War, Peace, and Free Trade: Coastal Transport in England and Wales during the latter Age of Sail (c.1650 to c.1850).
Oliver Dunn, Dan Bogart, and Eduard Alvarez

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Coastal transport before steam
Economic growth in Britain from the eighteenth century and before was increasingly driven by industrialisation and urbanisation that would have been impossible without efficient access to ample supplies of coal. The coasting trades allowed millions of tons of coal to be moved to areas of industry and large coastal populations, such as between the coal fields in the North East and London. Grain, metal wares and timber and a range of other goods were also shipped in bulk around Britain’s coast, allowing the rapid growth of coastal cities the development of industry, and the maintenance of a large permanent fleet and ready pool of sailors. Coastal connectivity and coal deposits was unique resource for Britain. Despite the scale of coastal transportation, the infrastructure is hard to observe now. Unlike rail, canal, or road systems, coastal shipping networks disappeared by the second half of the twentieth century when road and rail absorbed almost all the work of national cargo shipping. Historians have indeed pointed to the significance of the coastal transport network to Britain’s economic history. However, only a handful of publications have discussed coastal in relation to broader historical trends. John Armstrong has done much to advertise the significance of British coastal transport to economic development.1 The English Eastern coal trade between North-eastern coalfields served by Newcastle and Sunderland and large populations in the Southeast has been the special subject of interest due to what the trade can reveal about developing freight rates and the associated phenomenon of globalisation driven by integrating oceanic freight networks.2 Indeed, the history of these freight costs informs debates about early globalisation too.3

The coastal network
At the Cambridge Group for the History of Population and Social Structure, researchers have been collecting and analysing new sources to support the recreation of the historical coastal network using ArcGIS. This geographical mapping programme connects raw data with advanced geographical analysis tools. Using this we have been able to recreate coastal trade routes using historical sources to model a realistic coastal shipping networks from 1650 to 1911. Our intention is to calculate transport costs of coal, before considering other commodities such as grain and manufactures.

To this end, it has been necessary to determine historical sailing routes. These will allow ArcGIS to calculate journey times circa 1650, 1830, and 1911. In version 2 of the coastal network, Eduard Alvarez has imported a raster of current UK home waters bathymetry to create an accurate network based on modern information. In network version 3, we will use historical navigation charts with lighthouses and other sailing visibility factors to establish further routes sailing coasters likely travelled.

Within the GIS, connection between ports, or the routes ships followed were highly dependent on climatic conditions. Another important factor are the connections between ports that were highly dependent on waves, tides, seasonality, and other mostly unknown events and factors. The procedures,

or the way routes were navigated did not change significantly before very recent times and the invention of radar and GPS. For a long time, coastal navigation relied on charts and instruments such as sextants that depended on lighthouses and coastal visibility when navigating around the coast, and local and published information about sandbanks and bathymetry. We have created an early coastal network version based on modern bathymetrical information to determine the approximate distance ships may have sailed from the coast. The bathymetry data was obtained from 30" gridded data raster available from the European Marine Observation and Data Network (EMODnet): http://www.emodnet.eu/bathymetry.

We split our coastal routes into two main types: a national cabotage line, and from this, penetration, or entry lines to ports. Cabotage lines current follow a 25-meter iso-depth curve that follows the British coastline. This is an arbitrary interpolation, and for future network, we will base the curve on historical charts and other sources to account for capabilities in 1650, 1830, and 1911. This will allow routing based on historical evidence and follow the technological capabilities in the three different periods. Sandbanks might have shifted significantly since 1700, and lighthouses rapidly grew in number over the nineteenth century.

In some regions, this curve is naturally nearer the coast than others. Our intention was to define an approximate route ships would take to avoid grounding or sailing dangerously far from the coast. Penetration/port-entry lines also employed bathymetrical data to establish the route between port and nearest cabotage line by the maximum depth it was possible to sail.

The new coastal GIS version we are working on improves the current routes by adding historical data for lighthouses and elevation information to define contemporary ship visibility lines. Sandbank positioning and bathymetrical information will further determination of coastal shipping routes that avoided the risk of grounding.

Extensive work on the GIS system by Eduard Alvarez and Max Satchel enables detailed calculations made later using coal price data alongside a matrix of port-to-port distances to determine transport costs by commodity price distribution throughout England and Wales. Eventually, the GIS coastal network will be linked to other networks investigated by the Group, such as rail and river systems. An effective coastal GIS network is key to the aims of the wider transport project.
Figure 1 The ports and coastal routes GIS as described above. Ports, coastal routes and rivers come from CamPop work, bathymetry data obtained from EMODnet. Map by Eduard Alvarez-Palau at Campop.
Ports and landing locations

It was necessary to obtain an accurate list of ports from historical sources to add to the coastal GIS. In total, we have digitised and added 325 ports derived from the following sources:

- **1565-1700**

- **1680**

- **1780**

- **1842**
  - Daniel, J., *The Shipowner’s and Shipmaster’s directory to the port charges, all the depth of water in Great Britain and Ireland*, (Aberdeen), 269pp.

