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A comparative perspective on the determinants of the scale and productivity of maritime trade in the Roman Mediterranean

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Abstract: The scale and productivity of maritime trade is a function of environmental conditions, political processes and economic development that determine demand, and more specifically of trading costs. Trading costs are the sum of transportation costs (comprised of the cost of carriage and the cost of risk, most notably predation), transaction costs and financing costs. Comparative evidence from the medieval and early modern periods shows that the cost of predation (caused by war, privateering, piracy, and tolls) and commercial organization (which profoundly affects transaction and financing costs as well as the cost of carriage) have long been the most important determinants of overall trading costs. This suggests that conditions in the Roman period were unusually favorable for maritime trade. Technological innovation, by contrast, was primarily an endogenous function of broader political and economic developments and should not be viewed as a major factor in the expansion of commerce in this period.

> "For see how Caesar seems to provide us with a great peace, so that there are no longer any wars, or battles, or great banditry, or piracy, but it is possible to travel at all hours, to sail from sunrise to sunset." Epictetus, *Discourses* 3.13.9

1 Objective, approach, and argument

This meeting focuses on ship design and navigation techniques in the Greco-Roman period but seeks to contribute to a larger question, that of the relationship between maritime technology and economic performance.[1] My paper deals exclusively with the latter issue, concentrating in the first instance on the 'Roman' Mediterranean, broadly defined as the history of western Eurasia's main 'inner sea' from the First Punic War to the Islamic conquests. Rather than privileging shipping technology on *a priori* grounds, I ask which factors determined the volume of trade and its productivity in this period. As so often in the study of ancient history, comparative contextualization is essential. Changes in the volume of trade are only dimly perceptible in broad outlines, and in the absence of time series of freight charges it is impossible directly to measure variation in productivity over time. I therefore draw on comparative evidence from more recent and better documented historical periods in order to ascertain which variables were likely to have had a significant impact on the scale and productivity of maritime commerce in the Roman world. This indirect approach is designed to provide a general framework for the historical interpretation of observable details of ancient shipping techniques. I begin by very briefly considering macro-features that affected the overall scale of maritime trade before I move on to a more detailed survey of what have historically been the key determinants of shipping productivity.

I argue that imperial state formation was the single most important ultimate determinant of the scale, structure, and productivity of maritime commerce in the Roman period. Hegemony and subsequent direct rule created uniquely favorable conditions for maritime trade by cutting the costs of predation, transactions, and financing to levels that were lower than in any other period of pre-modern Mediterranean history. Technological change in ship design and navigational techniques, in as much as it occurred at all, was an endogenous function of these powerful framing conditions.

2 Determinants of demand: geography, state formation, and economic development

In the most basic terms, the scale and productivity of maritime trade is determined by demand and trading costs. Demand is a function of a variety of factors such as

[1] This paper has been prepared for the international conference *Maritime technology and the ancient economy: ship design and navigation*, American Academy in Rome, June 16-17, 2009. I am grateful to William Harris for his invitation and to Peter Bang for comments on this paper.

population size, per capita income, division of labor, and modes of coercion. What set the Roman period apart from all other periods of Mediterranean history was the creation of a single relatively stable and durable political entity that encompassed the entire region. As a result, the Mediterranean came to serve as the logistical core of the Roman empire. Given the advantages of sea transport over river or land transport, there can be little doubt that the presence of this 'inner sea' facilitated economic integration at a lower cost than in other pre-modern empires. This should not be taken to mean that favorable geographical conditions are a *conditio sine qua non* of successful large-scale state formation: the expansion of the Inka empire across difficult terrain provides a striking counter-example. Even so, empires with more challenging geographical and ecological endowments needed to invest more in infrastructure to achieve a commensurate level of economic integration: the effort expended on the construction of the Grand Canal in early medieval China is a case in point. However, while the presence and ecological characteristics of the Mediterranean Sea created an environment that was inherently conducive to connectivity and exchange, the actual scale and specific properties of links and transfers varied over time depending on framing conditions created by political processes and economic development.[2]

For much of the Roman period (as defined in the opening section), imperial state formation is widely considered to have been a key determinant of the scale and nature of maritime trade. In one version of this argument, state and elite demands – in the form of state taxation and private rent-taking – spurred inter-regional exchange. According to Keith Hopkins's well-known 'taxes-and-trade model', coerced flows of resources from the provinces to the capital city and the imperial heartland, and eventually also to the frontier armies, had to be counterbalanced by trade flows between 'tax-exporting' and 'tax-importing' regions.[3] In more general terms, the primacy of state demands in the development of Roman trade has most recently been emphasized by Peter Bang.[4] Chris Wickham's model of how trade declined as the Roman empire unraveled logically complements this approach: as state institutions and imperial elites whose demand for taxes, rents, and purchases had sustained inter-regional transfers on a large scale weakened or disappeared, these processes undermined the foundations of long-distance trade in general.[5] While this state- and elite-centered perspective has attracted some criticism, and the question of the overall significance of the imperial state for the development of trade is by no means settled, the debate is primarily concerned with the question of whether the central state and its associated elites played an absolutely crucial or merely a very significant role in commercial development: the overall importance of state formation is not in doubt.[6] This is true even of deliberately 'modernizing' studies that emphasize the scope of market exchange sustained by comparative advantage: in those scenarios, political unification is nevertheless viewed as creating a fertile ground for economic integration.[7]

[2] See esp. Horden and Purcell 2000, with Harris, ed. 2005.
[3] Hopkins 1980, 1995/6 = 2002.
[4] Bang 2007, 2008.
[5] Wickham 2005.
[6] Silver 2008 (on Hopkins); Haldon 2008 and Shaw 2008 (on Wickham).
[7] E.g., Temin 2001; Hitchner 2005; Silver 2007.

This means that Roman maritime commerce cannot be studied in isolation from broader political and economic developments. Consideration of the finer points of ship design and navigational techniques is meaningful only if our interpretation of these features is firmly grounded in an appreciation of the contextual conditions that mediated technological innovation.

3 Determinants of productivity and scale: risk, institutions, and organization

3.1 Defining basic determinants

I now turn to the second determinant of the scale and productivity of maritime trade, trading costs. Even as demand that was rooted in political conditions mediated the volume of trade, its scale was also a function of productivity: all other things being equal, the more costly it is to transfer goods across the sea, the less likely this transaction is to occur. At the same time, productivity itself would have been affected by the volume of trade, creating a measure of feedback between these variables.

