

# Speedier delivery: coastal shipping times and speeds during the Age of Sail

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Abstract

Coastal shipping has been described as the ‘vital spark’ igniting economic growth in Britain. We provide the first quantitative analysis of long-term changes in journey times and speeds in English and Welsh coastal shipping during the Age of Sail. We use Board of Trade Crew Lists, which reveal timings for numerous coastal journeys from 1835 to 1845. These are compared with journey times in the mid to late 1600s drawn from coastal port books and St. Paul’s Duty Books. The comparison also builds on a newly digitized coastal network, leading to calculations of journey speeds, defined as miles sailed per day, and voyage cycle times, defined as days between starting two identical voyages. We find evidence for significant changes in speed and time. Speeds were 2.90 times faster c.1840 compared to c.1660 and voyage times were 1.81 times longer c.1660 than c.1840. Average time spent in port changed less, remaining around 12 days. Our data provide evidence that total factor productivity in coastal shipping grew at a healthy rate prior to steam power. The findings have implications for the shipping productivity literature, which has largely focused on foreign trade, and to the industrial revolution literature more generally.

Keywords: shipping, coastal trade, productivity, industrial revolution

JEL code: N7, R40

The shipping sector has long been important to the British economy through its provision of low-cost transport services. The focus of this paper is coastal shipping in the Age of Sail, where the main cargoes were heavy commodities, like grain, coal, and other minerals. Coastal shipping has received much attention in the literature because commodities, like coal, provided the fuel for the industrial revolution, or as Armstrong called it the ‘Vital Spark’.<sup>1</sup> However, despite this growing

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<sup>1</sup> Armstrong, *The Vital Spark*.

attention, the literature lacks comprehensive national statistics on coastal trade during the Age of Sail. Willan gives numerous examples of what was shipped and where, and a host of local and firm-level studies provide more details.<sup>2</sup> Nevertheless gaps remain. This paper starts to fill this void by introducing new statistics on coastal trade and highlighting the key features of coastal shipping on the eve of the transition to steam c.1840. We use a new geographic information system (GIS) database of ports and coastal routes and a representative sample of more than 9,000 ship observations from all ports in England and Wales. This new data helps to document: (1) average distance traveled by coastal ships, (2) average ship size, (3) the degree of seasonality, (4) average journey speeds, and (5) average time to complete a coastal voyage.

Another major gap in the literature concerns productivity growth in coastal shipping. There is evidence the volume of coastal shipping grew from the mid-1600s to early 1800s.<sup>3</sup> Moreover, several scholars have argued for technological change in ports and coastal ships, greater skill of coastal crews, and organization gains from peace and an improved Navy.<sup>4</sup> However, there is no consensus on their overall quantitative significance. In fact, one view is that productivity changed little prior to steam.<sup>5</sup> We contribute by establishing the change over time in coastal journey speeds, measured in miles sailed per day, and ‘voyage cycle times,’ the number of days between departing for a port and the next departure to the same port without intermediate stops at other ports (i.e. consecutive voyages from A to B). Voyage cycles are informative because they capture both sailing time and time spent in ports.

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<sup>2</sup> Willan, *The Coasting Trade*; Armstrong and Bagwell, ‘Coastal Shipping’; Barker, *The Rise of an Early Modern Shipping*; Matthews, ‘Shipping and Local Enterprise’; Robinson, ‘Coastal Shipping’; Cook, ‘A True, Faire, and Just’; Skidmore, ‘Vessels and Networks,’; Wanklyn, ‘The Impact of Water Transport’.

<sup>3</sup> Ward, *The Finance of Canal Building*, p. 191 and Bogart, ‘Did the Glorious Revolution’, appendix.

<sup>4</sup> For example, see Armstrong, *The Vital Spark*; Ville, ‘Total Factor Productivity’; Craig, ‘Printed guides’.

<sup>5</sup> See Ville, ‘Defending Productivity and Hausman’, ‘The English Coastal Trade’. There is similar debate concerning foreign shipping, see Harley, ‘Ocean freight rates’.

Our main observations on coastal shipping times between 1835 and 1845 are drawn from crew lists held in Board of Trade records. They generate more than 9,000 observations c.1840. Crew list times are compared with data from a sample of surviving seventeenth century coastal port books collected and detailed by Dunn.<sup>6</sup> This work introduces a new method for extracting journey times and voyage cycle times from port books. Dunn's sample yields several thousand observations c.1660. Here we match journeys and voyages in Dunn's port book sample with our crew list sample based on destination ports, origin ports, and departure dates. Matching minimizes local differences associated with tides, currents, and seasonality. However, the matching is not perfect and we explore robustness in various ways. In our preferred matched sample, average journey speeds in crew lists were 41.2 miles per day versus 14.2 in port books. In other words, speeds were 2.90 times faster c.1840 compared to c.1660. Our evidence therefore rejects the hypothesis that little changed in coastal vessels and skill.

For voyage cycle times, the matching analysis shows less change. In our preferred sample, the average voyage cycle was 35.5 days in port books and 19.6 days in crew lists, implying voyage times were 1.81 times longer c.1660 than c.1840. Voyage cycle times changed less than speeds because port times, a significant component of voyage times, declined less. Some explanations are discussed below.

Our paper also provides new evidence on changes in voyage times in the east coast coal trade. Easton collects and analyzes entries of all ships arriving in London from Newcastle and Sunderland between 1689 and 1704 using St. Paul Duty Books.<sup>7</sup> We use Easton's data to construct more than 2,000 voyage cycle times and compare them with crew list voyage cycle

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<sup>6</sup> Dunn, 'Coastal shipping speed'.

<sup>7</sup> Easton, 'Securing Sea-coal'. We thank Easton for sharing his data.

times between London and either Newcastle or Sunderland c.1840. While focused on a single trade, this analysis eliminates the problem of matching on different port pairs. Our estimates reveal an average voyage cycle of 40.7 days for crew lists and 71.4 days from St. Paul. The ratio of times implies voyages were 1.8 times longer in c.1700 compared to c.1840. The change in voyage times are further used to estimate total factor productivity growth in the east coast coal trade. Our figures suggest TFP increased by 0.65 to 0.8 percent per year between 1700 and 1830. These estimates address a long-standing debate between Ville and Hausman on the degree of productivity change in coastal shipping.<sup>8</sup>

We contribute to a larger literature on the productivity of shipping pioneered by Davis and others.<sup>9</sup> Many studies emphasize speeds as a productivity indicator.<sup>10</sup> However, there is almost no evidence on speeds and times in coastal shipping. To our knowledge, we are the first to estimate speed and time for coasters across many routes. The main takeaway is that English and Welsh coastal shipping became speedier and much more productive during the Age of Sail.