- **1826**

- **1903**

Coasters – including colliers – landed at a wide range of locations, including beaches and large ports. An array of different loading apparatus moved goods from boats to shore. We are still developing means to account for the range of landing systems. At this pilot stage, we have compiled a historical port list drawn from the published sources above. The lists largely follow historic customs organisation of ‘head’ and ‘member’ ports. Ships’ masters travelled to the head port to certify cargoes and record their cargo in the coast port book. In return, they were granted a certificate showing they had landed goods legally, which enabled redemption of bonds left at their port of origin. Ships often landed away from customs ports.

Port tonnages and flows of coastal shipping as tonnage

Information about the location of coastal shipping in Britain between 1690 and 1830 is scarce, in terms of both where coasters were registered, and where they travelled. The surviving sources depended on customs records, and so flows of shipping are somewhat more evident in the archive compared with static ship registration by port. There appear to be very limited shipping statistics before 1709, although Ralph Davis has approximated collier tonnages for 1686 at 80,000, and about 92,000 tons including other coasters.4

Using this list of ports, we then aim to understand coastal shipping flows in terms of ships’ registered homeports and second, the numbers of ships plying various routes. Official practice has been to measure shipping by aggregate tonnage, usually using customs accounts that have since been lost. In 1854, Britain adopted gross register tonnage unit that accounted for steam ships’ engine and coal storage rooms, which were necessarily larger than sail ships, yet had smaller proportion of space designated for cargo. We have accurate data on coastal shipping flows available for the 19th centuries, and for foreign mixed with coastal in the 18th century by port. For static registered tonnages by port from the 18th centuries concerning coastal specifically, and from the nineteenth century for all shipping including that engaged in foreign trade. It is

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not always clear how to disaggregate these statistics into useful components, especially foreign-going versus coastal traffic recorded together in some sources.

Two unique sources of tonnages statistics for the 18th century survive in the British Library manuscripts archive. These reports are based on customs data, which was drawn from total shipping flows through ports. One gives by-port static registry of coastal vessels 1709-1780. This excludes London, with the explicit reason that it possessed no notable coasting fleet. Yet some have discounted this possibility, citing evidence that London possessed a small coasting fleet when compared to Newcastle (perhaps 1/6 of the size).

Its companion document lists flows of tonnages of the same ports, but unfortunately mixes coastal with foreign tonnage. We have digitized the coastal ships registered to each port (from Ms, 12555) for two years: 1709 and 1751. We have also digitized the flows between ports (Ms, 12556) for the same years. Unfortunately, 12556 also mixed foreign and coastal flows, and is less useful as a result. These two facts make it a difficult source of information about coastal shipping. Davis, Armstrong, and others before them, have drawn on the latter to calculate total registered coastal shipping tonnages in the eighteenth century because they distrust the statistics for registered shipping involved in coastal trade.

Using 12556, Calculations of port tonnages quoted by Davis (using mixed flows data) et al published but come with a series of serious caveats that Davis and later Armstrong made clear. The problem, as we have seen, was that it was necessary to separate coastal from international shipping, and simultaneously to eliminate double counting of ships in data for total shipping flows of international and coastal trade. Estimates were made along these lines, but we prefer to simply use (and trust) the registered tonnages report (12555), unlike Davis and Armstrong.

Figures are more complete for the 19th when parliament recorded shipping flows in more detail. Again, flows were recorded rather than registered tonnages. The Parliamentary Return for 1851 gives total coastal shipping flows by port (ships are counted more than once). Static registered tonnage of all shipping distinguishes ships by size (below and over 50 tons) and by steam and sail ships.

For coastal shipping tonnage flows between 1871-1913 there are published statistics drawn from the BPP Annual Statements of Trade and Navigation (1853-1870) and the Annual Statements of Navigation and Shipping (1871-1913) in the parliamentary papers. Like the 1851 Return, these give net capacity tonnage and ship numbers annually, dividing by sail and steam ships, and coastal and foreign trade. These cover multiple ports in England, Wales, Ireland, and Scotland.

However, so far we have only digitised only part of the 1851 BPP Return of coastal shipping, and parts of Ms Add 12555 and 12556. The statistics are summarised in charts below.

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5 Add Ms, 12555/12556: ‘The Musgrave Manuscripts’ 1709-1780.
6 Davis 1972, pp. 386-7.
Figure 2 British Library, Add MS 12555. Total of 96,941 tons registered in 1709, and 136,700 in 1751 (excluding London).
Figure 3 Parliamentary Return of shipping registered and cleared coastwise, at each of the ports of Great Britain 1851.
Prices and transport costs

Coal

Simon Ville argued that the improvement of British coastal transport during the period of sail ships benefitted the wider economy (measured as total factor productivity gains). Mainly using published freight rates and surviving company accounts, Ville calculated that coasting trade productivity increased by 'perhaps' as much as 200% 1700-1850, representing the period before the steam ship. Ville cites a range of improvements in technology, organisation, and infrastructure.

The national distribution of prices of coal and grain when applied to GIS can further demonstrate the benefits of coastal transport and its costs as with published freight rates. This is our preferred method. Geographical variation of coal prices across England and Wales is observable, and more so when applied to our coastal GIS network. Between 1650 and 1830, inland coal prices rise when observed further from coalfields along the coastal network, showing that the cost of coal rose in line with distance from coalfields in the North East, Lancashire, and South Wales.