Trading costs consist of three main elements: transportation costs, which are the sum of the cost of carriage, the cost of risk from natural causes, and what has been termed the cost of predation; transaction costs, defined as the costs involved in transferring goods from owners to consumers; and financing costs, representing the cost of moving goods from one time to another and caused by the fact that transfers take time.[8] This simple scheme shows very clearly that technological features and navigational capacity, subsumed within the rubric of carriage costs, are only two factors among many that contribute to overall trading costs. The main purpose of this section is to establish the *relative* weight of these two factors in the Roman Mediterranean on probabilistic grounds and from a comparative perspective.

This exercise requires us to take account of debates among historians of the more recent past that have been going on for decades. By 1973, Douglass North, Robert Thomas and Clyde Reed had developed a transactions-cost model of international trade stressing that its scale and productivity is not merely determined by the direct costs of shipping and selling goods but also by all other costs that are involved in the transfer of goods from producer to consumer: market information (obtained by accruing search or measurement costs), negotiation costs, and enforcement and protection costs, particularly to establish and defend property rights.[9] This ties in with an older debate that has revolved around the question of what was behind the expansion in 'Western' commerce between the late Middle Ages and the dawn of the steamship era in the mid-nineteenth century. There are two main schools of thought, an older one favoring the concept of a 'transport revolution' prompted by improvements in ship design and navigational techniques and a second, more recent but now more widely accepted one that emphasizes the significance of larger political and economic processes for the growth of seaborne

[8] For this trichotomy, see Kohn 2001: 2. Kohn does not account for risk from natural causes (storms, rocks etc) but limits transportation costs to the cost of carriage and the cost of predation. Since he only considers human action as predation we need to add loss from natural causes to complete his scheme.
[9] Munro 1991: 120 and n.39, referring to North and Thomas 1973 and Reed 1973.

commerce.[10] Very broadly speaking, recent scholarship has tended to identify the cost of predation and trading organization as the most powerful determinants of the productivity of maritime trade from the High Middle Ages into the nineteenth century.

3.2 Transportation costs

In an ambitious study of the origins of 'Western' economic success, Meir Kohn argues that, in the post-ancient period, variation in the cost of predation determined transportation costs in the short run. In the very long run, the cost of carriage declined, yet largely because of changes in organization than in technology per se. Instead, technological progress was primarily a consequence of organizational development.[11] This approach endogenizes technological change, defining it is an epiphenomenon of other factors.

Empirical investigation of the relative weight of the cost of carriage and the cost of predation in determining transportation costs is predicated on access to time series of freight rates that can be related to political and military conditions that accounted for the scale and nature of predatory intervention in maritime commerce. Owing to the limitation of the data, this is often difficult to accomplish for pre-modern history but not nearly as hopeless as in the case of antiquity.[12]

The seizure or destruction of cargo ships in war and attacks by privateers and pirates are the most dramatic manifestations of predation. The risk of hostile action had both short-term and long-term consequences for maritime commerce. War could double or triple freight rates in a matter of months or even weeks. Such short-term effects can be traced back as far back as the late Middle Ages. In 1431, for instance, Venetian freight charges for *alum* rose by 50 per cent above the median because the security situation required extra bowmen to be added to crews.[13] It has been shown that Dutch freight rates were exceptionally low during the Twelve Years' Truce with Spain (1609-1621), compared to earlier and later years, thereby illustrating the productivity gains that were possible under near-ideal conditions.[14] More generally, between 1500 and 1780, Dutch freight rates in years of war were 35 to 40 per cent higher than in years of peace.[15] Insurance rates for North Atlantic shipping reliably rose in times of armed conflict: from 6 to 14 per cent in the 1680s, from 3 to between 6 and 10 per cent in the 1690s, from 2 to 5 per cent in the 1710s to 1740s, and from 1.5 to 8 per cent in the 1730s to 1750s. When these conflicts intensified, however, rates shot up much higher, for example to 35 per cent in 1704.[16] Comparable evidence is likewise available for the much more recent past: the massive spikes in real global freight rates during the two World Wars are particularly

[10] E.g., Menard 1991: 230.
[11] Kohn 2001: 2.
[12] See, e.g., Menard 1991: 233-6. For Roman freight charges, see below, Section 4.
[13] Lane 1934: 262.
[14] Israel 1989: 124.
[15] van Zanden and Tielhof 2009: [20]. Of course, peace was rare, most notably occurring on average only every other year for a whole century from 1572 to 1678.
[16] Davis 1962: 318-9.

impressive examples.[17] And most recently, according to media reports, insurance rates for cargo ships passing the coast of Somalia have increased up to tenfold.

While a more comprehensive survey would add many more instances of this phenomenon, long-term effects were arguably more important. In the Mediterranean, inter-state conflicts became more frequent and protracted from the 1280s and especially from the beginning of the fourteenth century onwards, and the incidence of piracy increased accordingly. This had a massive impact on the scale of maritime commerce, documented by evidence for falling tax receipts from trade and port use as well as for actual trade volume. Sicilian freight rates are thought to have doubled in the fourteenth century.[18] Similarly, the Hundred Years' War and the Black Death in the fourteenth century and more generally the general political crisis associated with diminished state strength during the shift from late medieval to early modern states raised real freight rates between France and England very considerably in the long(ish) term (see Fig. 1).

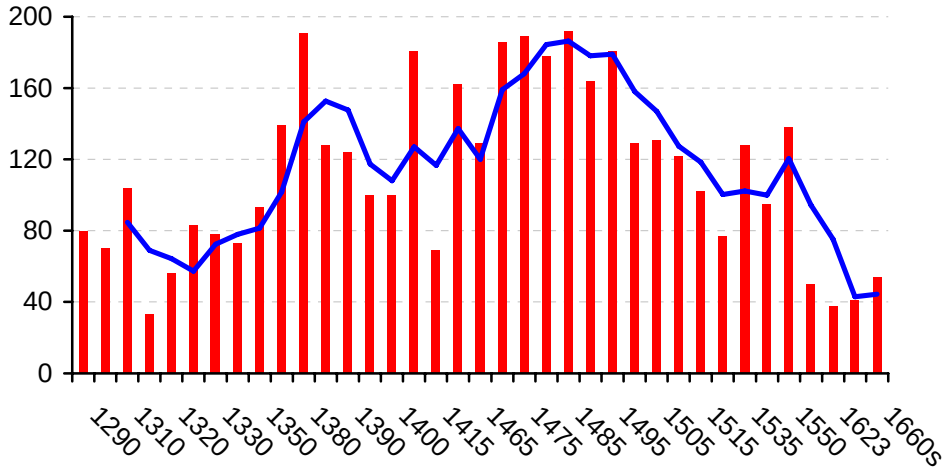

Fig. 1 Real freight charges on wine, Bordeaux to London, 1290-1669
Source: Menard 1991: 241-2

