctor	41–54 A.D.
10	*C. Plinius Caecilius Secundus*	20	Senatorial	111–113 A.D.
10	*Crinas di Massilia*	20	Doctor	54–68 A.D.
11	*P. Vergiulius Maro*	10	Court poet	19 B.C.
12	*M. Calpurnius Piso*	5	Senatorial	20 A.D.
13	*Aemila Pudentilla of Oea*	4	Magnate	158–159 A.D.
13	*C. Licinius Marinus Voconios*	4	Magnate	98–100 A.D.
14	*Herennius Rufinus of Oea*	3	Magnate	158–159 A.D.
15	*L. Apuleius of Madauros*	2	Magnate	140–150 A.D.
16	*M. Hortensius Hortalus*	1.8	Senatorial	16 A.D.

Table. 1: The 27 richest personalities of the Roman Empire in the period of Princedom (27 B.C.–285 A.D.). Source: Duncan-Jones 1982, pp. 343-344, Appendix 7

Shipwrecks

The recent archeological findings concerning shipwrecks in the Mediterranean Sea are probably the most important evidence about long-distance trade in the Roman world, but at the same time, they represent the heart of the debate about this argument. In the last thirty years, a huge number of shipwrecks have emerged from the depths of the Mediterranean Sea, causing scholars to question the previous arguments regarding the marginality of trade in the Roman era. From the pioneering works of Parker (Parker, 1990a, 1990b, 1992a, 1992b), which synthetized the great number of discoveries, the role of shipwrecks as an approximation of merchant activities in the Roman world was controversial. Nevertheless, the number of shipwrecks discovered shows a specific trend, denoting a great concentration of trade activity around centuries I and II AD (Fig. 1), overlapping with what is considered the wealthiest period of the Roman era. The trend derived by shipwreck discoveries, if reliable, provides some important considerations about Roman economic growth. The peak shows that before and after the Roman era, shipping activities dropped significantly, confirming the great economic wealth reached during this period in comparison with the other periods. However, the significance of this evidence has to be treated with caution.

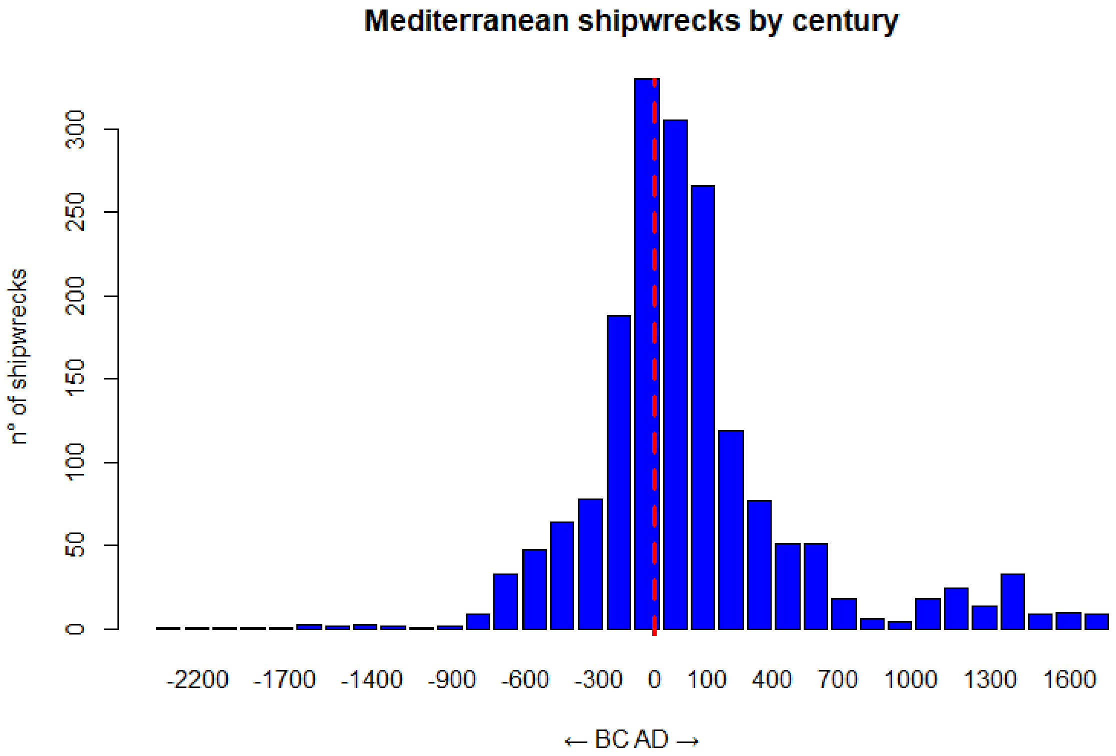

Figure 1: Mediterranean shipwrecks by century, using midpoints of date ranges. Source: our elaboration based on Oxford Roman Economy Project – own elaboration (accessed 28 September 2020).

Two main problems emerge when we use shipwrecks as an approximation for merchant activities. The first concerns the significance of the findings: wreck sites are usually located through the great heaps of amphorae, implying that larger wrecks have a far better chance of being noted by drivers (Pomey and Tchernia 1978, Broekaert and Zuiderhoek 2020). This bias in the observations creates quite a few problems in understanding the flow of mercantile activities because it overestimates the role of the largest ships with respect to the smallest ones. In addition, the main discoveries were concentrated near the coast, while the number decreased in open water, where the activities of drivers were more difficult. In this case, we cannot know how many wrecks are still in the depths of the Mediterranean Sea, making it very difficult to estimate the trade flow by inference. The second problem concerns the role of amphorae; in fact, as stated by Wilson (2009), the shipwrecks graph is partly a graph of amphora usage[37]. Wrecks are usually sighted

[37] See also Peacock and Williams (1989).

underwater from the mound formed on the seabed by their load; this protects the parts of the underlying hull from breakage. The shipwrecks we know about, therefore, are mostly amphorae cargoes, so warships, grain freighters, and ships carrying perishable cargoes are rarely found. In other words, by the early medieval period, the amphora had been largely replaced, at least in the west, by the barrel[38]. The barrel, being constructed mainly of wood, is more perishable underwater with respect to the amphorae, distorting the trend of discoveries and probably underestimating mercantile activities from the early medieval era onwards. This distortion makes the identification of the trade flow trend and, consequently, the path of Roman economic growth more nebulous.

Institutional framework

Other important proofs suggest that trade was not a marginal part of economic activities in the Roman world. Institutional involvement in the regulatory system of trade activity is one of these. In 218 BC, the *plebiscitum Claudianum* forbid senators and their sons from owning a sea-going vessel of more than 24 tons[39]. The opposition by the senate and the legislation in itself proves that in the third century BC, senators were involved in commercial shipping (Broekaert and Zuiderhoek 2020). In addition, elite participation in commerce was not eliminated; the law could be easily circumvented by using freedmen, slaves, and clients, while the elite provided them the capital to build or purchase the ships[40]. The presence of this law can also shed light on the fact that we find very little evidence in literary sources and epigraphy for ship ownership among the elite[41].
Another aspect regarding institutional normative framework concerns the state's demand for transport in the service of the imperial supply system, which appears to have aimed for the higher end of the average tonnage range and even well above that. In detail, we refer to the *Annona* practices, which provide wheat for the population of the largest city of the Empire, the first being Rome and later Constantinople. This wheat, and later also oil and meat, was shipped mainly from Egypt and North Africa, but also from other parts of the Empire, to feed the largest city population. In the age of *Augustus*, the wheat imports from Egypt were equal to 20 million modii per year, while under Nero, the imports from African regions probably fed the plebs of Rome for 8 months[42]. Tchernia (2011b) estimated that 786 ships were necessary to feed the Rome population. Even if there was no state merchant fleet to carry the tax and rent grain at its destination, this function was performed by private shipowners paid by the government. To incentivize private citizens to participate in these shipments, imperial institutions would provide financial subsidies. During the reign of *Claudius*, shippers gained special privileges for a ship of approximately 65 tonnages; during the reign of Trajan, a single ship of 330 tonnages or several ships of 65 tonnages was allowed. These norms provide us with two important indications: the private sector was involved in public transportation, and during the Roman age, the size of the ships was not lesser than during later historical periods. Data from the ancient

[38]Sealey (1985), Panella and Tchernia (1994), Tchernia (2006), Marlière (2002), Étienne and Mayet (2000).

[39]Livy 21.63.3-4. See Tchernia (2007) for the conversion of Livy's 300 amphorae into tons.

[40]D'Arms (1981), Clemente (1983), Bringmann (2003), Tchernia (2007).

[41]As suggested by Broekaert and Zuiderhoek (2020). For an opposite view see Rathbone (2003).

[42]Lo Cascio, E. (2000). pp. 17-56.

eastern Mediterranean, Byzantium, and early modern Europe and India all indicate that merchant fleets mainly consisted of smaller vessels, well below 100 tonnages, with the majority of ships situated in the categories of 60 tonnages or less[43]. In fact, even if the subsidies concern only the highest tonnages, meaning they were rather rare, we can suppose the during the reign of Trajan, in particular, ships of approximately 300 tonnages existed.

Harbor infrastructures

The improvement of Rome's harbor facilities under the reign of *Claudius* and later the building of the harbor of *Portus* under Trajan are proof of the importance of trade in the Roman economy. In fact, according to Wilson (2011), the peak in the discoveries of wrecks and largest ships in the Hellenistic and Roman worlds is matched by an increase in the provision of harbor infrastructures. Similar conclusions are pointed out by Schörle (2011), who suggests that ports are, to a certain degree, an indicator of trade and facilitate its development.

"*Portus* was the largest artificial harbor structure of the Mediterranean and could probably host some five hundred ships in its basins, and crucially, it had c. 13,900 m of wharfage space."[44]

This is actually a case where the institutional framework should have encouraged the construction of a larger ship (Wilson 2009). The story of Hieron's Syracusia, an impressive ship that was too large to dock at most Mediterranean ports except Syracuse and Alexandria[45], illustrates the necessity for port facilities to keep pace with developments in shipping and vice versa. In fact, from the point of view of innovation in the Roman world, this was not always due to the introduction of technical applications, as happened in the Industrial Revolution, but mainly concerned the law and institutions[46]. Roman law continuously developed tools in response to the needs of commerce and other economic activities. The improvements in ship transport were due more to improvements in port infrastructure than to improvements in ship technology. The scale and standardization in which these constructions operated were innovative. In the ancient world, the context of innovation mattered more than innovation itself. Some harbor infrastructures in the Roman world could potentially contain impressive numbers of ships in their basins. The number and scale of the artificial harbor and port facilities built and maintained around the Mediterranean between 200 BC and 300 AD stands out as unusual for any period before the Industrial Revolution. Tab. 2 illustrates the major harbor sizes in the Roman Empire. For comparison, a few major harbor sizes from elsewhere have also been added.

[43] Gibbins (2001), Makris (2002), Davis (1962), Houston (1988), van Zanden and van Tielhof (2009), Das Gupta (1985).

[44] Schörle (2011), p. 95.

[45] *Athenaeus Deipnosophistae* 5.209b.

[46] Erdkamp et al. (2020), pp. 1-36.

Site	Harbor area (ha)	Wharfage length (m)	Reference
Portus (total)	234	c. 13,890	Kaey 2011 (Chapter 2, n. 65): Morelli et al. 2011: 47-65.
Claudian basin	c. 200	2,860	Wharfage figure includes various canals
Trajanic hexagon	33.3	2,100	
Darsena	1.08		
Alexandria, Portus Magnus	>226	12,380	Calculated from the plan in Goddio and Fabre et al. 2008: 38
Puteoli (total)	67.9		Calculated from the plan in Brandon et al. 2008: 376 fig. 1
Puteoli (Portus Iulus)	53.9		Calculated from the plan in Brandon et al. 2008: 376 fig. 1
Puteoli (Portus Balanus)	14		Calculated from the plan in Brandon et al. 2008: 376 fig. 1
Antium	25-30		Felici 1995: 61
Ephesus	c. 18-24		Calculated from Google Earth
Cesarea Maritima (outer basin)	20		Oleson 1988: 152
Hadrumetum	20		Bartoccini 1958:12
Centumcellae	14	No more than 2000	Calculated from the plan in Caruso et al. 1991
Carthage (circular and rectangular harbors)	14		Romanelli 1925: 92
Terracina	11		Calculated form plan in De Rossi 1980: 100, fig. 25
Lepcis Magna	10.2	1200	Bartoccini 1958:12-13
Torre Astura	7.8		Calculated from Marzano 2007
Kenchreae (Corinth)	3		Kingsley 2004:140
Cosa	2.5		Gazda 1987:75
Giglio Porto	c. 2		Calculated from the plan in Ciampoltrini and Rendini 2004: 138, fig. 6[a]
La Mattonara	1.24		Calculated from the plan in Higginbotham 1997: 94, fig. 18
Villa port at San Simone	0.84		Degrassi 1955: 136
Ventotene (Pandateria)	0.7		Franco 1996: 297

[a] The units of the scale bar of this plan are not specified and the plan has clearly been greatly reduced from the stated 1:20000 scale; checking against Google Earth indicates that the scale bar must represent 30 m in 2 m and 10 m units.

Table 2. Comparative harbor sizes. Source: Schörle (2011), p. 96.

Elite classes' investments

Another important point to stress is understanding the role of the elite classes in trade activities. This discussion is important to understand the overall size and spread of Roman trade. Roman society was based on inequality (Garnsey and Saller 2014), and aristocratic classes were the basis of the Empire. Senators, knights, and decurions, using a very simplified classification, were the glue of Roman society.
Quoting Lo Cascio's (1991: 703) reference to the importance of the elite within Roman society: "an essential condition for the survival of a unitary political organization [the Empire] was, therefore, their [the aristocratic classes] safeguard."[47]

The Roman elite classes were the greatest owners of capital in the Roman world. The word capital here refers to capital goods, financial capital, land, slaves, and workshops. In the classical Roman farm lease (*locatio-conductio*), it was the landowner who provided the farm, fixed capital such as storage buildings, and any heavy equipment such as olive presses or wine presses, while the tenant provided mobile capital, such as tools, slaves, and livestock (Kehoe 1997, 2007, 2012; Aubert 2010; Erdkamp 2005).
In this regard, Kessler and Temin (2007) note that the merchant class was mainly composed of senators, knights, and freedmen. Trade seemed to frequently become the domain of landowners who used long-distance trade to mobilize their food surplus, reinforcing their position of prominence in Roman society[48]. Likewise, Broekaert and Zuiderhoek (2020), through a convincing analysis based on the costs of shipping, argue that the very high cost of building and arming a ship necessarily implies the involvement of members of elite classes, who were the only ones with access to this amount of capital resources. Rathbone (2003) also concludes that, through a lower estimation of shipping costs, commercial activity was almost totally controlled by a "medium-class", without elite investments, which downsized the volume of commercial activity in the Roman world.
Similar to Broekart and Zuiderhoek's conclusions, Manacorda (1989), through studies on amphoric epigraphy, points out that despite some exceptions, trade mainly revolved around the great landowners who were frequently members of the Roman aristocratic elite. Manacorda supports the hypothesis that the transport manager and the owner of the merchandise can identify with each other, reinforcing the supposition that land ownership was the main, though not the only, basis of political, economic, and social power in Roman society and that these landowners were also the main actors of Roman trade.
By contrast, Tchernia (2011a), following the same methodology, shows that the role of merchants could differ from the role of the manufacturer. According to his analysis, *L. Titius* was a shipowner and trader who exclusively engaged in buying, transporting, and selling; therefore, his profits were attributed solely to trade activity. The same could be said for *Sex. Arrius*, 40 other hypothetical merchants discovered on the caps of Dressel 1, and 400 others painted on Dressel 20 from Baetica. Nonetheless, Tchernia lists several opposite cases of almost-confirmed landowner merchants, such as the case of *Cornelius Lentulus* and *Sestius*, probably belonging to the *gens Sestia, C. Sornatius*, a member of Nero's family, and several others.

[47]Our translation
[48]Bang P. F. (2007).

Financial capital and credit market

Widening our analysis in credit markets, we find several pieces of evidence indicating that long-distance trade was not a marginal economic sector. Verboven (2020) states that Roman credit markets ranged from retail and short-term consumption credit offered by shopkeepers and deposit bankers, respectively, to loans to retailers or craftsmen for buying stocks or raw materials, to maritime loans (*Faenus nauticus*) to overseas merchants. However, he stresses that bank loans were not ordinarily available to finance maritime trading ventures, even if Roman merchants (much like their medieval and early modern successors) could not operate without credit and had to rely on middlemen to find creditors. A passage in the Digest[49] speaks about a maritime loan from Beirut to Brindisi, where agents of the creditor are mentioned, but no deposit bankers are involved. In some cases, the investments needed for merchant ventures could be very high. The famous Muziris papyri refer to the presence of a bottomry loan for a ship returning from India with a cargo valued at approximately seven million sesterces[50]. When Seneca refers to maritime loans, he distinguishes between intercessors who guaranteed repayment of the loans they arranged (in exchange for part of the profit) and *proxenetae* who merely gathered information and arranged and drafted contracts in exchange for a fee (*proxeneticum*). Cato advises that if people wished to obtain money for the shipping business, they should form a large association, and when the association had fifty members and as many ships, he would take one share in the company[51]. Finally, the most important evidence about the connections between long-distance trade and the credit market concern the famous Murecine tablets found in Pompei that record several transactions in the Puteoli harbor. These tablets show the businesses of the *Sulpicii* of Puteoli (*Caius Sulpicius Faustus*, *Cinnamus*, and *Onirus*), who were freedmen and sons of freedmen[52]. Verboven (2020) states that the tablets illustrate that the *Sulpicii* are well-connected businessmen specializing as financiers and credit intermediaries for long-distance traders. They show the sophistication and flexibility of Roman credit instruments and legal institutions. They documented how elite wealth found its way into merchant ventures.

Technology

A further extremely important factor to analyze is the high level of risk that long-distance trading involved in Roman times. Trade in open water was extremely difficult as the ships were not equipped with rudders and the hulls were maneuvered by rowing. Furthermore, ships were not equipped with a compass; thus, it was typical to sail along the coast, and only during the day, to maintain orientation. In addition, the limited space on board and the inability to store foodstuffs for long periods, combined with the inability to board, required short-distance navigation. These restrictions suggest that trade was limited in certain periods and seasons. Long-distance trade, for instance, was concentrated in the period from March to October; thus, economic activity in the harbors was limited by the

[49] *Digesta* 45.1.122.1.
[50] Verboven (2020).
[51] Plutarch, *Cato Maior* 21.5.
[52] See Verboven (2020) and Andreau (2020).

seasons, with peaks of work in the summer and depressions in the winter (Erdkamp 2016). The large number of shipwrecks that have been discovered could indicate how dangerous this activity was in ancient times.

In light of these various pieces of evidence that more or less emphasize the importance of long-distance trade in the overall Roman economy, we try to answer this hard question through a quantitative approach.

Caveats

When we speak about ancient data, some caution is necessary. Most of the following analysis is based on previous data that are not universally accepted by scholars. In addition, some estimates are based on rigid assumptions which may not be exact expressions of reality. For these reasons, we prefer to adopt a convergence analysis, where, to the best of our knowledge, we use all data available to find some order of magnitude about the role of merchant activity in the Roman world. We avoid basing our estimates only on one data source. Finally, we do not seek to provide precise estimations or definitive conclusions but only aim to provide some order of magnitude to better understand the dynamics of the Roman economy. If someone would object that this is only a pure didactic exercise, we would reply that it is better to try to have some answers using available data, although fragmentary, than none.

Income distribution in the Roman Empire: quantitative approaches

Many studies have attempted to quantify aggregate income and its distribution in the Roman Empire[53]. The first contribution on this subject was offered by Raymond W. Goldsmith in 1984[54]. Goldsmith's estimates are based on a supposition about the individual minimum subsistence level of consumption in terms of wheat. Through this technique, given the total population of the Empire, Goldsmith evaluates the total amount of wheat consumption in the Roman Empire (i.e., the total gross domestic product (GDP)). He assumes that an individual in Roman times consumed a minimum of 250 kg of wheat per year[55], as in Hopkins (1980). Supposing the mean price of a *modius* of wheat was equal to three sestertii[56], Goldsmith estimated that the total subsistence expenditure of an individual was equal to 112 sestertii per year. Adding further food expenditures[57], taxes (evaluated as 5% of total Roman Empire GDP), and other non-foodstuff expenditures, Goldsmith suggests an average subsistence level equal to 380 sestertii per year for

[53]For further references on the aggregate income and its distribution in the Roman Empire see Temin (2006b), Milanovic (2007), Scheidel and Friesen (2009), and Lo Cascio and Malanima (2009).

[54]Goldsmith, R. W. (1984).

[55]Goldsmith starts from the estimate of the consumption of soldiers and the enslaved of approximately 50 *modius* of wheat per year (approx. 340 kg), balanced with the lower quota consumed by women and children, for an average between the two of 35–40 *modius* (approx. 238–272 kg).

[56]Ancient sources indicate a price between 2 and 4 sesterces per day, excluding Egypt, which has a lower average price (Goldsmith, 1984, p. 266). The price is derived from Tacitus' observations on the price of wheat after the Great Fire of 64 A.D. (Ann. 15.39).

[57]Based on comparisons with other countries and other historical periods (Goldsmith, 1984, p. 267-268).

a population of 55 million people for the whole Roman Empire in 14 A. D.
Goldsmith is the first to attempt to split labor incomes, including the legion's *soldo*, from non-labor incomes. To make this, he supposes an average wage of 3.5 sestertii[58] per day and a working year of 225 days. This led to an average income per capita per year equal to 790 sestertii. Goldsmith then introduces a method to calculate the income of the elite classes. To separate elite income from labor income, Goldsmith defines the non-labor income as returns generated from ownership, including ownership of the enslaved, adding a further share of incomes from professional activities and institutional appointments. To evaluate these incomes, Goldsmith started from the wealth of an individual member of the elite classes, applying a return of 6% to simulate non-labor incomes[59]. Goldsmith splits the elite classes into four status levels: emperor, senators, knights, and decurions. The average patrimony of an emperor is evaluated to be 250 million sestertii; thus, assuming a return of 6%, the annual income of an emperor is estimated to be 15 million sestertii. The minimum wealth level to be a senator was 1 million sestertii. Therefore, the average patrimony of a senator was evaluated to be 2.5 million sestertii, and the average income was 150,000 sestertii. Aggregating the incomes of the 600 senators, we obtain an average aggregate income of 90 million sestertii. The 40,000 knights, with an average patrimony of 500,000 sestertii and an average income of 30,000 sestertii, lead to an aggregate income of 1,200 million sestertii. Finally, he estimates a decurion population equal to 360,000 with an average wealth of 200,000 sestertii and an average income between 8,000 and 12,000 sestertii, obtaining an aggregate income of approximately 3,000 million sestertii. In conclusion, Goldsmith supposes a total aggregate income for the Roman Empire equal to 20.9 billion sestertii divided between aggregate labor income, 17.325 billion sestertii, and aggregate non-labor income, 3.575 billion sestertii.
Later, some scholars tried to improve Goldsmith's estimates, including Temin (2006b), Maddison (2007), and Milanovic (2007). All these works reflect the analytical structure used in Goldsmith, but there are substantial differences in each model's setting. One of the most important differences is the assumption of price per *modius* of wheat. Temin, taking the much lower Egyptian prices, estimates a price of a *modius* of wheat equal to 1.78 sestertii, reaching an estimate of per head income that is less than half the estimate proposed by both Goldsmith and Maddison. He concludes that "per capita GDP in the early Roman Empire was near that of Uganda today", with a total aggregate income equal to 10.45 billion sestertii. By contrast, Milanovic uses an intermediate value, between the Goldsmith and Temin estimates, of 2.2 sestertii per *modius.* Another difference regards the income distribution between social classes. Milanovic (2007) assumes a more diversified Roman society, analyzing 11 social classes – including all military positions – with respect to the 7 described by Maddison and the 5 used in Goldsmith. This leads Milanovic to have a more concentrated distribution within the elite classes, with a share equal to 36% of the total income, while Maddison estimates 26.4% and Goldsmith 20%. Finally, different hypotheses have also been formulated about the size of the population of the Roman Empire. Both Milanovic and Goldsmith estimated the entire population to

[58]Most ancient sources indicate that an average daily wage of a male free adult is between 2.5 and 4 sesterces, which should be balanced with the presumably lower wages of women, children, and the enslaved (Goldsmith, 1984, p. 269).
[59]Average return on capital in low-income countries in the 1970s.

be 55 million people, while according to Maddison, it amounted to only 44 million.
We focus here on the work of Maddison for reasons that will be apparent in the next paragraph. Maddison adopts the major part of Goldsmith's estimates but lowers the share of consumption of goods other than food (from 39 to 34 percent of the total per capita income) and raises the share of government and investment[60] (from 8 to 13 percent and then 45 percent more as to the value of only wheat consumption)[61]. Furthermore, Maddison reduces the estimate of the population level to 44 million, causing Maddison's estimate for the total GDP to decrease to 16.72 billion sestertii. Maddison adjusts Goldsmith's estimate of the decurions population, reducing it from 360,000 to 240,000, but assumes the same per capita income as Goldsmith, approximately 8.33 sestertii. In this manner, he evaluates that the total income of the decurions class is 2,000 million sestertii. Furthermore, Maddison splits the income of the free workforce from the income of the enslaved. Assuming an average wage of 300 sestertii for one enslaved person and a population of 4.5 million enslaved, with an employment rate equal to 4/5 of the total workforce, Maddison argues that the total amount of the income of the enslaved was equal to 1,080 million sestertii. This modification that Maddison suggests produces a discrepancy between the total consumption evaluated starting from the minimum subsistence level, 16.720 billion sestertii, and the total amount of income, approximately 15.619 billion sestertii. Maddison argues that this residual, 1,101 million sestertii, was allocated to 50,000 owners who did not belong to any of the previous four categories. Maddison classified these groups as "other". In conclusion, Goldsmith posits that the total income of the elite was equal to 17% of the total GDP of the Roman Empire, and Maddison adjusts this share to 26%. In this manner, Maddison diversifies the labor incomes from the ownership incomes, adding the income from enslaved labor.

Table 3 illustrates the results of Maddison's income distribution in the Roman Empire (14 A.D.).

Social classes	Population (Income earners)	Tot. population (families)*	Per-capita income (sestertii)	Aggregate income per class per year (millions of sestertii)
Emperor	1	3	15,000,000	15 (0.09%)
Senators	600	1,629	150,000	90 (0.5%)
Knights	40,000	108,587	30,000	1,200 (7%)
Decurions	240,000	651,519	8,333	2,000 (12%)
"Other"	50,000	135,733	22,024	1,101 (6.6%)
Total elite	**330,601 (2%)**	**897,471 (2%)**		**4,406 (26%)**
Free workforce	14,220,000	38,602,529	790	11,234 (67%)
Enslaved	3,600,000	4,500,000	300	1,080 (6.5%)
Total nonelite	**17,820,000 (98%)**	**43,102,529 (98%)**		**12,314 (74%)**
Total	**18,150,601 (100%)**	**44,000,000 (100%)**	**380 (subsistence level)**	**16,720,000,000 (100%)**

[60]Based on the analogous estimate for England and Wales 1688 (Maddison 2007, pp. 32-6).
[61]Lo Cascio and Malanima (2009), p. 394.

Table 3: Population and income shares in the Roman Empire (14 A.D.). Source: Maddison (2007).
* The number of families is own estimation, Maddison has split only between free people (39,000) and not-free people (4,500). Based on this information, we divided free people into all classes (excluding slaves), and we obtained a medium family composed of 3 people.

Based on Maddison's results, the total income per year of the elite classes is equal to 4,406 million sestertii, the income of the free workforce is equal to 11,234 million sestertii, and the income allocated to enslaved labor is 1,080 million sestertii. Twenty-six percent of the collective income of the Empire was allocated to the elite classes, and 74% was allocated to the remainder of the population - the free workforce and the enslaved. Therefore, 26% of incomes were allocated to only 900,000 people, and the remainder of the employed population, approximately 43 million, shared 76%. In summary, 2% of the overall population in the Roman Empire managed one-fourth of the total wealth available in the Empire. The estimates proposed by Maddison, even if based on simplified assumptions, are considered plausible by Lo Cascio and Malanima (2009).
The works of Goldsmith, Temin, Maddison, and Milanovic[62] do not include an estimation of the income of long-distance traders. Therefore, through these results, it is difficult to identify the consistency of that part of trade activities to give us some information about opportunities for Smithian growth in the Roman world.
Looking at the wreckages discovered in the Mediterranean Sea and the evidence shown in the previous paragraph, we can argue that some seafaring groups of "large merchants" were present in the Roman world. In addition, Tchernia (2011b) quantified that the *annona* fleet was required to feed Rome each year during the first and second century AD and was composed of 786 ships with an average tonnage of 150-350 tons. This approximate estimation of the amount of wheat required to feed Rome's population, and of the amphorae in *Monte Testaccio* that was used to transport wine and oil, give us important suggestions about the size of merchant fleets in the Roman world. By contrast, it is more hazardous to establish how widespread these activities were in the overall Empire and to what degree the elite classes were involved in these businesses. In the following section, focusing on long-distance trade by sea, we attempt to fill this gap by using different archaeological findings, historiographical evidence, and comparative data extracted from different historical periods.
Starting with the studies of Maddison (2007), we know that the aggregate non-elite classes' income was equal to 12,314 million sestertii per year. Furthermore, we know that of this total amount, 1,080 million sestertii were spent on the subsistence of the enslaved, and 11,234 million sestertii were allocated to the free workforce. The aggregate elite classes' income was equal to 4,406 million sestertii, including 1,101 million sestertii allocated to 50,000 owners without a noble title or other qualifications, classified by Maddison as "other". Assuming that the per capita income of the long-distance trader in the Roman era was in an intermediate position between the aristocracy and free workforce, we can

[62] Milanovic (2007) presents in his estimation a group called "tradesmen", but this one is a very wide group that contains, presumably, any kind of merchant, from the largest one to the smallest. The same is true for Scheidel and Friesen (2009), although they estimated the incomes of a large general middle class. In any case, these results are very useful, giving us opportunities to comparison.

suppose that their income was similar to that of the decurions. Thus, we can suppose that the income share classified as "other" is more appropriate to represent a hypothetical average income of the large merchants in Roman times. Furthermore, because this share is estimated through a residual, we can posit that this amount may include the income share of large merchants. In addition, the share of "other" is potentially equal to 6.6% of the total GDP of the Empire—considering that the aggregate share of senators and knights is equal to 7.5%; thus, we can suppose that the relevance of this class, if confirmed, could be crucial for the macroeconomic equilibria of the Empire.