W.J. Hausman devised this method to analyse a sample of coal prices in Newcastle and London to calculate freight rates 1691-1911. Hausman found a -0.19% annual decline in real freight charges (using cost of living for deflator). Accounting for the effects of war, the real decline reported was -0.11%. Thus, according to Hausman, war was a big factor, as was taxation – a conclusion we also reach. Hausman agrees with Ralph Davis in arguing that although total volume of coal transported increased impressively over this period (400,000 to 9 million tons of coal transported by sea per year to London 1690-1910), compared to wider economic growth the performance of the British shipping industry was less impressive. Hausman’s evidence conflicts with evidence of declining freight rates, which indicate reduction in coastal transport costs during the age of sail. There was thus some debate over Hausman’s findings, which centred on whether his method had accounted accurately for the full range of costs attributable to coastal transportation.

C. Knick Harley presented evidence low productivity in English sail coasting before the steam era, when costs fell dramatically because of technological change in the form of steam propulsion. Harley ‘overturns’ Douglas North’s view that organisational (i.e. institutional) progress was key in the early modern period. Harley emphasised the importance of steam technology as the key agent of change in the coasting trade and shipping costs more generally. Harley like Ville used published freight rates between Newcastle and London.

Most except Hausman and ourselves have employed published commercial freight rates published in newspapers to measure changes in coastal transportation. However, freight rates are a problematic source for studying productivity in coastal transportation in England. For one, coal merchants normally did not freight coal, but traded using their own ships. Coal owners would on occasion freight ships to export their coal directly. Another question arises about the overall competitiveness of the rates. It seems likely, especially gleaning from parliamentary inquiries, that coal merchants and collier owners would benefit from high prices and were motivated to inflate freight rates, for example, in times of war.

Exploiting our GIS transport coastal model, we attempt to improve Hausman’s price distribution method based on coal prices, employing new sources and methodology to determine total transport costs (TCs) of shipping coal – while realistically accounting for voyage and capital charges, wages, tolls, profits, and taxes. Later we intend to disaggregate the wide range of shipping costs using original accounts. The following

8 Ville 1986.
charts detail labour costs, taxes, and dock charges drawn from collier accounts 1729, 1811 and 1830. Such information can refine and help refine the national average TCs derived from geographical coal price variation.

The following are based on three separate sources: (1) A broadside published by T.S. Willan originally a broadside in 1729 entitled *The state of coal trade*; (2) an 1811 log of a vessel transporting coal between Bude in West England and Cork in Ireland; (3) 1830 parliamentary report on coastal coal trade in which is included an account of its shipping costs. The accounts vary in style, and choices were made about the categorisation of the items listed, but there is acceptable consistency between the three accounts when it comes to the charges chosen for comparison. The cost of cargos along with freight and ship capital costs are excluded, as are insurance costs (for now). Freight and insurance costs are not comparable because the 1729/1811 voyages traded as own account, while in 1830 the ship was commissioned or freighted by a coal producers. Taxes include the national tax on coal transported by sea, the king's duty (5 and then 6s per ton of coal), and in London, the 'Richmod shilling' (1s per ton of coal). Labour costs are restricted to manual labour such as 'heaving out' ballast and "keel men", while port charges include pilotage and officials' fees as well as more obvious crane and cartage or otherwise facilities fees. In the London accounts, tolls covered charges related to the operation of lights and harbour facilities between Newcastle and London. Unfortunately, the 1830 account bundles significant items together ('other' below), reducing the accuracy of the source. The share of tolls and taxation was clearly a significant factor.
Summary of analysis using coal prices to infer coastal freight rates

Dr Dan Bogart has analysed the coastal network with coal price variation to produce an estimate of TTCs using CamPop’s coastal transport GIS. The method uses differences in coal prices between ports near the major coalfields and ports elsewhere to measure “trade costs” in coastal shipping. The trade costs include pure freight cost of crew, provisions, and ship rental along with insurance, port charges, taxes, loading & unloading costs.

The approach builds on a model of market integration, where there is a single supply location. As an illustration, consider two markets, the first with suppliers and consumers, and the second only with consumers. Think of market 1 as Newcastle and market 2 as London, where the latter has no local supply
of coal. Let the price in market 1 be $P$ and the price in market 2 is $P_2$. Trade costs are given by $TC$. The law of one prices states that $P_2 = P + TC$. Prices in market 2 cannot exceed $P + TC$ otherwise it would pay to ship coal from market 1 to market 2. If prices were any lower then $P_2$ then it would not pay to send coal from market 1 to market 2.

The equilibrium in this market can be solved as follows. Let $Q_{d1}(P)$ be the demand function in market 1, $Q_{d2}(P + TC)$ be the demand function in market 2, and $Q_s(P)$ be the supply function in market 1. The equilibrium price is solved by setting total demand equal to total supply, $Q_{d2}(P + TC) + Q_{d1}(P) = Q_s(P)$. The solution is a price paid to suppliers by consumers in market 1 $P^*$ and a quantity consumer in markets 1 and 2 $Q_{1*}$ and $Q_{2*}$. The solution is shown in figure 1 below. Demand is larger in market 2 leading to a larger consumption in the market 2. Notice that the difference in prices is given by $TC$. A different market outcome is shown in the next figure. Here consumer demand is lower in market 2, but everything else is the same. As a result, consumption in market 2 is lower and consumption in market 1 is higher. Note however that the price difference in the two markets is still given by $TC$. 