These data are of particular relevance for the purposes of this study. Russell Menard has shown that the volume of wine trade from Gascony to England peaked twice, around 1300 and again in the 1560s. The aforementioned crises separated these peaks by a prolonged slump. More importantly, however, the real cost of transport was almost the same around 1300 and in the seventeenth century, despite the fact that shipping technology and navigational techniques had significantly improved in the intervening centuries and especially in the early sixteenth century: yet at that latter point in time, shipping was still about 50 per cent costlier than it had been around 1300. This demonstrates that two different technological regimes were capable of generating comparable levels of productivity. It also suggests that productivity increases could

[17] Mohammed and Williamson 2004: 189.
[18] Munro 1991: 121-6.

greatly lag behind technological improvements. In this case, as in the high medieval Mediterranean discussed above, factors other than shipping technology determined actual performance.[19]

An even longer-term perspective is made possible by the incorporation of data about the subsequent Spanish and Portuguese wine trade to England. The resulting profile shows that notwithstanding very considerable improvements in shipping techniques, "freight charges in the mid-eighteenth century were only slightly lower than in the best years of the high Middle Ages". Menard concludes that "productivity gains rooted in better techniques played only a minor role in the growth of trade. Broad political and commercial developments fostered the safe shipment of large quantities across great distances by turning the oceans of the world into a vast inland sea dominated by Europe's metropolitan capitals".[20]

The formation of the Roman empire anticipated this process, albeit on a smaller scale: it was not 'the oceans of the world' but merely the Mediterranean Sea that was turned into an 'inner sea' dominated by the needs of the Roman metropole. Despite very considerable differences in scale, the logic of this transformation was essentially the same. It is helpful to think about this process in terms of the conceptual distinction between what Robert Lopez has called 'inner' and 'outer' trade. 'Outer trade' represented "a field of large risks and large profits, a frontier where good luck was almost as important as good management". 'Inner trade', on the other hand, functioned competitively and "success depended mainly on efficiency, quickness and almost meticulous weighing of transport charges … and marketing conditions".[21] Under Roman hegemony and later direct rule, all Mediterranean trade eventually became 'inner trade' while 'outer trade' continued to take place at the geographical margins, most notably in the Indian Ocean. Both before and after, conditions in the Mediterranean were less stable, risk was higher and less predictable, and the actual determinants of competitiveness varied accordingly.

In the final analysis, it was long-term instability that raised real freight rates well above otherwise feasible levels. Both ship size and crew size were sensitive to the risk of hostile action. In some cases, merchants might switch to smaller ships, prizing maneuverability and seeking to reduce the loss of capital associated with the loss of any one vessel. To name but one example, around 1300, ships engaged in the French-English wine trade averaged 120 tons, but by 1410 this mean had dropped to 70 tons in response to less favorable conditions. Technological progress could be stymied by increased risk: Portugal built a number of 2,000 ton carracks for the Indies trade but returned to the 500 ton format once several of these precious vessels had been lost.[22]

At other times, shippers might embark on an alternative strategy by opting for larger vessels that could carry heavier weaponry and larger crews for defensive purposes. The latter is particularly relevant here: "Before the advent of cannon, a ship's armament was its men – its crew and passengers: a ship was considered 'armed' or 'unarmed' according to the number of men it carried".[23] This was already true in antiquity, as the

[19] Menard 1991: 236-48.
[20] Menard 1991: 274-5.
[21] Lopez 1952: 333-4.
[22] Kohn 2001: 26-7.
[23] Kohn 2001: 8.

attempted seizure of cargo ships would necessarily involve hand-to-hand combat. Crews that were larger than required for operating a ship added to carriage costs. Moreover, war might increase overall demand for manpower, creating scarcity and driving up real wages. In addition, the risk of hostile action would have been priced into crew compensation.

The historical record shows that potential productivity increases through labor-saving developments that improved required cargo/staffing ratios did not always occur once they became technologically feasible. For example, although the legally ordained minimal crew size relative to a ship's tonnage in Venice fell by half between the thirteenth and the fifteenth centuries, therein reflecting technological progress, actual crew size grew in this period because of the worsening risk of predation through war and piracy.[24] It was only when the security situation finally improved that these potential efficiency gains were realized, with a delay of several centuries. And crew size mattered a lot: one recent study shows that labor productivity in the Dutch merchant fleet doubled between 1503 and 1780 while capital productivity remained largely unchanged.[25] Reductions in crew size were likewise a critical factor in the drop of transatlantic freight rates between 1675 and 1775, much of it as the result of the removal of guns.[26] In the seventeenth and eighteenth centuries, tonnage/crew ratios were consistently more favorable on routes that were free of pirates than on those infested with them.[27] Although Roman ships did not carry guns, the underlying principle was the same: ecumenical peace was inherently conducive to the use of skeleton crews.[28]

It was only in a reasonable safe environment that specialized cargo ships operated by relatively small crews became feasible. The Dutch fluyt ship is a case in point, made possible by Dutch sea power that allowed reductions in capital and labor costs.[29] In this scenario, technological change was a function of military strength: in the early modern period, comparatively peaceful conditions in the northern seas favored the use of larger and more efficient cargo ships, most notably in the Baltic grain trade, while these improvements spread only much later to the Mediterranean where predatory threats persisted for much longer.[30]

In the Roman period, Mediterranean maritime trade assumed the characteristics that later came to be typical of the Baltic trade, only more so. Victory in the First Punic War (241 BCE) laid the foundations for Roman naval hegemony that was never seriously challenged until the Vandal conquests of the mid-fifth century CE. Seven consecutive centuries without substantial inter-state naval conflict in the Mediterranean are extraordinary by any historical standard and must have lowered the risk of cargo loss through enemy action to levels not again seen until the nineteenth century. This process of pacification was further solidified by the gradual extension of direct Roman rule to

[24] Lane 1986: 239.
[25] van Zanden and Tielhof 2009: [9].
[26] Lane 1986: 235-6.
[27] North 1968: 959-60.
[28] Once again, current Somali piracy provides the most recent illustration of this principle, forcing cargo ships to add security personnel to otherwise minimal crews.
[29] Kohn 2001: 3; van Zanden and Tielhof 2009: [2].
[30] North 1968: 964; Kohn 2001: 22, 54. For the Baltic grain trade see now Tielhof 2002, esp. 197-208 on the Baltic grain trade as 'inner trade'.