The relevance of long-distance trade by sea in the Roman world: a quantitative approach to "convergences"

To quantify the total share of income held by long-distance trade, we applied a variety of methods that provide a convergent range of estimates of these activities in the Roman world at the time of its putative economic growth peak, roughly around the 1st and 2nd century AD. Our methodology is based on a two-step procedure. First, we exploit the similarity between income distribution in the Roman era and in England and Wales in the late 17th century to estimate, by analogy, the hypothetical per capita income of Roman long-distance traders. Second, we use a cost-side approach to estimate, using different data sources, the size of the large merchant class population, the share of elite involvement, and the total income derived by merchant activity as a percentage of GDP. The different estimations of the population are derived through the application of several computation methodologies:

A) Roman wreckages in the Mediterranean Sea.
B) comparative estimation with other countries in different historical periods: England and Wales 1688, China 1880.
C) the potential capacity of the main harbor basins in the Roman world.

Step 1

The reason for examining the per capita income of English large merchants at sea in 1688 is twofold. The first concerns the adoption of the more optimistic initial assumption; indeed, since England is generally considered one of the major naval powers of early modern history[63], we can suppose that the per capita income of the English merchant was one the highest in comparative perspective. Therefore, using the English merchant's per capita income as the basis for estimating the per capita income of the Roman long-distance trader, we are probably reducing the risk of underestimating trade activities in the Roman world. We take this risk into account by using methods of estimation concerning archaeological findings that are, by definition, an underestimation. The second concerns the specific nature of the data; an intertemporal comparison is possible for the similarity in the income distribution between the two ages.
We choose to adopt Maddison's estimation because the proportion of the "other" class with respect to the total employed population in the Roman age is similar to the relative

[63]Davis (1962).

size of the long-distance trader class estimated in England and Wales in 1688. Furthermore, the per capita income of the "other" class is higher than the equivalent estimate by Milanovic (2007) and Scheidel and Frisien (2009). Since we suppose that the income of the large merchants was at the top of the range of middle-class incomes in the Roman era, the "other" class identified by Maddison is the more appropriate choice.
Starting with Lindert and Williamson's (1982) estimates from England and Wales in 1688, we know that the average income per year of a large long-distance trader was approximately ten times the income of a manufacturing worker. From these results, we know that the most important social classes in England and Wales in 1688, Temporal lords and Baronets, had the same income ratio with the manufacturing worker as senators and knights had with respect to free workers in the Roman Empire. In more detail, we observe 159 and 39 for the ratio of Temporal lord/Manufacturing worker and Baronet/Manufacturing worker, and 190 and 38 for the ratio of Senator/Free worker and Knight/Free worker (Table 4).

Roman Empire 14 A.D.	Income ratio	England and Wales 1688	Income ratio
Senator/Free worker	189.87	Temporal lord/Manufacturing worker	159.47
Knight/Free worker	37.97	Baronet/Manufacturing worker	39.47
Long-distance trader/Free worker	Unknown	Long-distance trader/Manufacturing worker	10.53

Table 4: Income ratio of social classes in the Roman Empire (14 A.D.) and England and Wales (1688). Source: Maddison (2007) and Lindert e Williamson (1982), our elaboration.

In this manner, we used as a comparative unit of measure the income of a manufacturing worker in England and Wales of the XVII century and the income of a free worker in Roman times. Thus, we can estimate two coefficients that represent the income ratio of the relevant social classes in Roman times in 14 A.D. and England and Wales in 1688. The coefficients are estimated by dividing the income ratio of the Roman Empire to the income ratio in England and Wales in 1688 in two different scenarios. In more detail, the coefficient of Scenario 1 will be obtained by the ratio between Senator/Free worker to Temporal lord/Manufacturing worker and the coefficient of Scenario 2 by the ratio between Knight/Free worker to Baronet/Manufacturing worker (Table 5).

	Coefficients Roman Empire/England and Wales	Income per capita Roman long-distance trader (Sestertii)
Scenario 1 (optimistic)	1.20	9,900
Scenario 2 (pessimistic)	0.90	8,000

Table 5: ratio in income ratio of the most relevant social classes in Roman times in 14 A.D. and England and Wales in 1688. Source: Maddison (2007) and Lindert and Williamson (1982), our elaboration.

Multiplying these coefficients by the ratio, approximately 10.5, between the income of the long-distance trader and the income of a manufacturing worker in England and Wales in 1688, we can estimate the average income of a long-distance trader in Roman times in two hypothetical scenarios.
In Scenario 1 (optimistic), the income of a Roman long-distance trader is increased by approximately 20% with respect to the corresponding English income, and in Scenario 2 (pessimistic), the income of a Roman long-distance trader is decreased by 10%. Thus, we can use the two scenarios as limits for a guess about the average yearly per capita income of a long-distance trader in Roman times, which we estimate is in the range of 8,000-9,900 sestertii (Table 5). This income is higher than a decurion's income but lower than a knight's income if we consider the optimistic scenario. Hypothetically, the position covered by this class corresponds, tendentially, to the bourgeoise classes of the modern age; thus, it is in an intermediate position between the aristocracy and the working class. Indeed, observing the estimates of Lindert and Williamson (1982) for England and Wales in 1688, we note that the large merchants are in an intermediate position between the high and low nobility (Table 6). Obviously, the income distribution that Lindert and Williamson edit is, for historical reasons, more diversified with respect to the Roman Empire estimate by Maddison and Goldsmith; however, the position of large British merchants is similar to our estimate for Roman times. In Scenario 2 (pessimistic), the situation is more nuanced since the per capita income of a Roman long-distance trader is lower than that of a decurion by placing the traders' group in a more modest social position. In this case, we mitigate the effect derived by comparison with the naval power of England and Wales in 1688.

Social classes	Average income (pounds)
Temporal lords	6,060
Spiritual lords	1,500
Baronets	1,300
Knights	800
Esquires	563
Gentlemen	280
Persons in offices	240
Persons in lesser offices	120
Persons in the law	154
Clergymen	72
Lesser clergymen	50
Persons science and liberal arts	60
Merchants and traders by sea	**400**
Lesser M. and Ts. by sea	200
Merchants and Ts. by land	400
Lesser M. and Ts. by land	200
Shopkeepers and tradesmen	45
Artisans and handicrafts	85
Manufacturing trades	38
Building trades	25
Mining	15
Freeholders	91
Lesser freeholders	55
Farmers	42.5
Naval officers	80
Military officers	60
Common seamen	20
Common soldiers	14
Laborers and outservants	15
Cottagers and paupers	6.5
Vagrants	2

Table 6: Income hierarchy according to Lindert and Williamson for England and Wales in 1688. Source: Lindert and Williamson (1982).

Step 2
Cost-side approach

Estimating the total income share held by long-distance trade in the Roman world requires not only the merchant's per capita income but also the total population of the long-distance trader class and the share of elite investment involved in these activities. To estimate all of this, we used a cost-side approach. In a very recent work, Broeakaert and Zuiderhoek (2020) estimated, very convincingly, shipping costs in the Roman world. The cost of shipping was estimated for different ships on the basis of tonnage, and it is comprehensive of shipbuilding cost, crew wages, victuals, repair costs, depreciation, and equipment. The estimations assume a ship's lifetime is between ten and twenty years.
We will adopt a very similar approach to estimating the costs for different ship tonnages.

We first defined the lifetime of the ship, which we allow to vary according to ship tonnage. In accordance with French (1991), we can state that a large ship built for long journeys using high-quality raw materials averaged a longer lifetime than smaller ships. Data derived from Classical times suggest that, at least in theory, a Greek warship, if well looked after, could survive for a very long time, approximately to 25 years or more. However, the longevity of a ship is correlated to the quality of raw materials used to build it (especially wood). Regardless of random events, such as shipwrecks, wars, fire, and so on, which could reduce the expected lifetime of a ship, we can suppose that with the increase in tonnages, the average longevity of the ship tends to rise as well, although not in a strictly proportional way. Following Broekaert and Zuiderhoek (2020), we know that the cost of ships per ton decreases as the tonnage increases. For example, for a 25-ton ship, the average cost per ton was approximately 4,600 sestertii, while for a 400-ton ship, the average cost per ton decreased to approximately 2,500 sestertii (see Table 7). Starting from this premise, given a certain amount of capital to invest and the same risk tolerance, we can argue that it would be more convenient to invest in a larger ship rather than in two or more smaller ships (having the same total tonnage). Of course, we are aware of the fact that at the micro-scale, when considering the tonnage of the ships he was willing to buy, a single merchant or ship owner took into account the nature of his business, which affected the type and size of the required vessels. Notwithstanding this, at a macro level, we can suppose that in general, the abovementioned tendency was reasonable. Therefore, we assume that the lifetime increases with increasing tonnage, starting from a 10-year lifetime for a ship in the range of 0-25 tons to 20 years for a ship in the range of 275-400 tons.

Broekeart and Zuiderhoek collected a large range of ship costs based on tonnage, but in our analysis, we prefer to adopt a narrower classification obtained through the semisum of the extreme values of ship tonnage ranges. This reclassification takes into account the larger heterogeneity of the types of vessels present in the lower tonnages with respect to the larger ones. Our classification is summarized in Table 7 (1st, 2nd, and 3rd columns).

Tonnage range	**Years lifetime** t_i	**Total average cost of a single ship for years lifetime and tonnages range (sestertii)*** C_{ti}	**Minimum number of owners required (optimistic scenario)** n_m	**Minimum number of owners required (pessimistic scenario)** n_m	**Share of the ship owned by merchants in optimistic scenario (%)**	**Share of the ship owned by merchants in pessimistic scenario (%)**
$0 < t < 25$	10	49,114	0,6	0.7	100 (0)	100 (0)
$25 \leq t < 50$	12	135,832	1,3	1.7	100 (0)	100 (0)
$50 \leq t < 100$	14	261,728	2,1	2.8	100 (0)	100 (0)
$100 \leq t < 175$	16	410,875	2,9	3.9	100 (0)	77 (23)
$175 \leq t < 275$	18	620,444	3,9	5.2	77 (23)	58 (42)
$275 \leq t \leq 400$	20	872,941	4,9	6.6	61 (39)	46 (54)

Table 7: From the 1st to 3rd columns of capital investment and operating costs based on tonnages and lifetime, columns 4th and 5th show the minimum number of merchants required to manage the ship, and columns 6th and 7th illustrate the percentage of the single ship owned by traders (in brackets the corresponding single ship property owned by elite members). Source for shipping costs: Broekaert and Zuiderhoek (2020).

*The total average cost is calculated starting with the estimations of Broekaert and Zuiderhoek, which are adjusted to take into account a depreciation rate proportionate to the lifetime.

Knowing the total average cost of a single ship, based on tonnage, lifetime, and the yearly income of a single trader (cumulated for each year ship lifetime), we can calculate the minimum capital requirement to start long-distance trade activity. Furthermore, if the minimum capital requirement is too high (i.e., for the largest ships), we know how many merchants are necessary to manage a single larger ship (Table 7, columns 4 and 5)[64].

Taking into account the trader's budget constraint (1), we estimate the minimum number of owners required for a single ship, thus implicitly assuming the opportunity for traders to associate in business, as can be deduced in some rare and fragmentary ancient evidence[65]. In fact, to gain access to ships, we can imagine strategies that provide partnerships between merchants and shipowners that engage in trade, or money pooling by entrepreneurs to purchase a ship jointly. Roman jurists wrote many chapters about the responsibility of partners involved, reflecting the frequency of these agreements[66]. However, this kind of partnership, even if perfectly plausible, finds little confirmation in the sources. On the other hand, shared ownership can be traced to legal sources and papyri[67].

In trader budget constraint (1), we assume that the single merchant employs all his savings, excluding subsistence consumption, in shipping investments. In addition, we hypothesize that each merchant chooses the most appropriate ship on the basis of his business purpose. For example, merchants that trade in marble will be oriented towards larger ships.

$$[(w_i - b_s)t_i]n_m \leq C_{ti} \tag{1}$$

where w_i represents the trader's income per year, b_s is the minimum subsistence level per year[68], n_m is the number of merchants associated, and t_i is the ship's lifetime. Therefore, block $(w_i - b_s)t_i$ is the trader's cumulative savings.

We discover that only one trader is required for smaller ships, while more traders are required as tonnage increases. In fact, smaller ships could be directly managed by a single owner who might be assisted by his relatives or hired sailors[69], while larger ships required different management methods. Applying comparative evidence, we know that in Genoa during the 12th century, there were never more than three simultaneous owners of a ship[70].

[64] In this paper, we do not account for the second-hand market for ships due to the lack of data.

[65] For example, if we assume that the bottomry loans behind the cargo mentioned in the *Mauzirus* was equal to 700,000 sesterces, we can suppose that some financiers joined, possibly in a *societas*, to collect this amount (Verboven 2020).

[66] Cerami and Petrucci (2010).

[67] P. Bingen 77, SB 14.11850, *Digesta* 14.1.1.25

[68] According to Goldsmith (1984) this level is equal to 380 sestertii for each family member. When we use b_s we mean the minimum subsistence level of all family members.

[69] Broekaert and Verboven (2020), p. 117.

[70] Krueger (2014).

This important issue sheds light on the fact that elite investment was probably necessary for the largest ships. Assuming the putative maximum number of merchants for each ship is 3, we discover that for the largest merchants, with ships of 100 to 400 tons in the pessimistic scenario and 175 to 400 tons in the optimistic scenario, a percentage of the investment must be made by an outside investor (Table 7, columns 6th and 7th, value in brackets). Given the social structure of the Roman world adopted by Maddison, comparative evidence[71], and the rare ancient sources that prove the involvement of Roman elite classes in trade activities, we determine that the most plausible assumption is that this external financer was an elite member of society (see also Malmendier, 2009). In using the term “external financing by elite class members”, we imply both direct involvement in trade activities, such as silent investors, or indirect provision of financial capital through middlemen[72].

We can write these passages in mathematical terms as follows:

$$
\begin{gathered}
[(w_i - b_s)t_i]n_m \leq C_{ti} \\
n_m^* = min(n_m, 3) \\
I_E + [(w_i - b_s)t_i]n_m^* \leq C_{ti} \\
I_E > 0 \text{ only if } n_m > n_m^*
\end{gathered}
\tag{2}
$$

where n_m^* represents the theoretical number of merchants less than or equal to 3, and n_m is the effective number of merchants required to manage the ship. If the effective value of merchants is higher than the theoretical value, we suppose the existence of elite investment, represented by I_E.

a) Estimation through shipwrecks

At the beginning of the period, we introduced the list of different estimation methods that we applied for this purpose. The first method is based on evidence from shipwrecks. However, as pointed out in the second paragraph, the shipwreck estimation is not free from issues, so the outcome of this estimation is not definitive; it will help us to build, together with other estimation methodologies, an order of magnitude for the trade flow in the Roman period.

To estimate the population of the long-distance trader group and the income share of elites involved in these activities in the Roman Empire, we build a proxy by starting with the number of wreckages discovered in the Mediterranean Sea. Based on the data

[71] Comparative data shows that in preindustrial Europe, elites were always involved in trade activities (Scammel 1962, Morgan 1993, Nightingale 2000).

[72] Roman merchants could not operate without credit and had to rely on middlemen to find creditors (Verboven 2020). Wealthy deposit bankers (*trapezitai*) providing services to merchants and shippers are attested to in late Hellenistic Delos (Gerillanus: I. Delos 1725, 1726, 1727). The *Sulpicii* tablet shows how elite wealth found its way into merchant ventures. A sheet of papyrus dating back to AD 149, probably from Alexandria, records a maritime loan of 47,160 sestertii made by two elite businessmen to four Phoenician ship-owning merchants from Askalon (SB 14.11.850).

collected by the Oxford Roman Economy Project[73], we know that 823 wreckages dated from century II B.C. to III century A.D (Figure 1) were discovered. Once the number of wrecks is known, we have to estimate what percentage of shipwrecks is connected to it. Through the archival documents related to insurance activity by some Genoese businessmen and the notarial sources of the Venetian Republic, we attempt to estimate the average percentage of shipwrecks in Roman times, by analogy. Using ledgers from the late early modern age, we can attempt to estimate the percentage of shipwrecks in the Roman age. In the period between 1575 and 1578, the ledgers of Agostino Spinola[74] reported that 30 out of 172 insurance contracts received compensation, and of these 30, almost 53% were for shipwrecks. In 1622–1624, based on the safety paperwork of Filippo Sanmichele[75], 27 out of 49 insurance contracts received compensation, and of these 27, almost 33% were for shipwrecks. Aggregating these two estimates, we obtain a percentage of shipwrecks equal to 11% of the total trips. Tenenti (1959) studied the notarial sources related to Venetian sea traffic in the period 1592–1609 by collecting a sample of 1,021 sea trips. Of this large sample, 36% ended in a shipwreck (Table 8).

Outcome of the trip	N°
Reached destination	376
Shipwreck	**368**
Captured	115
Robbed	83
Damaged	69
Burned	8
Adrift	1
Unknown	1
Total trips	**1,021**

Table 8: Summary of the results of the 1,021 trips reported by notarial sources of the Venetian Republic 1592-1609. Source: Tenenti (1959), our elaboration.

The significant differences in the shipwreck percentage between the first two sources with respect to the third source are because of the data collected. The first two sources are related to a single expert insurer who succeeded in minimizing risk; the third source observes a wider sample of insurers, including fewer experts, who evidently underestimated the risk due to the lack of specific quantitative tools (Table 9).

Sources	No. of trips	Shipwreck percentage α
Spinola (1575–78)	172	9%
Sanmichele (1622–24)	49	18%
Tenenti (1592–1602)	1,021	36%
Total	**1,242**	**32%**

Table 9: Comparison of the three sources: Spinola, Sanmichele, and Tenenti.

[73] Strauss, J. (2013). Shipwrecks Database. Version 1.0.
[74] A. S. G., fondo famiglie, S. n. 292.
[75] A. S. C. G., fondo Albergo dei Poveri, n. 670, c. 6

Aggregating these three shipwreck percentages, we obtain a percentage of shipwrecks equal to 32% of the total sea trips.
At this point in the analysis, we know the traders' budget constraint, the cost of shipping by tonnage, and the rate of sinking, but we do not know how many and what kind of ships sailed in the Mediterranean Sea during the Roman Age. Were they small ships or large ones? Or better, how many large ships were in the overall total? Ancient data are rare and fragmentary, and wreck analysis suffers from amphorae distortion which leads to an overestimation of larger tonnages at the expense of smaller ones. Therefore, in this case, we have to find other solutions. Exploiting comparative evidence, we know that in other historical periods, such as Byzantium, early modern Europe, and India, merchant fleets were composed mainly of small vessels under 100 tons[76]. Broekaert and Zuiderhoek argue that the major parts of vessels in the Roman world were located in the first tonnage range - under 75 tonnages[77].
Papyri from Egypt on river shipping, as in the dataset collected by Poll (1996), are very useful sources of data on ship tonnage distribution. The Poll dataset, based on papyri analysis, collects information on approximately 163 Nile ships. Indeed, 76% of ships collected by Poll fall into the 0-100 tonnage range, following Broekaert and Zauiderhoek and comparative evidence estimations (Table 10).

Tonnage range	**Ptolemaic ships (number)**	**Roman ships (number)**	**Total ships (number)**	**% total N_{di}**	**Ships estimated by wrecks (n=823) S_{ti}**
0 < t < 25	20	47	67	41	338
25 ≤ t < 50	7	22	29	18	146
50 ≤ t < 100	12	15	27	17	136
100 ≤ t < 175	8	2	10	6	50
175 ≤ t < 275	17	0	17	10	86
275 ≤ t ≤ 400	13	0	13	8	66
Total	**77**	**86**	**163**	**100**	**823**

Table 10: Tonnages of Nile ships based on Poll (1996); in column 6, the outcome of our wreck data using the Nile ship distribution of tonnages.

Assuming that the tonnage distribution of the Nile ships is sufficiently generalizable, we can use this sample, adding shipwreck data, to estimate the total Mediterranean sailing ships involved in the trade activities during the Roman Age. On the basis of this assumption, we argue that the wrecks discovered also follow this tonnage distribution.

Mathematically, we can describe this passage as follows:

$$S_{ti} = W_{tot}\frac{N_{di}}{100} \tag{3}$$

where W_{tot} represents the total wrecks discovered (n=823), N_{di} is the Nile ships' distribution, taking into account tonnage range, and S_{ti} is the hypothetical number of wrecks estimated assuming this distribution (see Table 10, column 6th).

[76]See footnote n°42.
[77]Broekaert and Zuiderhoek (2020), p. 112.

Knowing these parameters, it is now possible to estimate the total number of ships that are hypothetically sailed in the Mediterranean Sea in a specific time period, taking into account the heterogeneity of vessels and the probability of sinking. This modeling is based on the following assumptions: 1) at the end of each ship's life cycle, all ships were disused, and 2) the probability of sinking was constant for each life cycle of the ship.
In mathematical terms:

$$MS_{tot} = \frac{\frac{1}{\alpha}(S_{t(0-25)} + S_{t(25-50)} + ... + S_{t(275-400)})}{4} \tag{4}$$

where S_{ti} represents the putative total wrecks within each tonnage class, assumed through the Nile ship distribution, α is the probability of sinking, and MS_{tot} is the hypothetical average number of total ships sailed in the Mediterranean Sea over the course of a century. Substituting our data, the estimation is:

$$MS_{tot} = 643 \text{ ships}$$

Given 643 ships and knowing equation (2) and identities (5) and (6), we estimate the share of elites' investment (7) and the size of the long-distance trader group (8) as follows:

$$\sum_{1}^{6} C_{ti} N_{di} MS_{tot} = \sum_{1}^{6} I_E + \{[(w_i - b_s)t_i]n_m^*\} N_{di} MS_{tot} \tag{5}$$

$$(r_s N_s + r_k N_k + r_d N_d + r_0 N_0) - b_s \sum_{0}^{S} N = \sum_{1}^{6} \{C_{ti} - [(w_i - b_s)t_i]n_m^*\} N_{di} MS_{tot} \tag{6}$$

$$I_{Etot} = \sum_{1}^{6} \{C_{ti} - [(w_i - b_s)t_i]n_m^*\} N_{di} MS_{tot} \tag{7}$$

$$T_{tot} = \frac{\sum_{1}^{6}(C_{ti} - I_E) N_{di} MS_{tot}}{(w_i - b_s)t_i} \tag{8}$$

where T_{tot} represents the population of the long-distance trader group, r_s represents the senators' annual rents, r_k, r_d, r_o represents the knight, decurion, and other owners' annual rents, and N_s, N_k, N_d, N_o describes the population of senators, knights, decurions, and other owners required to manage ships when $n_m > n_m^*$.
In this case, we are assuming that the elite classes also spent all their savings, excluding subsistence consumption, on shipping activities. Subsistence level does not mean strict biological subsistence but a wider basket of goods and services, as supposed by Goldsmith (1984) and Maddison (2007). However, this implicitly means that the senator's consumption level is equal to the trader's level; this is a simplification of reality since it ignores Engel's law. These assumptions may seem very restrictive, but it follows our strategy of using the more optimistic initial assumptions.
Finally, we estimate that the hypothetical long-distance trader group was composed of approximately 1,000 members in the optimistic scenario, and 1,200 members in the pessimistic scenario. Furthermore, the share of elites' investment represents 17% of total trade activities in the optimistic scenario and 29% in the pessimistic scenario. In comparison,

these values are higher than elite investment in trade activities in late seventeenth-century England, which is estimated to be approximately 10%[78]. This result suggests that in the Roman world the role of elite members was stronger in trade activities in comparison with England level in 17th century, implying a more inequal society, where the economic power was more concentrated and where gains derived by trade activities getting also, to a great extent, into the hands of aristocratic. However, most of the long-distance trade activity was still controlled by traders, even if to a lesser extent with respect to England and Wales in 1688, implying that the totally gains of trade activities improved also the economic condition of the most modest classes. In addition, these outcomes imply that in the optimistic scenario, each member of elite classes spent 0.7% of his personal income to finance trade activity and 1.2% in pessimistic scenario (Table 11, column 5th). In a few words, we estimate that each decurion, senator, or knight in the Roman world spent a fraction (from 0.7 to 1.2%) of his income on shipping activities. Even if this fraction seems small, we have to remember that this is an average value, if you suppose, for example, that only 1 in 10 elite members is involved in trade activity, this implies that the value shifts to approximately 10% of his personal income, a much more considerable amount. Taking into account Maddison's GDP estimation, the total income share of trade activity, combining merchants and elite investments, is approximately 1% of the total Roman GDP in both scenarios (Table 11).

Ships (n=643)	**Long-distance trade group population (members)**	**Share of merchants' investment in long-distance trade (%)**	**Share of elites' investment in long-distance trade (%)**	**Share of total elites' income spent in long-distance trade (%)**	**Share of total long-distance trade income in Roman GDP**
Optimistic scenario	986	83%	17%	0.7	0.95
Pessimistic scenario	1,165	71%	29%	1.2	0.95

Table 11: Summary of estimations based on shipwreck data.

As stated in the previous sections of the paper, quantitatively estimating the role of Roman trade activities using only shipwreck analysis could be misleading. In addition, if we consider Tchernia's estimation of using the *annona* fleet to feed Rome with 786 ships reliable, our estimation is too low. For this reason, we decide to insert other estimation methods to corroborate our analysis.

b) comparative estimation with other countries in different historical periods: England and Wales 1688, China 1880.

To more accurately estimate the possible number of ships, merchant population size, and elite investments, we exploit the data available concerning the merchant groups of other historical periods and countries. The first comparison concerns the English long-distance trader group in 1688. As already mentioned at the beginning of this paragraph,

[78]See Davis (1962).

we suppose that England and Wales in 1688 represent one of the virtuous examples of naval power in modern history[79]. In light of this, we would like to explore the conditions under which the Roman world could have reached the level of the naval power of the English. Knowing that the total income share of long-distance trade by sea in England and Wales in 1688 was approximately 4.5% of total GDP, we try to simulate the same income distribution within the Roman Empire. In comparison, a total share of income equal to 4.5% of Roman GDP corresponds to more than 752 million sestertii. Therefore, how much should the elites' investment amount to in this case? How many ships and traders?

In mathematical terms:

$$MS_{EW} = \frac{\alpha_{4.5}}{\sum_1^6 C_{ti} N_{di}} \tag{9}$$

where MS_{EW} represents the total number of ships required to reach the GDP share of England and Wales and $\alpha_{4.5}$ is the wealth requirement to reach 4.5% of the total Roman GDP.
Substituting the result obtained by equation (9) in equation (8) and taking into account equations (7) and (2), we obtain the following estimations (Table 12).

Ships (n=3,063)	**Long-distance trade group population (members)**	**Share of merchants' investment in long-distance trade (%)**	**Share of elites' investment in long-distance trade (%)**	**Share of total elites' income spent in long-distance trade (%)**	**Share of total long-distance trade income in Roman GDP**
Optimistic scenario	4,173	83	17	3.7	4.5
Pessimistic scenario	5,544	72	28	6.1	4.5

Table: 12: Summary of estimations based on England and Wales 1688 comparison.

The second comparison is based on a less optimistic assumption: the long-distance trade activity level of China in 1880. China of that time after centuries of isolationism was experience a declining phase. The country had almost succumbed to the western colonial powers and was even forced to suffer situations such as the Opium wars. The Chinese economy of the late nineteenth century was described, using the words of Mark Elvin, as a "high-level equilibrium trap". In these words, Elvin emphasized that the trouble that China's primarily agricultural economy experienced in accommodating population growth over the course of the late nineteenth and early twentieth centuries[80]. Dwight Perkins estimates 0.6 percent to be the annual agricultural and population output growth rate for this period; this estimate supports the view of a no-growth economy[81]. Therefore, despite the much temporal distance that separates China in 1880 from the Roman

[79] ibidem.
[80] Elvin (1972).
[81] Perkins (1969).

world, we can suppose that this economy was more similar to ancient economies than England and Wales in 1688. Not surprisingly, Milanovic's estimates argued that the GDI per capita - in 1990 Geary-Khamis PPP dollars – for China in 1880 was lower by about 40% in comparison with Roman Empire one[82]. Knowing that the total income share of long-distance trade activity in China in 1880 was approximately 1% of total GDP[83], we try to simulate the same income distribution within the Roman Empire. In comparison, a total share of income equal to 1% of Roman GDP corresponds to more than 167 million sestertii. Using the same methodology shown above, we obtain the following estimations (Table 13).

Ships (n=681)	**Long-distance trade group population (members)**	**Share of merchants' investment in long-distance trade (%)**	**Share of elites' investment in total long-distance trade (%)**	**Share of total elites' income spent in long-distance trade (%)**	**Share of total long-distance trade income in Roman GDP (%)**
Optimistic scenario	653	83	17	0.7	1
Pessimistic scenario	1,233	74	26	1.1	1

Table 13: Summary of estimations based on the 1880 comparison in China.

c) Potential capacity of the main harbor basins in the Roman world

The last estimation method is based on port infrastructures. For shipwreck findings, estimation through harbors also suffers from several problems. As argued by Houston (1988), the archeological findings of roman harbors probably overestimate the role of the main port infrastructure, underestimating the role of the smallest one. In addition, we cannot suppose that trade activities occurred only in harbors during the ancient era, and we have evidence that "harbors" without infrastructures were where ships docked[84]. Many harbors were probably built out of wood, a perishable material, leaving no marks for identification. However, in recent years, quantitative works concerning Roman harbors have increased, collecting many data about harbor size or wharfage length[85]. Another problem concerns the estimation of ship numbers through harbor size. Unfortunately, we do not have any accurate data about this, and we have only some fragmentary ideas about the potential capacity of harbor basins. The only data we can exploit, to the best of our knowledge, is a hypothetical statement about *Portus* basins and their potential capacity: approximately 500 ships for an area of 234 ha. We will then assume that the other Roman ports have the same capacity expressed in ships for hectares. This kind of

[82] Milanovic (2007), p. 76.

[83] Milanovic (2007, pp. 48) estimated that the mercantile activity in China in 1880 represented the 4.6% of total Chinese disposable income. Ojala and Tenold (2017) evaluated that in 1870s the Asian Sea-trade represented around a thirteenth of the total Asian trade. Putting together these estimates we can assume, very optimistically stated, that in China the long-distance trade was equal to about 1% of the total Chinese GDP.

[84] Houston (1988), pp. 560-564.