![Graph showing demand and supply functions](image_url)
In our application, we use coal prices to identify the trade costs in coastal shipping. Coal is useful because it was mined in a small number of locations and it was consumed in many locations. Coal was also shipped coastwise from the ports near the major coalfields like Newcastle, Swansea, Liverpool. Thus if we know that a port had no local supply of coal and we also know from which supplying port it received its coal, then we can calculate the coastal trade costs TC using the price difference, or \(P_2 - P\) in our model. Our aim is to identify the per mile coastal trade cost and so we write TC between ports 1 and 2 as \((\text{distance in miles between ports 1 and 2}) \times (\text{per mile coastal trade cost})\). Some of our coal price are for locations within 15km of a port, but not exactly in the port. Thus we add a second term for \((\text{distance in miles from market to the port}) \times (\text{per mile land trade cost})\). Also there may be some measurement error in our prices or our distance measures so we add a constant and an error term. The estimating equation is

\[
\text{Price coal consuming market } i - \text{Price coal supplying port 0} = \text{constant} + b_1 \times (\text{distance in miles between port } i \text{ and port } 0) + b_2 \times (\text{distance in miles between market } i \text{ and its nearest port } i) + \text{error}_i
\]

Where \(b_1\) measures the per mile coastal trade cost and \(b_2\) measures the per mile land trade cost. Note that our per land trade cost is measured with error due to differences in road, river, canal, and later rail transport. We do not emphasize this coefficient.

Our coal price data come from 3 sources and cover 3 time periods. For 1692 to 1703 we John Houghton’s, Collection of Letters. It gives coal prices in shillings per chaldron for 53 markets. For 1842-43 we use the poor law union prices reported in the parliamentary papers. It gives coal prices in shillings per ton in 423 markets. For 1905 we use the reports on workingman’s wages and prices. It gives coal prices in shillings per ton for 72 markets. We converted the price into pence per ton for comparison. We also converted Newcastle Chaldrons (53 cwt.) into London imperial Chaldrons (28 cwt.) before converting to tons. We restricted the market observations to towns within 15 km of ports. This left a sample of 26 towns c.1700, 224 towns in 1843, and 37 towns in 1905. For each of these markets we then identified their nearest port, and the straight line distance. We call these ports the consumer ports. Next we then identify ports that were near the major coalfields. These were additionally classified as supply ports. We also checked that the supply
ports had the lowest coal prices among the ports nearby. Our final step was to calculate the distance between each consuming port and its closest supply port.

Here are some summary statistics. The average price of coal in our 26 markets between 1691 and 1703 is 231 pence per ton. The prices differ in war and peace years. The Nine years war lasted from 1691 to 1697 and Queen Anne’s war lasted from 1702 to 1713. The average price is 254 pence per ton across 25 towns from 1691 to 1697 and 1702 to 1703. The average price is 217 pence per ton for 17 towns from 1697 to 1702. The average distance to the nearest supply port for our towns 26 towns is 276 miles by our coastal network.

The year 1843 was a time of peace. The average price of coal in our 224 markets in 1843 is 230 pence per ton. The average distance to the nearest supply port is 236 miles by our coastal network. The year 1905 was also a year of peace. The average price of coal in our 37 markets in 1905 is 276 pence per ton. The average distance to the nearest supply port is 200 miles by our coastal network.

The results of our regression analysis are in the following table. The R-square is fairly high in all regressions. Column 1 examines coal prices differences from 1691-1703. The key coefficient is on coastal distance. We find that the price difference rises by 0.55 pence per ton with each mile. Columns 2 and 3 run two specifications for war and peace years. The coefficient is quite different. In war years the price difference rises by 0.65 pence per ton with each mile and in peace years it rises by 0.44 pence per ton. Column 4 turns to 1943. The coefficient implies the price differences rises by 0.51 pence per ton with each mile. Column 5 examines 1905. The price rises by 0.22 pence per ton with each mile.

<table>
<thead>
<tr>
<th>Regression estimates</th>
<th>Dep. Var.</th>
<th>price consuming port-price supply port</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>war &amp; peace</td>
<td>war</td>
<td>peace</td>
<td>peace</td>
<td>war &amp; peace</td>
<td>war</td>
<td>peace</td>
</tr>
<tr>
<td>Coeff.</td>
<td>0.55844</td>
<td>0.64641</td>
<td>0.441427</td>
<td>0.51086</td>
<td>0.218391</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Err.</td>
<td>0.069665</td>
<td>0.067901</td>
<td>0.068097</td>
<td>0.023086</td>
<td>0.032916</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal distance, consuming port to nearest supplying port in miles</td>
<td>3.744323</td>
<td>6.206913</td>
<td>5.937526</td>
<td>1.735202</td>
<td>-1.6846</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Extension to Coastal Barley prices

We can apply the same approach for coal prices to grain prices. Regional barley market prices were collected from Corn Returns Online with wheat, beans, oats and rye. We focus on barley for the moment because there is more variation in its prices compared to the other agricultural produce, and this may be because barley production was comparatively specialised. Although all counties were barley producers, some areas produced very little. The prices come from contemporary published daily market quotations, originally used for commercial purposes. We selected all data for three years (for prices of barley): 1825, 1845, and 1865. All English and Welsh counties with coastal access were included. We follow a similar approach where we identify Y ports with local price minimums and regard these ports as supplying ports for barley. Others are treated as consuming ports for barley.