(virtually[31]) all coastal regions of the Mediterranean. Political unification was accompanied by a great diminution of piracy in the central decades of the first century BCE.[32] As later history shows, if left unchecked this source of predation was capable of placing a heavy burden on the productivity of maritime trade. State weakness at the turn from the medieval to the early modern periods created space for piracy so intense "as to obliterate the distinction between war and peace".[33] Piracy was often firmly embedded in social structures: nobles might operate their own vessels for privateering, and merchants could switch freely between trading and plundering.[34] Insurance rates for Caribbean routes in the early seventeenth century were insensitive to warfare because piracy was so endemic that it kept risk levels persistently high.[35] Policing of shipping routes and more generally growing state strength curtailed such activities and consequently depressed freight rates. For all its limitations, the Roman state can reasonably be assumed to have accomplished this goal on a scale that would have been the envy of most pre-modern sea merchants.

A final word on the cost of predation. This concept covers different types of exactions of resources, including more or less regularized levies on the flow of goods in the form of tolls and customs dues imposed by states or non-state actors as well as the kinds of hostile action discussed so far. The impact of tolls and customs dues can be expected to have been higher for international trade than for transfers that took place within a single-state environment. It may also have been inversely correlated with state strength: reduced government control over territory in general and over taxation in particular would have facilitated more widely diffused predation by local power holders.

The monopolistic position of the Roman state created an environment in which toll-taking was confined to a small group of actors, namely state agents and contractors (i.e., tax farmers) and local communities. Although this system left ample room for abuse and corruption, at the very least it would have reduced the uncertainties that characterized systems of more diffused predatory powers, and in so doing benefited trade.[36] Nominal state tolls were generally low, apparently 2.5 per cent for the principal customs districts, which probably numbered about a dozen. Port cities would levy their own municipal tolls, the size of which is generally unknown.[37] Even so, the overall burden is unlikely to

[31] Patches of the Mauretanian and Cilician coastline may have been partial exceptions, but in any case inter-state conflict was unheard of until the fifth century CE.

[32] See now esp. de Souza 1999: 195-210, plausibly arguing that even though piracy never completely disappeared, it was greatly attenuated for much of the monarchical period.

[33] Menard 1991: 246.

[34] Kohn 2001: 6.

[35] Davis 1962: 319.

[36] Bang 2008: 202-38 rightly draws attention to evidence of rent-seeking behavior by tax farmers and stresses the fact that the economic benefits of *pax Romana* must not be exaggerated. However, while his discussion provides a valuable corrective to overly optimistic appraisals of Roman rule that are still common among ancient historians and, especially, 'Classicists', the most meaningful comparison is perhaps not so much between practices in the Roman empire and in a modern environment (which inevitably highlights the shortcomings of the former) as between the relative burden of toll predation in a fairly stable super-state and in less settled conditions. My argument is simply that for all its defects, the Roman empire facilitated maritime trade at lower costs than before or after.

[37] Ausbüttel 1998: 90-1; Liebenam 1900: 24-5. (I have not (yet) been able to consult France 1999.) It is unclear whether the 3.33 per cent levy collected by the *koinon triakados* of Berytus (Beirut) was a state or municipal import or export tariff (de Laet 1949: 339-40): Pollard 2000: 176 deems an imperial toll more likely. State import tolls at the imperial borders were much higher (25 per cent).

have been very heavy, presumably under 10 per cent even if municipal export and import tolls had been of the same order of magnitude as the state *portorium*.[38]

With tolls low and the risk of hostile action increasingly negligible, it is therefore highly likely that the cost of predation accounted only for a modest share of Roman transportation costs, and almost certainly for a much smaller share than before or after the period of ecumenical peace. This notion receives support from a simple comparison with evidence for the structure of late medieval and early modern Mediterranean freight rates. In Fatimid Egypt, import dues in the Mediterranean port of Tinnis ranged from 10 per cent for precious metals and textiles to 20 per cent for cement and 30 per cent for most foodstuffs, while authorities in Alexandria charged more generalized *ad valorem* tolls of either 15.125 or 19 per cent.[39] In a case from the mid-fourteenth century, half of the cost of shipping cloth from Genoa to Anatolia derived from carriage and the other half from insurance, which represents a measure of overall risk of loss. Even more strikingly, in a sixteenth-century example, the cost of tolls and insurance was almost twice that of carriage for shipping grain from Sicily to Spain.[40] There can be little doubt that in an environment where the cost of predation could raise transportation costs by anywhere from 100 to 200 per cent, security conditions were among the most important determinants of overall trading costs, if not indeed the single most critical factor. By contrast, the share of the cost of predation in Roman imperial maritime transportation costs was undoubtedly vastly smaller than in the late medieval and early modern periods.[41] By analogy, it must also have been much lower than it had been prior to the Roman conquests or than it would be right after the demise of the Roman monopoly on state power. Therefore, in view of the sheer magnitude of *pax Romana* in the Mediterranean basin (relative to most other periods of documented western Eurasian history), and given the very considerable adverse consequences of war and piracy (and perhaps also diffused toll predation) in many of those other periods, I conclude that the – exceptionally low and predictable – cost of predation played a pivotal role in determining the overall productivity of Roman maritime trade.

The real cost of carriage was determined by the ratio of crew to cargo and the ratio of tonnage to cargo, that is, capacity utilization. As we have seen, crew size and compensation were themselves sensitive to the risk of predation, which speaks against a neat separation of the costs of carriage and predation in real life. Technological progress per se plays a minor role here: although changes in ship design might reduce the need for labor, as we have seen above ship design was itself to a significant degree shaped by the likelihood of predation. For these reasons, the crew/cargo ratio might ultimately best be seen as a variable that was largely endogenous to processes driven by variation in the risk

[38] Harbor dues of 2 per cent had become common among Greek cities of the pre-Roman period (Purcell 2005: 225) and need not have changed much under Roman rule. It is unclear whether late Roman port dues of 5 per cent in 2 ports in Numidia in 445 CE (*Nov. Val.* 13) and perhaps approximately 6 per cent in a Sardinian port around 590 CE (Durliat 1982: 10) reflect increasing toll predation by the state or merely the formal conflation of state and municipal tolls in this period (which had presumably amounted to a similar combined rate in previous centuries). For the latter process cf. briefly Bang 2008: 223-4. For subsequent Byzantine tolls, see Antoniadis-Bibicou 1963.