[85] Schörle (2011).

rough estimation has to be treated with much caution; however, it could be useful, along with the other estimations, in improving our quantitative analysis. Exploiting the dataset collected by Schörle (2011)[86], we roughly estimate the aggregate potential capacity of the 18 main Roman harbors. This estimation does not take into account the heterogeneity between ship tonnages and between harbor structures. The estimations are summarized in Table 14.

Ships (n=1,469)	**Long-distance trade group population (members)**	**Share of merchants' investment in long-distance trade (%)**	**Share of elites' investment in long-distance trade (%)**	**Share of total elites' income spent in long-distance trade (%)**	**Share of total long-distance trade income in Roman GDP (%)**
Optimistic scenario	2,246	83	17	1.6	2.2
Pessimistic scenario	2,659	72	28	2.7	2.2

Table 14: Summary of estimations based on harbor basing estimation.

Comparison between estimates

Before trying to extract some conclusions about our estimation, we remember the initial assumptions. The per capita income estimated for Roman merchants is probably higher with respect to other historical periods; however, the pessimistic scenario partially mitigates this effect. The savings rate of the elite classes is assumed to be very high because we include a very low consumption level and no other available investment choices. In a few words, we supposed the upper classes to be very thrifty.

In light of these assumptions, we note that the estimation derived by the comparison of England and Wales is probably too high. In this case, we calculated that each member of elite classes should have invested their own income share, ranging between 3.7% and 6.1%, in shipping activities. Using a similar argument exposed in the previous pages, if you suppose that 1 in 10 elite members was involved in shipping activities, the values derived from the England and Wales comparison imply an amount from 37% to 61% of personal income spent on shipping activities. In addition, taking into account that the level of consumption of these activities was probably higher, the share of income effectively involved in shipping activities was more consistent than the estimated share. In light of these observations, we can argue that, almost, in theory, this level of trade activity was hardly sustainable unless elite classes were very involved in commercial business. On the other side of the spectrum, if we take into account that just the size of the *Annona* fleet estimated by Tchernia was approximately 800 ships, we can consider the estimation based on shipwrecks (643 ships) to be a low estimate. The low estimate is probably due to the underestimation of the shipping activities implicitly contained in the shipwreck evidence.

[86] See Table 2, pp. 14-15 of this work.

		Long-distance trade group population (members)	Share of merchants' investment in long-distance trade (%)	Share of elites' investment in long-distance trade (%)	Share of total elites' income spent in long-distance trade (%)	Share of total long-distance trade income in Roman GDP
Shipwrecks (n=643)	Optimistic scenario	986	83	17	0.7	0.95
	Pessimistic scenario	1,165	71	29	1.2	0.95
England and Wales 1688 (n=3,063)	Optimistic scenario	4,173	83	17	3.7	4.5
	Pessimistic scenario	5,544	72	28	6.1	4.5
China 1880 (n=681)	Optimistic scenario	653	83	17	0.7	1.0
	Pessimistic scenario	1,233	74	26	1.1	1.0
Roman harbors (n=1,469)	Optimistic scenario	2,246	83	17	1.6	2.2
	Pessimistic scenario	2,659	72	28	2.7	2.2

Table 15: comparative estimations.

We can apply a very similar argument to the estimate based on the comparison to China; indeed, if we take into account Tchernia's estimation of the fleet used to feed Rome, the comparison with China could not be sufficient. In any case, we can observe that both estimations based on shipwrecks and the situation in China are similar to Tchernia's estimation, even if they are downward biased. This means that the order of magnitude of the two estimations is quite convergent. In fact, if we consider an *annona* fleet of 786 ships, this does not mean that the total merchant fleet in the Roman Empire was very different in size from this fleet. In fact, the *annona* of Rome was a colossal enterprise, unparalleled in the Roman world and in many following centuries. In addition, nothing prevents a great fleet from being used for other shipping trade activities during the year. Finally, introducing the harbors' estimation, the total number of ships and the amount of average elite investments seem the most plausible, if this estimation is reliable. In fact, this estimation is reasonable whether looking at Tchernia's estimation or if we observe the average investment estimation for the elite classes.
Last, if we combined the estimates derived using Shipwrecks analysis, the comparison to China, the harbor-based estimation, and the *annona* fleet size hypothesized by Tchernia, the range of estimations became narrower and, to some extent, more precise, from 643 to 1,469 ships. This range corresponds to a GDP share of total sea-trade activities that goes from approximately 1-2.2% of the total Roman GDP, and a share of elite investment in these activities that goes from 0.7-1.6% in the optimistic scenario and from 1.1-2.7% in the pessimistic scenario. Naturally, we are not absolutely sure of the reliability of these estimations; however, it seems reasonable to hypothesize that trade activities in the Roman world held a share of total GDP between 1% and 2.2% and that the involvement of elite classes was strong spread. Even if these values are lower than England and Wales one in 17th century, they are still surprisingly high. In fact, they are similar to those of some countries of the early 19th century, for example the value of exports in percentage

of GDP for Chile in 1827 was around 2.4%[87]. However, by exploiting comparative data of late seventeenth-century England we observe that the share of Roman elites' investment estimated in both scenarios is considerably greater than the corresponding England level. In England, the share of elites in trade activities was approximately 10%, while in the Roman world it ranged from 17% in the optimistic scenario to 28% in the pessimistic scenario. These results highlight that Roman world was a more inequal society respect to England of 17th century, where a relevant part of long-distance trade activities was into the hands of aristocracy.

Conclusions

On the basis of our estimations, we can suggest some conclusions. First, we have to reject the idea that trade was a marginal economic activity in the Roman world.
Second, high levels of trade activity as experienced in early modern England are not very probable. Considering this last scenario, the high level of elite involvement in trade is hardly sustainable considering the income redistribution of the Roman world.
Third, the convergent estimations obtained through shipwreck analysis and in the comparison with China seem reasonable; the share of elite investment is acceptable, and the order of magnitude is quite similar.
Fourth, estimations derived by harbor infrastructures, which should be considered with caution, seem even to raise the estimates in the comparison with China and the estimation of shipwrecks.
Taking into account Tchernia's estimation of 786 ships used to feed the Roman population, the harbor-based analysis seems to give the most plausible result. However, another important difference that emerges in our analysis is the central role of elite investment in trade activities. As emphasized by the scenario-based approach, a difference in Roman traders' per capita income implies important changes in income distribution, leading us to think that the level of elite involvement in the trade business was a very important variable. However, by exploiting the comparative data of late seventeenth-century England, the share of Roman elites' investments estimated by both scenarios is considerably greater. In light of all these outcomes, we posit that long-distance trade in the Roman world held a share of the total GDP that ranges from 1% to 2.2% but favors the supremum of this range. Therefore, the most plausible scenario is a society with a good level of market integration, and consequently high level of trade activities. In addition, we can suppose that if Roman world truly experienced these levels of long-distance trade, the level of division of labor that could be reached would be similar to that of civilizations much more recent, as Chile in 1827. In fact, taking into account the extension that the Roman Empire reached at the turn of 2nd century AD, the variety of climate conditions within it, the lowering of transaction costs - following *Pax Romana* - a widespread and intensive sea trade leads the emergence of high level of regional specialization able to trigger Smithian growth. Therefore, without forgetting the limits imposed by technology and energy sources available at that time, we can conclude that the Roman world was an exception of the Malthusian model, not only thanks to its extractive capacity linked with military power, but also for the existence of extensive and integrated markets. However,

[87] Fouquin and Hugot, (2016).

the benefits derived by Smithian growth were largely "captured" by the elite members, even if we can suppose that they allowed also an increase of well-being for the most modest social classes, as traders and everyone else involved in these businesses. In fact, even if the results highlight a strong involvement of the elite classes in trade activities, the role of traders was still predominant. In conclusion, Roman world experienced a considerable Smithian growth, which generally improved well-being, even if this probably increased inequality within Roman society.

References

Allen, R. C. (2003). Progress and poverty in early modern Europe, *Economic History Review*, 56:402-43.
Andreau, J. (2020), Capital and Investment in the Campanian Tablets, in Paul Erdkamp, Konread Verboven, Arjan Zuiderhoek (eds), *Capital, Investment, and Innovation in the Roman World*. Oxford University Press.
Ashraf, Q., Galor, O, (2011). Dynamic and stagnation in the Malthusian epoch, *American Economic Review*, 101: 2003-41.
Aubert, J. J. (2010). Productive investments in agriculture: instrumental fundi and peculium in the later Roman Republic, in J. Carlsen and E. Lo Cascio (eds.), *Agricoltura e scambi nell'Italia tardo-repubblicana.*
Bang, P. F. (2007). Trade and empire. In search organizing concepts for the roman economy. *Past Present*, Oxford, https://doi.org/10.1093/pastj/gtl031
Bateman, V. (2011). The evolution of markets in early modern Europe, 1350–1800. A study of wheat-prices, *Economic History Review* 64: 447–71.
Bintliff, J. (2014). Settlement patterns. In: Horden, P., Kinoshita, S. (Eds.), *A Companion to Mediterranean History*. Wiley-Blackwell, Malden.
Boserup, E. (1965). *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. Allen Unvin, London.
Bowman, A., Wilson, A. (2013). *The Roman Agriculture Economy. Organization, Investment, Production*. Oxford Studies on the Roman Economy, Oxford.
Bresson, A. (2016). *The Making of the Ancient Greek Economy: Institutions, Markets, and Growth in the City-States*, Princeton, NJ: Princeton University Press.
Bringmann, K. (2003). *Zur Überlieferung und zum Entstehungsgrund der lex Claudia de nave senatoris*, Klio 85: 312-21.
Broekaert, W., Zuiderhoek, A., (2020). Capital goods in the Roman Economy, in Paul Erdkamp, Konread Verboven, Arjan Zuiderhoek (eds), *Capital, Investment, and Innovation in the Roman World*. Oxford University Press.
Brun J. P. (2004). *Archéologie du vin et de l'huile dans L'Empire romain*. Paris: Editions Errance.
Brun J. P. (2005). *Archéologie du vin et de l'huile en Gaule romaine*. Collections des Hespérides. Paris: Editions Errance.
Buchanan, J. M., Yong, J. Y. (2002). Globalization as Framed by the Two Logics of Trade. *The Independent Review* 6(3): 399–405.
Casson, L. (1956). The size of ancient merchant ships, in *Studi in onore di A. Calderini e R. Paribeni*, Vol. 1, Milan, 231-8.

Casson, L. (1971). *Ships and Seamanship in the Ancient World.* Princeton, NJ.
Cerami, P., Petrucci, A. (2010). *Diritto commerciale romano. Profilo storico.* Giappichelli editore. Turin.
Chilosi, D., Murphy, T. E., Studer, R., Coşkun Tunçer, A. (2013). Europe's many integrations. Geography and grain markets, 1620–1913, *Explorations in Economic History* 50: 46–68.
Clark, G. (2007). *A Farewell to Alms. A Brief Economic History of the World.* Princeton, NJ.
Clemente, G. (1983). Il plebiscito Claudio e le classi dirigenti romane nell'età dell'imperialismo, *Ktéma* 8: 253-9.
D'Arms, J. H. (1981). *Commercial and Social Standing in Ancient Rome.* Cambridge University Press, Cambridge.
Dark, K. (2001). Proto-industrialization and the Economy of the Roman Empire. *Montignac.*
Das Gupta, A. (1985). Indian merchants and the Western Indian Ocean: The early seventeenth century, *Modern Asian Studies* 19.3: 481-99.
Davis, R. (1962). *The Rise of the English Shipping Industry in the Seventeenth and Eighteenth Centuries*, St John's Newfoundland: International Maritime Economic History Association.
Duncan-Jones, R. P. (1977). Giant cargo-ships in Antiquity, *CQ* 27.2: 331-2.
Duncan-Jones, R. P. (1982). *The Economy of the Roman Empire: Quantitative Studies.* Cambridge University Press, Cambridge.
Economou, E.M., Kyriazis, N. A. (2021). Achieving Sustainable Financial Transactions under Regimes without a Central Bank—An Intertemporal Comparison, *Sustainability*, 13(3), 1071.
Economou, E. . L., Kyriazis, N.C, Kyriazis, N.A. (2021), Money Decentralization under Direct Democracy Procedures. The Case of Classical Athens, *Journal of Risk and Financial Management*, 14(1), 30; https://doi.org/10.3390/jrfm14010030.
Erdkamp, P. (2001). Beyond the Limits of the 'Consumer City'. A Model of the Urban and Rural Economy in the Roman World. *Historia: Zeitschrift für Alte Geschichte*, Bd. 50, H. 3, pp. 332-356.
Erdkamp, P. (2005). *The Grain Market in the Roman Empire: A Social, Political and Economic Study.* Cambridge University Press, Cambridge.
Erdkamp, P. (2015). Agriculture, Division of Labour, and the Paths to Economic Growth. In *Ownership and Exploitation of Land and Natural Resources in the Roman World*, Oxford University Press.
Erdkamp, P. (2016). Economic growth in the Roman Mediterranean world: An early good-bye to Malthus?, *Explorations in Economic History* 60 1-20, https://doi.org/10.1016/j.eeh.2015.11.004.
Erdkamp, P. (2020). Population, Technology, and Economic Growth in the Roman World, in P. Erdkamp, K. Verboven, A. Zuiderhoek (eds), *Capital, Investment and Innovation in the Roman World.* Oxford University Press.
Erdkamp, P., Verboven, K., Zuiderhoek, A. (2020). *Capital, Investment and Innovation in the Roman World.* Oxford University Press.
Elvin, M. (1972). *The Pattern of the Chinese Past*, Stanford University Press, Stanford.

Étienne, R., Mayet, F. (2000). *Le vin hispanique.* Paris.
Finley, M. I. (1973). *The Ancient Economy.* University of California Press, Berkley.
Finley, M. I. (1999). *The Ancient Economy, updated edition with new foreword by I. Morris.* Ann Arbor, MI.
Fouquin, M., Hugot, J. (2016). Two Centuries of Bilateral Trade and Gravity Data: 1827-2014, *CEPII Working Paper* 2016-14, May 2016, CEPII
Foxhall, L. (1990). The Dependent Tenant: Land Leasing and Labour in Italy and Greece. *The Journal of Roman Studies*, Vol. 80, pp. 97-114.
Frankel, R. (1999). *Wine and Oil Production in Antiquity in Israel and Other Mediterranean Countries.* Sheffield: Sheffield Academic Press.
French, C. J. (1991). The longevity of ships in colonial trade: Some further evidence, *International Journal of Maritime History* 3.1: 155-63.
Garnsey, P., Saller, R. (2014). *The Roman Empire - Economy, Society and Culture.* Bloomsbury, London.
Gibbins, D. (2001). Shipwrecks and Hellenistic trade, in Z. H. Archibald, J. K. Davies, V. Gabrielsen, and G. J. Oliver (eds), *Hellenistic Economies.* London New York, 273-312.
Goldsmith, R. W. (1984). An Estimate of the Size and Structure of the national product in the Early Roman Empire. *Review of Income and Wealth* 30.3: 263-288.
Goldstone, J.A. (2002). Efflorescence and economic growth in world history. Rethinking the "Rise of the West" and the Industrial Revolution, *Journal of World History*, 13:323-89.
Goodchild, H. (2006). Modelling Roman demography and urban dependency in central Italy, in B. Croxford et al., TRAC 2005. *Proceedings of the fifteenth annual Theoretical Roman Archaeology Conference*, Oxford: Oxbow books.
Goodchild, H. (2009). Modelling the productive landscape of the middle Tiber Valley, in F. Coarelli and H. Patterson (eds), Mercator Placidissimus. The Tiber Valley in Antiquity. Rome, 769–96. Goodchild, H., Witcher, R. (2010). Modelling the agricultural landscapes of republican Italy, in J. Carlsen and E. Lo Cascio (eds), *Agricoltura e scambi nell'Italia tardo repubblicana.* Rome Bari, 187–220.
Grantham, G. (1993). Division of labour. Agricultural productivity and occupational specialization in pre-industrial France. *Econ. Hist. Rev.* 46, 478–502.
Grantham, G. (1999). Contra Ricardo. On the macroeconomics of preindustrial economies. *Eur. Rev. Econ. Hist.* 2, 199–232.
Hansen, G. D., Prescott, E. C. (2002). Malthus to Solow. *American Economic Review* 92.4: 1205-1217.
Homer, S., Sylla, R. (1963). *A History of Interest Rate.* Wiley. Haboken, New Jersey.
Hopkins, K. (1978). Economic Growth and Towns in Classic Antiquity, in Philip Abrams and E. A. Wrigley (eds), *Towns in Societies: Essays in History and Historical Sociology.* Cambridge University Press, London.
Hopkins, K. (1980). Taxes and Trade in the Roman Empire (200 B.C. – A.D. 400).*The Journal of Roman Studies*, Vol. 70, pp. 101-125.
Houston, G. W. (1988). Ports in perspective. Some comparative materials on Roman merchant ships and ports, *American Journal of Archeology* 92: 553-64.
Jongman, W. M. (2006). The rise and fall of the Roman Economy. Population, rents and entitlement, in P. F. Bang, M. Ikeguchi, H. G. Ziche (eds), *Ancient Economies, Modern*

Methodologies. Archaeology, Comparative History, Models and Institutions. Edipuglia, Bari.
Kehoe, D. (1997). *Investment, Profit, and Tenancy: The Jurists and the Roman Agrarian Economy.* Ann Arbor, MI.
Kehoe, D. (2007). *Law and Rural Economy in the Roman Empire.* Ann Arbor, MI.
Kehoe, D. (2012). Contract labour, in W. Scheidel (ed.), *The Cambridge Companion to the Roman Economy.* Cambridge, 114-30.
Kelly, M. (1997). The Dynamics of Smithian Growth. *Quarterly Journal of Economics* 112(3): 939–964. doi:10.1162/003355397555398.
Kessler, D., Temin, P. (2007). The organization of the grain trade in the Early Roman Empire, *Economic History Review*, 60, 2, pp. 313-332.
Goldewijk K., Geertje, J. (2013). The relation between stature and long bone length in the Roman Empire, *Research Report EEF-13002*, University of Groningen, Research Institute SOM (Systems, Organisations and Management).
Koepke, N., Baten, J. (2005). The Biological Standard of Living in Europe during the Last Two Millennia. *European Review of Economic History*, 9, 61-95.
Kron, G. (2014). Comparative evidence and the reconstruction of the ancient economy: Greco–Roman housing and the level and distribution of wealth and income. In: de Callataÿ, F. (Ed.), *Quantifying the Greco–Roman Economy and Beyond.* Edipuglia, Bari, pp. 123–146.
Krueger, H. C. (2014). Navi e proprietà navali. *Società Ligure di Storia Patria.*
Lampe, M., Sharp, P. (2019). Accounting for the wealth of Denmark: a case study of Smithian growth using the emergence of modern accounting in Danish dairying, *The European Journal of the History of Economic Thought*, 26:4, 659-697, DOI:10.1080/09672567.2019.1634751
Lewit, T. (2020). Innovation, in Oil and Wine Presses in the Roman Empire. In: Erdkamp P., Verboven K. and Zuiderhoek A. (ed.), *Capital, Investment, and Innovation in the Roman World.* Oxford: Oxford University Press.
Lindert, P. H., Williamson, J. G. (1982). Revising England's Social Tables, 1699-1812. *Explorations in Economic History*, 19, pp. 385-408.
Lo Cascio, E. (1991). Fra equilibrio e crisi, in A. Schiavone (eds), *Storia di Roma*, II, 2. Einaudi, Torino.
Lo Cascio, E. (edited by), 2000. *Roma Imperiale.* Carocci Editore, Roma.
Lo Cascio, E. (2003). Innovazione tecnica e progresso economico nel mondo romano. *Proceedings of the Capri Meetings on the history of the ancient economy*, Capri April 13-16.
Lo Cascio, E. (2009). *Crescita e declino – Studi di storia dell'economia romana.* L'Erma di Bretschneider, Roma.
Lo Cascio, E., Malanima, P. (2009). GDP in Pre-Modern Agrarian Economies (1-1820 AD). A Revision of the Estimates. *Rivista di Storia Economica*, Società editrice il Mulino, issue 3, pp. 391-420.
Lo Cascio, E., Malanima, P. (2014). Ancient and pre-modern economies GDP in Roman Empire and Early Modern Europe, in F. de Callataÿ (eds), *Quantifying the Greco-Roman Economy and Beyond*, Edipuglia, Bari.
MacIntosh Turfa, J., Steinmayer A. G., Jr. (1999). The Syracusia as a giant cargo vessel, *International Journal of Nautical Archeology* 28.2: 105-25.

Malmendier, U. (2009). Law and Finance "at the Origin". *Journal of Economic Literature*, 47 (4): 1076-1108. DOI: 10.1257/jel.47.4.1076.

Makris, G. (2002). Ships, in A. E. Laiou (ed.), *The Economic History of Byzantine. From the Seventh through the Fifteenth Century*. Washington, DC, 91-100.

Maddison, A., (2007). *Contours of the World Economy 1-2030 A.D.* Oxford University Press, Oxford.

Malthus, T. (1798). *Saggio sul principio della popolazione.* Stamperia dell'Unione Tipografico-Editrice (1868), reprint.

Manacorda, D. (1989). Le anfore dell'Italia repubblicana: aspetti economici e sociali. *Publications de l'École Française de Rome*.

Marichal, R. (1988). Les graffites de la Graufesenque. *Gallia Supplément* 47, Paris.

Milanovic, B., Lindert, P.H., Williamson, J.G. (2007). Measuring ancient inequality. *National Bureau of Economic Research*, working Paper 13550,
http://www.nber.org/papers/w13550.

Morgan, K. (1993). Bristol West India merchants in the eighteenth century. *Transaction of the Royal Historical Society* 3: 185-208. Nightingale, P. (2000). Knights and merchants: Trade, politics and the gentry in late Medieval England, *Past and Present* 169: 36-62. North, D. C., Weingast B. R. (1989). Constitutions and Commitment: The Evolution of Institutions Governing Public Choice in Seventeenth-Century England. *The Journal of Economic History*, Vol. 49. No. 4, pp. 803-832. North, D. (1991). *Institutions, Institutional Change and Economic Performance.* Cambridge University Press, Cambridge.

North, D. (1994). Economic Performance Through Time. *American Economic Review*, 84(3): 359-368.

North, D. (2005). *Understanding the Process of Economic Change.* Princeton University Press, Princeton, N.J.

Oddo, L., Le Donne, A. (2020). Pandemie e rivoluzioni: il caso della "Peste" Antonina. *Culture della Sostenibilità*, n°26. DOI 10.7402/CdS.26.002.

Ojala, J., Tenold, S. (2017). Maritime Trade And Merchant Shipping: The Shipping/Trade Ratio Since The 1870s. *The Journal of Maritime History*, 29(4), 838-854.

Ortman, S. G., Lobo, J. (2020). Smithian Growth in a Non-Industrial Society, *Science Advances*, 6: eaba5694.

Panella, C., Tchernia, A. (1994). Produits agricoles transporte´s en amphores: L'huile et surtout le vin, in *L'Italie d'Auguste a' Dioclétien.* Rome, 145–65.

Parker, A. J. (1990a). Classical antiquity: the maritime dimension, Antiquity. *A Quarterly Review of Archaeology* 64 (June): 335–46.

Parker, A. J. (1990b). The pattern of commerce as evidenced by shipwrecks, in T. Hackens and M. Miró (eds), PACT 27, *Le commerce maritime romain en Méditerranée occidentale/ El comercio maritime romano en el Mediterráneo occidental*: 147–68.

Parker, A. J. (1992a). *Ancient Shipwrecks of the Mediterranean and the Roman Provinces*, British Archaeological Reports International Series 580. Oxford.

Parker, A. J. (1992b). Cargoes, containers and stowage: the ancient Mediterranean. *International Journal of Nautical Archaeology* 21 (2): 89–100.

Peacock, D.P.S, Williams, D.F. (1986). *Amphorae and the Roman economy, an introductory Guide.* London New York, 54-66 on long-distance movement of goods in amphorae.

Pedersen, M., Riani, C., Sharp, P. (2021). Malthus in preindustrial Northern Italy? *Journal of Population Economics*, https://doi.org/10.1007/s00148-020-00812-3.
Perkins, D. H. (1969). *Agricultural development in China*, 1368- 1968. Chicago: Aldine Press.
Persson, K. G. (2008). The Malthusian delusion. *European Review of Economic History*, 12:165-73.
Persson, K. G. (2010). *An Economic History of Europe Knowledge, institutions and growth*, 600 to the present. Cambridge: Cambridge University Press.
Persson, K. G., Sharp, P. (2015). *An Economic History of Europe. Knowledge, Institutions and Growth, 600 to the Present.* 2nd ed. Cambridge: Cambridge University Press.
Polanyi, K., et al. (1957). *Trade and Markets in the Early Empires.* Free Press and Falcon's Wing Press.
Polanyi, K. (1968). *Primitive, Archaic and Modern Economies.* Doubleday Company, Inc.
Poll, I. J. (1996). Ladefähigkeit und Grösse der Nilschiffe. *Archiv für Papyrusforschung und verwandte Gebiete* 42: 127-38.
Pomey, P., Tchernia, A. (1978). Le tonnage maximum des navires de commerce romains. *Archaeonautica* 2: 233-52.
Rathbone, D. (2003). The financing of maritime commerce in Roman empire, I-II AD, in E. Lo Cascio (ed.), *Credito e moneta nel mondo romano.* Atti degli incontri capresi di storia dell'economia antica (Capri 12-14 ottobre 2000). Bari, 197-229.
Ronin, M. (2020). Funding Irrigation. In: Erdkamp P., Verboven K. and Zuiderhoek A. (ed.), *Capital, Investment, and Innovation in the Roman World.* Oxford: Oxford University Press.
Rostovtzeff, M. (1957). *The Social and Economic History of the Roman Empire.* Oxford University Press.
Sachs, J. D. (2020). *Terra, popoli, macchine. Settantamila anni di globalizzazione.* Luiss University Press.
Scammell, G. V. (1962). Shipowning in England c. 1450-1550. *Transaction of the Royal Historical Society* 12: 105:22.
Scheidel, W. (2009). In search of Roman Economic Growth. *Journal of Roman Archaeology*, DOI: https://doi.org/10.1017/S1047759400020584
Scheidel, W., Friesen, S. J. (2009). The size of the Economy and the Distribution of Income in the Roman Empire. *The Society for the Promotion of Roman Studies.* Scheidel, W., Morris, I., R. Saller, R. (2007). *The Cambridge Economic History of the Greek –Roman World.* Cambridge University Press, Cambridge.
Schörle, K. (2011). Constructing port hierarchies: harbours of the central Tyrrhenian coast. In D. Robinson and A. Wilson (eds), *Maritime Archaeology and Ancient Trade in the Mediterranean*:93–106. Oxford, Oxford Centre for Maritime Archaeology.
Schumacher, R. (2012). Adam Smith's Theory of Comparative Advantage and the Use of Doxography in the History of Economics. *Erasmus Journal for Philosophy and Economics* 5(2): 54–80. doi:10.23941/ejpe.v5i2.105.
Schumacher, R. (2016). Adam Smith and the 'Rich Country–Poor Country' Debate: Eighteenth-Century Views on Economic Progress and International Trade. *European Journal of the History of Economic Thought* 23(5): 764–793.

Sealey, P. R. (1985). *Amphoras from the 1970s Excavations at Colchester Sheepen* (BAR British Series 142). Oxford.
Smil, V. (2010). *Why America Is Not a New Rome.* Cambridge, Massachusetts; London, England: The MIT Press. doi:10.2307/j.ctt9qf8v. Sylos Labini, P. (1984). *Le forze dello sviluppo e del declino.* Editori Laterza, Bari.
Sylos Labini, P. (1986). *Le classi sociali degli anni '80.* Editori Laterza, Bari.
Tchernia, A. (2006). La crise de l'Italie impe ́riale et la concurrence des provinces, *Cahiers du Centre de Recherches historiques* 37: 137–56.
Tchernia, A. (2007). Le plebiscitum Claudianum, in J. Andreau and V. Chankowski (eds), *Vocabulaire et expression de l'économie dans le monde antique.* Bordeaux, 253-78.
Tchernia, A. (2011a). *The Romans and Trade.* Oxford University Press, Oxford.
Tchernia, A. (2011b). Staple Provisions for Rome, in A. Tchernia (ed.), *The Romans and Trade.* Oxford University Press, Oxford, pp. 188-196.
Temin, P. (2006a). The Economy of the Early Roman Empire. *Journal of Economic Perspectives*, Vol. 20, Number 1, p. 133-151, DOI: 10.1257/089533006776526148.
Temin, P. (2006b). Estimating GDP in the Early Roman Empire, in E. Lo Cascio (ed.), *Innovazione tecnica e progresso economico nel mondo romano*, Bari, Edipuglia, pp. 31-54.
Temin, P. (2013). *The Roman Market Economy.* Princeton University Press, Princeton.
Tenenti, A. (1959). *Naufrages, Corsaires et Assurances maritimes à Venise 1592-1609.* S.E.V.P.E.N., Paris.
Valli, V., (2005). *Politica economica. Introduzione all'economia dello sviluppo.* Carocci Editore, Roma.
Van Zanden, J. L., Van Tielhof, M. (2009). Roots of growth and productivity change in Dutch shipping industry, 1500-1800. *Explorations in Economic History* 46: 389-403.
Verboven, K. (2020). Capital markets and Financial Entrepreneurs in the Roman world", in P. Erdkamp, K. Verboven, A. Zuiderhoek (eds), *Capital, Investment and Innovation in the Roman World.* Oxford University Press.
Voigtländer, N., Voth, H. J. (2013). The three horsemen of riches. Plague, war, and urbanization in early modern Europe. *Review of Economic Studies* 99.2: 248-54.
Waliszewski, T. (2014). *Elaion. Olive Oil Production in Roman and Byzantine Syria-Palestine.* Warsaw: Warsaw University Press.
Wallinga, H. T. (1964). Nautika I: The unit of capacity of ancient ships, *Mnemosyme* 17: 1-40.
White, K. D. (1970). *Roman farming.* Cornell University Press, New York.
Whittaker, C.R. (1985 [1987]). Trade and the aristocracy in the Roman Empire. *Opus* 4, 49-75.
Whittaker, C. R. (1989). Amphorae and trade, in *Amphores romaines et histoire e ́conomique: Dix ans de recherche* (CEFR 114). Rome, 537–9.
Wilson, A. I. (2009). Approaches to quantifying Roman trade, in A. K. Bowman and A. I. Wilson (eds), *Quantifying the Roman Economy: Methods and Problems*, Oxford Studies on the Roman Economy 1. Oxford: 213–49.
Wilson, A. (2011). Developments in Mediterranean Shipping and Maritime Trade from the Hellenistic Period to AD 1000, In *Maritime Archaeology and Ancient Trade in the Mediterranean*, edited by D. Robinson and A. Wilson, 33–60. Oxford Centre for Maritime Archaeology Monograph 6. Oxford: Oxford Centre for Maritime Archaeology.