We also contribute to a literature on the productivity of the British economy. Our results support several studies showing that modest to high productivity was present in sectors not relying on steam power.<sup>11</sup> We add to this literature by shedding light on a sector—coastal shipping—that has had little attention in the debate on sectoral productivity growth.<sup>12</sup>

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<sup>8</sup> Ville ‘Total Factor Productivity’ and Hausman ‘The English Coastal Trade’.

<sup>9</sup> Davis, *The Rise of English Shipping*; North, ‘Ocean freight rates’; Shepherd and Walton, *Shipping*; Harley, ‘Ocean freight rates’; Menard, ‘Transport costs’; van Zanden and van Teilhof, ‘Roots of growth’; Unger, *Shipping and economic growth*; Solar, ‘Opening to the east’.

<sup>10</sup> See Ronnback, ‘The speed of ships’; Vinnal, ‘The world refuses to shrink’; Solar and Hens, ‘Ship speeds’; Solar and Ronnback, ‘Copper Sheathing’; Kelly and O’Grada, ‘Speed under sail’; Solar and deZwart, ‘Why were Dutch East Indiaman’.

<sup>11</sup> Among others this includes sectors like coaches, canals, and watchmaking. See Gerhold. ‘the development of stagecoaches’; Bogart, Lefors, and Satchell, ‘Canal Carriers’; Kelly and O’Grada, ‘Adam Smith’.

<sup>12</sup> See McCloskey, ‘The industrial revolution’ and Crafts, *British Economic Growth*.

## I.

This section provides background from the previous literature and discusses how voyage time influenced shipping costs and how changes in time relate to technology, skill, and other factors. We begin with coastal vessels. They came in various sizes ranging from capacities of 15 tons to several hundred. The most common vessel for short coastal hauls, say under 100 miles, was the flat or sloop. They were usually single-masted, single-decked, and flat bottomed. The most common vessel type for long hauls was the brig, brigantine, ketch, or schooner with two masts.<sup>13</sup> Vessels generally had many owners. Shareholders had diverse backgrounds, but merchants and masters were most common in the 1600s and 1700s.<sup>14</sup> By the nineteenth century, ship ownership was more concentrated with implications for operation.<sup>15</sup>

Shipping was organized around voyages from a home port. One type was the ‘liner’ voyage, where ships sail from port A to port B and then return to A. The liner voyage was usually organized around a primary good, like coal. The backhaul good could be ballast or in some cases manufactures and groceries. In general, the cargo varied by origin and destination port.<sup>16</sup> The second voyage type could be described as ‘shuttling’, where ships sailed from port A to B and then to ports C, D, etc. before returning to A. Shuttling allowed ships to exploit new trading opportunities discovered en route.<sup>17</sup>

Crews always included a master and seamen. They could also include specialists like the mate, carpenter, and cook. More seaman were needed to man a large ship, but there were labor

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<sup>13</sup> Skidmore, ‘Vessels and Networks’, p. 162.

<sup>14</sup> Skidmore, ‘Vessels and Networks’, p. 168.

<sup>15</sup> Ville, ‘The growth of specialization’; Barker, *The Rise of an Early Modern*, p. 125.

<sup>16</sup> Willan, *The Coasting Trade*, provides a detailed description of trade by east, south, and west coast ports.

<sup>17</sup> Barker, *The Rise of an Early Modern*, p. 78. One could also call this tramping.

savings in larger ships.<sup>18</sup> Crews were generally hired for the duration of the voyage. The crew were paid a wage, which accounted for their skill-level and length of voyage. Crew were also compensated with food rations while on journeys. The crew's contract ended when the ship returned to home port and a new crew would be hired for the next voyage.<sup>19</sup> The supply of labor appears to have been elastic except during wartime because of naval impressment.<sup>20</sup>

The master was the most important crew member. They had to know the winds, tides, shoals, and lights on their route. Masters also acted on behalf of ship owners negotiating with merchants on freight rates. Masters also acted as factors, buying goods in the origin port and selling in the destination port.<sup>21</sup> There is also evidence of masters working part-time in agriculture or elsewhere. However, the more successful masters were specialized and literate.<sup>22</sup>

There were many hazards in coastal sailing. Sinking in a storm was one significant risk. Fewer ships sailed during winter because of dangerous seas. Instead, ships often laid up and repairs were performed.<sup>23</sup> Enemy warships and privateers presented another risk. Ships stayed in port to avoid capture or sailed in winter with greater risk. Protection was offered by Royal Navy convoys, but their effectiveness was mixed in the seventeenth and early eighteenth century.<sup>24</sup> Insurance offered some help, but it was expensive and usually restricted to cargoes.<sup>25</sup>

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<sup>18</sup> Willan, *The Coasting Trade*, pp. 16-17, compares tons per man on large colliers and small ships.

<sup>19</sup> Barker, *The Rise of an Early Modern* p. 88, 134; Willan, *The Coasting Trade*, p. 17.

<sup>20</sup> Willan, *The Coasting Trade*, p. 32.

<sup>21</sup> Factoring was especially common in the coal trade, see Armstrong, *The Vital Spark*.

<sup>22</sup> See Cook, 'A true, faire, and just account', p. 13; Matthews, 'Shipping and local enterprise', p. 147.

<sup>23</sup> Barker, *The Rise of an Early Modern* p. 118; Willan, *The Coasting Trade*, p. 25.

<sup>24</sup> Willan, *The Coasting Trade*, p. 28; Easton, 'Securing sea-coal', p. 40.

<sup>25</sup> Davis, *Rise of the English*, p. 87-88; Leonard, *Marine Insurance*, p. 41; Matthews, 'Shipping and Local Enterprise', p. 140.

Turnbull's study of John Wilson & Son, a Leeds linen merchant, illustrates how war reduced the cost advantage of coastal shipping. Turnbull shows that the firm made extensive use of coastal ships, but less so during three major wars between 1754 and 1800. The correspondence between Wilson and its agents suggests insurance could be purchased, but rates were higher in wartime and even higher if convoys were not available. The correspondence also reveals that ships often stayed in port during war, forcing the firm to rely on road transport.<sup>26</sup>

Throughout the literature on coastal shipping there is an emphasis on the importance of *time* as a determinant of shipping costs and profits.<sup>27</sup> Since crews were hired for a voyage, shorter voyages meant lower labor costs. Capital costs also depended on time. One can think of masters as paying ship owners a rent to compensate for interest, depreciation, and the replacement cost of their ship. The master would pay a higher rent, the greater the time required to complete a journey. Considering both capital and labor, coastal shipping had the following cost function:  $C = D(wL + rK)$ , where  $D$  is the number of days to complete a voyage,  $w$  is the day wage including rations,  $L$  is the number of crew,  $r$  is the daily rental rate per ton burthen, and  $K$  is capital measured as the tonnage of the ship. It follows that the marginal cost of shipping a ton on cargo will be proportional to the length of the voyage  $D$ .