The summary statistics for barley prices are show in the table below. In the full sample of coastal towns the average price of barley declines over time. The variation also declines particularly from 1825 to 1845. We also analyze towns with above median barley prices in 1825 because their higher prices make it more likely that they are a consuming port. In the sub-sample, the same patterns of price declines and lower variation are also evident.

Table: Summary statistics for barley prices in coastal towns.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1825</td>
<td>4.4854</td>
<td>0.4309</td>
<td>3.8612</td>
<td>6.1735</td>
<td>129</td>
</tr>
<tr>
<td>1845</td>
<td>4.0394</td>
<td>0.2442</td>
<td>3.1814</td>
<td>4.5719</td>
<td>179</td>
</tr>
<tr>
<td>1865</td>
<td>3.6903</td>
<td>0.3282</td>
<td>2.9043</td>
<td>4.3921</td>
<td>161</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1825</td>
<td>4.7842</td>
<td>0.4184</td>
<td>4.3938</td>
<td>6.1735</td>
<td>64</td>
</tr>
<tr>
<td>1845</td>
<td>4.1108</td>
<td>0.2436</td>
<td>3.1814</td>
<td>4.5719</td>
<td>53</td>
</tr>
</tbody>
</table>

The table below shows the summary statistics for the distance to the nearest barley supplying coastal town. In the full sample, the average distance is fairly stable, and rises by 1865. This pattern suggests that a smaller number of coastal towns supplied barley in 1865. The increase in distance is most evident for the sub-sample of towns with above median barley prices in 1825.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1825</td>
<td>122.92</td>
<td>50.94</td>
<td>0</td>
<td>205.65</td>
<td>129</td>
</tr>
<tr>
<td>1845</td>
<td>111.7</td>
<td>73.26</td>
<td>0</td>
<td>287.5</td>
<td>179</td>
</tr>
<tr>
<td>1865</td>
<td>145.23</td>
<td>105.02</td>
<td>0</td>
<td>386.86</td>
<td>161</td>
</tr>
</tbody>
</table>

The results of our regression analysis are in the following table. Column 1 examines barley prices differences in 1825 for the full sample. The key coefficient is on coastal distance. We find that the price difference rises by 0.0030 shillings per cwt. with each mile. Columns 2 and 3 run two specifications for 1845 and 1865. The coefficients are quite different. In 1845 the price difference rises by 0.00187 shillings per cwt. with each mile and in 1865 it rises by 0.00156 shillings per cwt. Notably the coefficient for 1865 is half as large as for 1825. Columns (4)-(6) repeat for the sub-sample of coastal towns with above median 1825 barley prices. The coefficients are similar in showing a decline over time, but the rate at which they decline is less. The coefficient in 1865 is two-thirds the coefficient in 1825.

It is useful to convert the coefficient estimates in pence per ton to make them comparable with our estimates for coal. We use the conversion 20 hundredweight in one ton. Our estimates for the full sample imply a barley coastal trade cost of 0.73 pence per ton per mile in 1825, 0.45 in 1845, and 0.37 in 1865. Our estimates for the sub-sample imply a barley coastal trade cost of 0.66 pence per ton in 1825, 0.60 in 1845, and 0.44 in 1865. Our estimate of coal coastal trade costs in 1843 was 0.51 pence per ton mile, and thus it lies in the middle of these estimates, but a bit closer to the barley sub-sample. The trends of downward coastal trade costs in the nineteenth century is also found in both the coal and barley estimates, although the time frame is different. The annual rate of change in coastal trade costs for barley is between 1 and 1.6% between 1825 and 1865. The annual rate of change in coastal trade costs for coal is 1.15% between 1843 and 1905. We regard the barley estimates as broadly supporting our analysis for coal.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1825</td>
<td>121.96</td>
<td>52.28</td>
<td>9.92</td>
<td>205.65</td>
<td>64</td>
</tr>
<tr>
<td>1845</td>
<td>118.4</td>
<td>74.59</td>
<td>0</td>
<td>287.5</td>
<td>53</td>
</tr>
<tr>
<td>1865</td>
<td>192.49</td>
<td>113.29</td>
<td>36.01</td>
<td>386.86</td>
<td>48</td>
</tr>
</tbody>
</table>
We use our coefficient estimate as our estimate of coastal transport costs per ton mile in pence at various dates. One issue besides war is inflation. The costal freight costs per mile are in nominal terms, and thus they will tend to rise because of general price increases. To place them into real or relative terms we conduct two exercises. First we deflate by the cost of living index. Second, we deflate by shipping input costs using wages, capital prices, and fuel costs.