Wilson, A. (2020). Roman Water-Power: Chronological Trends and Geographical Spread. In: Erdkamp P., Verboven K. and Zuiderhoek A. (ed.), *Capital, Investment, and Innovation in the Roman World*. Oxford: Oxford University Press.
Wirsching, A. (2000). How the obelisks reached Rome: Evidence of Roman double-ships, *International Journal of Nautical Archeology* 29.2: 273-83.
Wirsching, A. (2003). Supplementary remarks on Roman obelisk-ships, *International Journal of Nautical Archeology* 32.2: 121-3.

Primary Sources

Archivio Storico del Comune di Genova (A. S. C. G), fondo Albergo dei Poveri, n. 670, c. 6.
Archivio di Stato di Genova (A. S. G.), fondo famiglie, S. n. 292.

Dataset

Strauss, J. (2013). Shipwrecks Database. Version 1.0. Accessed: January 15, 2020, http://oxrep.classics.ox.ac.uk/databases/shipwrecks_database/

3 The impact of the Antonine Plague in Roman Egypt: the failure of wage claims under the Caesars

Abstract

The death rate of the Antonine Plague and its effects on the Roman world are a debated subject since the 19th century. In the last two decades, an increasing amount of papyrological findings shed light on the demographic and economic consequences of the Antonine Plague in the Roman Egypt. However, both results and conclusions on this subject remain quite controversial. This paper suggests a novel interpretation, introducing archeological evidence never used before to interpret Antonine Plague economic consequences: *petitiones* discovered in North Africa and Asia Minor. These archeological findings shed light on the possible extra-economic measures adopted by *conductor*, in league with roman officers and administrators, to stem rising wages and falling rents triggered by the outbreak. In this case, a high mortality rate would not lead to an increase in real wages and a decrease in real rents, but quite steady streams of income for landowners at expense of worse living conditions for farmers.

Keywords: Roman world, Antonine Plague, *petitiones*, Malthusian model, wavelet coherence.

JEL: N17, N37, O11.

Introduction

Although the Antonine Plague and its consequences have been intensely studied since the late 19th century no reliable estimates on mortality rate currently exist[1]. Just as there are no a definitively evidences that indicates where and when the epidemic began. There was an anecdote that circulated among the Romans at that time, which told the origin of the Antonine Plague as a punishment for their impious sack of Seleucia in 165 AD, during which a noxious vapor was released from the temple of Apollo following to theft of its statue and looting of the temple by the Roman troops (*Ammianus Marcellinus*, *Res Gestae*, 23.6.23–24). Behind this legend, as observed by Harper (2017), there is a hidden attempt to discredit the co-emperor *Lucius Verus* and his general, *Avidius Cassius*, responsible for the sack of Seleucia, who would plan a coup, without success, against the emperor *Marcus Aurelius* in 175[2]. However, there is some truth in this fairy tale. The earliest first attestation of the Antonine Plague can be found in the same year in Smyrna, in Turkey, when the famous Greek orator *Aelius Aristides* described in the Sacred Tales

[1]For an overview, see: Niebuhr (1849), Seeck (1910), Boak (1955), Gillian (1961), McNeil (1976), Duncan-Jones (1996).

[2]Although the version of *Ammianus Marcellinus* be neutral, there are other documents about the event that blaming *Avidius Cassius* for sacked Seleucia Cf. *Marius Maximus, Historia Augusta.*

the disease that was spreading around him.

“infected nearly all my neighbors... if anyone tried to move, he immediately lay dead before the front door... Everything was filled with despair, and wailing, and groans, and every kind of difficulty.” (*Aelius Aristides*, Or. 48.38, tr. Behr)

On the basis of fragmentary and isolated information about this grave event, we know that probably the virus of the Antonine Plague was already present in Parthia since 165 AD, and was then transported by the legions involved in the campaign against the Parthian Empire way to Rome in 166 AD[3]. At the same time, epidemics were surging among the troops at Aquileia by 168 AD and still in 189 AD has been attested a disease outbreak in Rome, showing how Antonine Plague was clapping for at least 25 years (Cf. Lo Cascio, 1991). The Roman historian *Cassius Dio* wrote about it as a terrible plague noticed to all.

“Moreover, a pestilence occurred, the greatest of any of which I have knowledge; for two thousand persons often died in Rome in a single day.” (*Cassius Dio*, *Historia Romana*, [(72)73], 14.3.)

Ammianus Marcellinus still remembers that epidemics two centuries later, by saying that the disease spread from the frontiers of Persia all the way to the Rhine and to Gaul[4]. Similar stories come from *Eutropius* and *Orosius*[5] and by the most famous doctor of the day, Galen, who directly confronted with what he renamed the “Great Pestilence”. Galen gave to scholars the best description of the symptoms of the Antonine Plague, from which it has been deduced that probably it was a smallpox outbreak[6]. However, despite his renown, the remedies suggested by the personal doctor of Emperor *Marcus Aurelius* to defeat the disease had the tang of desperation: stabian milk and Armenian dirt[7].
Moving away from primary evidences to concentrating on large-scale analysis, the Roman world in the 1st century showed all the “structural” features to trigger what is considered the first pandemic in history (cf. Harper 2017, p. 64). The Empire’s population oscillated from a minimum of 44 million inhabitants (Maddison 2007) to a maximum of 60 million (Temin 2006), and for the 2nd century we have suggestions of a peak of 75 million (Harper 2017). The urbanization levels were one of the highest ever recorded, between 14% (Maddison 2007) and 18% (Wilson 2011), similar to values for England in the 18th century[8]. Rome reached approximately 1 million inhabitants to the height of the Roman Empire, reaching an impressive urban density level from 40,000 to 50,000

[3]However relevant the contagion through the legions returning from the East, the episode of Smyrna attests that the plague had already arrived in western Asia Minor in the spring-summer of 165, while the troops were still at the Parthian front. The contagion then spread, very quickly, on the major trade routes, which supplied the armies. Galen records the plague in Rome in 166, even before the return of *Lucius Verus*.

[4]*Ammianus Marcellinus*, *Res Gestae*, 23.6.24.

[5]*Eutropius*, *Breviarium ab urbe condita* 8.12; *Orosius*, *Historiarum adversus paganos libri septem*, 7.15.5.

[6]See Littman and Littman (1973) and Harper (2017), pp. 98-115.

[7]Cf. Flemming, R. (2019), pp. 219-244.

[8]From 13% to 16% (Bairoch et al, 1988).

people per square kilometer (Lo Cascio 2000), values much higher than those experienced by contemporary overcrowded Indian cities. In addition, there were at least a dozen of cities with a population exceeding 100,000 inhabitants throughout the Empire. Life in these gigantic metropolises in ancient times means lives in an unwealthy environment. Cities with their overcrowded quarters and narrow streets, supply systems, sewage, and sanitation have distinct disease ecologies (Harper 2017, p. 80)[9]. Furthermore, the Roman Empire witnessed the building of one of the first "highways" of mankind. Thousands of miles of Roman roads crossed the Empire, legions and civilians moved from one end of the Roman world to the other in a manner never before seen, while hundreds of ships crossing the Mediterranean Sea (cf. Parker 1990, 1992, Wilson 2009). The geospatial model created by Walter Scheidel and Elijah Meeks shows very vividly the impressive number of streets and maritime routes that connected every province of the Roman Empire[10]. Unfortunately, this multitude of streets and ships in addition to transport people and goods spread viruses and germs in every part of the Empire. Figure 1 gives us a glimpse of how the Antonine Plague could widespread in the territories under Roman rule: Italy, Britain, Gaul, Germany, Illyricum, Asia, North Africa among others seem to be affected by the "Great Pestilence". While for some scholars it may have even traveled as far as China[11]. The whole Empire seems to suffer the Antonine Plague.

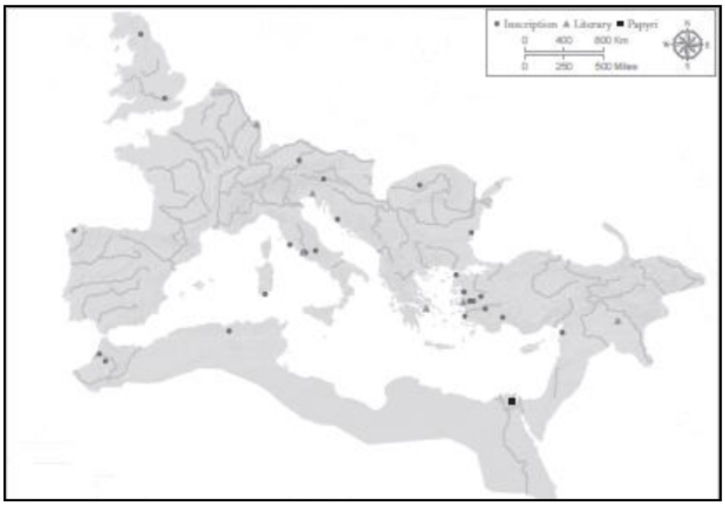

Figure 1: Possible indications of the Antonine Plague, from Harper (2017), p. 102.

With regards to mortality rates, the model of Zelener (2012) estimated that for a possible non-immune population to the smallpox virus, with levels of population density similar to that of the Roman world, the mortality rate accomplished in the Empire following the Antonine Plague oscillated around 22%. Similar results were provided by Paine and Storey (2012), who hypothesized a mortality rate of more than 30%. However, Littman and Littman (1973) suggested that the mortality could not have been more than 10%.

[9]See Voigtländer and Voth (2009, 2013) for a deepening on the role of high urbanization level as catalyst for epidemics and mortality.

[10]https://orbis.stanford.edu/

[11]Hanna (2015).

Conversely, Kron (2012) argued that any smallpox outbreak in the former would have been "far from catastrophic" [12].
The most important evidence, but also the most debated, about the diffusion and mortality rates of the Antonine Plague comes from Roman Egypt, one of the most densely populated areas of the Roman Empire (Tacoma 2012). Thanks to relevant papyrological evidence it can be said that Roman Egypt showed a strong loss of population during the Antonine Plague period; around 20-30% in over twenty Delta villages (Cf. Rathbone 2007). Describing the Egyptian situation, Lo Cascio (1991) argued that over a period of only three months, in 178-79 AD, around one-third of taxpayers of the village of Soknopaiou Nesos in the Fayyum would have died. Following the author, the only cause able to explain such a level of mortality, in such a short period, would be the outbreak of a catastrophic disease. Similarly, always in the Fayyum, the papyri of Karanis highlights a relevant decrease in the number of taxpayers, therefore in the village's population, in 145-46 AD, and 171-74 AD. Unfortunately, it is very difficult to assess the consistency of epidemics in the long run; however, it is nevertheless indicative that in Karanis, as in Theadelfia, from the 2nd and 4th century the population decreased respectively by 90 and 96% (Bagnall 1985). However, as Lo Cascio himself points out[13], such a radical reduction is attributable to deterioration of the network of irrigation channels, which provided a vast amount of water for artificial irrigation of Fayyum's zones, rather than epidemic itself. This point of view was recently further emphasized by Wilson (2013), who reinterpreted a part of the consequences of the Antonine Plague in Roman Egypt also as a climate and/or an agriculture productivity crisis. Similarly, Elliot (2016) interpreted the apparent plague's effects are more likely the results of agricultural, political, and climatological causes.
Another subject of heated debate concerns the prices distortion that occurred in the Egyptian labor market and its relationship with institutional arrangements concluded, consensually or not, during the outbreak of disease. These studies connect back to the well-known neo-Malthusian and neo-classical equilibria approaches, widely used to interpret epidemics' effects on the economic system. Following this approach, Lo Cascio (1991) and Scheidel (2012) suggested that institutional arrangements may have affected the economic dynamics triggered by Antonine Plague in Roman Egypt. Lo Cascio underlines the possible use by landowners and Roman administration of extra-economic measures to limit farmers' mobility, while Scheidel, through a comparison with Mameluke society, suggests that institutional arrangements distorted real wages trend in the post-epidemics period. However, despite numerous interpretations, the magnitude of the Antonine Plague in the Roman Empire, especially in Roman Egypt, and its effects on the economy are still a very debated issue. This paper suggests a novel interpretation. It investigates the effects of the Antonine Plague on labor and rent markets in Roman Egypt through the analysis of archeological evidence never used before to interpret Antonine Plague economic consequences: *petitiones* discovered in North Africa and Asia minor.

[12] Kron (2012), p. 239.
[13] Lo Cascio (1991), p. 709.

The Neo-classical and Neo-Malthusian equilibria: proxies for epidemics in Roman Egypt

In recent times, another approach has gradually emerged to evaluate the impact of the Antonine Plague in Roman Egypt: a combination of the neo-classical and neo-Malthusian equilibria. Assuming perfectly competitive markets, so flexible prices, the neo-classical general equilibrium interprets every change in the supply (and demand) schedule as a corresponding change in prices. Higher goods, capitals, lands, or labor shortage implies, *ceteris paribus*, an increase of prices, interest rate, rents and wages, and vice-versa in a case of oversupply. Whereas, on the one hand, the neo-Malthusian equilibria suppose that an increase (decrease) in income level determines an increase (decrease) in fertility rate and a reduction (increase) in mortality rate, while, on the other hand, a push in population causes a decrease of incomes due to the existence of fixed factors of production, particularly land[14]. The link between these approaches and epidemics is immediately evident. Following the neo-Malthusian model, the high-mortality rate due to epidemics leads to a reduction in the population level, with consequent general temporary improvement in per-capita income for the survivors. Specifically, a high mortality rate among farmers, implies a general increase in per-capita share of foodstuff for farmers' families, whereas a general reduction of the population reduces the number of farmers per unit of land, leading to a decrease in rents, due to a drop in the ratio land to population. Whereas, given that an epidemic leads to a shortage in the labor market, due to deaths among male workers, the neo-classical general equilibrium suggests that this scarcity produces, *ceteris paribus*, a general increase in the price of labor, so an increase in wages. In addition, we can suppose that a high mortality rate among farmers and agricultural workers leads to a contraction in the supply of foodstuff, with a consequent increase in their prices, for instance, wheat prices. Finally, high mortality among farmers implies a sudden rise in land supply, leading to a decrease in rents for landowners. However, the rise in incomes due to a reduction in population level and the increase in wages following the scarcity in the labor market, if the epidemic is extremely virulent, tend to be higher than the inflation level caused by supply reduction of foodstuff, leading to an expansion in real wages and improving living standard, and consequently, landowners' rents drop. This dynamic is confirmed for the Black Death in the late Middle Ages among others by Penn and Dyer (1990), Munro (2004), Clark (2007), and Malanima (2012). In summary, both neo-Malthusian and neo-classical equilibrium come, through different assumptions, to the same conclusion: virulent epidemics lead to a drop in rents and higher general inflation level but at the same time they produce a rise in real wages and income.

Following this approach, Scheidel (2012) observed that daily and monthly wages of Egyptian unskilled workers outweighs, after the Antonine Plague, rise in prices of some relevant consumer goods as wheat, wine and oil, while land rental prices, both in money or in kind, decreased. In fact, in one exceptionally well-documented village, the total amount of land devoted to annual-cycle crops declined between 158/9 and 216 AD, while the share of land devoted to arboriculture (multiyear-cycle) increased, indicating both a reduction in demand for staple crops, indicative of population decline, and an increase in crops devoted

[14] For a more information about Malthusian model, see: Clark (2007), Voigtländer e Voth (2009, 2013), Erdkamp (2016).

for non-essential produce, such fruits and wine[15]. These results imply that in the period from 100-160s to 190-260s relevant increase in real daily and monthly wages for unskilled workers occurred, with a less marked depreciation for wine and oil in real terms, and a strong depreciation in land prices (Fig. 2).

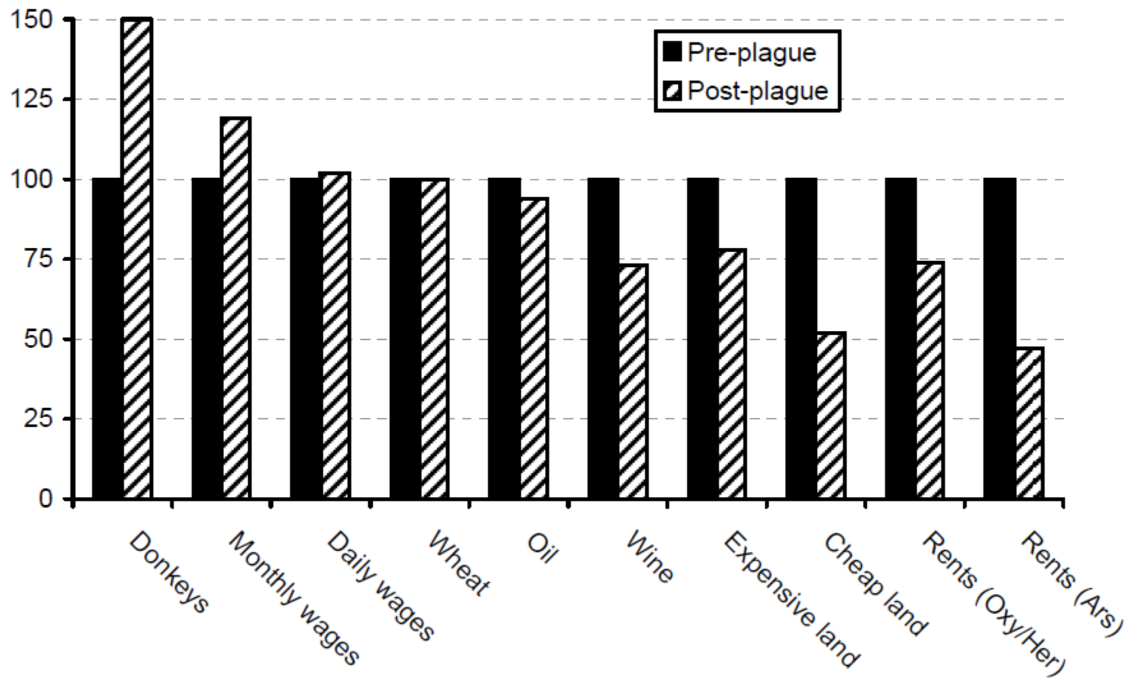

Figure 2: changes in real prices and rents between 100-160s and 190-260s AD. All values standardized at 100. Source: Scheidel (2012), p. 19.

However, Scheidel himself observed that real wages variation look very little in comparison with doubling in real wages level observed in England in the centuries following the Black Death[16]. To explain this phenomenon, Scheidel suggests as a cause of Egyptian real wages stability the role played by wheat's prices inflation, which is due to the demand pressure for grain for export to Rome. Given that Egypt was a major grain exporter, outside demand may have kept prices above the level that would otherwise have, with consequent slowing down the rise of Egyptian real wages. However, one flaw of this argument is that the plague affected not only Egypt but many other parts of the Empire too; as population fell there, so should export demand have declined[17].
On the other hand, Scheidel explains real wages stability following the Antonine Plague due to the existence of "institutional arrangements". This latest conclusion is taken from a comparison between the collectivistic, short-term-oriented Mamluk landholders of the 15th century and the Roman Egypt landowners. Scheidel suggests that, as Mamluk doggedly attempted to preserve rents even after the Black Death and thus preventing a

[15]Cfr. Scheidel (2002: 110-111), on Theadelfia in the Fayyum, based on Sharp (1999: 185-189).
[16]Cf. Munro (2004).
[17]Cf. Bagnall (2000), pp. 290-291.

relevant increase in wages, this kind of dynamics could be valid also for Roman Egypt landowners during the Antonine Plague. Although, in the Roman times the seemingly weaker position of Roman-Egyptian landowners should suggest a lack of the institutional or market power to exploit workers to the same degree as the Mamluks. However, Duncan-Jones (1994) showed a different perspective, arguing that evidence in Roman Egypt gives the impression that tax-revenues were maintained as far as possible, sometimes even if crop-yields were inferior, and even if crop-rotation meant shortfalls in production.

The adoption of the extra-economic measures as a potential source of markets distortion: exploring *petitiones* findings

The state intervention in the economy is also nowadays considered a potential source of markets distortion. For this reason, to assume general neo-classical equilibria for ancient economies, also for the most advanced, is potentially misleading. In fact, from the second half of the 20th century, Neo-institutional school, in opposition to the neo-classical school, started to speak about the importance of the "rules of the game" as driving force for markets competitiveness and economic success. Property rights, norms to safeguard the commerce and democracy regime are all factors that improve economic performance, while their complete or partial absence can distort the market-based mechanisms: not all economic systems work the same way[18]. To expect perfect flexibility of prices in grain market in the Roman world is risky. Elliot (2021) makes the same flaw when he adopts legionaries' real wages stability during the Antonine Plague as proof of the minimal impact of the epidemic. He underestimates that in normal circumstances, the standing army of 30 legions in the imperial period would require between 7,500 and 10,000 new soldiers each year to maintain its fighting strength, while during the reign of *Marcus Aurelius*, the establishment of two completely new legions (*Legio II* and *III Italica*), the potential effects of the Antonine Plague, and the high losses troops suffered during the campaigns on west borders must have increased recruitment to at least 50,000 for a few years (Herz 2007). However, a quintupled demand for soldiers did not impact on soldiers' real wages[19]. So maybe the real question is, why did some prices remain stable during the Antonine Plague? Or why variation look very little in comparison with doubling in real wages level observed in England in the centuries following the Black Death?

One of the most credible hypotheses to explain the different prices and wages trends occurred in the post-Antonine Plague compared to the post-Black Death one rests on the different role played by Roman and late-medieval institutions. As stated in the previous paragraph, this hypothesis has already been partially explored by Lo Cascio (1991) and Scheidel (2012).

In the Roman world, as in many historically later societies, the institutional context was strongly influenced by the conditions of public finances. One of the most important items of expenditure was the army. In the period of the Principate, the Roman army had a size

[18]See for example North and Weingast (1989) and more recently Acemoglu and Robinson (2012).
[19]Cf. Duncan-Jones (1996), p. 117, and Harper (2017), p. 118.

of about 250,000 men (Temin, 2006), a smaller size than the armies of later periods[20]; however, military spending remained the most burdensome for the imperial coffers, so much so that the balance between the costs borne by the Empire and its productive base was chronically precarious. The situation was made more complex by the fact that in the Roman world the concept of sovereign debt through the issue of government bonding was unknown[21]. Therefore, to overcome these problems, the only solutions were reducing expenses or increase revenues through heavier taxation. Given that in the 2nd century a resize of the army was not possible due to increasing barbarians' attacks, the second hypothesis was the most workable, even if was very difficult to traduce into practice. As pointed out by Garnsey and Saller (2014), Roman society was based on inequality; the aristocratic classes were the foundation of the Empire. The senators, knights, and decurions – using a very simplified classification – were the glue of Roman society. Thus, to keep from antagonizing the upper classes, a modest tax burden was imposed on them, and consequently, most of the tax burden was on the shoulders of the lower classes.
Quoting Lo Cascio (1991: 703) referred to the importance of the elite within the Roman society:

"essential condition for the survival of a unitary political organization [the Empire] was, therefore, their [the aristocratic classes'] safeguard"[22].

This state of affairs led to a paradox: on the one hand, the need to replenish the imperial coffers; on the other, the fear of damaging the income of the aristocratic classes through taxation higher than normal. Therefore, in normal times a low taxation was the practice adopted by the Roman state. As stated above, starting in the 60s of the second century, the balance between income and expenditure of the Empire broke down. If, on the one hand, this deficit could be partially explained by new military needs, the Quadi and Marcomanni were pushing upon the northern border, taking advantage of a *limes* unprotected because of the campaigns in Parthia, on the other hand, this situation of financial emergency seemed to have deeper roots. It is likely that this fiscal crisis, in addition to being determined by the increase in military expenditure, also had among its causes a strong contraction in revenues, which can be justified by a downsizing of the productive base of the Empire caused by the Antonine Plague. This dynamic was seriously endangering the integrity of the Empire. The landowning classes, strengthened by the support of the Roman state, would thus be pushed to implement extra-economic measures aimed at the containment of wage claims of peasants, such as tying farmers and their descendants to their landlords' estates (cf. Lo Cascio 1991). With such a constraint, the mobility of the workforce was effectively canceled, nipping in the bud any possible change in the power relations between peasants and landowners capable of triggering a relevant and lost-lasting increase in real wages, similar to that which occurred in the aftermath of the Black Death[23]. Although it is not possible to have reliable indications on

[20]Public spending in Roman times has been estimated at about 5% of the national product (Maddison 2007), a lower percentage than, for example, in Medici Florence, where public spending was between 1/3 and 1/4 of the national product (Goldsmith 1984).
[21]Verboven (2020).
[22]Our translation.
[23]Cf. North and Thomas (1976), Munro (2004), Acemoglu and Robinson (2012).

how such extra-economic measures took place during the Antonine Plague period, some archeological evidence contained in the epigraphic dossier known as *petitiones*[24] seems to indicate a close relationship between the use of institutionalized violence by Roman elites, the interest of landowners and the Antonine Plague. This dossier expresses the "cry of help" raised by various rural communities, mostly Asian and African, harassed from the abuses by civil and military officers, in the period from the reign of *Commodus* to the Severans. A time when the consequences of the Antonine Plague could potentially scourge these Roman provinces[25].

The various petitions, written by colonists living in North Africa and Anatolia, and addressed to the emperors, in particular the one called *Saltus Burunitanus*, show how at the end of the 2nd century many farmers complained to the emperor about the working conditions in the imperial estates. The peasants complain of beatings by soldiers, imprisonment and the obligation to provide additional free labor to the landowners, all indications that seem to highlight the desire of the leaseholder (*conductor*) to make the most by available manpower to increase or maintain productivity and profits. The petition (*libellus*) to the emperor *Commodus* by the colonists (imperial tenants) in 181-182 of his imperial estate of *Saltus Burunitanus* - Tunisia (Souk el -Khmis) - concerns the complaints about the collusion that has come about between the procurators and leaseholder of the domain, *Allius Maximus*, who have exploited the peasants beyond measure. The peasants complained that they had been reduced to poverty and demanded that the procurators and leaseholders be denied the right to production quotas, since, as is written in the letters of the procurators (contained in archives of the administrative district of Carthage), each year the peasants cannot be employed for more than two days for plowing, two days for hoeing and two days for harvesting. The leaseholders have demanded more than what was stipulated in the work guidelines contained in the letters of procurators. The farmers lashed out at the leaseholders who were favored by the procurators, due to the bribes that tenants gave out to the latter in exchange for protection and support for their abuses. Actually, the procurator supported *Allius Maximus* by sending soldiers against the peasants, forcing them to work over the allowed legal limits.

[24] Hauken, T. (1998).

[25] In the manuscript of Hauken there is also a petition datable to *Antoninus Pius* and other for the period from Jordan to Philip the Arab, however, the most of dossier is datable between the reign of *Commodus* and of the Severans.

Figure 3: *Saltus Burunitanus* petition.

A second petition to Emperor *Commodus* from the colonists of an imperial possession of Proconsular Africa (Gasr Mezaur) in 181 indicates the presence of a problem not very different from that in *Saltus Burunitanus.* In this case, the leaseholder used the settlers in a brick factory without offering any compensation, since such work - in the opinion of the tenants - was covered by days of free labor. Note that the amount of work in Gasr Mezuar was significantly higher, 16 days, than specified for *Saltus Burunitanus* (6 days but distributed differently). Consequently, for both settlers and tenants, the work would be of great importance, not to mention a central issue, in this estate. Furthermore, the requirement to engage in general, uncompensated activities, and in this case, brick making, would take the settlers out of their familiar agricultural context, and dangerously close to an unfree condition, working side by side with slaves. We can thus conclude that the conflict centered not on the right to change the amount of work but on the right to change the kind of work the colonists could do.
A third petition was sent by the peasants of an imperial estate in the region of Philadelphia (Aga Bey Koyu, Asia, Lydia, Turkey) to two or more emperors, probably *Septimius Severus*, 197-211, or Caracalla, 188-217. The petition recounts that 23 soldiers with police functions (*kolletiones* and *frumentarii*) arrived at the imperial estate under the pretext of liturgies and magistracies. These soldiers arrested nine peasants who were then sent under escort to the procurator of equestrian rank *Aelius Aglaus*, who also managed the affairs of the proconsul. After that, they freed one of the nine after demanding a cash ransom for his safety of over a thousand drachmas, however, they held the others in chains.
Finally, from the Turkish village of Süsüzoren, an inscription reproduces a rescript sent

around 205 AD by Emperors *Septimius Severus* and Caracalla to their colonists of the village of Tymion and Simoe, in response to a petition of supplication that unfortunately is currently unknown[26]. In their petitions, the peasants had evidently complained of being subjected to unjust and oppressive exaction by certain officers and administrators, who demanded forms of tax contribution or compulsory provision of labor, well above what was provided for by customary practices. Furthermore, as noted by Filippini (2012), these settlers may have been Christians of the Montanist faith, whose apocalyptic preaching had developed by the time of *Marcus Aurelius* in Phrygia, in the rural villages of Tymion and Pepouza. Filippini points out that this inscription together with the emergence of the Montanist sect can probably be read as a consequence of a period of strong turbulence, whether due to external causes, increasing incursions at the borders of the Empire, and internal causes, an epidemic.

All this evidence seems to paint a picture where leaseholders, helped by local elites and supported by the army, were able to impose to the farmers extra-economic measures, to limit economic damages to the roman elites caused by pandemic, as supposed by Lo Cascio (1991). Specifically, evidence suggests that farmers were exploited beyond customary and legal limits, from which deduce the will of landholders to increase, or more probably, maintain production level in a period of potential "economic recession", to protect their land rents.