Voyage times  $D$  can be divided into sailing and port times. It is useful to analyze both in more detail. We model sailing time as  $S = z_s/A_s$ , where  $z_s > 0$  is the realization of a random variable. It captures factors like weather and has some distribution  $F_s$ , like the log normal.  $A_s > 0$  captures the technology of vessels and crew knowledge. Better technology and knowledge

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<sup>26</sup> Turnbull, 'Scottish Linen', p. 63.

<sup>27</sup> See for example, Ville, 'Total Factor Productivity', p. 356; Hausman, 'Size and Profitability', p. 463.

increase  $A_s$  and hence lower mean sailing time and lower variance. However, since randomness is still a factor some sailing times could be longer, even with better technology.

Several scholars argue that the technology and skill of coastal sailing improved. Armstrong emphasizes the transition from the square to fore-and-aft rig in the nineteenth century. Armstrong claims such ships easily reached speeds equal to 100 miles a day.<sup>28</sup> Barker describes greater training and education of Whitby mariners with “enormous benefits” to its shipping community during the eighteenth century.<sup>29</sup> Craig describes a growing body of printed instructions and navigation charts available for enterprising and literate masters after 1750.<sup>30</sup>

Port times were determined by different factors than sailing times. Nevertheless, we can use a similar formula,  $P = z_p/A_p$ , where  $z_p > 0$  is the realization of a random variable like weather with distribution  $F_p$ , and  $A_p$  is a parameter for better technology or infrastructure. One argument is that shipping became more specialized and hence masters spent less time in port acting as merchants or performing alternative tasks. Especially notable according to Ville is the shift to year-round trading and the end to winter lay ups.<sup>31</sup> Technology also changed. In Newcastle, riverside staithe and spouts replaced loading by keelboats, and along with steam-tugs, helped to get ships to sea more quickly.<sup>32</sup> Ship congestion was also alleviated by port improvements. London built several wet docks after 1800 in response to higher volumes. London was not alone. Pope and Swann identify 391 acres of wet dock in 1830, compared to zero in

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<sup>28</sup> Armstrong, ‘Significance of Coastal’, pp. 83-84. Copper bottoms may have been another speed factor. They were important for foreign shipping and to the extent that foreign ships became coastal ships they could matter. See Solar and Rönnbäck ‘Copper Sheathing’.

<sup>29</sup> Barker, *The Rise of an Early Modern*, p. 65.

<sup>30</sup> Craig, ‘Printed guides for Mariners’, p. 33.

<sup>31</sup> Ville ‘The Growth of Specialization’ p. 706; Ville ‘Total Factor Productivity’, p. 361.

<sup>32</sup> Ville, ‘Total Factor Productivity’, p. 362-365.

1660.<sup>33</sup> Another potential factor was the increasing safety of coastal waters. *Pax Britannia* meant that ships no longer waited for convoys or searched for crew following impressment.<sup>34</sup>

Despite these claims of significant change, some scholars have argued for slower or moderate change in coastal vessels and knowledge prior to steam. Hausman uses differential trends in coal prices between Newcastle and London to infer that technological changes did not significantly bring down coastal shipping costs.<sup>35</sup> Similarly, Harley argues productivity growth in ocean shipping was minimal before 1850.<sup>36</sup> Overall these arguments imply sailing speeds and port times were broadly similar over time.

Later in this paper, we analyze changes in speed and time across several coastal routes between the seventeenth and nineteenth century (Section IV). We also analyze changes in the east coast trade (section V) along with an assessment of its productivity growth (Section VI). First, section II describes the Board of Trade crew lists and new GIS data on ports and section III uses crew lists to provide new facts about the coastal shipping sector around the year 1840.

## II.

The 1835 Merchant Shipping Act required that all masters in the coastal trade complete forms (a.k.a. crew lists) that record details of voyages and crews employed during the previous six months. The lists were generally filed in late June or late December, giving a bi-annual report on the ship's movements and crew. The lists between 1835 and 1844 have survived and are

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<sup>33</sup> Pope and Swan, 'The Pace and Progress', p. 43. Also see Jackson, 'Ports', p. 194;

<sup>34</sup> Solar. 'Opening to the east', emphasizes the importance of *Pax Britannia* for eastern trade.

<sup>35</sup> Hausman, 'the England Coastal Coal Trade', p. 591.

<sup>36</sup> Harley, 'Ocean Freight Rates'.

available at the National Archives within the Board of Trade records.<sup>37</sup> The lists are organized by registration port and contained in several boxes, arranged alphabetically by ship name.

Crew lists are available for English, Welsh, Scottish, and Irish registration ports. This paper focuses on the first two because our sources for the seventeenth century deal with England and Wales. We sample crew lists in two steps. In step one, the first ten crew lists in the first box for all 71 registration ports were selected and photographed. The aim was to create a random sample of ships sailing into or out of each registration port. The selection of the first ten lists is approximately random because alphabetical listing by ship name is not obviously correlated with ship performance and characteristics.<sup>38</sup> In step two, we resampled lists from London and 25 other ports that are more common in our seventeenth century sources.<sup>39</sup>

The crew lists always contain the port of registry and a list of the captain and crew. Some also contain registered tonnage and cargoes. Importantly for our purposes, crew lists describe ship movements for a six-month period. Recorded movements were not standardized, but there are three common formats. The first format records departure dates for a series of liner voyages, defined as leaving port A for port B and returning from B to A. For example, the ship *Six Brothers* of Rochester is listed as departing from Maidstone for Sunderland on 23 February 1836 and the same on 15 April, 21 May, and 27 June 1836.<sup>40</sup> From this format, we infer (i) the date of departure, (ii) origin and destination ports, and (iii) time between voyages in days. When two

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<sup>37</sup> BT98, Registry of Shipping and Seamen: Agreements and Crew Lists, Series I. For more details see Watts and Watts, 'My Ancestor was a Merchant Seaman', p. 51.

<sup>38</sup> Barker, *The Rise of an Early Modern*, pp. 168-69, discusses the naming of ships. Our reading is that ships were named for many reasons, but none were related to the performance of the ship or the master.

<sup>39</sup> We resampled between 15 and 30 lists from Whitby, Sunderland, Newcastle, Bridlington, Bridgewater, Gloucester, Chepstow, Milford, Penzance, Southampton, St. Ives, Truro, Boston, Dover, Falmouth, Exeter, Fowey, Gweek, Hull, Ipswich, Kings Lynn, Maldon, Colchester, Chichester, and Newport,

<sup>40</sup> See Rochester Crew lists BT98/ P7233156.

consecutive voyages are between the same port-pairs, like Maidstone and Sunderland, we measure the ‘voyage cycle time’, or the number of days between starting two identical voyages.