[39] Cahen 1964: 242-53, esp. 244-5. In terms of magnitude, these dues are more similar to Roman border tolls than to internal *portoria*, which were much lower (see above).

[40] Kohn 2001: 52.

[41] For the limits of conjectural calculations, see below, Section 4.

of predation. Tonnage/cargo ratios, on the other hand, depended more on the efficiency of cargo storage within a given vessel. It is well known that standardization of packaging can lead to huge productivity gains. A classic example is the introduction of standard containers in the tobacco trade from Virginia to Britain in the second quarter of the seventeenth century. While tobacco had initially been shipped either loose or in rolls or randomly packed in bags, by the 1630s most of it was shipped in hogsheads. This change accounted for a dramatic plunge in freight rates within a short period of time: in fact, Menard estimates that 80 per cent of the savings attained between 1620 and 1775 accrued from improved packaging whereas better ships, bigger markets and safer seas together accounted for the remaining 20 per cent.[42] Increasing compression of cotton for shipment similarly improved the load factor and thus productivity in the first half of the nineteenth century.[43]

At first sight, the widespread use of amphoras in the Roman world might be considered an analogous storage-maximizing strategy. However, not only was shipping of liquids in amphoras not an innovation of that period, it was also markedly less productive than the use of wooden containers. According to one estimate, wine carried in earthen containers could not represent more than 60 per cent of the cargo while wine in wooden barrels would make up 90 per cent.[44] This suggests that for a long time, the use of amphoras deprived Roman shipping of very significant productivity gains that could readily have been achieved. This means that the contribution of productivity increases in areas *other than* the cost of predation was smaller than it would have been if storage space had been more efficiently used – and this, in turn, raises the relative importance of changes in the cost of predation even further.

Finally, capacity utilization affected actual carriage costs in a variety of additional ways. Finding back cargo – that is, filling ships on both legs of a round-trip journey – was particularly important, as was the ability to create a profitable mix of lightweight but valuable with cheap and heavier commodities. Shipping speed also enters the equation: while this factor might seem to support an argument in favor of the significance of technological progress, we must bear in kind that overall transfer times were affected not merely by ship design and navigational techniques that helped determine sailing times but also and potentially more substantially by delays caused by the need to wait for cargo in port. All these features – availability of back cargo, cargo mix, and waiting times – are a function of commercial organization.[45] In the most general terms, the creation of more integrated and stable market (or even just of clusters of markets) throughout the Roman-controlled Mediterranean and consequent growth of information regarding supply and demand can be expected to have reduced organizational inefficiencies that adversely influenced transportation costs.[46]

[42] Menard 1991: 255, 257, 263.
[43] Harley 1988: 857.
[44] Lane 1986: 234.
[45] Kohn 2001: 19-22.
[46] I return to the question of organization in Section 3.5 below.

3.3 Transaction costs

Although the Roman empire did not bring about complete legal or monetary unification and certainly did not provide arbitration services on a modern scale, it nevertheless created an environment that can be expected to have lowered transaction costs to levels that were rare in pre-modern history.[47] This alone would have served to depress overall trading costs relative to those encountered in earlier and later periods.

More specifically, certain kinds of transactions costs, such as information and negotiation costs, are largely fixed costs, which means that a larger trade volume brought economies of scale. "Conversely, therefore, a declining sales volume itself led to rising unit transaction costs."[48] This means that a large trade volume per se lowered transaction costs even in the absence of actual institutional change. Once again, Roman maritime trade ought to have benefited from this nexus.

3.4 Financing costs

Financing costs are sensitive to the scale of risk, both from predation and from natural causes. In the unstable late medieval Mediterranean, for instance, financing contracts increasingly shifted risk from investors to operators, and interest rates on loans rose.[49] This invites comparison to the only known ship leasing contract on papyrus, dating from Alexandria in 10 BCE, in which it is the lessor who bears the risk of damage from storm, fire, and hostile action.[50] Risk from natural causes was in part determined by the routing and timing of maritime transport which was in turn largely a function of the structure of demand and of the risk of predation.[51]

Above all, however, financing costs depend on the nature of financial institutions. In a recent study of the financing of maritime commerce in the Roman empire of the early monarchy, Dominic Rathbone has drawn attention to the increasing sophistication of credit arrangements and long-distance payments that can be glimpsed from a variety of documentary sources.[52] He stresses the importance of enforceable contracts and the existence of banks with trans-regional contacts for the expansion of commerce. The institution of the *societas*, which permitted the pooling of resources and the spread of risk, appears to have flourished in the late Republican and early imperial periods. Banks were instrumental in transferring large amounts of money without moving commensurate quantities of coin. According to Peter Temin practices of financial intermediation appear to have been more developed in this period than those even of eighteenth-century France.[53] Whatever the details, we may safely conclude that Roman-era institutions kept financing costs low relative to rates that had prevailed, and would do so again, under less favorable conditions.

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[47] For a general discussion, see Lo Cascio 2006.
[48] Munro 1991: 120.
[49] Munro 1991: 127.
[50] Rathbone 2003: 207 (*P.Köln* III 147).
[51] For the structure of demand, see above, Section 2, and below, Section 3.5.
[52] Rathbone 2003. Cf. also Hopkins 1983.
[53] Temin 2004; Rathbone and Temin 2009. Cf. also Jones 2006, and more generally Harris 2006, 2008.

3.5 State formation and shipping organization

As we have seen, the organization of shipping affects variables such as the cost of carriage and transaction costs. In this section I consider more specifically the question of how political processes molded organizational features. The relationship between state formation, commercial organization and shipping productivity is illustrated by the divergent development of the British and French transatlantic slave trade in the seventeenth and eighteenth centuries. In terms of staffing levels, British slave ships were much more efficient than their French counterparts: between 1662 and 1713, the mean ratio of slaves to crew on British vessels was around 9 to 1 whereas on French ones it was as low as 3 or 4 to 1. This was partly due to the fact that French slave ships also engaged in privateering, which required larger crews. More interestingly, however, elevated French staffing levels were also facilitated by protectionism: since both the British and the French barred foreign ships from bringing slaves to their respective American colonies, French shippers faced no competition on productivity per se.[54] It is true that ancient societies did not employ mercantilist policies. Nevertheless, we would expect barriers to free trade to be more substantial in a multi-state system characterized by frequent conflict and the lack of credible international institutions than in a single market underwritten by a monopolistic empire. Thus, *ceteris paribus*, political conditions in the Roman imperial period would have favored competition on price that must have put downward pressure on crew size and the cost of carriage in general.