The first real trade cost calculation is summarized in the table below. It uses the cost of living index from Clark (2005). If we use 1700 as the base year, then the real per ton per mile cost in 1843 falls to 0.34 pence and the real per ton per mile cost in 1905 falls to 0.167 pence. The annual percentage decline is shown in the bottom panel. The decline in real terms is -0.349% from 1700 to 1843, -1.15% from 1843 to 1905, and -0.586% from 1700 to 1905. These figures imply large reductions in real coastal trade costs.
The comparison are different if we separate war and peace years c. 1700. The average trade cost per ton per mile in war years c. 1700 is 0.6464 pence and in peace years c. 1700 it is 0.4414 pence. The following table shows the percentage decline in nominal and real terms using these two figures. If we use war years in 1700 as the comparison then the real decline in coastal trade costs is much larger. The annual percentage decline from 1700 to 1843 in real terms is -0.453%. If we use peace years as the comparison then the real decline from 1700 to 1843 is -0.180%. Thus the peace dividend accounts for most of the decline in real coastal trade costs in the age of sail.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost in 1700 Prices</th>
<th>Percentage annual change 1700-1843</th>
<th>Nominal</th>
<th>Real</th>
<th>1843-1905</th>
<th>Nominal</th>
<th>Real</th>
<th>1700-1905</th>
<th>Nominal</th>
<th>Real</th>
</tr>
</thead>
<tbody>
<tr>
<td>1700</td>
<td>0.5584</td>
<td>66.7</td>
<td>1</td>
<td>0.5584</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1843</td>
<td>0.5108</td>
<td>99.6</td>
<td>1.49</td>
<td>0.3420</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1905</td>
<td>0.2184</td>
<td>87.2</td>
<td>1.31</td>
<td>0.1670</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Our second trade cost calculation uses shipping input costs. Here we also interpret our calculations as productivity. Using the price dual method, productivity is estimated by the difference between input price growth and output price growth. The starting point for the dual method is the assumption of perfect competition, constant returns to scale, and zero profits. Specifically, let the output in a sector be denoted by $Y_t$ and $P_t$ is the price. The inputs are labour and capital, $L_t$ and $K_t$, and the rental rate of capital and wage rate of labour are $r_t$ and $w_t$. Using the zero profit condition, revenues equal costs, or $P_tY_t = r_tK_t + w_tL_t$. Differentiating with respect to time and dividing the right side and left side by $P_tY_t$ one gets $\Delta pt + \Delta yt = a*(\Delta rt + \Delta kt) + (1-a)*(\Delta wt + \Delta lt)$, where $\Delta x$ denotes variable $X$’s annual growth rate, $a=rt*Kt/Yt$.
and \((1-a) = wt/Lt/Pt*Yt\). Notice that \(a\) is the share of revenues paid to the owners of capital and \((1-a)\) is the share of revenues paid to labour, or alternatively the shares of each input's payment in total costs. Rearranging this expression gives the 'primal' and 'dual' expression for productivity growth \(\Delta At\).

\[
\Delta At = \Delta yt - a*\Delta kt - (1-a)*\Delta lt = a*\Delta rt + (1-a)*\Delta wt - \Delta pt. \tag{1}
\]

The first step is to identify the weights for our 3 inputs in freight services, labour, capital, and fuel. The weights are based on average of the cost shares provided by Solar (2013) for shipping in the age of sail. The cost share weights in our analysis are 0.6 for capital, 0.3 for labour, and 0.1 for fuel. The weights are different for the age of steam, and so for the moment we focus on the 1840 period and earlier.

The prices of inputs are taken from secondary sources. As our wage rate for labour, we use Clark's (2010) series on the daily wages of craftsman. The day wage is 17.7 pence around 1680 and 42.1 pence around 1830. For fuel we use the price of oats, a main source of food. Oats are 1.45 shillings a bushel around 1680 and 2.8 shillings a bushel around 1830 (Clark, farm prices). For the rental rate of capital, we use the formula \((r+d)*(pk)\), where \(r\) is the interest rate, \(d\) is the depreciation rate, and \(pk\) is the price of capital goods. The interest rate is around 4.75% in 1680 and 3.5% in 1830 (Clark, 2010). The depreciation rate is equal to 3% in both years. The price of capital goods are based on East India Company ships which were around 18.5 pounds a ton in 1680 and 30 pounds a ton in 1830 (Clapham, Solar 2013). Thus, the rental rate of capital is \((4.75+3)*18.5=143.3\) in 1680 and \((3.5+3)*30=195\) in 1830.

The rate of growth of the three input prices is given in rows 1-3 of table x. The weighted average growth rate is 0.341 (see row 4), implying input prices increased by 0.341% on average every year.

The price of coastal freight services is taken from our averaging of peace and war years c.1700 and in 1843. The average annual percentage decrease in trade costs is -0.063% as shown earlier. The TFP growth estimate is reported in row (6) and calculated by subtracting (5) from (4). Our baseline estimate gives an average annual rate of TFP growth in freight equal to 0.404%. The TFP growth rates are different depending on whether we take war or peace years c.1700 as the baseline. Using war as the baseline, the TFP growth rate is 0.508% per year. Using peace as the baseline, the TFP growth rate is 0.237% per year. Thus the peace dividend accounts for about half of the productivity change in coastal shipping from 1700 to 1843.

<table>
<thead>
<tr>
<th>Table (x): TFP calculations coastal shipping</th>
<th>annual rate of change 1700 to 1840 in %</th>
<th>weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>row</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>rental rate of capital</td>
<td>0.206</td>
</tr>
<tr>
<td>2</td>
<td>wages</td>
<td>0.579</td>
</tr>
<tr>
<td>3</td>
<td>fuel prices</td>
<td>0.44</td>
</tr>
<tr>
<td>4</td>
<td>input prices combined</td>
<td>0.341</td>
</tr>
<tr>
<td>5</td>
<td>Coastal trade costs</td>
<td>-0.063</td>
</tr>
<tr>
<td>6</td>
<td>TFP (baseline)</td>
<td>0.404</td>
</tr>
</tbody>
</table>
19

<table>
<thead>
<tr>
<th></th>
<th>Coastal trade costs, comparing war c.1700 with peace c.1840</th>
<th>-0.167</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>TFP comparing war c.1700 with peace c.1840</td>
<td>0.508</td>
</tr>
<tr>
<td>9</td>
<td>Coastal trade costs, comparing peace c.1700 with peace c.1840</td>
<td>0.104</td>
</tr>
<tr>
<td>10</td>
<td>TFP comparing peace c. 1700 with peace c.1840</td>
<td>0.237</td>
</tr>
</tbody>
</table>

Notes: see text for calculations.