The second common format records the date of departure of a voyage and the date of returning to the origin port. For example, the ship *Anne and Jane* of Yarmouth is recorded as leaving Yarmouth for Shields on 27 June 1837 and returning to Yarmouth on 9 July 1837. The next voyage to Shields is recorded on 13 July 1837 and a return to Yarmouth on 29 July 1837.<sup>41</sup> In this case, we additionally infer the time spent in the origin port between voyages. For example, the *Anne and Jane* spent 4 days in Yarmouth between its first and second voyage.

The third common format is the most valuable for researchers. It records departure and arrival dates for journeys within a voyage. A journey is defined as a sailing from port A to port B. The crew list for the *Charles Rash* illustrates.<sup>42</sup> It describes departures and arrivals for 13 journeys in the first half of 1838. The first journey is between Newport and Plymouth. The second between Plymouth and Truro. The third is between Truro and Neath. In this format, we observe the number of days between departure and arrival, or the ‘journey time.’ We also observe time in origin and destination ports and the proportion of overall time spent in ports.

Our database contains movements for 570 ships between 1835 and 1845, or c.1840. Nearly all ships appear to be sailing vessels, not steamships. We consulted *the Return of the Name and Description of all steam vessels Registered in the Ports of the United Kingdom*.<sup>43</sup> It gives the name of all steamships, the registration port, and other characteristics like tonnage in 1845. We matched our 570 ships to this source based on name and registration port. The *Albion* of Hull and

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<sup>41</sup> See Yarmouth BT98/ P7303447.

<sup>42</sup> See Whitby BT98/ P7243333.

<sup>43</sup> P.P. XLVII, p. 545.

*Elizabeth* of Newcastle were the only crew list ships matched to the list of steam ships in the 1845 Return. Other sources identify three other candidate steamships in the crew list.<sup>44</sup>

The low number of steamships in our data (5 of 570) should not be surprising since the general adoption of coastal steamers is generally dated from the late 1840s, or after our we stop sampling crew lists.<sup>45</sup> Moreover, the 1845 Return reveals that most steam ships are registered in a small number of ports: London, Newcastle, Hull, Liverpool, Bristol, and Southampton. Our sample is based on a random sample from each port. Therefore, our sample under-weights the population of ports with most steamships. In any case, steamships obscure our analysis of change during the Age of Sail, and so these ships are dropped from the analysis.

The data on ship movements are combined with a new GIS database of ports and coastal shipping routes. It identifies ports in use between 1540 and 1836 in several published sources.<sup>46</sup> Most origin and destination ports identified in crew lists are also recorded in the published sources. If not, we add them to the published list. In most cases, added crew list ports probably had little infrastructure, but for ease of exposition we call them ports. Each port in the database is assigned geographic coordinates based on historic and modern maps.

The main source for coastal shipping routes are nautical charts published by Collins in the earliest and most complete 1693 edition of *Coastal Pilot*.<sup>47</sup> The charts list the main landmarks mariners could use to locate their position in relation to the coast. Those landmarks were also used to describe directions on specific coastal routes. They also estimated distances between landmarks

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<sup>44</sup> Peter Solar has a wider range of sources on steamships. Solar kindly reviewed our list and found 4 possible matches to his records, including the *Elizabeth* of Newcastle. We should also note that a match does not guarantee that a ship was a steamer because of common names and switching registration ports.

<sup>45</sup> Hughes and Reitner, 'The first 1945 British Steamships', p. 360.

<sup>46</sup> See Alvarez-Palau, E. J., et. al., 'Historical landing locations'.

<sup>47</sup> See Alvarez-Palau et. al., 'Historical landing locations'.

enabling navigators to plan their route. Collins was a respected source of navigational guidance and approved by Trinity House. Publishers Mount & Page made no significant revisions to given route information between all editions running until 1792 and continued to publish them commercially as dependable guides. Continuity across successive editions of Collins' charts suggest the routes he originally detailed did not significantly change over the period of this study.<sup>48</sup>

Coastal routes are constructed by geolocating listed landmarks and plotting connections according to the orientations described in Collins. All the connections are required to be within the visibility range from the coast in good weather and in daylight. Although night visibility improved with the construction of lighthouses in the nineteenth century, daylight visibility is used to employ the simplest model of coastal routes and one that is comparable to the seventeenth century. We also construct a set of penetration lines to connect ports with circumscribing routes from Collins. The penetration lines are designed to maximise water depth from the port to the sea using bathymetrical data.

[Figure 1 here]

All the ports and coastal routes are shown in figure 1. Notice the large number of ports in operation during the Age of Sail. Notice also that direct and indirect paths are allowed in estuaries. For example, in the southwest, ships do not need to follow the coastline and the Severn estuary when sailing between Cornwall and Wales. Instead they can use landmarks and follow a more direct path. While the GIS lines imply a precise route, the reality for any voyage was different depending on the conditions. The GIS calculated port-to-port distances are approximations, but they are probably not far off.

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<sup>48</sup> Verner, 'Captain Collins' Coasting Pilot', p. 16.

### III.

The data in crew lists provide new insights on coastal speeds, times, and routes c.1840. We estimate population outcomes, like average travel speeds, by weighting port level means according to their population share. Notice that our data has the features of a stratified random sample, where registration ports are the strata and ships are the individuals observed. The population share of each port, which serves as the weight, is based on coastal sailing tonnage entering registration ports in England and Wales according to a return in the parliamentary papers for 1841.<sup>49</sup> The example of the average coastal journey speed provides an illustration. We first calculate the mean journey speed for each registration port. Call it  $\mu_i$ , where  $i=1, \dots, n$  is the index for registration ports. Next let  $T_i$  represent the coastal sailing tonnage entering port  $i$  and let  $T = \sum_{i=1}^n T_i$  equal the total tonnage entering all ports. The ratio  $T_i/T$  is the weight for port  $i$ . The estimate for population-weighted average journey speed is  $\sum_{i=1}^n (T_i/T)\mu_i$ .

Our first statistic of interest concerns ship size. We observe the tonnage of ships involved in 3,429 journeys. The average size of ships (weighted by port population share) was 75.71 tons (see table 1). Ships were much bigger in ports like London (134 tons on average), but they were medium-sized overall. Our estimate suggests that ships got bigger over time. Willan estimates that ships were 30 to 40 tons in the late seventeenth century.<sup>50</sup>

[table 1 here]

The crew list sample reveals the distance for 7,107 coastal journeys between 1,298 English and Welsh port-pairs. The average distance between port pairs is estimated at 252.43

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<sup>49</sup> *The Return of shipping registered*, (P.P. LII), p.379. The three largest ports for entering tonnage are London, Liverpool, and Bristol with shares equal to 0.224, 0.071, and 0.041 respectively.

<sup>50</sup> Willan, *The Coasting Trade*, p. 13.

miles (see table 1). To put this figure into perspective, the estimated sailing distance between London and Newcastle is 378.2 miles. In Liverpool and Bristol, two other large ports, the average journey distance was 156.5 and 193.6 miles, respectively. Thus, the important east coast coal trade serving London was an outlier in its distance.