The role of organization as a determinant of productivity occupies center stage in a debate about changes in freight rates from the seventeenth to the nineteenth centuries. Douglass North argued that in the seventeenth and eighteenth centuries, falling labor costs (as a function of falling costs of predation) and declining port time (as the result of better organization of trade) accounted for productivity improvements, whereas between 1814 and 1860, increases in ship size (as a result of improved security and organization) and improved load factor (again a sign of better organization) were responsible.[55] He therefore concluded that "the decline of piracy and privateering and the development of markets and international trade shared honors as primary factors in the growth of shipping efficiency" in these periods while technological innovation per se (rather than its actual diffusion that was mediated by these factors) did not play a comparable role.[56]

Knick Harley challenged this interpretation, arguing that North's focus on North American data distorted the picture: lower American export freight rates before 1860 "reflected special circumstances in the shipment of raw cotton and cannot be generally be applied to ocean shipping".[57] Conversely, revised British data point to fairly stagnant shipping productivity between 1741 and *c.*1850. It was only the introduction of steam ships – that is, technological innovation – that brought increasingly radical productivity improvements.[58] Harley concluded that in the century or so prior to the American Civil War, decline in ocean freight rates resulting from improved organization rather than

[54] Eltis 2000: 119, 125-6, 129-31.
[55] North 1968, esp. 964.
[56] North 1968: 967.
[57] Harley 1988: 852.
[58] Harley 1988: 853 fig.1, 860-2.

technology was particular to the experience to the relatively young American economy, reflecting its maturition and integration into global commercial networks. Global productivity growth lagged behind until it was finally spurred on by the advent of steamship technology.[59]

Although remote in time, this argument is arguably of some relevance to our understanding of Roman shipping. In the late first millennium BCE, Mediterranean maritime commerce was by no means 'new' in the sense that the North American export trade had been new in the eighteenth century. Roman power expanded into a region that had long been tied together by international shipping. At the same time, as I have tried to show above, changes in the scale and structure of demand, in the cost of predation, and in transaction and financing costs would nevertheless have been conducive to increased shipping productivity. From a comparative perspective, an intermediate scenario between rapid progress (exemplified by American export freight rates from the mid-eighteenth to mid-nineteenth centuries) and stagnation (exemplified by British freight rates in the same period) might therefore seem the most likely outcome.

More specifically, Roman state formation influenced the organization of maritime commerce by shaping demand and through direct intervention. The disproportionate weight of demand in the imperial capital cities is a case in point. On the one hand, the concentration of consumers and capital in Rome and later Constantinople created exceptionally favorable preconditions for economies of scale and productivity increases: transaction and information costs were minimized, and this as well as guaranteed demand and seasonal constraints on shipping schedules all encouraged the deployment of unusually large vessels.[60] The monarchical regime came to invest heavily in port facilities, albeit only with some delay. The emperor Claudius offered to compensate Rome-bound (grain) merchants for damages caused by storms. Later rulers conferred exemption from sundry state obligations (*munera*) on merchants and ship-owners who provisioned Rome on behalf of the *annona*. In addition, legal privileges (in the form of various status upgrades) accrued to individuals who built ships for trade in general, in at least one case if a tonnage threshold of 10,000 *modii* or *c.*68 tons was reached. Exemptions for owners of ships of 50,000 *modii* (or of several that jointly reached that limit) are mentioned in the mid-second century CE. Associations (*corpora*) of shippers for Rome's supply likewise appear in the record in the second century CE, and around 200 CE this activity became a *munus*. The duties and privileges of *navicularii* in the late Roman period take up considerable space in the legal sources.[61]

At the same time, the pull of these privileged markets may also promoted inefficiencies. Demand for goods in Rome and later Constantinople that was not matched by exports would cause shortages of back cargo and compel ships to carry ballast on return voyages. Evidence suggestive of the re-exportation of goods that had been brought in together with state-owned cargo awaits systematic study but the scale of this phenomenon should not be overrated.[62] Rather, cargo ships returning from Ostia/Portus

[59] Harley 1988: 868-9.
[60] E.g., Rathbone 2003: 198.
[61] For evidence and detailed discussion, see esp. Sirks 1991: 40-4 (Claudius), 45-61 (exemptions), 61-7, 71-3 (other privileges and tonnage-related rules), 81-107 (early *collegia*), 108-45 (Severan *munus*), 146-251 (late antiquity). In less stable times, during the Second Punic War, the Roman state had been forced to guarantee cargo value for shippers who were willing to send supplies to Spain.
[62] Peña 1999: 8, 40-1 n.43.

regularly carried sand as ballast: we even know of a *corpus saburrariorum*, attested in 156 and 210 CE, whose members dug up sand for this purpose.[63] Themistius' later claim in the fourth century CE that Constantinople exported only earth, sand, and trash (*Or.* 4.61a) points in the same direction. However, the lack of empirical evidence makes it impossible to gauge to what extent these inefficiencies offset the benefits arising from concentrated and stable demand.

4 Scale and productivity in Roman maritime trade

The discussion so far has been concerned with factors that were *likely* to have influenced maritime trading costs in the Roman period. Quantifiable empirical evidence would be required to measure their *actual* impact. Unfortunately, such data as do exist suffer from a variety of deficiencies. The question of variation in the scale of ancient shipping is usually addressed by focusing on the chronological distribution of shipwrecks in the Mediterranean. This index shows a strong increase mostly in the late third and second centuries BCE, a peak in the first centuries BCE and CE, and, depending on how wrecks are dated, a more or less precipitous drop thereafter (Fig. 2).

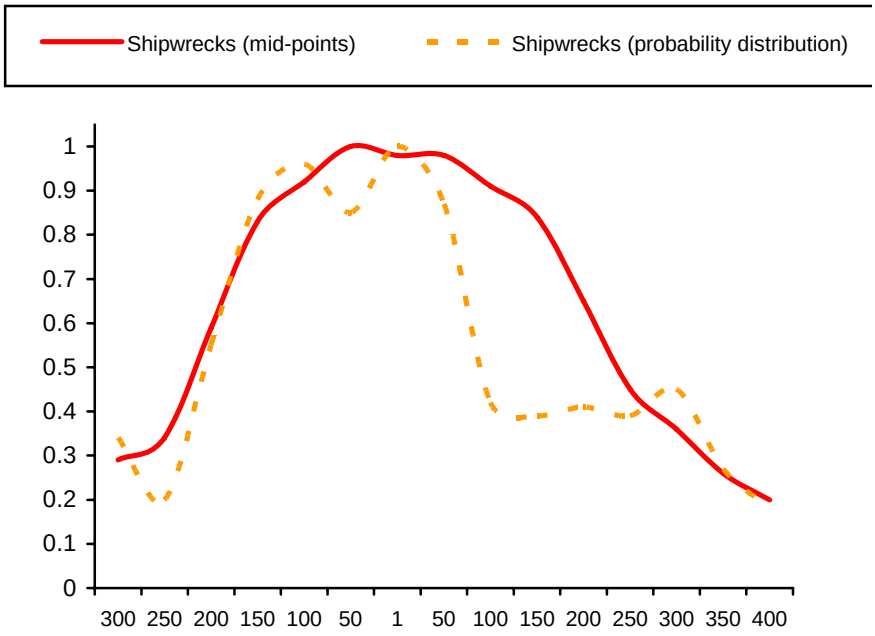

Fig. 2 Standardized distribution of Mediterranean shipwrecks (1 = highest level)
Source: Parker 1992: 549 fig.3; Wilson 2009