Citing Lewis referring to economic condition of local elites in the Roman Egypt:

"In the late second and early third centuries decades of economic recession, further aggravated by ever-increasing taxes and assessments and by requisitions imposed to sustain the internecine struggles over the imperial succession and the wars on the empire's frontiers, succeeded in undermining the fortunes of many a hitherto well-to-do family." (Lewis, 1983:182)

Naturally, there is no guarantee that these behaviors were a consequence of the high mortality rate experienced in Asia and Africa during the Antonine Plague; however, we think that probably some relationship between these events truly exists. Unfortunately, there are not similar documents attested for Roman Egypt. However, the beginning of the Revolt of Boukoloi in 166-172 seems to show some features related both to the diffusion of Antonine Plague and the to fiscal pressure exercised by the Roman rule on agricultural sector in Roman Egypt. In the Roman period, there was an increase in fiscal pressure on the peasants of Egypt to favor an extension and intensification of wheat cultivation in the most favorable areas; however, this was detrimental to some traditional activities of the inhabitants of the northern part of the delta, such as cattle or sheep breeding, hunting, and fishing. In this context, it is legitimate to believe that one of the causes of the Boukoloi revolt was the exasperation of ruined taxpayers who saw in the Roman policies of management of their land a threat to their ancestral way of life and to their standard of living. Exacerbated by a context of over-indebtedness and by the arrival in Egypt of the Antonine Plague, which engendered a multiplication of the flow of miserable and desperate fugitives decided to seek a subsistence in illegality, the latent discontent shared by a number of taxpayers of the north-east of the delta encouraged the Revolt of

[26]Tabber and Lampe (2008).

Boukoloi. However, this insurgency was violently repressed. In 167-168 the Roman army carried out an operation in Petetei, a place populated by herders, which was probably one of the insurgents. On this occasion, the majority of the taxpayers of the village, as well as individuals - most probably insurgents - from the neighboring villages of Psenharpokratis and Psenbienchis were killed. In light of this evidence, it is possible to state that intensive exploitation of resources and farmers by Roman authorities in Delta Nile are pre-date to Antonine Plague. However, this latter was fundamental to fire the uprising[27], suggesting the presence of relevant pressure by roman authorities, and probably also by local elites, both in fiscal and work terms, during epidemic period.

Methodology: a wavelet-based approachs

Over the last past years, when dealing with empirical literature concerning the relationship between demography changes and income variables in the field of economic history usually followed Vector Autoregression (VAR) based specification[28]. However, these applications usually regard the Early Modern age or, more rarely, the Medieval one. Ancient economic history is most refractory to adopt these advanced econometric models.
Specifically, in studies concerning the Antonine Plague, most of the literature is based on descriptive statistics analysis about trend of wheat prices, rents, and wages (Scheidel 2012, Harper 2016, Elliot 2021). The tendency is not to use more complex estimation models, probably due to the scarcity and uncertainty of data concerning the ancient world. However, the application of new computational methods is not impossible, nor be discouraged.
In VAR empirical applications concerning the neo-Malthusian approach, the variables under consideration were mostly assumed endogenous. Even if, recent empirical literature from economics and finance (Kristoufek 2015; Phillips and Gorse 2018; Kang et al. 2019) recognized that non-linear approaches have some advantages over usually applied VAR-based approaches. Firstly, the choice on VAR specification usually comes after the application of common stationarity tests, which are well known to be biased, as originally noted by Elliot (1998). Furthermore, usually there might be a certain delay between the cause and consequence in economic dynamics or demographic ones. Therefore, using a VAR model the effects can be captured only with a specific frequency of data within the sample.
On the other hand, wavelet coherence is a non-linear estimation approach that provides results in time and frequency domains and overcomes the issue of selecting a proper frequency of data within the sample. In recent time, this approach was primarily applied for studies about macroeconomics, specifically about credit and monetary policy issues, given that it allows more relaxed assumptions with respect to VAR models[29]. This kind of flexibility might be very useful for studies on ancient economies, which by definition use uncertain data frequency. A wavelet-based approach allows to partially overcome this difficulty, given that it analyses any possible relationship in data both in frequency and

[27]Cfr. Blouin (2014, 2010).
[28]See, for example: Nicolini (2007), Møller and Sharp (2008), Pedersen et al. (2021).
[29]See, for example: Oddo and Bosnjak (2021) and Gomez-Gonzalez (2014).

time domains. In other words, wavelet analyses relationships between two variables contemporaneously and at a different time for each temporal period. For example, wavelet says how changes in population level in 165 AD affect wheat prices at the same time, and if these changes happened in 165 AD might affect wheat prices in 170, 175, or 180 AD and so on for any temporal span of analysis. In addition, wavelet explores if it is the population that affects wheat prices or vice versa. Therefore, following this approach is possible to minimize errors in dating archaeological evidence, which usually is the most relevant source of data for ancient history. To the best knowledge of the authors, this is the first time when wavelet coherence is adopted to analyze the effects of the Antonine Plague on real wages and rents in Roman Egypt. Phase differences are illustrated by arrows. A zero-phase difference indicates that the considered time series are positively correlated and move together. The arrows pointing right indicate a positive correlation, whiles the arrows pointing left represent a negative correlation. The arrows pointing up mean that the first time series leads the second by a right angle and the arrows pointing down indicate that the second time series leads the first by a right angle. Consequently, the arrows can illustrate a combination of positions.

Empirical results

To evaluate the effects of the Antonine Plague in Roman Egypt, we will proceed to the analysis of the relationships between variations in the population levels, real wages, and real rents through wavelet coherence.
Following neo-Malthusian and neo-classical equilibria approaches, we know that an increase in mortality rate due to virulent epidemic should lead to an increase in real wages and a decrease in rents. Therefore, in this case Wavelet coherence evaluates the magnitude of these changes from equilibrium level in time and frequency domain.
Data about population, real wages, and rents in Roman Egypt are collected by the dataset of Harper (2016). The data of real wages and rents have a long history. These data derived by the main contribution of Johnson (1936), who was the first to collect them, then these data were reworked among others by Drexhage (1991), and finally they were further cleaned out by Rathbone (1997) in his important study of grain, wine, and donkey prices, which historians tend to use as the basis for their studies of the Antonine Plague. Data on population levels are built up putting together the best known literature on this subject by Harper. There is relatively broad consensus about population trend in Roman Egypt, although absolute scale of growth and contraction remains disputed. The population of Roman Egypt grew from the reign of *Augustus* down to the smallpox pandemic in AD 165, with a peak at 5 millions of inhabitants. After this epidemic outbreak the population grew again for some 80 years until the so-called Plague of Cyprian started in 250s AD. The average annual growth rate over this period has been estimated at 1%, with the exception of above mentioned pandemics. The Antonine Plague mortality has been estimated by Harper around 10-20% (Harper 2016b).
Naturally, these data do not uniformly cover all the periods considered. Despite some gaps, adopting Kalman Filter algorithm (KF) we were able to compile two complete time series of real wages and real rents level for the Roman Egypt at annual frequency from 78 AD to 250 AD, while for population level we preferred to adopt a power low with

exponential varying between 0 and 1 to filling missing values (Tab. 1, Fig. 4.). KF it is a quite common method used in cliometrics for flexible estimations of time series. Both, the KF's measurement and transition equation may be multivariate and parameters are allowed to be time-varying. In addition, missing values in the observations are supported. If particular observations contain missing values, these are removed and the measurement equation is adjusted accordingly[30].
The time span of analysis includes the Antonine Plague, which affected Roman Empire approximately from 165 AD to190 AD (Lo Cascio 1991).
Furthermore, this period should not be biased by any other demographic shock attributable to virulent epidemics, given that the time series are cut before the plague of Cyprian, which started in 250s AD.

Tab 1 summarized data used in this paper.

Data	Description	Frequency	Sources
Population	Population level in Roman Egypt	Annual	Harper (2016), sheet 19
Real wages	Wages for unskilled workers - calibrated with wheat prices (artabas)	Annual	Harper (2016), sheet 15
Real rents	Rents in kind - annual payments in wheat (hl/hectare)	Annual	Harper (2016), sheet 18

Table 1: variables adopted in this analysis.

[30] See Harvey (1990).

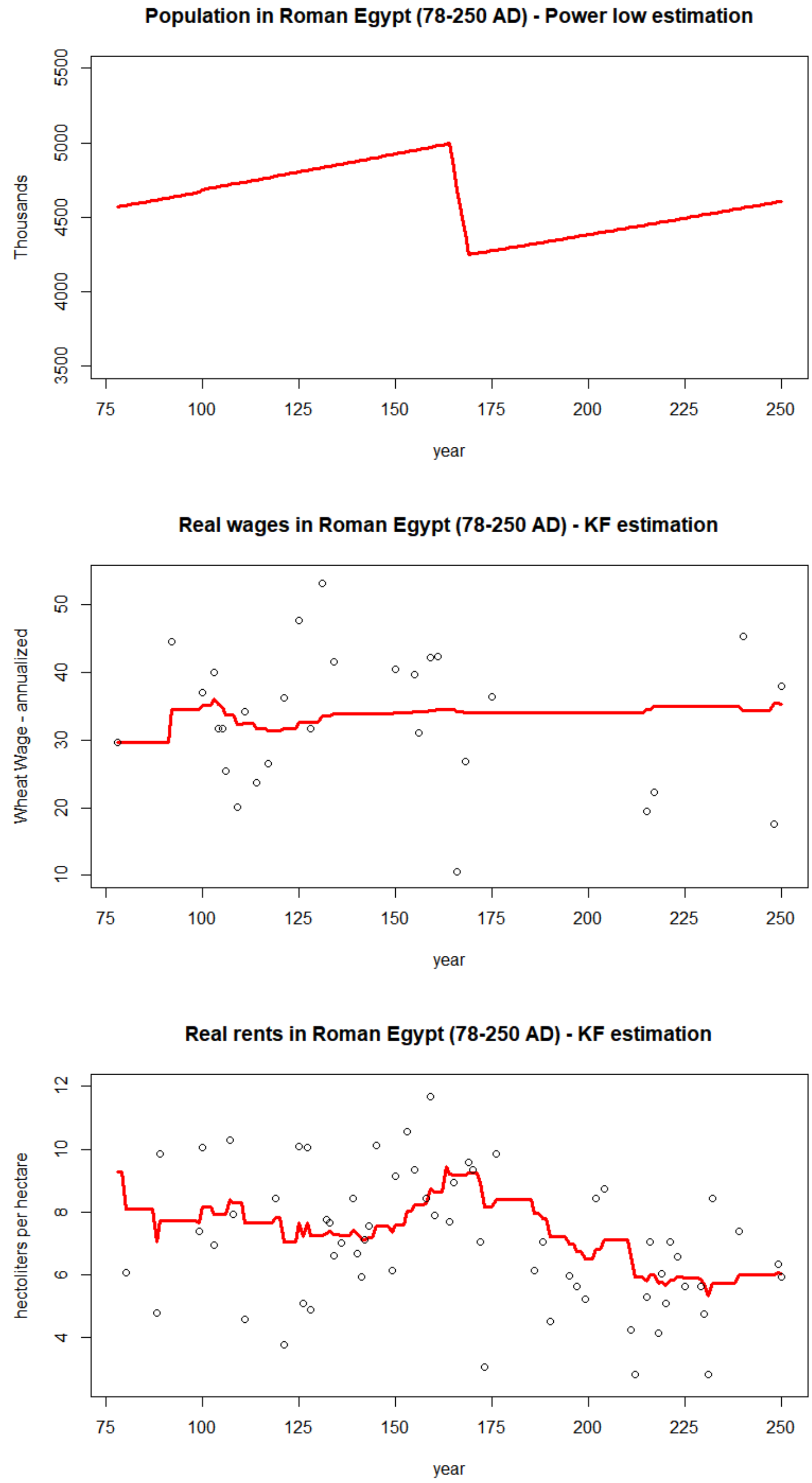

Figure 4: Population level, real wages and real rents level in the Roman Egypt (78–250 AD). Source: Harper (2016).

Population and Real Wages

Following neo-Malthusian and neo-classical frameworks, a virulent epidemic should cause an increase in real wages, due to both a rise in per-capita income for survivors and a contraction in the supply of labor with consequent increase in nominal wages higher than average inflation level.
Fig. 5 shows the relationship between population level and real wages in Roman Egypt in the period 78-250 AD. As we can see on the right-hand side of the picture, dark red color regions denote a high degree of correlation while blue colored area denotes a low degree of correlation between population level and real wages. The areas out of bounded regions were not significant while holding the significance level at 5%, for which correlation in these zones should be considered carefully. Furthermore, higher scales represent long-term co-movements while lower scale represents short-term co-movements. A unit in scale corresponds to 1 year. In other words, higher scales mean a long-run relationship between population and real wages, while lower scales represent a short-run relationship. At the top of the figure is displayed the temporal length of the analysis, from 78 to 250 AD.

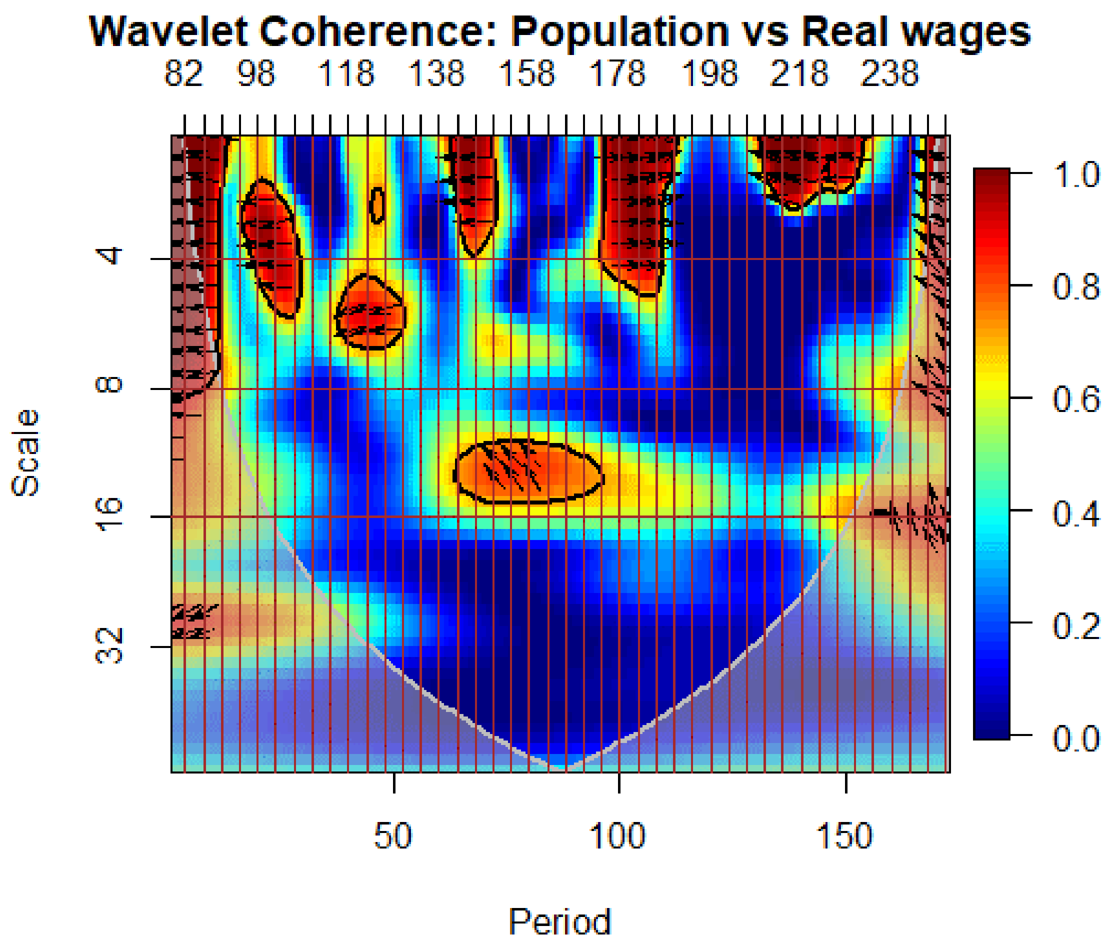

Figure 5: Wavelet Coherence between Population and Real Wage, 78 – 250 AD.

Observing Fig. 5, it is immediately evident that except for the period corresponding the Antonine Plague wavelet coherence shows an inverse relationship between population and real wages, in accordance with the neo-Malthusian and neo-classical theory: population increase led to reduction in real wages and vice versa. In addition, it shows low scale behavior, indicating that the relationship between population and real wages triggers relevant variations only in the short-term, approximately not more than 10 years. Whereas the only area with a direct relationship corresponds almost exactly with the Antonine Plague period, approximately from 174 to 190 AD. In fact, the arrows point to the right, indicating a positive relationship between changes in population and real wages. Therefore, as we know that in this period a reduction in population level occurred, we can suppose that a decrease in the population led to a drop in real wages and not an increase, as instead supposed by neo-Malthusian and neo-classical equilibria. This result seems unexpected, as, it highlights very clearly that during the Antonine Plague a reduction in population is directly proportional with decrease in real wages and not to an increase as instead predicted by both Malthusian and neo-classical theories. Finally, one cannot say much about leading variables, given that arrows are almost totally horizontal. With the partial exception for the negative relationship highlighted at medium scale (i.e., from 10 to 14 years) that shows that population leads real wages; in accordance with the neo-Malthusian and neo-classical theory.

Population and Real Rents

As stated in previous paragraphs, both neo-Malthusian and neo-classical equilibrium assume that contraction in population leads to a decrease in real rents and vice versa.
Fig. 6 presents relevant positive relationship between population levels and real rents only in the beginning of the outbreak disease, approximately from 162 to 166 AD. This means that variations in population levels are positively related to relevant changes in rent levels. In addition, arrows point up, indicating that changes in population lead real rents fluctuations and not vice versa, in accordance with neo-Malthusian and neo-classical theories. However, this relationship disappears during the acute epidemic phase, as pointed out also by Duncan-Jones, who states that "rents in wheat show little clear alteration"[31]. These results might suggest that after an initial decline in real rents probably triggered by the Antonine Plague outbreak, landowners adopted extra economic measures to offset this dynamic, thus preventing the self-regulation in rents market.

[31]Duncan-Jones (1996), p. 123.

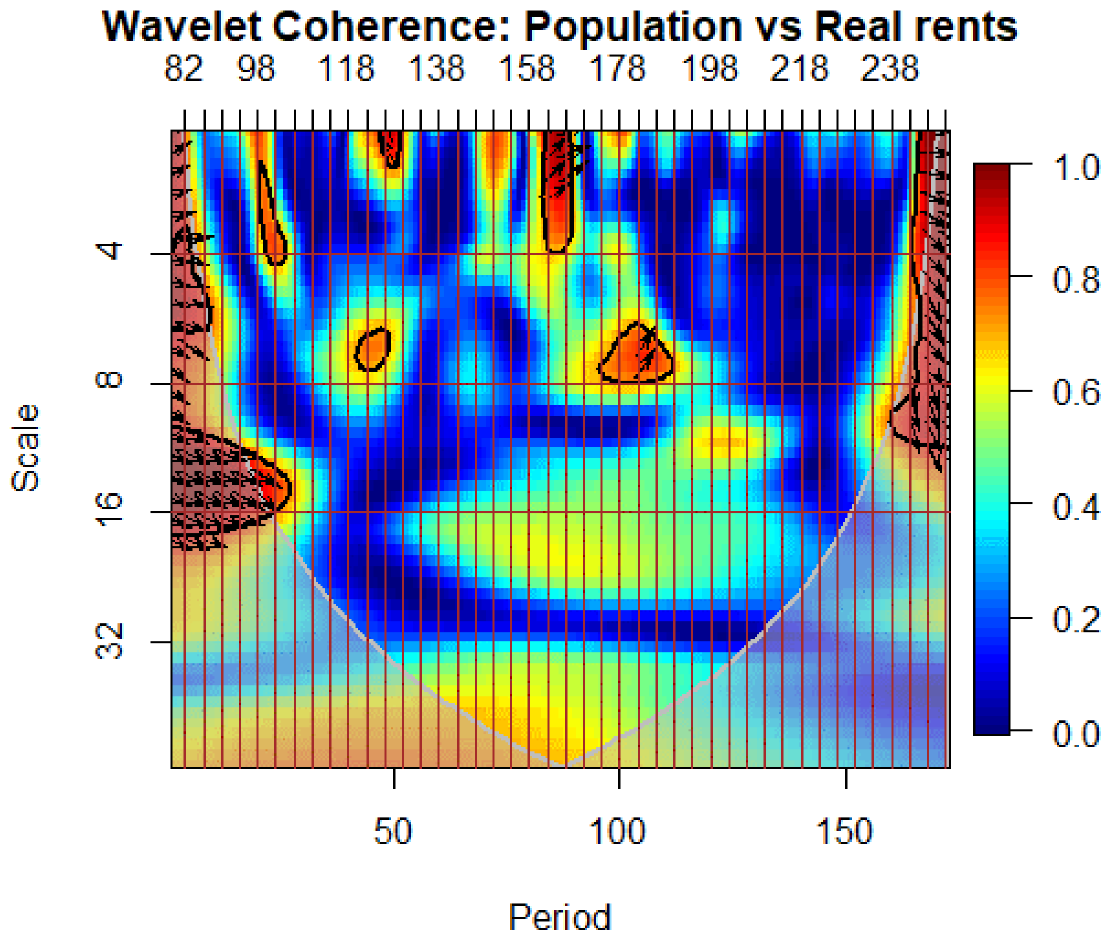

Figure 6: Wavelet Coherence between Population and Real rents, 78 – 250 AD.

Conclusions

The integration of primary evidence as the *petitiones* in the Antonine Plague literature has proved to be of particular importance in two respects: it not only allows us to better contextualize the role of institutional arrangements between workers and landowners during the epidemics outbreak but also adds new information for interpreting some puzzle concerning the apparent stability of real wages and real rents experienced in the Roman Egypt following the Antonine Plague.

Putting together new sources, the literature on the Antonine Plague in Egypt, and the main results obtained with wavelet coherence approach, we can summarize these four stylized hypotheses: 1) population is generally inversely proportional with real wages, 2) population is directly proportional with real wages during the outbreak of the Antonine Plague, 3) shifts in population affects real rents levels only in the beginning of the outbreak, 4) this relationship disappears during the acute epidemic phase.

The first and second statements suggest that both neo-Malthusian and neo-classical theory were the norm in the Roman Egypt, implying the existence, to some extent, of competitive markets. However, self-regulation system breaks out during the epidemic outbreak. Whereas the third and fourth one indicate the implementation of extra economic measures to hold the effects of the Antonine Plague on rents market. Therefore, we can suppose that harmful consequences on production level due to a contraction in the population level has been dammed through the application of extra-economic measures, for which land rents have not been affected in a relevant way by the population contraction. Therefore, extra-economic measures might also explain the controversial results in real wages trend: force farmers to make additional works jam the market labor self-regulation system. Thus, labor scarcity was partially offset by exploiting workers, limiting fluctuations in production and in real wages levels. In this sense, real rents and real wages were stable, meaning benefits for landholders and worse living conditions for farmers.

References

Acemoglu, D., Robinson, J. A. (2012). *Why nations fail: The Origins of Power, Prosperity, and Poverty.* London: Crown Business.

Bairoch, P., Batou, J., Chevre, P. (1988). *La population des villes européennes: banque de données et analyse sommaire des résultats, 800–1850.* Genève: Librairie Droz.

Bagnall, R.S. (1985). *Agricultural productivity and taxation in later Roman Egyp*t. TAPA, 115: 289–308.

Bagnall, R. S. (2000). P.Oxy. 4527 and the Antonine Plague in Egypt: Death or Flight?, *Journal of Roman Archeology*, vol. 13, pp. 288-92.

Blouin, K. (2010). La révolte des "boukoloi" (delta du nil, égypte, ca 166—172 de notre ère): regard socio-environnemental sur la violence. *Phoenix*, 64(3/4), 386-422.

Blouin, K. (2014). *The Boukoloi Uprising1. In Triangular Landscapes: Environment, Society, and the State in the Nile Delta under Roman Rule*, Oxford University Press.

Boak, A. E. R. (1955). *Manpower Shortage and the Fall of the Roman Empire.* Ann Arbor: University of Michigan Press.

Clark, G. (2007). *A Farewell to Alms. A Brief Economic History of the World.* Princeton, NJ.

Drexhage, H. J. (1991). *Preise, Mieten/Pachten, Kosten und Löhne im römischen Ägypten bis zum Regierungsantritt Diokletians.* St. Katharinen: Scripta Mercaturae.

Duncan-Jones, R. (1994). *Money and Government in the Roman Empire.* Cambridge: Cambridge University Press. doi:10.1017/CBO9780511552632

Duncan-Jones, R. (1996). The impact of Antonine plague. *Journal of Roman Archeology*, vol. 9, pp. 108-36.

Elliot, C. P. (2016). Climate Change, Plague and Local Violence in Roman Egypt. *Past & Present* 230: 3-31.

Elliott, G. (1998). On the robustness of cointegration methods when regressors almost have unit roots. *Econometrica*, 66(1), 149-158,
https://www.jstor.org/stable/2998544.

Erdkamp, P. (2016). Economic growth in the Roman Mediterranean world: An early

good-bye to Malthus? *Explorations in Economic History* 60, 1-20, https://doi.org/10.1016/j.eeh.2015.11.004
Flemming, R. (2019). Galen and the Plague. In Petit C. (Ed.), *Galen's Treatise (De indolentia) in Context: A Tale of Resilience*, pp. 219-244, Leiden; Boston: Brill.
Gilliam, J. (1961). The Plague under Marcus Aurelius. *The American Journal of Philology*, 82, 3: 225-251.
Goldsmith, R. W. (1984). An Estimate of the Size and Structure of the national product in the Early Roman Empire. *Review of Income and Wealth* 30.3: 263-288.
Gomez-Gonzalez, J. E., Ojeda-Joya, J., Zarate, H., Tenjo-Galarza, F. (2014). Testing for Causality between Credit and Real Business Cycles in the Frequency Domain: An Illustration. *Applied Economics Letters* 21 (10): 697–701. doi:10.1080/13504851.2014.884689.
Hanna, E. (2015). The Route to Crisis: Cities, Trade, and Epidemics of the Roman Empire. *Vanderbilt Undergraduate Research Journal*, vol. 10, https://doi.org/10.15695/vurj.v10i0.4109.
Harper, K. (2016). Database of Prices, Wages, and Rents for Roman Egypt from the First through Seventh Centuries AD, *DARMC Scholarly Data Series* 2016-5, Center for Geographic Analysis, Harvard University, Cambridge MA 02138.
Harper, K. (2016b). People, Plagues, and Prices in the Roman World: The Evidence from Egypt. *The Journal of Economic History*, 76(3), 803-839. doi:10.1017/S0022050716000826
Harper, K. (2017). *The Fate of Rome. Climate, Disease and the End of an Empire*, Princeton, NJ: Princeton University Press.
Harvey, A. C. (1990). *Forecasting, Structural Time Series Models and the Kalman Filter.* Cambridge University Press.
Hauken, T. (1998). *Petition and response: An epigraphic study of petitions to Roman emperors*, 181-249. Bergen: Norwegian Institute at Athens.
Herz, P. (2007). Finances and costs of the Roman army. *In A companion to the Roman army*, P. Erdkamp, ed., pp. 306-322. Malden MA, Oxford and Carlton. Johnson, A. C. (1936). *Roman Egypt to the Reign of Diocletian. An Economic Survey of Ancient Rome.* Volum II. Baltimore: Johns Hopkins Press.
Kang, S. H., McIver, R. P., Hernandez, J. A. (2019). Co-movements between Bitcoin and Gold: A wavelet coherence analysis. *Physica A: Statistical Mechanics and its Applications*, https://doi.org/10.1016/j.physa.2019.04.124.
Kristoufek, L. (2015). What are the main drivers of the Bitcoin price? Evidence from wavelet coherence analysis. *PloS one*, 10(4).
Kron, G. (2012). Nutrition, Hygiene, and Mortality: Setting Parameters for Roman Health and Life Expectancy Consistent with Our Comparative Evidence. *In L'Impatto della "Peste Antonina"*, edited by Elio Lo Cascio, 193-250. Pragmateiai 22. Bari. Edipuglia.
Lewis, N. (1983). *Life in Egypt Under Roman Rule.* Oxford: Oxford University Press.
Littman, R. J., Littman, M. L. (1973). Galen and the Antonine Plague. *The Journal of American Philology* 94: 243-55.
Lo Cascio E. (1991). Fra equilibrio e crisi. In: Schiavone A. (ed.), *Storia di Roma.* Torino: Einaudi, pp. 701-731.