One might expect greater coastal shipping activity during the fall harvest and summer when daylight was greatest, and weather was less fierce. Our data confirm these expectations. Table 1 reports the estimated share of coastal departures by month. January and February have the lowest share of departing journeys at 5.5%. The peak departure season (late summer to autumn) has twice as many departures as the off-peak season (winter).

We now turn to estimates of coastal shipping speed and times. The crew lists yield sailing times for 2,591 journeys between 1,815 port-pairs. The journey speed is the GIS calculated distance in miles divided by number of days sailing. Using weighting for registration ports as described above, the estimated average journey speed is 45.17 miles per day (see table 2).

[table 2 here]

How fast or slow was 45.17 miles per day? Speed is commonly measured in nautical miles per hour (1 knot = 1.15 mph). Assuming coastal ships sailed for 12 hours a day then the average speed in knots is 3.26. These figures suggest that coastal shipping was slower than other trades at the same time. For example, Kelly and O'Grada estimate that East India Company ships generally sailed between 5 to 6 knots by 1830.<sup>51</sup> Ronnback estimates that transatlantic slave

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<sup>51</sup> Kelly and O'Grada, 'Speed under Sail'.

ships sailed around 4 knots in the 1830s.<sup>52</sup> Coastal vessels were apparently not the ‘speediest’ ships in the British merchant fleet c.1830.

There was substantial variation in journey speeds, as one might expect given the vagaries of weather and dependence on wind for all motive power. Figure 2 shows a kernel density plot for the distribution of journey speeds across our entire sample. The 25<sup>th</sup> percentile speed was 20.1 and the 75<sup>th</sup> percentile speed was 60.6. There is also a noticeable right tail to the speed distribution. The 90<sup>th</sup> percentile was 94.7 miles per day, or between 4 and 8 knots. At this higher end, coastal vessels approached the speeds of East India ships. But at the lower end of the distribution, say the 10<sup>th</sup> or 25<sup>th</sup> percentiles, speeds were far lower at 10 to 11.

A full analysis of speed determinants is beyond this paper, but there are some factors which need to be established for our comparative analysis. First, we estimated the relationship between miles per day (mpd) and dummy variables for departure month using December as the comparison. Daily speeds were around 10 to 11 mpd higher for departures in May and June, perhaps because of longer daylight and better weather conditions. Speeds were also higher for departures in March, April, July, and August, but the differences are not statistically significant.

Second, departure and arrival ports were important determinants of speed. We estimate a regression including dummy variables for 147 of 148 observed origin ports and 153 of 154 destination ports. The R-square of 0.342, implying 34 percent of the variation is explained by indicators for origin and destination ports.<sup>53</sup> The data also show that ship size and cargo types affect speed, but once we control for origin and destination ports in the same regression their

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<sup>52</sup> Ronnback, ‘The Speed of Ships’, p. 489.

<sup>53</sup> Space limitation prevent us from reporting the coefficients describing speed in each port.

effects are not precisely estimated.<sup>54</sup> This is fortunate because we lack ship size and cargo for many journeys, but we always observe origin and destination ports.

Our data also reveal the average time for a voyage cycle. Recall a ‘voyage cycle’ includes sailing time from port A to port B, time spent in port B, time sailing from B to A, and time spent in port A before sailing to B again. Our data yields 2,568 voyage cycle times between 242 port-pairs. The average voyage time is estimated at 31.65 days (see table 2). Furthermore, we extracted 4,472 port times spread across 235 ports. The average time in days was 12.02. The distribution reveals many shorter port times than the mean. Twenty-five percent of the port time observations were 4 days or less. Fifty percent were 8 days. The share of time spent in port relative to total voyage time is computed for 498 voyages. The average share is 0.60. This implies that port times were a more important factor than sailing speed in affecting voyage times.

#### IV.

The literature provides indirect evidence for improvements in coastal shipping between the mid-seventeenth and early nineteenth centuries, but we don’t know whether they translated in greater speeds or lower voyage times. To address this issue, we introduce another source—port books—and describe methods for comparing speeds and times with those from crew lists.

Coastal port books arise because merchants shipping between English and Welsh ports were obliged to post a bond to ensure they did not fraudulently export the goods. Customs officers recorded ship’s inward and outward journeys. A written receipt, the *cocket*, listed goods designated

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<sup>54</sup> We observe tonnage for 1,112 journeys. A bivariate regression shows a positive and significant relationship between journey speeds and tonnage (one extra ton is 0.1 higher mpd). We also observe cargo type for 332 journeys. The main types are: (i) copper, (ii) coal, (iii) culm, (iv) iron, and (v) ballast. In a regression with five indicators for cargo type (other is the comparison), we find journeys carrying copper and coal are faster by 10 to 17 mpd.

for specified destination ports and recorded the date. At the destination port, a dated certificate was given to redeem the bond and sometimes the officer also recorded the arrival date.

We use the *cocket* date as the departure date for the journey on the assumption it was the last step before sailing. This assumption allows us to calculate journey times, whenever arrival dates are available in port books. As an illustration, one entry in the Spalding Port Book states that a *cocket* was issued for the *Providence* on 8 September 1678 in London and it records an arrival in Spalding on 26 September 1678.<sup>55</sup> In our methodology, the journey time is 18 days. Note that *cocket* and departure dates may not be the same in reality. However, Dunn's comparison with the available log books suggests the *cocket* date gives a reasonable estimate of journey time.<sup>56</sup>

Most port books are not currently available at the National Archives as a result of mould on the records, so it is not currently possible to create a large stratified random sample as we did with crew lists. Fortunately, some port books are accessible in the E190 and E122 record series and are analyzed by Dunn.<sup>57</sup> The 'port book' sample has 3,100 journey times between 130 port-pairs and 2,639 voyage cycle times between 111 port-pairs in various years between 1651 and 1683. The average observation year is 1662, so we use c.1660 as the approximate date. Because of the sources, the data are skewed towards a small set of destination ports. The most common are Bridgewater, Kings Lynn, and Spalding. The origin ports are more diverse, however.

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<sup>55</sup> Spalding Port Book, E122/230/19<sup>56</sup> See Dunn, 'Coastal shipping speed'.

<sup>56</sup> See Dunn, 'Coastal shipping speed'.

<sup>57</sup> Dunn 'Coastal Shipping' uses TNA E190: Bridgewater 1672-1676 and 1677; King's Lynn 1661/1662. From TNA E122, Dunn uses Arundel 1656/1681, Barnstaple 1653, Cardiff 1654/1656, Colchester 1651/1656, Exeter 1655, Faversham 1656, Hastings 1656, Ilfracombe 1654, Looe 1653, Maldon 1650/1653, Plymouth 1652-4, Milford Haven 1651, Penryn 1650-1, Sandwich 1652, Scarborough 1655, Shoreham 1657, and Spalding 1678/1681/1683.