[63] Sirks 1991: 264-5.

However, a number of confounding variables interfere with extrapolation from the time distribution of shipwrecks to changes in the volume of exchange.[64] First of all, the number of shipwrecks is not directly correlated with their size: changes in ship (and cargo) size might have been a more important determinant of trade volume than the sheer number of vessels plying the seas. In the present case, a secular increase in mean ship size would have translated to a greater increase in trade volume than indicated by variation in the number of wrecks. Second, changes in shipping routes could have affected the relative visibility of shipwrecks and hence the shape of the observed distribution: wrecks are easier to detect in coastal waters than at greater depths far from land. Third, changes in the nature of the cargoes – most notably in the presence of ceramic containers and marble – may well have rendered wrecks from some centuries – especially from the 'peak' period in Fig. 2 – more visible and therefore more likely to be found and studied than those of vessels that had carried organic products in sacks and barrels, which may arguably have become more common in later centuries.[65] We cannot hope to ascertain to what extent these countervailing factors canceled each other out, and cannot simply assume that they did and that the picture conveyed by the observed distribution of dateable shipwrecks does indeed reflect the direction and scale of change in maritime trading volume.

This is particularly unfortunate given that the overall shape of the observed distribution up to the first century CE, *if* it could be taken as a credible index of actual maritime trading volume, would be consistent with the predictions advanced in the previous sections. From that perspective, gradual growth from the beginning of Roman naval hegemony in the mid-third century BCE onward is a perfectly plausible outcome. Even so, the apparent lack of further net increase in the early monarchical period and especially the sustained decline in the mid- and late monarchical periods would be much more difficult to account for. For instance, it is hard to imagine that overall levels of maritime trade in the fourth century CE, when the empire was still intact, were not higher than they had been in the third century BCE. Yet in view of the various sources of distortion noted above, it would probably be unwise to put too much weight on apparent matches or discrepancies between predicted developments and the observed distribution of Mediterranean shipwrecks.

We are likewise unable to demonstrate an increase in *average* ship size under Roman rule. The best we can say is that large ships, from 200 to 400 tons or even more, appear to have been more common in this period, and even if they had mainly been involved in supplying capital cities and armies or in moving marble their presence would have served to pull the overall tonnage mean upwards.[66] However, it is not possible to demonstrate that merchant ships of this period were consistently larger than they had

[64] This paragraph summarizes my discussion in Scheidel forthcoming a.

[65] See esp. Parker 1992: 26 (ship size); Arnaud 2005: 217, and more generally 98-148 (routes); Wilson 2009 (ship size and cargo visibility). Moreover, finds from the eastern Mediterranean are greatly underrepresented in the present sample.

[66] A census of Venetian shipping in 1423 counted 3,300 sailing ships, 3,000 of which were of (often much) less than 100 tons and only 35 exceeded 240 tons: Lane 1934: 102. In view of the evidence we have (see below, n.63) it is hard to imagine that only 1 per cent of Roman cargo ships displaced more than 240 tons but even this impression cannot be properly verified.

been before, and it is similarly impossible to measure or even estimate how the share of cargo moved by ships above a certain tonnage threshold changed over time.[67]

What is more, Rathbone's recent suggestion that Roman merchant ships cost (somewhat) less to build than in fifteenth-century Genoa or seventeenth-century England is based on data so flimsy as to be essentially worthless for the purposes of such an estimate.[68] Hence, while is it probable that economies of scale and especially the lack of features to ward off hostile action held down Roman construction costs, it is not strictly speaking feasible to verify this point.

Our only information about freight rates is derived from the famous edict specifying price controls for a large number of goods and services that the tetrarchs issued in 301 CE. The most fundamental problem with this source is that it does not even purport to record actual (that is, typical or mean) prices but merely imposes price ceilings. It is only to the extent that these ceilings corresponded to market prices that the reported sums can be used as evidence for economic history. Moreover, as Pascal Arnaud has recently argued, the maximum permissible freight charges listed in the edict – expressed in *denarii* per *modius kastrensis* – are best understood as "a strange mixture of empirical data and of bureaucratic simplifications and (mis-)calculations, relying above all upon an abstruse, arithmetical view of ancient seafaring".[69]

Any comparisons involving these data consequently call for great caution and a healthy dose of skepticism. Moreover, a further and very serious problem has to my knowledge never been acknowledged in existing research. As the price caps notionally applied across the empire, it is not legitimate to relate caps on freight charges to caps on goods. For instance, a freight charge of 16 *denarii* from Alexandria to Rome could not have raised the price of a *modius kastrensis* of wheat by 16 per cent (i.e., a proportion derived from adding the freight charge to a price of 100 *denarii*) because the retail price of 100 *denarii* could not exceed this price cap and must therefore have included any applicable shipping costs. In other words, if we were to take the provisions of the edict seriously, only goods that cost less than the stated price cap at source could have been shipped anywhere without the final seller incurring a loss.[70] Under these circumstances, wheat that had been shipped from Alexandria to Rome and sold there for 100 *denarii* per *modius kastrensis* could not have cost more than 84 *denarii* back in Alexandria without the transaction generating a net loss, and freight charges would have equaled at least 19 per cent of the original price.

An example for pre-modern shipping costs in peaceful conditions is provided by the observation that Dutch freight charges of rye from Danzig to Amsterdam in the late

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[67] For representative discussions of the evidence, see Casson 1995: 170-3, 183-4, and more recently Rathbone 2003: 199-201.