Lo Cascio, E. (2000). *Roma Imperiale. Una metropoli antica.* Carocci Editore, Roma.
Maddison, A. (2007). *Contours of the World Economy 1-2030 A.D.* Oxford: Oxford University Press.
Malanima, P. (2012). The economic consequences of the Black Death. In: Lo Cascio E. (ed.), *L'impatto della Peste Antonina.* Bari: Edipuglia.
McNeill, W. H. (1976). *Plagues and peoples.* Garden City, New York: Anchor Press/Doubleday.
Møller, N., Sharp, P. (2008). Malthus in co-integration space: a new look at the relationship between demography and living standards in pre-industrial England. Working Paper, Department of Economics, University of Copenhagen.
Munro, J. (2004). Builders' Wages in Southern England and the Southern Low Countries, 1346-1500: A Comparative Study of Trends in and Levels of Real Incomes, University of Toronto, *Working Paper* 21.
Nicolini, E. A. (2007). Was Malthus right? A VAR analysis of economic and demographic interactions in pre-industrial England. *European Review of Economic History* 2(1), pp. 99-121, https://doi.org/10.1017/S1361491606001894
Niebuhr, B.G. (1849). *Lectures on the History of Rome*, III. London: Taylor, Walton and Maberley.
North, D., Thomas, R. P. (1976). *L'evoluzione economica del mondo occidentale.* Milano: Mondadori.
North, D. C., Weingast, B. R. (1989). Constitutions and Commitment: The Evolution of Institutions Governing Public Choice in Seventeenth-Century England. *The Journal of Economic History*, Vol. 49. No. 4, pp. 803-832.
Oddo, L., Bosnjak, M. (2021). A comparative analysis of the monetary policy transmission channels in the U.S: a wavelet-based approach, *Applied Economics*, Vol. 59, Issue 38, Pages: 4448-4463.
DOI:10.1080/00036846.2021.1904113.
Paine, R. R., Storey, G. R. (2012). The Alps as a Barrier to Epidemic Disease during the Republican Period: Implications for the Dynamic of Disease. In *L'Impatto della "Peste Antonina"*, edited by Elio Lo Cascio, 179-91. Pragmateiai 22. Bari. Edipuglia.
Parker, A. J. (1990). Classical antiquity: the maritime dimension, Antiquity. *A Quarterly Review of Archaeology*, 64: 335–46.
Parker, A. J. (1992). Ancient Shipwrecks of the Mediterranean and the Roman Provinces, *British Archaeological Reports International Series*, 580. Oxford.
Pedersen, M., Riani, C., Sharp, P. (2021). Malthus in preindustrial Northern Italy? *Journal of Population Economics*, https://doi.org/10.1007/s00148-020-00812-3
Penn, S. A., Dyer, C. (1990). Wages and earnings in late medieval England: evidence from the enforcement of the labour laws. *The Economic History Review*, 43: 356-376.
https://doi.org/10.1111/j.1468-0289.1990.tb00535.x
Phillips, R. C., Gorse, D. (2018). Cryptocurrency price drivers: Wavelet coherence analysis revisited. *PloS one*, 13(4).
Rathbone, D. (1997). Prices and Price Formation in Roman Egypt. In *Économie Antique Prix et Formation Des Prix Dans Les Économies Antiques*, edited by Jean Andreau, Pierre Briant, and Raymond Descat, 183–244. Saint-Bertrand-de-Comminges: Musée archéologique départemental.
Rathbone, D. (2007). Roman Egypt. In *The Cambridge Economic History of the Greco-*

Roman World, edited by Walter Scheidel, Ian Morris and Richard P. Saller, 698-719. Cambridge: Cambridge University Press.
Scheidel. W. (2012). Roman Wellbeing and the Economic Consequences of the "Antonine Plague". In: Lo Cascio E. (ed.), *L'impatto della Peste Antonina*. Bari: Edipuglia.
Seeck, O. (1910). *Geschichte des Untergangs der antiken Welt*: Bd. I. Berlin: Nabu Press.
Sharp M. (1999), The Village of Theadelphia in the Fayyum: Land and Population in the Second Century. In: Bowman A.K. and Rogan E. (ed.), *Agriculture in Egypt: From Pharaonic to Modern Times*, Oxford: Oxford University Press.
Tabber, W. and Lampe, P. (2008). *Pepouz and Tymon: The Discovery and Archeological Exploration of a Lost City and an Imperial Estate*, Berlin-New York 2008.
Tacoma, L.E. (2012). Settlement and population. In: Riggs C. (ed.), *The Oxford Handbook of Roman Egypt*. Oxford: Oxford University Press.
Temin, P. (2006). The Economy of the Early Roman Empire. *Journal of Economic Perspectives*, Vol. 20, Number 1, p. 133-151, DOI: 10.1257/089533006776526148.
Verboven, K. (2020). Capital markets and Financial Entrepreneurs in the Roman world, in P. Erdkamp, K. Verboven, A. Zuiderhoek (eds), *Capital, Investment and Innovation in the Roman World*. Oxford University Press.
Voigtländer, N., Voth, H. J. (2009). Malthusian Dynamism and the Rise of Europe: Make War, Not Love. *American Economic Review* 99 (2), pp. 248–254, https://doi.org/10.1257/aer.99.2.248
Voigtländer, N., Voth, H. J. (2013). The three horsemen of riches. Plague, war, and urbanization in early modern Europe. *Review of Economic Studies* 80(2), pp. 774–781, https://doi.org/10.1093/restud/rds034
Wilson, A. I. (2009). Approaches to quantifying Roman trade, in A. K. Bowman and A. I. Wilson (eds), *Quantifying the Roman Economy: Methods and Problems*, Oxford: 213–49.
Wilson, A. (2011). City sizes and urbanization in the Roman Empire. In: Bowman A.K. and Wilson A.I. (ed.), *Population, Settlement, and the Roman Economy*, Oxford: Oxford University Press.
Wilson, A. (2013). The Mediterranean Environment in Ancient History: Perspective and Prospects. In *The Ancient Mediterranean Environment between Science and History*, 259-76. Leiden; Boston: Brill.
Zelener, Y. (2012). Genetic evidence, density dependence and epidemiological models of the "Antonine Plague". In: Lo Cascio E. (ed.), *L'impatto della Peste Antonina*. Bari: Edipuglia.

Appendix

More formally, assuming Morlet wavelet given in equation (1):

$$\psi^M(t) = \frac{1}{\pi^{\frac{1}{4}}} e^{i\omega_0 t} e^{\frac{-t^2}{2}} \tag{1}$$

where ω_0 presents central frequency controlling the number of oscillations and t represents time, while i indicates the imaginary part. The most relevant advantage of Morlet wavelet is to allow for time-dependent amplitude and phase for different frequencies. The continuous wavelet transform is given in equation (2):

$$W_x(\tau, s) = \frac{1}{\sqrt{s}} \int_{-\infty}^{\infty} x(t) \overline{\Psi\left(\frac{t-\tau}{s}\right)} dt \tag{2}$$

Where $x(t)$ denotes considered time series, s represent frequency, and τ location pointing the position of the wavelet. Following the wavelet transform equation (2), the time series $x(t)$ is decomposed in terms of wavelets. To compute the size and significance of the local correlation between the two of the considered time series, cross wavelet transform and cross wavelet power firstly need to be considered. The cross wavelet transforms of two considered time series $x(t)$ and $y(t)$ is given by equation (3):

$$W_{xy}(\tau, s) = W_x(\tau, s)\overline{W_y(\tau, s)} \tag{3}$$

Where $W_x(\tau, s)$ represents continuous wavelet transform of the observed time series $x(t)$ and $\overline{W_y(\tau, s)}$ represents complex conjugate continuous wavelet transform of the observed time series $y(t)$. The cross-wavelet power is represented as $|W_{xy}(\tau, s)|$. Eventually, the squared wavelet coherence coefficient is presented in equation (4):

$$R^2(\tau, s) = \frac{|S(s^{-1}W_{xy}(\tau, s))|^2}{S(s^{-1}|W_x(\tau, s)|^2)S(s^{-1}|W_y(\tau, s)|^2)} \tag{4}$$

Where S denotes a smoothing operator. The squared wavelet coherence coefficient ranges from 0 to 1 like square of standard correlation coefficient. A useful property of wavelet coherence analysis is its property to provide phase differences between considered time series. Wavelet coherence phase difference is represented in equation (5):

$$\phi(\tau, s) = tan^{-1}\left(\frac{I(W_{xy}(\tau, s))}{R(W_{xy}(\tau, s))}\right) \tag{5}$$

where R represents the real part and I imaginary part of the cross wavelet transforms in equation (3).

4 The paradox of 'Malthusian urbanization': Urbanization without growth in the Republic of Genoa, 1300 to 1800

Luigi Oddo and Andrea Zanini

Abstract*

This paper investigates the relationships between urbanization and long-term economic growth in the pre-industrial world. To this end, we compiled a novel dataset collecting all currently available data on urban and rural populations in an Italian pre-unification state, the Republic of Genoa. Data show the paradoxical coexistence of high urbanization levels with cyclical Malthusian stagnations. Putting together empirical results and historical evidence, we interpreted this puzzle, highlighting how a high degree of urbanization could be the consequence of widespread poverty, rather than a measure of rising standards of living. To describe this phenomenon, we coined the term 'Malthusian urbanization'.

Keywords: Malthusian model, Economic growth, Republic of Genoa, Urbanization, Pre-industrial economy.

JEL: N13, O11, N93.

Introduction

From the second half of the 20th century, the role of urbanization in the development process has become an extensively investigated topic. In standard urbanization models, from the pioneering studies by Lewis (1954) on *urban pull factors*[1], then passing on the great classics of the subject by de Vries (1984) and Bairoch (1988), who stressed *rural push* factors, cities have almost always been represented as a factor of economic development in the pre-industrial world. Urbanization levels and city sizes have often been used as empirical proxies for the level of income per capita (De Long and Shleifer 1993; Acemoglu et al. 2002, 2005; Malanima 2005; Maddison 2008; Dittmar 2011).

The role of urbanization as a factor of economic growth has also been included in the literature concerning Malthusian population theory. Clark (2007) and Voigtländer and Voth (2009, 2013) suggested that high urbanization rates helped keep down fertility and to drive up death rates, allowing living standards to rise, but through purely Malthusian mechanisms. Overall, both urbanization models and Malthusian population theory basically support the principle, even if through different mechanisms, city growth was a factor

*Published in *European Review of Economic History* on 2 February 2022, DOI: heab027. Luigi Oddo wrote paragraphs 1 and 4, Andrea Zanini wrote paragraphs 2, while both authors wrote introduction, paragraph 3 and conclusion.

[1]Cf. Valli (2005), pp. 126–131.

of economic advancement in the pre-industrial world.
However, in the last 20 years, the idea that urbanization level is closely correlated with levels of income and growth has started to be questioned, especially in the literature concerning developing countries (Fay and Opal, 2000). The experience of the Third World in the second half of the 20th century clearly shows that changes in income do not explain shifts in urbanization. Urbanization continues even during periods of negative growth. On this basis, we aimed to shed light on the relationships between urbanization and economic growth in the pre-industrial era, analyzing the case of the Republic of Genoa from 1300 to 1800 with a novel dataset of cities and rural populations. Genoa was one of the most powerful Italian maritime republics, probably exhibiting one of the highest degrees of urbanization in Europe in the Late Middle Ages. Before the discovery of the Americas, it shared with Venice dominance of the commercial sea routes between East and Northwest Europe (Balard 1983; Karpov 1993). Genoa is considered one of the cradles of European financial capitalism, developing typical elements of the Financial Revolution of the 17th and 18th centuries long before the Netherlands and England (Fratianni and Spinelli 2006; Felloni and Laura 2014). However, this trading-financial power was chronically scourged by an adverse morphology of the territory, dotted with impervious hills that make the hinterland less suitable for agriculture (Lopez 1964, 1970); this induced the Genoese to develop other economic activities, such as maritime trade, and specific food policies to overcome the structural shortage of foodstuffs. Moreover, the scarcity of raw materials within the republic affected the expansion of manufacturing, therefore representing a structural limit for the urban economy. Actually, despite brief periods of economic prosperity, generally driven by seaborne trade or finance, both historical studies and demographic data provide some evidence that Malthusian stagnation was the norm in the Republic of Genoa either in the Middles Ages or in the Early Modern Age (Savelli 1984; Costantini 1978).
The coexistence of these contradictory elements raises the following question: is a high degree of urbanization always a sign of economic advancement in the pre-industrial world? Putting together empirical results and historical evidence, we have portrayed a different scenario, highlighting how a high degree of urbanization could be the outcome of widespread poverty, rather than a measure of rising standards of living. To describe this phenomenon, we coined the term 'Malthusian urbanization'.
The first section introduces the literature concerning the role of urbanization in long-term economic growth. In the second section, we briefly explain the economic history of the Republic of Genoa. The third section explores urbanization in the republic in light of new data. The fourth section presents the Vector Autoregression model (VAR) that we applied and its results. Finally, section five concludes the study.

Urbanization and long-term economic development

From the dawn of civilization until the advent of the Industrial Revolution, the world has become increasingly urbanized. This has led scholars to believe that development and urbanization are strongly correlated over time. To analyze this relationship, two different frameworks stand out: Malthusian population theory and the urbanization model literature. The Malthusian population theory is a modern reinterpretation of the well-known hypothesis developed by Thomas Malthus (1798/2015), who asserts the impossibility of sustaining growth in a population, which follows a geometric progression, through an increase in food production, which instead follows an arithmetic progression. From these assumptions, Malthus deduced a spontaneous tendency that would bind most of the population close to the subsistence level, except for short periods of alleviation triggered, in turn, by overpopulation-induced mortality crises: the 'positive checks' of disease, famine, and war. Inspired by this insight, Lee (1973) and, subsequently, Lee and Schofield (1981) formalized a model in which population and wages are controlled by an equilibrating mechanism, paving the way to the 'modern' Malthusian model[2]. In more recent times, Clark (2007, pp. 27–30) further elaborated this approach in his controversial book 'A Farewell to Alms'. Following this author, we can summarize the three main relationships that characterize the modern Malthusian model, as follows:

(1) The preventive check, whereby fertility rises along with per capita income (i.e. people marry earlier when wages are above the equilibrium level, and marry later when they are below); (2) the positive check, when mortality is inversely proportional to per capita income; and (3) diminishing returns to labor, when the population increases, and per capita income in both the short and long term tends to fall due to the existence of a fixed land supply.

The simultaneous action of these three key dynamics leads to Malthusian long-term equilibrium, since any increase in productivity and in income implies a rise in population, and consequently, due to diminishing returns, a drop in income until reaching the previous equilibrium level[3]. In contrast to the post-Malthusian growth regime, the Malthusian growth regime was characterized both by a weak increase in population and production level. However, the rise in population was higher than production in the long run. The outcome is a fall in per capita product. This means that, in the Malthusian world, cases of growth were episodic and not sustained; they represented temporary 'efflorescences' rather than long upward rises (Goldstone 2002; Malanima 2021).

The unified growth theory (UGT) incorporates the main assumptions of the modern Malthusian model, suggesting that the economic history of humankind is generally divided into two phases: Malthusian stagnation and sustained economic growth following the Industrial Revolution. In UGT, the critical passage between a world mired in the Malthusian trap to (for some countries) a heavenly place fueled by sustained economic growth is explained by the interaction between the rate of technological progress and the demographic transition (Galor 2011).

Although Malthusian theories do not focus directly on urbanization subject, in works by Clark (2007, p. 104) and Voigtländer and Voth (2009, 2013), urbanization levels play an important role in explaining the transition between Malthusian stagnation and the post-Malthusian regime; it is linked to the *killer cities* concept: European cities of the pre-industrial era with high population densities, polluted water sources, and unhygienic practices experienced high urban mortality rates. Following these authors, there is a direct

[2]The modern Malthusian model is a later interpretation resulting from the application of some mechanism of the neoclassical general equilibrium model to demographic subjects, such as the concept of 'long-run equilibrium', which, however, is totally missing in Malthus' discussion (Alfani 2021). Thus, whenever we use the term 'Malthusian model' in the remainder of the text, we will refer to this latter interpretation and not to Malthus' original thinking

[3]Cf. Pedersen et al. (2021).

relationship between rising urbanization, the incidence of mortality, and higher per-capita income. Clark (2007) suggested that high urbanization rates helped keep down fertility and to drive up death rates, allowing living standards to rise. According to Voigtländer and Voth (2013), rising urbanization is explained through Engel's law: with higher per capita income, expenditure shares of manufacturing goods and urbanization both increase. This leads to higher living standards through the rise in mortality rates within cities. Following this view, city growth acts as a 'positive check' mechanism, allowing for rising per capita income and take-off from Malthusian stagnation.

On the other hand, standard urbanization models explain city growth largely through rural-urban migration in response to an expected urban-rural wage or utility gap. Migration flows could be triggered by both *rural push* and *urban pull* factors. For example, migration could result from a *rural push* if the country experiences an agricultural revolution that increases food productivity and frees up labor for cities (Cf. Schultz 1953; Gollin et al. 2002). Then, there are various *urban pull* factors. If the country experiences an industrial revolution, the rise in urban wages attracts workers from the countryside (Cf. Lewis 1954; Lucas 2004; Henderson et al. 2013). In turn, *urban pull* factors might cause agricultural productivity to rise. Two models have usually been adopted on this subject: the first was developed by Wrigley (1985), and the second by Persson (1991, 2015). In both cases, agricultural productivity is related to the ratio of the urban to the rural population. Rising urbanization implies heavy demand for the rural sector, which consequently leads to a rise in agricultural productivity and farmer income.

With regard to pre-industrial Italy, several scholars have investigated the relationships between long-term economic growth and demography. For a long time, following Braudel's contribution (1966), the development of the Italian pre-industrial economy was interpreted as a kind of U-shaped curve, with an increase in prosperity in the late Middle Ages, depression during the 17th century, and recovery starting in the 18th century (Caracciolo 1973; Cipolla 1989). As pointed out by Malanima (2011), urbanization rates reflect this trend, given that "urbanization is an important indicator of labour productivity in agriculture as well as industry and trade" (Malanima 2006, p. 109). Specifically, Malanima (2005) argued that urbanization in Italy was characterized by slow progress from the 10th century to 1350, by declining urbanization for the period 1350–1860 and then a massive increase from 1860 to 2000. With regard to the 17th century, Alfani and Percoco (2019) argued that unfavorable epidemiologic conditions caused long-lasting damage to the size of the urban population and to urbanization levels, triggering the relative decline experienced by Northern Italy.

Nevertheless, some recent papers concerning mostly the contemporary economy have expressed doubt about the assumption that the rise in urbanization is always synonymous with economic development. Analyzing the urbanization phenomenon in Africa in the second half of the 20th century, Fay and Opal (2000) argued that changes in income do not explain changes in urbanization: urbanization continues even during periods of negative growth. Similarly, Chen et al. (2014) underlined that urbanization *per se* is not sufficient to trigger growth. Jedwab et al. (2017) suggested that internal urban population growth might also matter. The resulting urbanization *per se* may not necessarily be conducive to further economic growth, as urban congestion effects might limit the benefits from agglomeration. Gollin et al. (2016) observed that although urbanization could be driven by both resource rents and industrial development, in the first case, cities expanded in different ways and initially, with lower living conditions, they could improve the population's welfare in the long run. Overall, for most of the literature, urbanization is considered a hallmark of economic development, especially in the pre-industrial world[4]. Among more recent works, Brunt and García-Peñalosa (2021) stressed the existence of a causal link between urbanization and growth: When rural workers move to cities, the resulting urbanization produces technological change and productivity growth, thus creating a positive feedback loop between city size and productivity that sets off sustained economic growth. However, there are some exceptions concerning the pre-industrial framework. Cermeño and Enflo (2019) claimed that such an interpretation is possible on the condition that agricultural productivity in neighboring countrysides increases to sustain a growing urban population. Moreover, Jedwab and Vollrath (2015) stated that from 1500 until the mid-20th century, urbanization rates rose dramatically for the richest countries, but remained roughly constant for countries at the lowest levels of income per capita. With regard to Italy, Chiarini and Marzano (2014, 2019) advanced a controversial idea, suggesting that from 1310 to 1870, the Italian economy was in a Malthusian trap since the increase in urbanization took place at the expense of the countryside.

This paper introduces elements of rural-urban migration models within the Malthusian population theory to provide a different perspective on the interactions between urbanization levels and demographic dynamics in the pre-industrial world. Focusing on the Republic of Genoa, this approach brings out that if high levels of urbanization do not reflect substantial increasing productivity in agriculture and growing urban labor demand, urbanization *per se* is not sufficient to take-off from Malthusian stagnation.

The economy of the Republic of Genoa: An overview from 1300 to 1800

In the 12th century, Genoa was emancipated from the Holy Roman Empire and became a self-governing commune. In the following centuries, the city gradually extended its sovereignty over the surrounding areas, spread along the coast—the two Rivieras—and toward the hinterland to the back of the city. At the end of the 13th century, the *Districtus* (the domain, later *Dominio di terraferma*) of the medieval commune probably reached its largest extent, covering (albeit with some discontinuity) an area of approximately 1,664 square miles, mostly coinciding with present-day Liguria. Genoa thus became the capital of a small pre-unification state, which, despite cyclical political instability, was able to survive up to the end of the 18th century (Figures 1–2) (Guglielmotti 2018).

[4]Cf. Jedwab and Vollrath (2015), p. 2; see also Allen (2003).

Figure 1. Republic of Genoa (borders of 1790)

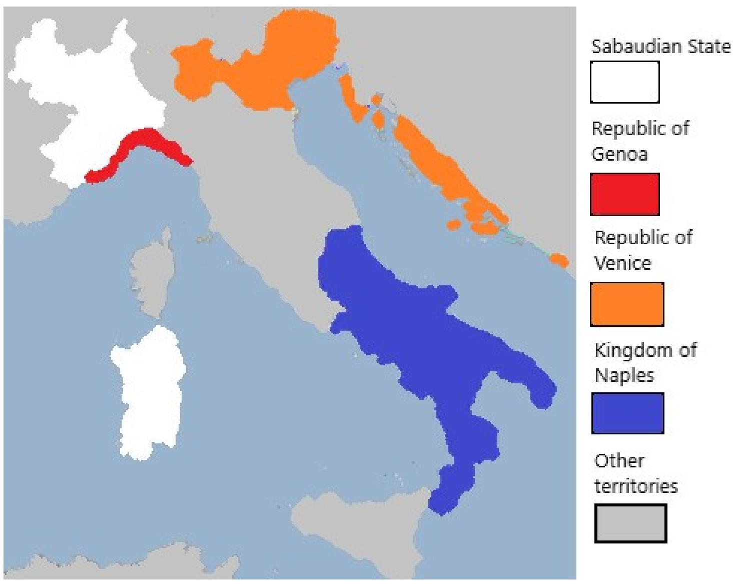

Figure 2. Map of Italy in 1790

From a geographic point of view, Genoa's dominion consisted of a narrow strip of land squeezed between the mountains and the sea. Behind the capital, the extent of the state was wider, crossing the mountain range and reaching the so-called *Oltregiogo*, a strategic area due to the presence of trade routes connecting the Mediterranean Sea with the Po Valley (Grendi 1976, pp. 15–40). Throughout the period considered, agriculture was the most widespread economic activity. Although subsistence farming prevailed, there were also some commercial crops whose production represented an important flow of exports: olive oil, citrus fruits, and, to a lesser extent, wine. Along the coastline, where a relevant

portion of the population lived, agriculture was supplemented by typical maritime activities, especially fishing and coastal trade (Quaini 1972; Massa 2007). However, as the state's territory was less suitable for cereals, domestic production was chronically insufficient to feed the population; therefore, it was always necessary to import large quantities of foodstuffs. Over time, this practice evolved into a veritable food-provisioning policy, with dedicated departments in Genoa and in the state's main cities, aiming to prevent famines and keep food prices under control (Massa 1998). Despite these imports, there was not a surplus of food in the republic; in fact, provisioning policies aimed to avoid a dramatic spread of hunger and malnutrition that could trigger social tensions and ultimately threaten the state's political stability (Grendi 1970, p. 109; Gatti 1972, p. 137).
Local manufacturers also contributed to the republic's economic development. In the late Middle Ages, wool production emerged as an urban activity in Genoa and Savona, but starting in the 15th century, silk manufacturing rose in Genoa, while wool declined. In the 16th century, silk production drove urbanization, attracting hundreds of workers from the countryside to Genoa. However, in the late 16th century, there was a ruralization of silk weaving, in line with a process of proto-industrialization. Other types of production included paper and iron, which were based within the dominio in various manufacturing hubs strategically located near waterways that provided energy (Massa 1998, 2007). These products were not merely aimed at the domestic market but were exported across Europe, especially silk and paper (Felloni 1995, pp. 387–388; Massa 2007, pp. 115–120). However, from the second half of the 17th century, these activities entered a phase of gradual decline that was interrupted only in the last decades of the 18th century, when the wool industry resumed and the cotton industry expanded. Despite this revival in manufacturing, the new enterprises were not able to provide as many new job opportunities to meet the demand of the growing urban population (Calegari 1969, pp. 39–89). Moreover, manufacturing production was heavily dependent on imported raw materials. Therefore, the scarcity of cereals and raw materials represents a structural condition that helps to explain Genoa's propensity for international trade and its early and rapid fortune as a leading commercial power in the Mediterranean, rivaling Pisa and Venice (Lopez 1964, 1970).

As the capital played an important role in demographic, political, and economic aspects, its economic ups and downs heavily influenced the economic growth of the entire state. In particular, from 1300 to 1800, the city of Genoa constituted between 15% and 20% of the republic's total population. However, some of the important urban centers that emerged during this period seem to have followed a partially autonomous path of development where their own economic activities played a relevant role. This was particularly true for Sanremo, which became a critical commercial center for olive oil and citrus fruit cultivated in the neighboring area, and for Novi. The latter was one of the few cases that involved a non-coastal city. Specifically, Novi emerged as an agricultural market for cereals and other foodstuffs from the Po Valley; during the 17th century, it also played a financial role as host of the Genoese exchange fairs (Massa 2007, p. 117; Marsilio 2008). Returning to the city of Genoa, in the Middle Ages, it became a significant maritime power, launching a phase of both colonial and commercial expansion that, at its peak, reached the shores of the Mediterranean and Black seas, thus forming the extensive foreign domains called the *dominii d'oltremare*. Genoa—together with Venice—dominated the spice trade, redistributing oriental products throughout Europe. However, most of its commercial empire was subsequently lost due to clashes with other maritime powers and the Turks advancing through Europe following the fall of Constantinople (1453). Consequently, from the early 17th century, only the islands of Capraia and Corsica remained under Genoa's influence (the latter was sold to France in 1768)[5].

In an international context increasingly influenced by the national Great Powers, the small Republic of Genoa fell within the sphere of Spanish influence between the 16th and 17th centuries (Kirk 2005, pp. 1–28). This historical alliance was concluded in 1528 between the Genoese admiral Andrea Doria and Emperor Charles V. In exchange for Spain's military protection, Genoese bankers supplied the Iberian monarchy with the capital necessary to carry out a highly expensive expansionist policy. Thanks to the command of innovative financial techniques and credit instruments, Genoese financiers quickly gained a leading role, and the city became a crucial financial center, leaving international trade in the background, at least temporarily. In addition, Genoa played an important logistical function owing to its geographic location. Situated in a strategic position, it served as a commercial hub for the western Mediterranean routes and as a privileged access point for reaching the Po Valley (Zanini 2020, p. 9).

As a result, in the early 17th century, Genoa experienced a rediscovered dynamism that led to an increase in living standards and created new employment opportunities in the city, driving the growth of the population from 71,000 inhabitants in 1600 to 77,000 in 1625, including an influx of migrants. However, the transformation from commercial to financial power has to be put in a wider international context. Between the 16th and 17th centuries, maritime trade began to decline due to the geographic discoveries of the late 15th century that turned traders' attention toward Atlantic routes, leaving the Mediterranean in a more marginal role. In addition, in the late 16th century, the rising Northern European commercial powers—in particular, the Dutch and the English—started to dominate trade in the Mediterranean once again (Felloni 2003; Piccinno 2017).

In the following years, the republic's financial power started to decline when several financial crises shocked the Spanish monarchy, marking the end of the so-called 'century of the Genoese', a period defined by Spanish historian Felipe Ruiz Martín and lasting from 1528 until the bankruptcies of 1627 or 1647. Such turmoil also affected trading activities in the port of Genoa, which started to diminish as well. However, the urban population continued to grow, although at a slower pace. This increasing trend halted from 1656 to 1657, when a devastating plague hit the city. Most likely, this epidemic caused the deaths of 42,000 people and a mass exodus from the city to the countryside. After this exogenous shock, Genoa started to gradually recover in the 1670s (Zanini 2020, pp. 14–16).

One consequence of the plague was a return to trading activities supported by a free-port policy. The revival of the Genoese seaborne trade led to a clash with the new rising economic power that had replaced weakened Spain: the France of Louis XIV. Eventually, these frictions culminated in a real armed confrontation, ending with several bombardments of Genoa by the French fleet during the spring of 1684. This changed the international role of the Republic of Genoa, which had formally adopted a policy of neutrality (Zanini 2020, pp. 16–17).

In the first half of the 18th century, the Genoese government had to face several disruptive

[5] Kirk (2019).

internal and external events. The first concerned revolts on the island of Corsica, and the second involved the War of the Austrian Succession. All of these incidents worsened public finances and affected the state's entire economy. However, their impact was not long-lasting: in the second half of the century, the republic emerged again as an international financial market able to provide a huge amount of capital to both public and private borrowers throughout Europe. However, this new phase was shorter than the 'century of the Genoese', as it ended with the outbreak of the French Revolution (Felloni 1971). The last years of the century were characterized by economic stagnation up to the fall of the republic in 1797. Overall, starting from the second half of the 16th century, the evolution of international trade and finance increasingly affected the stages of the urban economy, while manufacturing activity played an even more subordinate role. This had an impact on the urban labor market: during phases of prosperity, the development of trade and finances helped to increase the wealth of Genoese businessmen, while their impact on the increase in urban labor demand was quite modest (Bulferetti and Costantini 1966).

Exploring the phenomenon of urbanization in the Republic of Genoa: A new dataset

In the literature on medieval and early modern Italy, several studies investigate relationships between demography and long-term economic growth. The Republic of Genoa has rarely been included in analyses concerning Italy as a whole or focusing on Northern Italy. This is because data are scarce and dispersed in several bibliographic sources and archival series. Among the few works that include the area under consideration, the studies of Karl Julius von Beloch (1965) on the Italian population and the long-term analysis by Paul Bairoch et al. (1988) stand out. While the first does not cover the entire period from 1300 to 1800, figures proposed by the second study on medieval Genoa have been defined by Giuseppe Felloni as 'completely abstruse' and based on an unreliable source[6]. Special references also need to be made to the database compiled by Paolo Malanima[7], which offers a wide and deep illustration of the population levels of eight Ligurian cities from 1300 to 1861. However, this database provides only a 100-year time frequency and offers no information about the republic's total population.

In this paper, we provide a new dataset of cities and rural populations for the Republic of Genoa from 1300 to 1800 on a 25-year basis, which is the outcome of painstaking work collecting unpublished and published sources, including information derived by state and ecclesiastical censuses, as well as existing literature on population issues (including a copious body of local research). Naturally, these data do not uniformly cover all the periods considered; in particular, they are very limited for the Middle Ages, while they become more abundant from the 16th century onward. Despite some gaps, we were able to compile two complete time series of urbanization and population level for the Republic of Genoa at a 25-year frequency from 1300 to 1800, considering the *Dominio di terraferma*, such as the 1790 boundaries[8]. This new dataset on population and urbanization for the Republic of Genoa for 1300 to 1800 provides an opportunity to study the relationships between

[6]Felloni (2001), p. 297 (authors' translation).

[7]See https://www.cnr.it/en/institutes-databases/database/324/italian-urban-population-1300-1861

[8]For the full list of sources, see the Supplementary Material.

urbanization and long-term economic growth in a single pre-unification Italian state in a Malthusian world. In addition, observing the long-term demographic evolution within a homogeneous, long-lasting political and socioeconomic entity, such as a pre-unification state, allows us to further diversify studies on Italy, given the specificity of the Genoese economic-political model and its geographic features. The space-time continuity of this long-term analysis is ensured since the spatial extent of the Commune of Genoa (subsequently the Republic of Genoa) reached its greatest expansion after the end of the 13th century and continued, with a few minor changes, until the end of the 18th century[9].