Ideally, we want to compare crew list and port book journeys that share the same origin and destination ports to minimize differences due to routes. Unfortunately, there are only 59 journeys in the crew list dataset that can be matched with a port book journey with the same origin and destination port. To enlarge the sample, we also consider 1,793 crew list journeys that share an origin port with at least one port book journey. There are many port book journeys sharing an origin port, so we select the one with the shortest straight-line distance between its destination port and the crew list destination port. If there are several port book journeys with the same distance, the closest departure day to the crew list journey is selected.<sup>58</sup>

The sample of comparisons is further enlarged using the 194 crew list journeys sharing the same destination port with at least one port book journey. Using the same steps, we identify port book journeys that have the closest origin port and for these pairings the closest departure date. Combining the two groups yields 1987 (=1793+194) crew list journeys matched to port book journeys with the nearest origin port (when the destination port is the same) or the nearest destination port (when the origin port is the same).

In the next step, we eliminate duplicate crew list journeys matched to more than one port book journey. We select the match with the port book journey having the shortest distance to nearest origin or destination port and closest departure day. Removing duplicate crew list journeys reduces the matched set to 1866. A further refinement is desired because there are duplicate port book journeys (539 port book journeys are matched to 1866 unique crew list journeys). We select the

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<sup>58</sup> Regarding the closet departure dates, we ignore the year of sailing. For example, if a crew list journey departs on 15 January, the closet port book journey could be in any December, January, or February departure regardless of year. For 165 out of 1793 cases, there are multiple port book journeys sharing the closet departure date. Here we calculate average port book speed for comparison with crew list speed.

‘best’ crew list journey match for each of the 539 port book journeys using the shortest distance to nearest origin or destination port and closest departure day.

The mean distance between the nearest origin or destination port is 100 km across the 539 unique matches. As this is quite far, we restrict attention to matches where the discrepancies in the distances are less than 60 km. Therefore, our final sample for studying speeds includes 241 unique crew lists journeys matched to 241 unique port book journeys, of which 39 exactly match on origin *and* destination. The rest share either an origin or a destination port. It is also worth noting the final sample consists of shorter journeys (161 miles on average) compared to the average journey distance in the crew lists (252 miles, see table 2). This suggests our final sample will probably understate the change in speeds over time, since longer-distance journeys were faster.<sup>59</sup>

Figure 3 shows the kernel density plots for the distribution of journey speeds across four unique crew list and port book matched samples. The upper left is the matched sample sharing both an origin and destination port. The others share either an origin or destination port. We focus on the upper right-hand graph. It has 87 matched observations using the nearest origin or destination port within 20 km. This 20 km sample suggests that on average journey speeds in the crew list sample were 2.90 (41.2/14.2) times faster than average journey speeds in the port book sample. The mean difference is statistically significant with a p-value 0.00. The Kolmogorov–Smirnov statistic tests whether the two distribution functions are statistically different, and more specifically whether crew lists journey speeds are generally higher than port book speeds. The Kolmogorov test statistic has a p-value 0.00, rejecting the null of the same distribution.

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<sup>59</sup> In an unreported regression, we find that journey speeds increase with origin and destination port distance.

The difference between the crew list and port book distributions are similar across the other matched samples in figure 3, indicating that the distance to the nearest origin or destination port is not affecting the results up to 60 km. Conclusions are also similar after controlling for individual ships in the matched samples. Among the 241 matched journeys with distance less than 60 km, there are 91 unique crew list ships and 125 unique port book ships. Including dummy variables ships observed more than 5 or 10 times in either sample does not affect the mean difference. We also analyzed the crew list-port book speed difference for the sample of 241 matches. There are only 3 outliers where the speed difference is greater than 100 mpd.

What about the variance in speeds? Despite the noticeable right tail in the crew list sample, the coefficient of variation (standard deviation divided by the mean) is higher in all port book samples. It appears there was more variation in speeds c.1660 than c.1840.

We now turn to a comparison of voyage cycle times. At the outset it is worth emphasizing the problems in measuring voyage cycles in port books. In some cases, we only know the number of days between a ship's departure from port A to B and the next departure from A to B. However, suppose a ship sailed to another port C in between (i.e. from port B to C and then from C to A).<sup>60</sup> We have two solutions to this problem. First, we drop port book voyage cycles greater than six months. Six months is the time-frame for observing a ship in crew lists, and thus there are no crew list cycles lasting more than 182 days. While we are potentially throwing out some 'true' cycles longer than 182 days, for example lying up in port for ship repairs, this will only bias in favor of finding shorter port book voyage times. Second, we study a sub-sample of voyage cycles where we can rule out unrecorded onward journeys. They are described in Dunn and result from analysis

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<sup>60</sup> Such unrecorded onward journeys are not uncommon in port books. See Cook, 'A true, faire', p. 15.

of ‘outward’ and ‘inward’ copies of port books.<sup>61</sup> Here we identify ships sailing from B to A in between two A to B journeys. In other words, we can rule out unrecorded B to C journeys.

The matching procedure between port books and crew lists is like the speed analysis above. Voyages with the nearest origin and departure date are matched if they share the same destination. Voyages with the nearest destination and departure date are matched if they share the origin. We further refine to eliminate duplicate crew list and port book voyage cycle observations. The best matches based on shortest distance and departure date are selected for each crew list or port book observation matched more than once. The only difference is that we re-label the most eastward of the port-pair as the ‘origin’ and the westward the ‘destination’. It makes two cycles of the form port A-B-A and B-A-B equivalent, which they are since both involve time in ports A and B and time sailing from A to B and B to A. We again restrict the sample to matches where the nearest origin or destination port is less than 60 km to improve the precision. In the final sample, there are 376 unique crew list voyage cycle times matched to 376 unique port book voyage times.<sup>62</sup>

Figure 4 shows the kernel density plots for the distribution of voyage cycle times across four crew list-port book matched samples. Focusing on matches less than 20 km distance yields accurate matches and a reasonably large sample (n=210). The average voyage cycle was 1.81 times longer (35.5/19.6) in the port books than crew lists. The difference in average times is statistically significant with a p-value 0.00. Moreover, the Kolmogorov–Smirnov test rejects the null hypothesis that the two distribution functions are equal (p-value 0.00). In terms of the CV, there is little difference. A right-tail is present in crew lists and port books.

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<sup>61</sup> Dunn, ‘Coastal shipping speed’.

<sup>62</sup> The mean crew list distance is 153 miles in the matched sample with n=376. The overall average is 252 miles. Since journey speeds are greater at longer distances, we are biasing against finding shorter voyage times in crew lists.