War costs
Our analysis results indicate that improving wartime organisation may have been a significant factor in the transport of resources around the British Isles. This analysis supports a history of declining risk to merchant shipping in home waters over the eighteenth century. Ralph Davis gives us contemporary estimates that in the first three Anglo-Dutch wars (1652-54, 1664-67, and 1672-74) English losses at sea amounted to approx. 500 ships spread between three wars. By comparison, English privateers captured thousands of unarmed Dutch cargo ships (‘fluyts’), incorporating these directly into the English merchant fleet.¹⁴ The fluyts easily compensated for losses. By contrast, during the Nine Years War (1689-1697) as many as 4,000 English ships (estimate) were lost to French privateers in home waters, most after 1692 when French naval strategy focussed on trade disruption and privateering.¹⁵ Heavy losses and public outcry was followed by policy changes that featured a revenue allocation in 1694 for continuous naval convoying in home waters. Shortly after, a Convoying Act in 1708 marked a permanent decline of British losses in the European theatre through the eighteenth century.¹⁶ Merchant shipping losses continued in the low thousands in a war with France and Spain 1739-48, and the American War of Independence (1778-83), but these mainly occurred in distant colonial seas, meaning the coastal network was effected less. Spanish nor American naval capability did not reach the coasts of England and Wales at this time. Mitigation of war risk meant fuller protection for the vital coastal trades, and these factors seem to explain considerable improvement in coastal shipping productivity between 1700 and 1843.

Captured ships and losses at sea accompanied knock-on war costs: delays resulting from fears of the presence of enemy war ships meant coasters required convoys. This would have made coordination of coastal transportation difficult and costlier, although convoys were clearly better than naval attack. Fears of naval impressment of crews also made it difficult and expensive to hire and retain sailors. During war, some sailors resided inland for long periods to escape armed press gangs around the ports. Much of these transport costs would have been paid for by higher wartime prices of goods transported by sea and higher freight charges and shipping costs generally. This severity of disruption should have reduced as home waters

¹⁴ Davis, 1972, pp. 303-4.
¹⁵ Ibid.
became safer over the eighteenth century. Coastal shipping was always vulnerable to acts of war, and the shock of war forms a crucial factor when measuring coastal transportation costs over time.

Taxes
War disruption was important, but was not the only contributing factor to changes in transport costs. The coastal coal trade attracted very heavy taxation after the mid-seventeenth century. After the Great Fire of London in 1666, emergency taxes fell on all British coal transported to the capital by ship to aid the city’s rebuilding. This was the church tax, named because it funded the public rebuilding of churches, including St Pauls. Like many customs, this was an emergency levy that became permeant even as emergency receded.

However, the heaviest tax was the king’s duty, followed by the Richmond shilling. Between 1691 and 1831, the King’s Duty applied to all coal transported coastwise nationally, and by 1830 amounted 6s per ton of coal. The Duke of Richmond’s shilling amounted to 1s per ton of coal brought to London. Charles II created the Richmond Shilling for an illegitimate son – the first Duke of Richmond – and the government eventually purchased this private tax at enormous cost from his descendants in 1799.

On March 1 1831, parliament abolished the King’s Duty and the Richmond Shilling. From one day to the next, a large proportion of the cost of coal transportation disappeared.17 The aim was to improve the internal supply of coal and reduce fuel costs to industry and to the public. It seems this policy was influenced by British political preference for free trade in the nineteenth century. Coal merchants had paid the taxes directly, so in a perfect market coal transport costs should have declined swiftly. However, a parliamentary report noted that savings from the abolition of the duty was not immediately passed onto the consumer because of the ‘combination’ of coal merchants.18 It is unclear when savings achieved by tax cuts affected general price of coal in Britain.

We should also consider the abandonment of the Tudor-era customs system in 1799, which almost certainly reduced costs of administration for coastal trades across the country; for example, the time it took to declare and have cargoes checked as part of the port books system as reduced. An army of customs officers levied their fees at the quayside whilst undertaking the work of accounting and checking coastal cargoes. Presumably, these fees and delays vanished with the port books by 1799, saving time and money for coastal shipping operators.

It is unclear exactly when the tax and administrative relief added to the general reduction in real ton per mile transport cost of coal. By 1843, one would expect lower coastal transportation costs in the coal trade as a result, and this reduction, together with peace dividend may explain Dan Bogart’s regression analysis showing a marked decline in costs by 1843 – a time of peace and free trade. After labour costs, taxation was the heaviest cost for coal merchants, so abolition should have had a significant impact on prices. Earlier in this paper, the voyage accounts of two colliers were summarised, and from these accounts, we can see the king’s duty coupled with the Richmond shilling amounted to 52% of costs for the voyage in 1729, and with local tolls, this proportion rises to an astonishing 64%. The King’s duty with tolls appears to have amounted to 50% of the 1811 voyage costs in the West of England. In 1830, the year before abolition, the figure is 34% the king’s duty and the Richmond shilling.