To estimate the republic's urbanization level, the first step is to decide on a criterion to define which human settlements can be considered cities in the period of analysis. One of the most common criteria adopted in the literature is to fix a threshold in terms of inhabitants, commonly established at 5,000 or 10,000, depending on the context. This solution is particularly useful in avoiding problems concerning the use of qualitative criteria, including the exercise of political or ecclesiastical power in the surrounding area, the existence of a food provisioning system, the development of a relief system for the poor, the presence of guilds, and complex social organization. However, a strict adoption of threshold criteria (10,000 or even 5,000) in certain specific contexts is limiting since it implies the exclusion of several settlements that truly performed urban functions (Chittolini 2015; Ginatempo 2018). To understand if this also happened in the Republic of Genoa, we tried to seek evidence in coeval documents for when a place was labeled as a 'city'. This last check showed us that in many cases, the term 'city' was adopted to identify settlements with far fewer than 5,000 inhabitants, although meeting most of the abovementioned qualitative criteria[10]. Considering all this information, we thought it appropriate, as in Alfani (2004), to lower the threshold to 4,000 inhabitants within the city center, thus not considering a sparse population, even if belonging to the same administrative jurisdiction. Given these premises, from 1300 to 1550, only two urban centers—Genoa and Savona[11]—had more than 4,000 inhabitants, while in the following period, the number of cities gradually increased to twelve: Genoa, Alassio, Chiavari, Novi, Ovada, Porto Maurizio, Sampierdarena, Sanremo, Sarzana, Savona, Spezia, and Ventimiglia.

From half a millennium perspective, the total population of the Republic of Genoa[12] rose from 285,000 to 490,000 inhabitants from 1300 to 1800, at an annual compound interest rate of 0.001%. In the same period, the urbanization level also rose from 22% to 30%. Therefore, the state experienced a positive demographic trend, even at a very low pace, and a gradual rise in the urbanization ratio. Specifically, in the late Middle Ages, the Republic probably experienced one of the highest levels of urbanization in Europe. However, after reaching an apex in 1325, the urbanization level drastically declined, with the republic regaining the previous level only in 1575. In addition, urbanization shows a substantial rate of growth—something approaching 'modern growth' in urban terms—only from 1775 onward (Figure 3). These results seem to imply, on the one hand, an absolute stagnation in the level of urbanization that lasted two-and-a-half centuries and, on the

[9] In fact, Savona entered formally into the orbit of Genoa only in 1528; however, its geographic proximity caused it to belong to the same economic area long before that date.

[10] A detailed analysis of qualitative criteria of Genoese cities is available in the Supplementary Material.

[11] See footnote 9.

[12] Keeping constant its 1790 boundaries, hence not adapting the area considered to the historical boundaries proper to each epoch.

other hand, a modest rate of growth that began at the end of the 16th century and lasted almost until the fall of the republic in 1797, with the exception of some surges experienced during the ‘century of the Genoese’ and the last quarter of the 18th century. Even looking at the population tendency, it is possible to notice this long-run stagnation, temporarily interrupted by rapid growth in the republic’s golden age. However, this efflorescence and its consequences (i.e. an urbanization level, on average, that was higher in the following centuries) cannot be perceived by observing urbanization phenomena at the scale of Northern Italy (Figure 4). We found that analyzing urbanization from the perspective of macro-areas (i.e. Northern Italy, Central Italy, and Southern Italy) tends to flatten the profound differences between Italian pre-unification states, thereby distorting the perception of the economic trends of pre-industrial Italy.

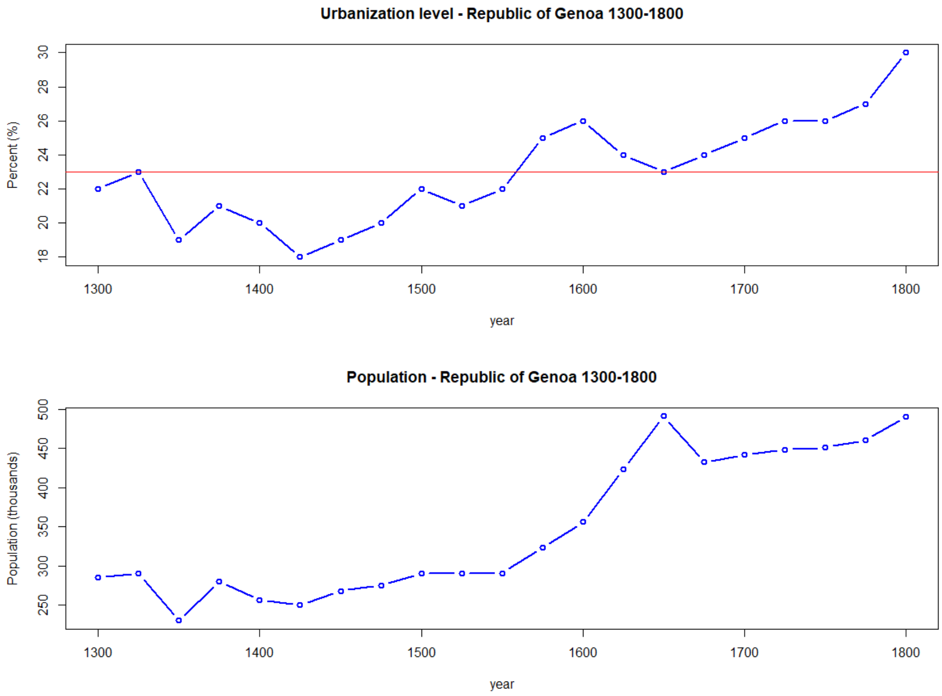

Figure 3. Urbanization level (cities $\geq$ 4,000) and population level (thousands) in the Republic of Genoa (1300–1800). The horizontal line represents the average urbanization level. Source: supplementary material.

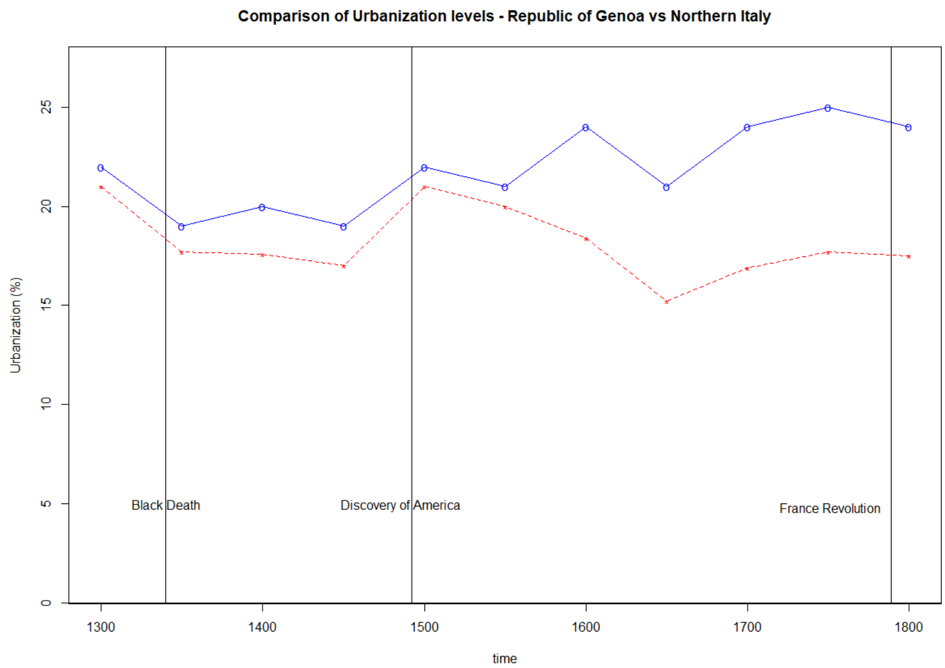

Figure 4. Comparison between the urbanization level for the Republic of Genoa (solid line) and Northern Italy (dotted line), 1300 to 1800. Threshold adjusted to enable comparison: cities $\geq$ 5,000. Sources: supplementary material and Malanima (2005).

Elsewhere in North Italy during the late Middle Ages, the urbanization level was very high in comparison with the rest of Europe (Figure 5); however, in the following periods, it remained substantially stagnant (Malanima 2002; Chiarini and Marzano 2019) at a pre-unification state level (Figure 6). This dynamic thus raises the question: why did the rise of urbanization during the late Middle Ages not result in a transition to sustained growth?

First, the trend of Genoese urbanization was interspersed by several declining phases due to structural and external factors, or a combination of both. The first phase entails the territory's morphology and orography, characterized by a scarcity of fertile soil and low agricultural productivity, which increased the Genoese population's vulnerability to famines, and to the structural limits of the urban economy (i.e. rigid labor demand available in cities). This was constrained by the minimal expansion of the manufacturing sector. The second stage is strictly connected to the international context—in particular, the rise of the Ottoman Empire and Atlantization—and to the many plagues that regularly ravaged the republic, specifically the Black Death from 1348 to 1350 and the epidemics of 1524, 1528, 1579 to 1580, and 1656 to 1657[13]. However, after the plague from 1656 to 1657, the Republic of Genoa did not experience any external negative shocks of such magnitude and long-lasting impact. Despite this, there was no significant change in urbanization and population rate of growth, which continued to follow a very modest trend, except for the surge in urban population experienced in the last quarter of the 18th century. This led us to conclude that external factors, while relevant, are not sufficient

[13]For a general overview on the history of Genoa, see Puncuh (2003); Assereto and Doria (2007).

to explain the stagnation that characterized the republic's economic growth in the long run. Therefore, the morphologic and orographic features and the structural limits of the urban economy were probably the main causes for the lack of sustained economic growth in the long run, despite the high level of urbanization reached in the late Middle Ages.

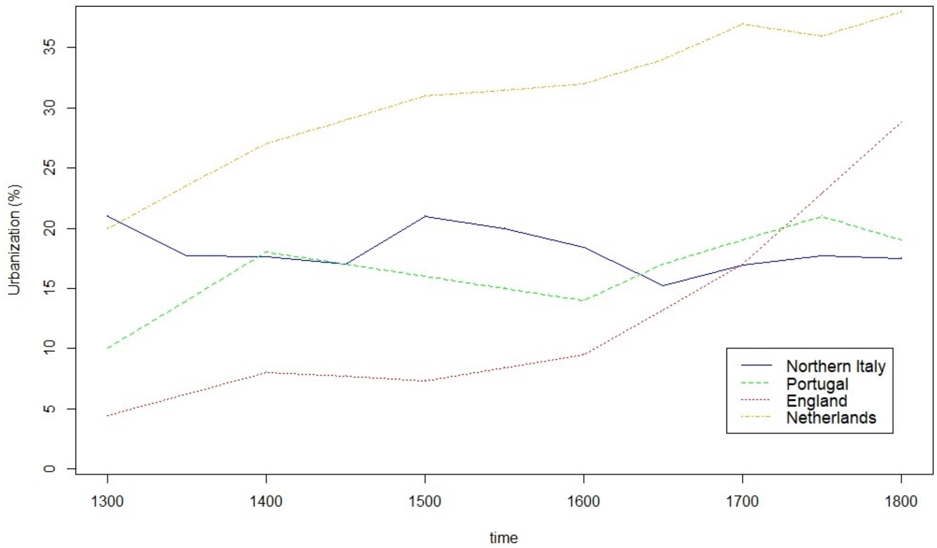

Figure 5. Comparison of urbanization levels; Northern Italy vs. some pre-industrial European states (1300–1800). Threshold adjusted to enable comparison: cities ≥ 5,000. Sources: Malanima (2005) for Northern Italy data, Allen (2003) for data from England, Bairoch et al. (1988) and McEvedy and Jones (1978) for data from the Netherlands and Portugal.

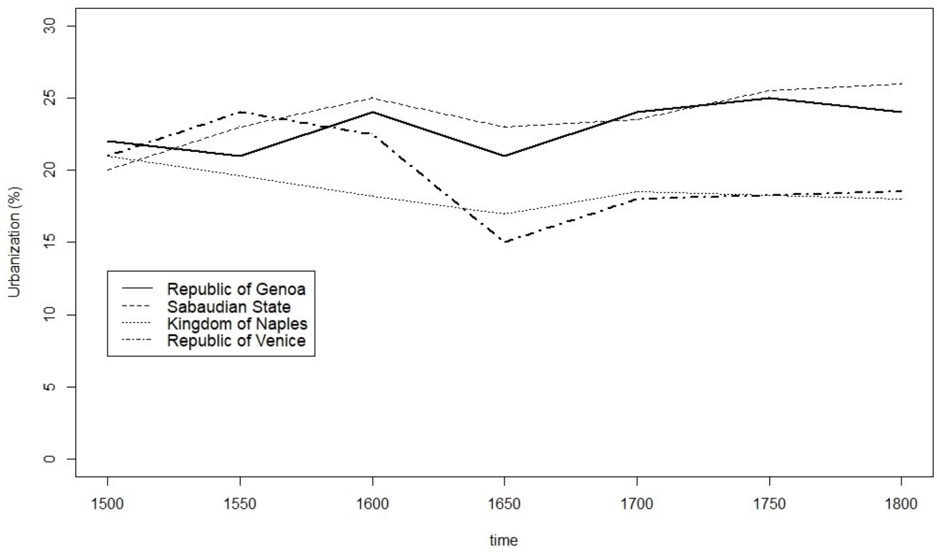

Figure 6. Comparison between urbanization level for the Republic of Genoa and some other pre-unification Italian states (1500–1800). Threshold adjusted to enable comparison: cities $\geq$ 5,000. Sources: supplementary material and Alfani (2020) for data on other pre-unification states.

In addition to the long-term tendency in population, until the end of the 17th century, the combination of structural and external factors triggered both temporary and permanent migration, which strongly affected Genoa's urbanization trend (Alfani 2004). The outbreak of an epidemic often determined the mass emigration of a large portion of the urban population, which tried to escape an unfortunate fate by taking refuge in the countryside. Once the contagions were over, many survivors returned to within the urban walls, often encouraged by city authorities concerned with rapidly repopulating the city to avoid excessive wage inflation and to promote economic recovery (Savelli 1984, p. 174). However, there is no evidence that supports the idea of 'explosive' urban population growth in the short term due to temporary migration, except for the last quarter of the 18th century. In fact, beyond temporary immigration, there is another reason, probably more persistent, that accounts for the urbanization trend observed in the republic: permanent migration. When farmers who migrated from the countryside started families in cities, subsequently, their children grew up and gradually entered the labor market, leading in the long run to a saturation of job opportunities in cities and a deterioration in living conditions in urban areas. Admittedly, when a famine occurred, many farmers tended to migrate, albeit temporarily, to cities, especially Genoa, which could offer more opportunities to overcome the crisis due to the supposed relative abundance of food and to the presence of a well-structured social support system. To prevent this situation, since the early 17th century, a special deputation, the *pro elemosine pauperum Dominii*, was created with the purpose of distributing alms (namely, relief in kind, such as victuals) to the poorest households in the state (Costantini 1978, pp. 187–188). However, if the food shortage was severe, the action of the deputation was insufficient, so that the Genoese authorities organized a special distribution of cereals and other foodstuffs in the state's different jurisdictions (Gatti 1973). In other words, during the Early Modern Age, several policies aimed at controlling the urban population were brought into play, which included encouraging immigration from the countryside after a plague, trying to create the conditions to support the urban population, providing job opportunities, cheap food supplies, and a relief system for the poor. On the other hand, the Genoese authorities sought to expel unwanted inhabitants, such as vagrants, beggars, and unemployed people, as well as to discourage the immigration of peasants in less favorable economic phases. The government was aware that the high growth of the urban population might trigger several problems, including a rise in unemployment and an increase in the cost of living (victualing and housing) that could generate social tension, and ultimately stress for the social relief system. Therefore, the Genoese authorities carefully monitored population dynamics and adopted various kinds of measures, depending on the circumstances, to avoid problems associated with overpopulation; in other words, their efforts aimed at maintaining an 'optimal' level of the urban population (Costantini 1978, pp. 463–464; Savelli 1984, p. 174). Evidence of such procedures has been found in a decree issued on the occasion of the 1539 economic downturn, where all building workers who were not native to Genoa were ordered to leave the city and to return to their birthplace or elsewhere; otherwise, they were liable to scourge or imprisonment (Savelli 1984, p. 174). This measure also highlights that in a period of economic vitality, as during the 'century of the Genoese', a high degree of urbanization triggered by both temporary migration and internal urban growth (i.e. permanent migration) does not always imply an increase in living standards; in other words, 'Malthusian urbanization'. The importance of this phenomenon in the history of the republic also seems supported by analyzing famines from 1550 to 1800 (Figure 7). It is quite evident that famines generally occurred during rising urbanization phases, underscoring that they are related to periods of consistent migration from the countryside (where the pressure of the population on resources tends to increase), as pointed out by Alfani and Ó Gráda (2018). The links between famines and high urbanization are also confirmed after the end of 'big' external shocks by proclamations issued during the 1678 to 1679 famine, which show an 'anticyclical policy' implemented by Genoese authorities to counterbalance inflows of migration from the countryside[14]. These measures included an entry ban in the republic on foreign beggars and the expulsion of non-native beggars from the city of Genoa. Similar decrees were adopted during the 1691 to 1693 period, partially coinciding with the famine of 1693 to 1695[15].

These dynamics also seem supported by analyzing the long-term trend of the few data available for Genoese real wages[16], which, conversely to urbanization level, show a gradually declining trend from 1500 to 1800 (Figure 8). The decoupling of real wages and urbanization level seems to suggest that labor demand within cities was not able to meet the supply of labor of the growing urban population. This evidence, even if not implying a causal relationship, indicates a rise in urbanization detached from an increase in real income, probably due to long-lasting migration from the poorer countryside.

[14]Archivio di Stato di Genova (ASG), Archivio Segreto (AS), no. 1023, doc. 78 and 81.

[15]ASG, AS, no. 1025, doc. 55 and 63.

[16]Unfortunately, available data on real wages covered only the 16th to 18th centuries and refer simply to building workers employed in Genoa.

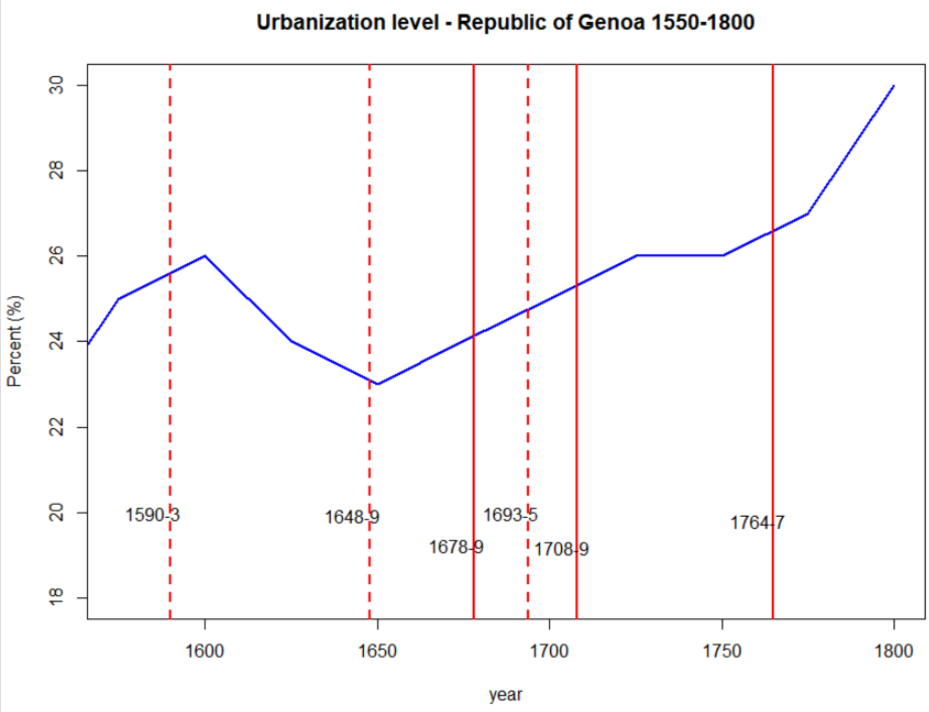

Figure 7. Urbanization level (cities $\geq$ 4,000) and famines in the Republic of Genoa (1575–1800). Vertical dotted lines show the most harmful famines in northern Italy, while vertical solid lines indicate the most widespread famines in Liguria. Sources: supplementary material and Alfani, Mocarelli and Strangio (2017) for famine data.

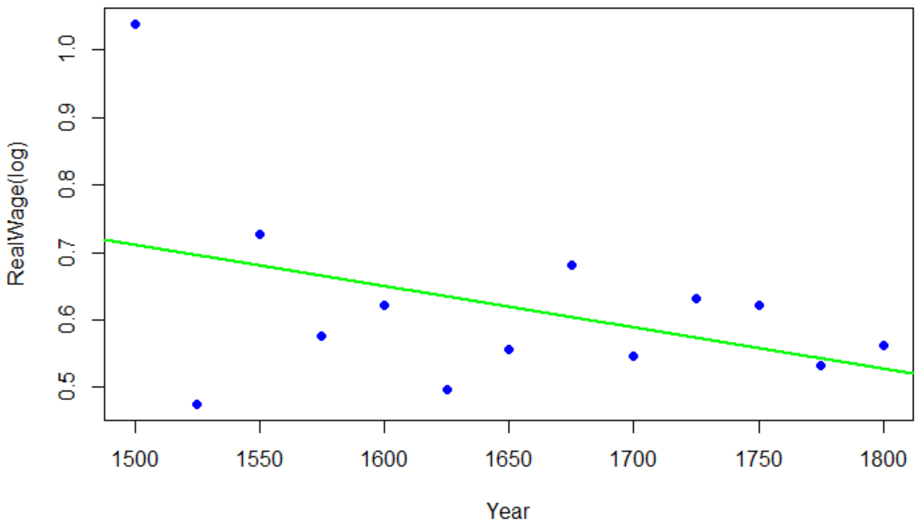

Figure 8. Real wage (log) for Genoese workers in the building sector (1500–1800). The solid line represents a linear trend. Sources: Felloni (1977); Sivori Porro (1989, 1994).

Malthusian urbanization is also especially evident in the last decades of the 18th century, when Genoa's urbanization level experienced one of the strongest increases in the republic's history, rising from 27% to 30% in just over two decades. This trend is well explained in coeval documents that attest to the growing immigration of peasants from the poor villages of the Genoese domain and the neighboring imperial fiefs to the coastal towns and, above all, to Genoa, where a higher net migration counterbalanced the natural decrease of the period (Felloni 1998, p. 1315). However, despite several attempts to develop manufacturing activities, as already observed by Giovanni Battisti Pini, a local erudite of the time, the structural limits of the Genoese industrial sector were not able to generate enough job opportunities, which resulted in the spread of poverty within cities[17]. If the Genoese political economy was unable to offer suitable solutions, this critical situation would have forced poor and unemployed people to migrate abroad (Costantini 1978, pp. 463–464). Therefore, what apparently was the most significant increase in urbanization in the state's history was actually a Malthusian urbanization phenomenon.

Testing the Malthusian urbanization hypothesis

In this section, we aim to strengthen the evidence shown in the previous section about the occurrence of the Malthusian urbanization phenomenon in the Republic of Genoa from 1300 to 1800.

As stated above, in this paper, we argue that in the Genoese context, a high level of urbanization was not always related to improving living standards, but may have been a consequence of rising poverty in the countryside, pushing farmers toward cities and resulting in the long-term saturation of the urban labor market. Therefore, when introducing this evidence in the 'standard' Malthusian model, we should hypothesize the following relationships:

(1) The check mechanisms, when a temporary increase in per capita income leads the population and, consequently, urbanization to increase, due to migration from the overpopulated countryside to cities; and (2) diminishing returns, whereby a rise in urbanization above the structural limits of a city's economy leads to a decrease in urban incomes due to a fixed labor demand available in cities.

The simultaneous action of these main dynamics allows us to explain the coexistence of city growth and Malthusian stagnation.

Given these features, we adopted a VAR model to investigate the emergence of both check mechanisms and diminishing returns, using as endogenous variables the rate of population growth and the rate of urbanization growth. The application of the VAR approach is particularly suitable given the endogenous nature of these demographic variables (Nicolini 2007; Møller and Sharp 2008; Pedersen et al. 2021). In addition, as proposed by Chiarini (2007) and Chiarini and Marzano (2019), we inserted a dummy variable into the model to add information on epidemic-induced mortality that affected the republic's demography from 1300 to 1800[18], which the population variable, by lacking a mortality index, might

[17] However, the actual order of magnitude of this migration phenomenon is lower than perceived at the time.

[18] For the full list of plagues see the Appendix.

not capture[19]. Table 1 summarizes the variables used to estimate the VAR model.

Variables type	Description	Denomination
Endogenous variable	Rate of population growth (%), 25-year frequency.	*Pop*
Endogenous variable	Rate of urbanization growth (%), 25-year frequency.	*Urbaniz*
Exogenous variable	Dummy variable for the plague.	*X*

Table 1. Description of the variables included in the VAR model

Once we estimated the VAR model[20], we obtained and plotted the orthogonal impulse response functions (OIRFs). The results are as follows.

The check mechanisms

Figure 9 shows the effect of a shock in the rate of population growth on the urbanization level. Immediately after the shock, the rate of growth of urbanization rose, reaching a positive peak at the end of the first period, 25 years after the shock. After this point, the urbanization level dropped, reaching a negative peak at the end of the second period, approximately 50 years later; after this point, it gradually returned to the initial level, approximately in the third period, after 75 years.

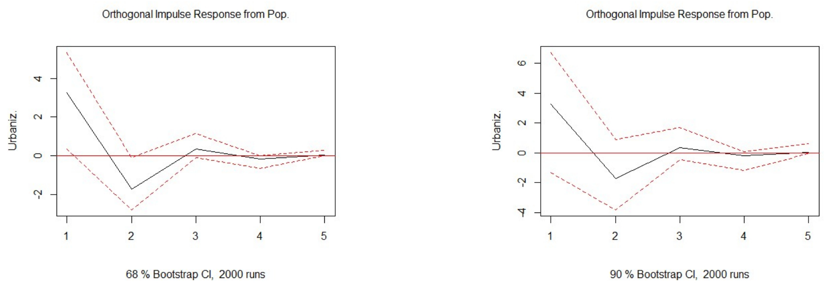

Figure 9. Response of the urbanization rate of growth to the population rate of growth (68% and 90% CI)

At first glance, the most classical explanation for this trend is the countryside's inability to support the expansion of the rural population beyond certain levels without significant improvements in agricultural productivity. This means that in the first phase, an increase

[19]The results of the estimated VAR model (excluding the dummy for epidemics) are basically the same: both eigenvalues and post-estimation tests are substantially equal to the VAR model with a dummy.

[20]A detailed analysis of model specification, the stationarity of variables, lag selection criteria, the identification strategy, and post-estimation specifications is available in the Appendix.

in the population rate of growth led to overpopulation and hidden unemployment in the countryside. Therefore, the expectation of better job opportunities and improved living conditions induced migration flows to cities. In this case, it is not an increase in rural productivity and agrarian income that determines the rise in urbanization; instead, the agricultural sector's inability to sustain an increase in the rural population triggers the expansion of the size of cities. These results support our hypothesis that any unsustainable increase in the rural population should lead to a rise in urbanization.

Diminishing returns

Figure 10 shows a negative relationship between the population and urbanization rate of growth immediately in the second period, reaching a negative peak after 50 years.

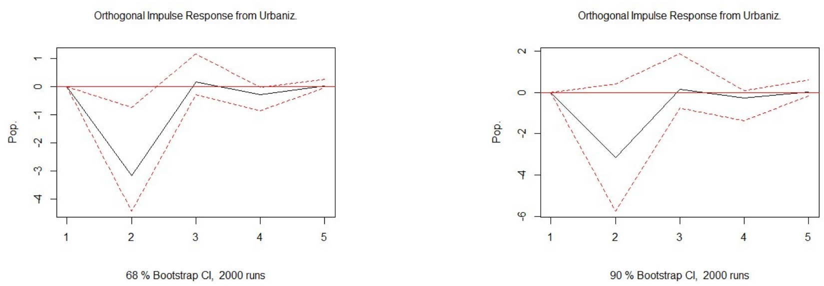

Figure 10. Response of the population rate of growth to the urbanization rate of growth (68% and 90% CI)

From this point of view, this dynamic converges with the idea that an increase in urbanization indicates a decline in the population rate of growth in the long term. In line with our hypothesis, these results describe a decrease in the standard of living in the urban context due to overpopulation, a rise in the cost of living, and an increase in the unemployment level in cities. Therefore, worse urban living standards lead to an increase in mortality and a reduction in the fertility rate within cities. Hence, although Figure 10 shows a *killer city* dynamic, this should not be interpreted as a demographic transition typical of the post-Malthusian regime (Sato and Yamamoto 2005; Voigtländer and Voth 2013). More likely, it is evidence of poor living conditions in the countryside and in cities that led to lower fertility (i.e. postponing marriage) and higher mortality rates in both the rural and urban populations.

Conclusion

The innovation proposed in this paper by focusing on a little investigated area, the Republic of Genoa, is critical in two respects: it not only allows us to better understand the economic development of this area, but also adds new information for interpreting urbanization in the pre-industrial world.
The orographic conditions and the low productivity that characterizes the rural part of the state, together with the structural limits of the urban economy, offer us new evidence

into how Malthusian stagnation took place despite a high level of urbanization. Both the historical evidence and the quantitative analysis show how, in the Genoese context, an increase in urbanization *per se* is not always a reliable approximation of a rise in rural marginal productivity or better living conditions in cities. Conversely, urbanization is an approximation of overpopulation and worse living conditions in the countryside, leading masses of desperate farmers to migrate to cities. In turn, the economic structure of cities was not able to totally absorb these consistent and long-lasting migration flows; therefore, when the urban labor market reached the saturation point, the excess urban population left the cities. From this point of view, this counterintuitive phenomenon is explained, on the one hand, by the scarcity of arable land and low technical progress that constrains any increase in productivity, and on the other hand by the structural limits of the urban economy, unable to perform a relief-valve function for the excess labor supply. Therefore, the rise in urbanization cannot match sustained economic growth. The natural consequence is urbanization growth that follows a stop-and-go trend, where city populations inflate and deflate cyclically.

From this angle, although we do not deny some periods of efflorescence during the history of the republic, generated by the expansion of urban activities, for most of Genoese history, the rise in urbanization was predominantly triggered by long-lasting migration from the poor and overpopulated countryside, rather than by economic growth driven by the urban sector. In conclusion, the Republic of Genoa from 1300 to 1800 exhibits all the features of Malthusian stagnation, despite a high level of urbanization.

References

ACEMOGLU, D., JOHNSON, S., ROBINSON, J. A. (2002). Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution. *The Quarterly Journal of Economics* 117, pp. 1231–1294.
https://doi.org/10.1162/003355302320935025

ACEMOGLU, D., JOHNSON, S., ROBINSON, J. A. (2005). The rise of Europe: Atlantic trade, institutional change and economic growth. *American Economic Review* 95, pp. 546–579.