[68] Rathbone 2003: 201-2, drawing on papyrological references, and cf. again 227. In any case, his estimate for Roman ship-building costs of 1.25-1.5 tons of wheat equivalent per ton of capacity is quite similar to that of 1.6-1.9 tons for late medieval and early modern Europe and moreover depressed by the inclusion of ancient river boats that were presumably less sturdy and thus cheaper to build.

[69] Arnaud 2007 (quote from 334). Cf. Rougé 1966: 369-76 for an earlier discussion.

[70] It is therefore misleading to say that an 800-mile voyage would have raised the price of wheat by 10 per cent (Duncan-Jones 1982: 368). When Rougé 1966: 371 states that according to the edict, the cost of shipping wheat from Alexandria to Rome accounted for one-sixth of the value of the wheat, this implies that he also thinks that transportation charges of 16 *denarii* added 16 per cent to a (previous) wheat price of 100 *denarii*.

seventeenth century added some 20 per cent to its Danzig price, for a voyage of at least 1,550km.[71] Under less favorable conditions, shipping a unit of grain from Sicily to Spain (a similar distance) in the sixteenth century added 27 per cent in carriage costs (and another 46 percent in tolls and insurance) to its price at the export port.[72] The edict of 301 CE caps freight charges for the same route at somewhere around 4, 6, or 8 (or more) *denarii*, depending on how we derive freight rates for this route which is not directly attested in this source.[73] This implies *minimum* freight charges equivalent to between 4 and 9+ per cent of the price of wheat in Sicily, and similar rates if tolls of 5 or 10 per cent are taken into account.[74] Yet for barley or rye, which were capped at 60 *denarii* per *modius kastrensis*, the share of freight rates would have been correspondingly higher. Given the nature of the evidence, it is impossible to tell just how far removed these estimates are from reality. However, it is worth noting that for carriage and tolls to have raised the price of Sicilian grain by 73 per cent by shipping it to Spain (as in the sixteenth-century example), the price of a *modius kastrensis* of wheat in Roman Sicily would have had to be as low as 58 *denarii*, or less if we allow for profits from trade. We are left with the impression that if – but *only if* – the caps recorded in the price edict provide a reasonable approximation of actual conditions, it was at least possible that real freight rates in the Roman period were significantly lower in real terms than they were well over a millennium later. Nevertheless, it is impossible to substantiate empirically whether they actually were as low as they could have been. Moreover, if the decreed price caps are not in fact internally consistent, even this very limited conclusion becomes untenable. For this reason alone, more elaborate comparisons with other pre-modern freight rates hold little promise.[75]

This does not necessarily mean that there is no hope at all. The problem of comparing real freight rates over time might be addressed by expressing nominal shipping charges as multiples of labor wages. Papyrological records of daily wages of unskilled rural workers in Roman Egypt in the first three centuries CE suggest that the maximum daily wage for a farm laborer of 25 *denarii* ordained by the edict of 301 CE is plausible in real terms, that is, in relation to the stated maximum price of wheat.[76] In principle, it should therefore be possible to relate the real freight charges represented by the caps imposed by this edict to real freight charges in later periods from which information about both nominal shipping costs and rural wages has survived. Whether

[71] Estimated from van Tielhof 2002: 216.
[72] Kohn 2001: 52.
[73] See the tabulation in Arnaud 2007: 336. Oriens to Spania: 20 *d*(*enarii*) minus Oriens to Sicilia or Africa: 16*d* = 4*d*. Oriens to Baetica: 22*d* minus Oriens to Sicilia or Africa: 16*d* = 6*d*. Africa to Spania: 8*d*. Sicilia to Galliae: 8*d*, implying that Sicily to the Iberian peninsula would be >8*d* given the greater distance.
[74] Reckoning with a maximum Sicilian wheat price of 92-96 *denarii*/*modius kastrensis* (without tolls) or 83.5-91.5 *denarii*/*modius kastrensis* (with tolls).
[75] Medieval freight rates in the Cairo *geniza* texts are not helpful because they do not separate carriage costs from tolls, do not cover grain, and record only the weight and not the volume of traded goods: see Goitein 1967: 339-46. A survey of Genoese and Venetian sources might generate better results but cannot mitigate the weaknesses of the Roman evidence.
[76] Scheidel forthcoming b. Note that this relationship does not confirm that the price of wheat was generally around 100 *denarii* in 301 CE: all it does is to lend credibility to the ratio between a stated wage (25*d*/day) and the stated price of a commodity (100*d*/*modius kastrensis* of wheat). Actual nominal (but not real) wages and wheat prices could have been lower depending on location.

this is feasible in practice remains to be seen: this exercise is well beyond the scope of the current paper.[77]

5 Did technology matter?

The comparative evidence surveyed in this paper strongly suggests that the cost of predation was a crucial determinant of trading costs. Transaction and financing costs also played an important role. In as much as technological change in maritime commerce occurred, it was critically mediated by other factors and its actuation is therefore best regarded as an endogenous phenomenon. Technological progress was contingent not only on key variables such as the security situation and the structure of demand but also on additional factors that cannot readily be specified for the Roman period, such as changes in the cost of labor (as after the Black Death) or in the cost of timber (as in the fifteenth century).[78] All this leaves little room for nautical technological innovation as a significant driving force of economic development.

Ecumenical peace and predictable demand favored the deployment of durable,[79] modestly staffed, and, in some contexts, large merchant ships in the Roman period. This particular configuration of circumstances was intrinsically disconducive to more than marginal technological innovation. This logical prediction is borne out by the simple fact that basic ship-building techniques did not change in this period and that major innovations such as framing-first construction are not documented in the Mediterranean prior to the fifth or sixth century CE.[80]

This does not mean that the study of ship design and navigational techniques is wholly irrelevant to our understanding of Roman economic history. To the extent that conditions in that period reduced the relative weight of the cost of predation, transactions and financing, and in so far as the lack of monopolies and other organizational hurdles within a very large politically unified sphere encouraged open competition for market share on performance – above all, on price – alone, technological adjustments that improved features such as sailing speed, loading speed, and crew/cargo ratios without requiring dramatic alterations of established designs ought to have been sought out and embraced by the shipping community. These are the changes we must look for in the record, yet without forgetting even for a moment that it was broader and antecedent political and economic developments that facilitated their implementation.

[77] The massive impact of the Black Death on late medieval and early modern real wages would undoubtedly complicate any comparisons.
[78] Kohn 2001: 37.
[79] Very solidly built ships make sense in an environment in which losses were relatively unlikely: according to McGrail 2008: 623-4, cheaper ship-building techniques became more common in the increasingly unstable environment of late antiquity.
[80] McGrail 2008: 624, 628.

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