As a robustness check, we also examine the matched sample where we can rule out unrecorded onward voyages using inwards and outwards port books. Briefly, we have 132 unique crew list voyages where the origin matches exactly to the port book voyage and the destination is less than 40 km, or the destination matches, and the origin is less than 40 km. In this sample, the mean voyage cycle times are 17.9 days for crew lists and 27.3 days in port books. Thus, port book voyage cycles are shorter when we eliminate the measurement error of onwareds journeys, but the magnitude of the difference with crew list cycle times is largely the same. A further robustness check examines whether repeat observations of ships in either sample affects the results. Ships observed more than 10 times in port books have statistically similar voyage times as other ships. But we find some ships observed more than 10 times in crew lists have longer voyage times. Thus, after accounting for their idiosyncrasies, crew list voyage times are even shorter on average.

The change in sailing versus port time is illuminated by bringing in the earlier estimates for journey speed. The average port to port distance in the matched voyage cycle sample is 154 miles. Therefore, sailing from A to B and from B to A at the average journey speed c.1840 implies 7.5 days of sailing time in crew list observations. Deducting average sailing time from average voyage cycle time in crew lists implies a port time of 12.1 (19.6-7.5) days. For port books, sailing at the average speed c.1660 implies 21.7 days of sailing time between ports 154 miles apart. Deducting average sailing time from the average voyage cycle implies a port time of 13.8 (35.5-21.7) days. Putting these together, port times are estimated to decline from 13.8 to 12.1 days on average, while sailing times decline from 21.7 to 7.5 days. Sailing times evidentially changed more.

We have additional evidence supporting modest change in port times. Maldon and Spalding are the only two in the port books dataset with reasonably large numbers of observations on port times (n=153 Spalding, n=42 Maldon). Both ports were involved in the grain trade with London

and are typical of a small east coast port.<sup>63</sup> Dunn estimates that average port times were 18 days in Spalding and 14 days in Maldon.<sup>64</sup> In the crew lists, we have 44 observations on port times in Maldon with an average of 10.9 days, about 3 less than in port books. There are 4 observations on Spalding in crew lists. The average is 16.5 days, around 2 to 3 less than port books.

Based on this evidence it appears that port times changed relatively little from c.1660 to c.1840, while sailing times fell much more. At this point, we can only conjecture why. Technological change was perhaps modest in the average port (unlike London). It is also possible that port improvements between 1660 and 1840 were barely enough to offset port congestion caused by the dramatic rise in coastal shipping volumes.

## V.

The literature has long emphasized the importance of the east coast coal trade. According to Armstrong, it was 20 times larger than the London road carrying trade in terms of ton miles c.1825.<sup>65</sup> We summarize its change over time beginning with summary statistics from our crew list sample (see table 3). We observe 43 journey speeds from London to the two northeastern coal ports: Sunderland and Newcastle (including Shields). The average speed is 58.1 mpd, higher than the 46.1 mpd average across all journeys. Therefore, colliers sailing north were faster. The average speed for 5 observations from Sunderland or Newcastle to London is 30.6 mpd. While a small sample, it suggests colliers to London (with a full coal load) were slower.

There are 117 voyage cycle times between London and Sunderland or Newcastle in our sample. The average is 40.7 days. The 90<sup>th</sup> percentile is 50, implying there were few outliers in the right

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<sup>63</sup> Willan, *The Coasting Trade*, p. 137.

<sup>64</sup> Cook, 'A True, Faire, and Just account', p. 12 makes a similar estimate for Maldon.

<sup>65</sup> Armstrong, 'The Significance', p. 66.

tail. The average port time in London for voyages beginning in Sunderland or Newcastle was 12.4. The average time in the two northeastern coal ports was 10.5. The difference is not statistically significant, implying statistical equality in port times.

We now compare with east coast coal voyage cycle times drawn from a different source. Easton collects a large database of collier arrivals in the surviving St. Paul's Coal Duty Books between 1689 to 1695 and between 1700 to 1704.<sup>66</sup> The 1689 to 1695 period overlaps with the Nine Years War and the latter overlaps with the War of Spanish Succession starting in 1702. Easton transcribes data from several hundred colliers arriving in London from Sunderland and Newcastle. The entries provide names of ships and masters, date of entry into London, and tonnage of coal. Ships returning multiple times are also coded.<sup>67</sup>

[table 3 here]

We use Easton's data to calculate the number of days between ship arrivals in London, yielding 2,600 observations. We refine this sample to 2194 observations after excluding 311 voyage cycles greater than six months and 95 less than 20 days. Less than 20 days appears to be an error since the lowest voyage cycle between the north-east and London is 27 days in crew lists. Six months is chosen as the upper bound in the Duty books because a crew list only covered ship movement for six months. Even after these refinements, measurement error is still concerning because we do not know whether ships went to other ports in between London arrivals. To explore this further, we examine the number of times a ship is observed from 1688 to 1695 and from 1700 to 1704. The most common outcomes were once or twice, but some are

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<sup>66</sup> Easton, 'Securing sea-coal'.

<sup>67</sup> These records are available at the London Metropolitan Archive, CLC/313/I/E. Registers of ships bringing coal from Newcastle to London, compiled in connection with the Coal Duty, 1687-95/6 & 1700-5 (Ms 25472/1-3)

observed more than 10 times in either period. We think the latter are more likely to spend the entire year in the east coast coal trade (i.e. they were specialized ships). The sub-sample of ships observed more than 10 times has 1,691 observations.

A comparison of voyage cycle times between St. Paul's Duty Books and crew lists reveals changes over time in the east coast coal trade. Figure 5 shows kernel density estimates of the two distributions. The average voyage cycle is 40.7 days for the crew list sample and the average is between 70.1 and 71.4 days in the St. Paul samples. The ratio of times is around 1.8, implying voyage cycles were 80 percent longer c.1695 than c.1840. The CV is also larger c.1695. Some of the variance difference may be due to measurement error from ships leaving coal trade, but even in the sample of specialized ships the CV is significantly larger. The comparisons between voyage times are very similar if we also condition on tonnage, which is in the St. Paul Books.

[figure 5 here]

There is also an interesting change in seasonality across the two time periods. For St. Paul's observations, the share of all arrivals to London in each month is calculated. In the crew lists, we calculate the share of departures in each month for all journeys from the northeast to London. Using departures to London rather than arrivals, significantly increases our sample size ( $n=265$ ) so we prefer that over arrivals. The histogram for the shares of departing or arriving voyages in each month is shown in figure 6. In St Paul, a higher share of voyages begin or end in summer (June to August, or 6=8) and a much lower share being or end in December (=12). Overall there were more December voyages in the crew lists. This is significant since winter sailings were thought to be dangerous. Perhaps nineteenth century ships could better withstand the winter weather than seventeenth century ships.