ALFANI, G. (2004). La dinamica della popolazione dell'Italia settentrionale nel Cinquecento. Dal generale al particolare e viceversa: casi, comparazioni, questioni. *Cheiron* 21(2), pp. 95–131. https://doi.org/10.1400/59797

ALFANI, G. (2020). Pandemics and asymmetric shocks: evidence from the history of plague in Europe and the Mediterranean. *Journal for the History of Environment and Society* 5, pp. 197–209.
https://doi.org/10.1484/J.JHES.5.122475 ALFANI, G. (2021). Economic Inequality in Preindustrial Times: Europe and Beyond. *Journal of Economic Literature* 59(1), pp. 3–44. https://doi.org/10.1257/jel.20191449

ALFANI, G., MOCARELLI, L., STRANGIO, D. (2017). Italy, in ALFANI, G., C. Ó GRÁDA (eds), *Famine in European History*, Cambridge: Cambridge University Press, pp. 25–47.

ALFANI, G., Ó GRÁDA, C. (2018). The timing and causes of famines in Europe. *Nature Sustainability* 1, pp. 283–288. https://doi.org/10.1038/s41893-018-0078-0

ALFANI, G., PERCOCO, M. (2019). Plague and long-term development: the lasting effects of the 1629–30 epidemic on the Italian cities. *The Economic History Review* 72, pp. 1175–1201. https://doi.org/10.1111/ehr.12652

ALLEN, R. C. (2003). Progress and poverty in early modern Europe. *Economic History Review* 56(3), pp. 402–443, https://doi.org/10.1111/j.1468-0289.2003.00257.x

ASSERETO, G., DORIA, M. (eds) (2007). *Storia della Liguria*. Rome–Bari: Laterza.

BAIROCH, P. (1988). *Cities and Economic Development: From the Dawn of History to the Present*. Chicago: University of Chicago Press.

BAIROCH, P., BATOU, J., CHEVRE, P. (1988). *La population des villes européennes: banque de données et analyse sommaire des résultats, 800–1850*. Genève: Librairie Droz.

BALARD, M. (1983). Gênes et la Mer Noire (XIIIe–XVe siècles). *Revue Historique* 270, pp. 31–54.

BELOCH, K. J. (1965). *Bevölkerungsgeschichte italiens*, Vol. 3, *Die Bevölkerung der republik Venedig, des Herzogtum Mailand, Piemonts, Genuas, Corsicas und Sardiniens. Die Gesamtebevölkerung Italiens*. Berlin: W. De Gruyter (2nd ed.).

BRAUDEL, F. (1966). *La Méditerranée et le Monde méditerranéen à l'époque de Philippe II*. Paris: Armand Colin (2nd ed.).

BRUNT, L., GARCÍA-PEÑALOSA, C. (2021). Urbanisation and the Onset of Modern Economic Growth. *The Economic Journal*. https://doi.org/10.1093/ej/ueab050

BULFERETTI, L., COSTANTINI, C. (1966). *Industria e commercio in Liguria nell'età del Risorgimento (1700–1861)*. Milan: Banca Commerciale Italiana.

CALEGARI, M. (1969). *La società patria delle arti e manifatture. Iniziativa imprenditoriale e rinnovamento tecnologico nel riformismo genovese del Settecento*. Florence: Giunti.

CARACCIOLO, A. (1973). La storia economica. In *Storia d'Italia*, Vol. 3. Turin: Einaudi, pp. 515–693.

CERMEÑO, A. L., ENFLO, K. (2019). Can kings create towns that thrive? The long-term implications of new town foundations. *Journal of Urban Economics* 112, pp. 50–69. https://doi.org/10.1016/j.jue.2019.06.001

CHEN, M., ZHANG, H., LIU, W., ZHANG, W. (2014). The Global Pattern of Urbanization and Economic Growth: Evidence from the Last Three Decades. *PLoS ONE* 9(8): e103799. https://doi.org/10.1371/journal.pone.0103799

CHIARINI, B. (2007). The Economic Consequences of Population Growth in Italy: From the 13th Century to 1900: A Discussion on the Mathusian Dynamics. Available at SSRN:*http://ssrn.com/abstract=1019035*

CHIARINI, B., MARZANO, E. (2014). Urbanization and Growth: Why Did the Splendor of the Italian Cities in the Sixteenth Century not Lead to Transition? *CESifo Working Paper No. 5038.*

CHIARINI, B., MARZANO, E. (2019). Urbanisation and Agricultural Productivity: Why Did the Splendour of the Italian Cities in the Sixteenth Century Not Lead to Transition? *Kyklos* 72, pp. 3–28. https://doi.org/10.1111/kykl.12192

CHITTOLINI, G. (2015). *L'Italia delle civitates. Grandi e piccoli centri fra Medioevo e Rinascimento*. Rome: Viella.

CIPOLLA, C. M. (1989). *Le tre rivoluzioni e altri saggi di storia economica e sociale*. Bologna: Il Mulino.

CLARK, G. (2007). *A Farewell to Alms: A Brief Economic History of the World.* Princeton: Princeton University Press.
COSTANTINI, C. (1978). *La Repubblica di Genova nell'età moderna.* Turin: Einaudi.
DE LONG, J. B., SHLEIFER, A. (1993). Princes and Merchants: European City Growth before the Industrial Revolution. *The Journal of Law Economics* 36(2), pp. 671–702. https://doi.org/10.1086/467294
DE VRIES, J. (1984). *European Urbanization, 1500-1800.* Cambridge, MA: Harvard University Press.
DITTMAR, J. E. (2011). Information technology and economic change: the impact of the printing press. *Quarterly Journal of Economics* 126 (3), pp. 1133–1172. https://doi.org/10.1093/qje/qjr035
FAY, M., OPAL, C. (2000). Urbanization Without Growth: A not-so- uncommon Phenomenon. *The World Bank Policy Research Working Paper Series* 2412.
FELLONI, G. (1971). *Gli investimenti finanziari genovesi in Europa tra il Seicento e la Restaurazione*, Milan: Giuffrè.
FELLONI, G. (1977). Italy. In WILSON Ch., PARKER G. (eds), *An introduction to the Sources of European Economic History 1500–1800.* Vol. I. London: Weidenfeld and Nicolson, pp. 1–36.
FELLONI, G. (1995). Stato genovese, finanza pubblica e ricchezza privata: un profilo storico. In ZILLI I. (ed), *Fra spazio e tempo. Studi in onore di Luigi De Rosa*, Naples: Esi, pp. 381–404.
FELLONI, G. (1998). Popolazione e sviluppo economico a Genova (1777–1939). In *Scritti di Storia Economica.* Genoa: Società Ligure di Storia Patria, pp. 1303–1321.
FELLONI, G. (2001). Ricchezza privata, credito e banche: Genova e Venezia nei sec. XII–XIV. In ORTALLI G., PUNCUH D. (eds), *Genova, Venezia, il Levante nei secoli XII–XIV.* Genoa: Società Ligure di Storia Patria, pp. 295–318.
FELLONI, G. (2003). Organización portuaria, navegación y tráfico en Génova: Un sondeo entre las fuentes de la Edad Moderna. In RIBOT GARCÍA L., DE ROSA L. (eds), *Naves, puertos e itinerarios marítimos en la Época Moderna.* Madrid: Actas, pp. 237–267.
FELLONI, G., LAURA, G. (2014). *Genoa and the History of Finance. Twelve Firsts?* Genoa–Rome: System Graphic.
FRATIANNI, M., SPINELLI, F. (2006). Did Genoa and Venice kick a financial revolution in the quattrocento? *Working Paper. Oesterreichische Nationalbank*, 112. GALOR, O. (2011). *Unified Growth Theory.* Princeton and Oxford: Princeton University Press.
GATTI, C. (1972). Una congiuntura difficile: 1677–78. Approvvigionamenti e consumi di grano nella Repubblica di Genova. *Università degli Studi di Genova Annali della Facoltà di Giurisprudenza* 11, pp. 135–166.
GATTI, C. (1973). Progetti di riforma del Magistrato d'Abbondanza genovese nella prima metà del Seicento. *Università degli Studi di Genova Annali della Facoltà di Scienze Politiche* 1, pp. 319–348.
GINATEMPO, M. (2018). La popolazione dei centri minori dell'Italia Centro-Settentrionale nei secoli XIII–XV. Uno sguardo d'insieme. In *I centri minori italiani nel tardo medioevo. Cambiamento sociale, crescita economica, processi di ristrutturazione (secoli XIII-XVI).* Florence: Firenze University Press, pp. 31–79.
GOLDSTONE, J. A. (2002). Efflorescence and economic growth in world history. Re-

thinking the "Rise of the West" and the Industrial Revolution. *Journal of World History* 13, pp. 323–389. https://doi.org/10.1353/jwh.2002.0034

GOLLIN, D., PARENTE, S. L., ROGERSON, R. (2002). The role of agriculture in development. *American Economic Review* 92(2), pp. 160–164. https://doi.org/10.1257/000282802320189177

GOLLIN, D., JEDWAB, R., VOLLRATH, D. (2016). Urbanization with and without industrialization. *Journal of Economic Growth* 21, pp. 35–70. https://doi.org/10.1007/s10887-015-9121-4

GRENDI, E. (1970). Genova alla metà del Cinquecento: una politica del grano? *Quaderni Storici* 5(1), pp. 106–160. https://www.jstor.org/stable/43900349

GRENDI, E. (1976). *Introduzione alla Storia moderna della Repubblica di Genova.* Genoa: Bozzi.

GUGLIELMOTTI, P. (2018). Genoa and Liguria. In BENEŠ C. E. (ed), *A Companion to Medieval Genoa.* Leiden: Brill, pp. 49–71.

HENDERSON, J. V., ROBERTS, M., STOREYGARD, A. (2013). Is Urbanization in Sub-Saharan Africa Different? *Policy Research Working Paper* No. 6481. Washington, DC: World Bank.

JEDWAB, R., VOLLRATH, D. (2015). Urbanization without growth in historical perspective. *Explorations in Economic History* 58, pp. 1–21. https://doi.org/10.1016/j.eeh.2015.09.002

JEDWAB, R., CHRISTIAENSEN, L., GINDELSKY, M. (2017). Demography, urbanization and development: Rural push, urban pull and... urban push? *Journal of Urban Economics* 98, pp. 6–16. https://doi.org/10.1016/j.jue.2015.09.002

KARPOV, S. P. (1993). The grain trade in the Southern black Sea region: The thirteenth to the fifteenth century. *Mediterranean Historical Review* 8(1), pp. 55–73. https://doi.org/10.1080/09518969308569647

KIRK, T. A. (2005). *Genoa and the Sea. Policy and Power in an Early Modern Maritime Republic 1559–1684.* Baltimore and London: The Johns Hopkins University Press.

KIRK, T. A. (2019). The Republic of Genoa and Its Maritime Empire, in STROOTMAN R., VAN DEN EIJNDE F., VAN WIJK R (eds), *Empires of the Sea. Maritime Power Networks in World History.* Leiden: Brill, pp. 153–175.

LEE, R. (1973). Population in Preindustrial England: An Econometric Analysis, *The Quarterly Journal of Economics* 87(4), pp. 581–607, https://doi.org/10.2307/1882026.

LEE, R. D., SCHOFIELD, R. S. (1981). British Population in the Eighteenth Century. In *The Economic History of Britain since 1700*, Vol. 1: 1700–1860, eds. Roderick Floud and Donald McCloskey. Cambridge, U.K.: Cambridge University Press, pp. 17–35.

LEWIS, A. W. (1954). Economic development with unlimited supplies of labor. *The Manchester school* 22, pp. 132–191. https://doi.org/10.1111/j.1467-9957.1954.tb00021.x

LOPEZ, R. S. (1964). Market expansion: the case of Genoa. *Journal of Economic History* 24, pp. 445–464. https://doi.org/10.1017/S0022050700061179

LOPEZ, R. S. (1970). Venice and Genoa: Two Styles, One Success. *Diogenes* 18, pp. 39–47. https://doi.org/10.1177/039219217001807103

LUCAS, R. E. (2004). Life Earnings and Rural–Urban Migration. *Journal of Political Economy* 112 (S1), S29–S59. https://doi.org/10.1086/379942

MADDISON, A. (2008). Statistics on World Population, GDP and Per Capita GDP,

1–2008 AD. *GGDC*, Groningen.
MALANIMA, P. (2002). *L'Economia Italiana. Dalla Crescita Medievale alla Crescita Contemporanea*. Bologna: Il Mulino.
MALANIMA, P. (2005). Urbanisation and the Italian economy during the last millennium. *European Review of Economic History* 9(1), pp. 97–122. https://doi.org/10.1017/S1361491604001327
MALANIMA, P. (2006). An age of decline. Product and income in eighteenth century Italy. *Rivista di Storia Economica* 22, pp. 91–133. https://doi.org/10.1410/22147
MALANIMA, P. (2011). The long decline of a leading economy: GDP in central and northern Italy, 1300–1913. *European Review of Economic History* 15(2), pp. 169–219. https://doi.org/10.1017/S136149161000016X
MALANIMA, P. (2021). Past growths: Pre-modern and modern. *Journal of Global History* 16(2), pp. 301–308. https://doi.org/10.1017/S1740022820000418
MALTHUS, T. (2015). *An essay on the principle of population and other writings* (ed. R. MAYHEV). London: Penguin (original work published 1798).
MARSILIO, C. (2008). *Dove il denaro fa denaro: Gli operatori finanziari genovesi nelle fiere di cambio del XVII secolo*. Novi Ligure: Città del Silenzio.
MASSA, P. (1998). The Genoese Guilds (XVI–XVII Centuries). The Food Administration Offices and the Food Sector Guilds in Genoa: Organisation and Conflict. In GUENZI A., MASSA P., PIOLA CASELLI F. (eds), *Guilds, Markets and Work Regulation in Italy, 16th–19th Centuries*. Aldershot: Ashgate, pp. 246–265.
MASSA, P. (2007). Un'economia di frontiera fra terra e mare. In ASSERETO G., DORIA M. (eds), *Storia della Liguria*. Rome–Bari: Laterza, pp. 115–131.
MCEVEDY, C., JONES, R. (1978). *Atlas of world population history*. London: Lane.
MØLLER, N., SHARP, P. (2008). Malthus in co-integration space: a new look at the relationship between demography and living standards in pre-industrial England. *Working Paper, Department of Economics, University of Copenhagen*. www.econ.ku.dk.
NICOLINI, E. A. (2007). Was Malthus right? A VAR analysis of economic and demographic interactions in pre-industrial England. *European Review of Economic History* 2(1), pp. 99–121. https://doi.org/10.1017/S1361491606001894
PEDERSEN, M., RIANI, C., SHARP, P. (2021). Malthus in preindustrial Northern Italy? *Journal of Population Economics* 34, pp. 1003–1026. https://doi.org/10.1007/s00148-020-00812-3
PERSSON, K. G. (1991). Labour productivity in medieval agriculture: Tuscany and the 'Low Countries'. In CAMPBELL B. M. S., OVERTON M. (eds), *Land, Labor and Livestock, Historical Studies in European Agricultural Productivity*. Manchester: Manchester University Press, pp. 124–143.
PERSSON, K. G. (2015). *An Economic History of Europe: Knowledge, Institutions and Growth, 600 to the present*. Cambridge: Cambridge University Press (2nd ed.).
PICCINNO, L. (2017). Genoa: a City with a Port or a Port City? In BLOCKMANS W., KROM M., WUBS-MROZEWICZ J. (eds), *The Routledge Handbook of Maritime Trade around Europe, 1300–1600*. London: Routledge, pp. 159–176.
PUNCUH, D. (ed.). (2003). *Storia di Genova Mediterraneo, Europa, Atlantico*. Genoa: Società Ligure di Storia Patria.
QUAINI, M. (1972). Per la Storia del paesaggio agrario in Liguria. Note di geografia

storica sulle strutture agrarie della Liguria medievale e moderna. *Atti della Società Ligure di Storia Patria* n.s. 12(2), pp. 201–360.
SATO, Y., YAMAMOTO, K. (2005). Population concentration, urbanization, and demographic transition. *Journal of Urban Economics* 58, pp. 45–61.
https://doi.org/10.1016/j.jue.2005.01.004
SAVELLI, R. (1984). Dalle confraternite allo stato: il sistema assistenziale genovese nel cinquecento. *Atti della Società Ligure di Storia Patria* n.s. 24(1), pp. 171–216.
SCHULTZ, T. W. (1953). *The Economic Organization of Agriculture.* New York: McGraw-Hill.
SIVORI PORRO, G. (1989). Costi di costruzione e salari edili a Genova nel secolo XVII. *Atti della Società Ligure di Storia Patria* n.s. 29(1), pp. 339-423.
SIVORI PORRO, G. (1994). Note sull'edilizia genovese del Cinquecento. *Atti della Società Ligure di Storia Patria* n.s. 34(2), pp. 261-284.
VALLI, V. (2005). *Politica economica. Introduzione all'economia dello sviluppo.* Rome: Carocci.
VOIGTLÄNDER, N., VOTH, H. J. (2009). Malthusian Dynamism and the Rise of Europe: Make War, Not Love. *American Economic Review* 99 (2), pp. 248–254.
https://doi.org/10.1257/aer.99.2.248
VOIGTLÄNDER, N., VOTH, H. J. (2013). The three Horsemen of Riches. Plague, War, and Urbanization in Early Modern Europe. *Review of Economic Studies* 80(2), pp. 774–781. https://doi.org/10.1093/restud/rds034
WRIGLEY, E. A. (1985). Urban Growth and Agricultural Change: England and the Continent in the Early Modern Period. *The Journal of Interdisciplinary History* 15(4), pp. 683-728. https://doi.org/10.2307/204276
ZANINI, A. (2020). La Superba: Its Institutions and Fortune. In BOBER J., BOCCARDO P., BOGGERO F. (eds), *A Superb Baroque: Art in Genoa, 1600–1750.* Princeton and Oxford: Princeton University Press, pp. 5–21.

Appendix

VAR model

Model specification

Based on Nicolini (2007), we model our endogenous variables in a VAR model with a specification of the form:

$$A_0 \begin{pmatrix} Pop_t \\ Urbaniz_t \end{pmatrix} = A_1 \begin{pmatrix} Pop_{t-1} \\ Urbaniz_{t-1} \end{pmatrix} + \Phi D_t + G X_t + \mu_t \tag{1}$$

where the variable *Pop* represents the rate of growth of the population; the variable *Urbaniz* is the rate of growth of urbanization; D_t is the (2x1) vector of the deterministic component; X_t is the (2x1) vector of the exogenous variable (treated as the dummy), which represents the Plague effect; u_t represents a (2x1) vector containing the shocks in each of the variables; and G are the parameter matrices; and A_1 is a (2x2) matrix and

$$E(\mu_t \mu'_\tau) = \begin{cases} I & \text{if} \quad t = \tau \\ 0 & otherwise \end{cases}$$

In this case, each variable in t depends on its own lagged values and on contemporaneous and lagged values of all other variables. The shocks u_t can be linked to a particular variable, and they are not affected by contemporaneous effects of the other variables since they are already being taken into account with the coefficients of the matrix A_0.

Pre-estimation specifications

For the analysis of time series, the unit root test needs to be conducted first to judge the stationarity of the data. If the time-series data show a stationary sequence it admits a Wold representation[21] and the analysis of the vector autoregression model can be adopted. The results of the augmented Dickey-Fuller and Phillips-Perron tests for the series of *Pop* and *Urbaniz* are presented in Table A1.

	Pop	*Urbaniz*
	Philipps-Perron*	
PP	–5.2996	–4.9143
	Augmented Dickey Fuller**	
ADF	–2.6802	–3.4326

Table A1. Phillips-Perron and ADF tests.

*Z statistics critical values:	**Test critical values:
1% level: –3.806	1% level: –2.66
5% level: –3.019	5% level: –1.95
10% level: –2.650	10% level: –1.6

Both tests reject the null of a unit in the two time series at the 1% significance level, which suggests that the vector of the endogenous variables can be assumed to be covariance stationary in which the variables are affected by shocks with only temporary effects. Given that *Pop* and *Urbaniz* are stationary, we can express each variable of the system as a sum of these "fundamental" shocks:

$$A(L)\begin{pmatrix} Pop_t \\ Urbaniz_t \end{pmatrix} = \mu_t$$

Where L is the lag operator and $A(L) = A_0 - A_1 L$
To estimate the parameter of interest in (1), the system is presented in the reduced form:

[21] Wold's theorem states that every covariance-stationary time series can be written as Vector Moving Average, i.e. the sum of two time series, one deterministic and one stochastic.

$$\begin{pmatrix} Pop_t \\ Urbaniz_t \end{pmatrix} = \pi \begin{pmatrix} Pop_{t-1} \\ Urbaniz_{t-1} \end{pmatrix} + \Phi D_t + GX_t + \epsilon_t$$

where

$$A_0^{-1}\mu_t = \epsilon_t$$
$$A_0^{-1}A_1 = \pi_1$$

and

$$E(\epsilon_t \epsilon_\tau') = \begin{cases} \Omega & \text{if} \quad t = \tau \\ 0 & otherwise \end{cases}$$

Lag selection criteria

The estimation of the VAR model implies a choice about the lag length. Following Nicolini (2007), we have two options. The first concerns the data-oriented strategy, which, through the application of several information criteria, chooses the best trade-off between parsimony and realism of the model[22]. The second strategy is to test a particular hypothesis suggested by the theory. The Malthusian model involves many variables that are very different from each other. Wages, for example, need a small period (a few years) to take effect on other variables, such as per capita income; however, for other variables concerning demographic dynamics, the picture changes drastically. For example, it makes no sense to expect changes in the productivity level the year after a change in the birth rate. For these kinds of dynamics, we need more time spans to identify their effects. In our VAR model, both endogenous variables are demographic variables; therefore, we can expect a long time span before seeing some effect due to their interactions. In addition, the time series adopted in our analysis are very low-frequency—25-year frequency—suggesting that a minimum number of lags is probably sufficient to capture some effects. Given these characteristics, we think that a lag order of 1 is appropriate to investigate the emergence of the Malthusian urbanization in the Republic of Genoa during the period 1300–1800. In any case, we used both strategies in this article. The order of the VAR model is also estimated based on the information criterion. According to Schwarz criterion minimization, we chose the VAR model with lag order 1; therefore, both strategies converge on the VAR model with lag order 1.

Identification strategy

A common approach to identify the shocks within a VAR model is to decompose the variance-covariance matrix $\sum = PP'$ obtained by a Choleski decomposition, where P is a lower triangularization of matrix A_0^{-1} with positive diagonal elements.
The lower triangularity of the matrix A_0^{-1} implies that the variable of the first row will

[22]Where, for parsimony, we mean the tendency to minimize the number of estimated coefficients to improve the flexibility of the model and, for realism, the opposite strategy, which prefers a fit in the best way of the data at the expense of flexibility.

never be sensitive to a contemporaneous shock of any other variable and the last variable in the system will be sensitive to shocks of all other variables. Therefore, given the particular ordering of the endogenous variables, each variable is allowed to react within the current period to a shock in any of the variables that precede it, but it must be completely insensitive to shocks in variables that follow it.
The choice in the ordering of the endogenous variables becomes extremely important in our analysis. In this model, we adopt the solution used by Chiarini and Marzano (2019, pp. 26–27) to order urbanization after the variable population since, in our specific case, with two endogenous demographic variables, population dynamics can be considered a "deep" parameter that justifies the ordering of urbanization after the variable population and not vice versa.

Postestimation specifications

When the VAR model was estimated, it was necessary to conduct some tests to verify its stability. As shown in Figure A1, all the eigenvalues are within the unit root; therefore, the VAR system is stable.

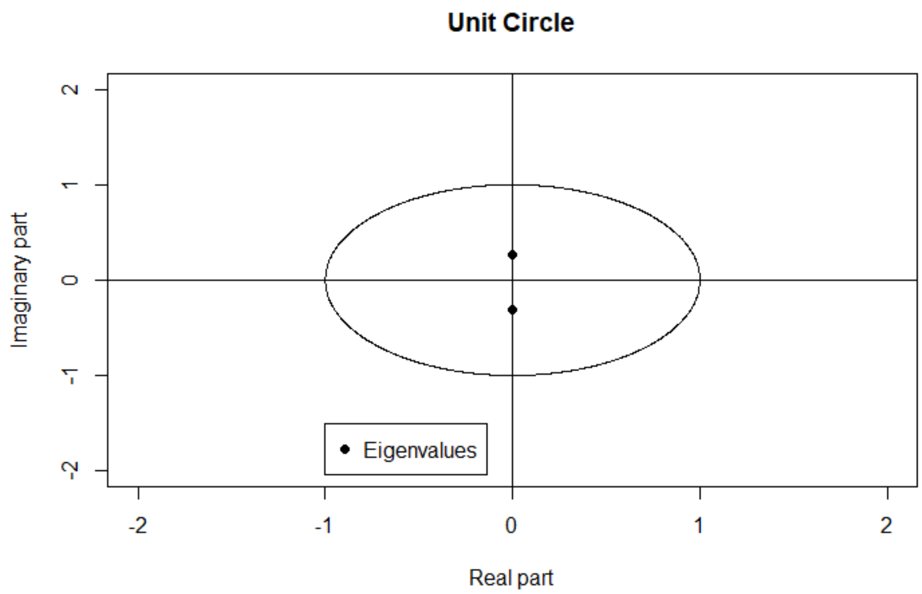

Figure A1. Roots of the companion matrix

To test the validity of our VAR model, we conduct other tests to verify the following:
- the presence of autocorrelation
- the approximation to a normal distribution
- the homoscedasticity of the model

Table A2 illustrates the main results of these tests.

Test	Null-hypothesis	p-value
Asymptotic Portmanteau test	H0: no-autocorrelation	0.9858
Jarque-Bera test	H0: normal distribution	0.168
ARCH-LM test	H0: no-heteroskedasticity	0.472

Table A2. Asymptotic Portmanteau test, Jarque-Bera test and ARCH-LM test

All tests do not reject the null hypothesis; therefore, we can state that there is no evidence to reject the hypothesis that our VAR model is not autocorrelated, that it is not normally distributed and that it is not heteroskedastic.

Variance decomposition

Another common instrument to measure the relative influence of each variable on the variability of the others is to look at the variance decomposition (VC), which indicates the portion of the total variance of each element of our endogenous variables due to each disturbance u_t.
Table A3 shows that the percentage of urbanization rate of growth variance explained by population rate of growth is quite large in the first three periods, while the percentage of population rate of growth variance explained by urbanization rate of growth is more modest.

Percentage of variance of *Pop* due to:	*Pop*	*Urbaniz*
after 25 years	100.00	0.00
after 50 years	88.61	11.38
after 75 years	88.66	11.33
Percentage of variance of *Urbaniz* due to:	*Pop*	*Urbaniz*
after 25 years	18.46	81.53
after 50 years	22.36	77.63
after 75 years	22.40	77.59

Table A3. Variance decomposition after 25, 50 and 75 years

Growth/differences versus Levels

Usually, in the literature concerning the Malthusian model, it is assumed that check mechanisms operate through levels. The cumulative impulse response function allows the identification of responses in levels using data on growth/differences. Figure A2 highlights that an increase in the population initially leads to a rise in urbanization; however, the urbanization level tends to collapse and stagnate in the long term.

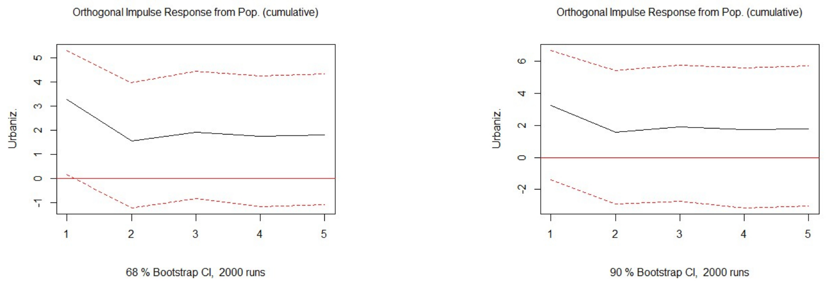

Figure A2. Response of the urbanization level to the population rate of growth (68% and 90% CI)

Generalized Impulse Response Functions (GIRFs)

The simulation results reported in Figure A3 are quite robust when the order of the population and urbanization variables are inverted in the model. In particular, there is still strong evidence of diminishing returns since the population falls after a positive shock to urbanization. The generalized impulse response is qualitatively similar to those detected in the original model, albeit less significant. Thus, the robustness check confirms that the economic mechanisms at work are unaffected by the ordering of the variables, confirming our hypothesis that "Malthusian urbanization" took place in the Republic of Genoa.

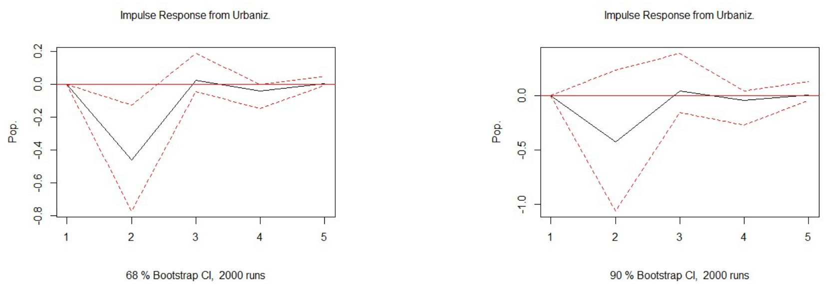

Figure A3. Response of the population rate of growth to the urbanization rate of growth (68% and 90% CI)

Epidemics in the Republic of Genoa

The VAR model takes into account the plague that affected the Republic of Genoa in the period 1300–1800. The plagues take place in the years as follows: 1348–50, 1383, 1400–13, 1422–25, 1428–31, 1435–39, 1493, 1499–1506, 1522–30, 1579–80, and 1656–57.

Declaration of authorship

I hereby declare that the report submitted is my own unaided work. All direct or indirect sources used are acknowledged as references. I am aware that the Thesis in digital form can be examined for the use of unauthorized aid and in order to determine whether the report as a whole or parts incorporated in it may be deemed as plagiarism. For the comparison of my work with existing sources, I agree that it shall be entered in a database where it shall also remain after examination, to enable comparison with future Theses submitted. Further rights of reproduction and usage, however, are not granted here. This paper was not previously presented to another examination board and has not been published.

Location, date

Name