[figure 6 here]

As one more point, recall the St. Paul's Duty Books include observations on years of peace (1700-01) and war (1695-98 and 1702-04). The mean voyage cycle time during peace was 54.5 days (st dev. 34.4) and during war 72.0 days (st. dev. 37.8). Thus, voyage time were 1.32 times longer in war years. This provides some evidence war negatively affected coastal shipping and therefore greater peace by the mid-nineteenth century accounts for some of the lower times.

## VI.

We now address one of the most debated issues in coastal shipping: the degree of productivity growth in the east coast coal trade. Briefly, Ville argues for larger change, while Hausman argues for less.<sup>68</sup> Following Ville's method, the annual output of a master in the coal trade is  $V * C$ , where  $V$  is the annual number of voyages and  $C$  is the average cargo size of their ship. Therefore, the ratio of output per master between 1830 and 1700 is the ratio  $V_{1830}/V_{1700}$  multiplied by the ratio  $C_{1830}/C_{1700}$ . Ville assumes cargo size increased from 200 to 300 tons between 1700 and 1830.<sup>69</sup> Ville also assumes 7 voyages for 1700 and between 8 and 15 for 1830. The uncertainty in 1830 comes from the sources. Witnesses in parliament gave various figures on annual voyages. Therefore, Ville concludes that output per master increased anywhere between 1.71 and 3.21 times (1.5\*1.14 or 1.5\*2.14).

Our figures for annual voyages are different. If divide 365 by the average voyage cycle time for specialized ships drawn from St. Paul's Duty Books, then we get an estimate of 5 annual

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<sup>68</sup> Ville, 'Total Factor productivity change'; Ville, 'Defending Productivity'; Hausman, 'The English Coastal Trade'.

<sup>69</sup> Ville, 'Total Factor Productivity' p. 360. Hausman also provides evidence that average ship size increased from roughly 210 tons in the early 1700s to 280 tons in the 1830s.

voyages c.1700.<sup>70</sup> Dividing 365 by the average crew list time implies 9 annual voyages c.1830, or an increase of 80 percent. Therefore, using our figures, output per master increased by a factor of 2.7 (1.5\*1.8), with more annual voyages accounting for 66 percent of the increase.

It is also possible to estimate total factor productivity (TFP) growth with some assumptions. First, let the output of a master be defined by the production function  $AK^\beta L^{1-\beta}$ , where  $A$  is TFP,  $K$  is capital measured as shipping capacity in tons, and  $L$  is labor measured as the number of crew. The coefficient  $\beta$  can be interpreted as the share of costs which went to compensating ship owners versus crew in competitive factor markets. Under these assumptions, the ratio of output per master in 1830 and 1700 is the expression  $(A_{1830}/A_{1700}) * (shipsize_{1830}/shipsize_{1700})^\beta * (crewsizes_{1830}/crewsizes_{1700})^{1-\beta}$ . To fill in the variables, we use the ratio (3/2) for  $(shipsize_{1830}/shipsize_{1700})$  following Ville. Ville also reports that tons per crew increased from 8 to 25 between 1700 and 1830.<sup>71</sup> Given that ship size increased, this implies a *decrease* in crew size from 25 (200/8) to 12 (300/25). It is possible that 8 tons per crew is too low in 1700.<sup>72</sup> As an alternative, we assume 18 tons per crew in 1700 or a crew size of 11 (200/18) in 1700.

Hausman provides data detailing the cost structure for a east coast coal voyage in 1738.<sup>73</sup> We focus on cost components related only to shipping. The wages for master, mate, carpenter, cook, six men, and four boys equaled £28 plus victuals at £12 for a total labor cost of £40. Insurance, interest, and depreciation on the ship total £300 annually, or £43 per voyage if we assume 7 voyages per year. Summing £40 and £43 gives a total cost of £83. The resulting cost shares to

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<sup>70</sup> The caveat is that we may miss some ship downtime (perhaps for repairs) if it occurred close to 30 June or 31 December. We think this is a relatively small bias however.

<sup>71</sup> Ville 'Total Factor Productivity', p. 360, 367.

<sup>72</sup> See Willan, *The Coasting Trade*, p. 16; Armstrong, 'The Significance of Coastal', p. 75.

<sup>73</sup> Hausman, 'Size and Profitability', p. 470-471.

labor and shipowners are 0.48 and 0.52, which is plausible given shipping is an industry that uses labor and capital extensively.

In the final step, we solve for the increase in TFP consistent with our estimate that output per master increased 2.7 times. Specifically, we solve for  $(A_{1830}/A_{1700})$  using the formula  $2.7 = (A_{1830}/A_{1700}) * (3/2)^{0.52} * (12/25)^{0.48}$ . Our estimate is that TFP increased 3.11 times or at a rate of 0.88 percent per year between 1700 and 1830. Alternatively, assuming crew size increased from 11 to 12 implies TFP increased 2.10 times or a rate of 0.57 percent per year.

Hausman estimates TFP growth using trends in the real price difference between Newcastle and London coal. Hausman provides two estimates between 1691 and 1860. One is 0.02 percent per year and is based on the wholesale price deflator. The second is 0.36 percent per year, based on the cost of living deflator. In both, coal prices come from a splicing of several series.<sup>74</sup> Our estimates suggest that Hausman's lower bound estimate does not accurately capture TFP growth in the east coast coal trade. We also think our estimates of TFP growth (between 0.57 and 0.88 percent per year) should be preferred to Hausman's upper bound estimate since ours are based on a large sample of observations comparing two sources: crew lists and St. Paul's Duty books.

## VII.

We provide the first quantitative analysis on long-term changes in coastal shipping times and speeds across many routes from c.1660 to c.1840. We introduce new data, the Board of Trade crew lists and a newly digitized coastal network. From these sources, journey speeds and voyage cycle times are calculated. They are compared with similar metrics drawn from two seventeenth century sources, port books and St. Paul's Duty books. We find speeds were 2.90 times faster

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<sup>74</sup> Hausman, 'the English Coastal Coal Trade', p. 591.

c.1840 compared to c.1660 and voyage times were 1.81 times longer c.1660 than c.1840.

Overall, there is consistent evidence that coastal shipping provided speedier delivery by the second quarter of the nineteenth century. Finally, our data provide evidence that coastal shipping was one of several sectors that experienced healthy productivity growth without steam power.

Our findings also raise questions for future research. What caused speeds to rise specifically? Was the main driver better technology embodied in ships, or was it mainly better skill on the part of crews? Which types of master and shipowners pushed the technological frontier by sailing faster and speeding up turnaround times in ports? The existing literature would suggest it was the specialized and skilled masters, but it is not obvious that was true. How did war and peace affect the skill level of masters entered the trade? Finally, there were improvements to ports from 1660 to 1840, including the construction of wet docks and the introduction of staithes and steam tugs. Did the added capacity and better technology offset the effects of greater congestion? Answers to these questions will help us better understand the coastal transport revolution, which was equally if not more significant than the inland transport revolution.

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