18 Parliamentary Papers Online, ‘Select committee on the state of the coal trade; together with minutes of evidence’, 2 August 1836. Question 377.
Travel times

Sources of coastal voyage data

The coastal port books. The National Archives.

One of the most challenging aspects of this project has been to gather data for early modern coasting voyages and process these in a way that makes sense given the opaque early modern customs recording practices, poor source survival rate, and naturally chaotic nature of a transport system powered mainly by wind and tides.

Where possible, coast port books housed in The National Archives provided information about port-to-port sailing speeds (by date) and routes in the seventeenth century. Port books provide a wealth of additional information about cargoes and local merchants involved in myriad coastal trades. In this pilot project, only dating and vessel names were transcribed. Description of cargoes remain unaddressed. It may be possible to return to transcribe the remaining information. A critical task was to determine the relationship between the dating of customs documentation in the coastal port books and the real movement of ships between ports in the seventeenth century. The port books recorded certificates and bonds, but rarely the actual arrival and departure of ships. This was challenging, and the problem was not satisfactorily resolved until the creation of a sufficiently large dataset that allowed linkage of careers of individual vessels between accounts with their movements disentangled from the confusing certificate dating.

Oliver Dunn has transcribed and digitised coastal port books from ports including Scarborough, Colchester, Maldon, Spalding, Sandwich, Milford, and lesser-documented ports such as Ilfracombe. This has created a database comprising of 2500 observations for individual coastal voyages, mainly derived from large books covering coastal traffic between Newcastle, Colchester, and Maldon (coal), and between the latter ports and London (food/metal-ware). This sample was not selected intentionally, but rather restricted by the poor survival rate of coast port books and the unfortunate timing whereby the main port book archive (TNA E190) was removed for conservation in 2015. We were restricted to a subsection of E190 devoted to coasting trade: E122. With access to E190, the source-base for study of seventeenth century coasting trade could be expanded.

The coast port books normally recorded the port of origin and destination for coasters, but not intervening stages. According to a contemporary customs manual, intervening stops were marked on the verso of certificates, but few of these documents have survived. It is currently unclear whether coasting ships typically made multiple stops on routes.

Coast port book dates solely give the creation of customs bond certification with corresponding outwards 'cocket'. The problem is these did not often reflect departure and arrival of coasters. When we initially processed the coastal port books data, a great degree of variation emerged in the voyage timings based on customs certification dates, even on similar or identical routes. There were normal voyage delays, such as weather, war, accidents, yet the variation seemed to be more severe even considering such explanations. It became apparent certificates were often dated long after a vessel had departed on an onward voyage – weeks or even months after – meaning that certificates clearly did not always mark actual movements of shipping, more the slow operation of customs and other delays. Coasters regularly left before obtaining legal certificates, presumably with the aim of collecting these on a return voyage. By ordering thousands of voyage data by date and vessel name in Excel, individual trade routes emerged, despite this initial drawback. For example, it has been possible to exclude the problematic arrival certificates by analysing the production of repeat outward certificates ('cocket'). This effectively date two consecutive voyages originating from an identical port, capturing the departure, arrival at port 2, return journey and onset of second identical route. We call this a trade cycle, which is the most reliable information given the reliability of outwards certification compared to chaotic inwards certificates, but also because the dating of cycles incorporates port loading times, which are a variable of great interest to the project.

19 TNA E122 Exchequer: King’s Remembrancer: Particulars of Customs Accounts, c1272-c1830.
Based on port books and crew lists Bogart and Dunn have generated direct sailing times (where possible) and trade cycles for 1690 time-slice using port books from 1650-70.

*St Paul’s records, 1689-95 Guildhall Archive.*

We were fortunate to be provided with a second source of voyage data for the seventeenth century. Records of the Church Tax collected in London were transcribed and digitised by Mr. Callum Easton for an MPhil thesis, submitted to the University of Cambridge, and who kindly provided this data to the project. Easton’s data was taken from records of tolls collected from Newcastle coal imports to London, between 1689-1695. This period covers the Nine Years War and French naval actions against coastal shipping, and so gives insight into wartime coastal operations during a period of stress. The entries provide names of ships and masters, whilst giving the date of their entry into London and payment. Individual ships can be traced as returning to London with coal repeatedly. This allows for analysis of the trade cycles of individual colliers operating between London and Newcastle, providing the consecutive arrival dates of identical colliers. In practice, this dataset allows around 1500 observations of such cycles drawn from approximately 2500 voyages along this route. It took a little effort to arrange and analyse the entry dates to determine the cycles on this route.

Similar to the port books, the trade cycle represents here the time elapsed in days between two consecutive arrivals, which encompasses x1 unloading at London x1 loading at Newcastle, and, plus x1 return voyage between the two (and events along the way). The cycles in E122 are records of two consecutive departures from the same port. The cycles include non-operational times on this route, which could be over a year. In consideration of this, we have only included cycles of more than one week and less than one year. Having possession of individual ships accounts for this route, we know it is unlikely that the cycle could have been completed in under a week on this route. When ships did not return to London in less than one year, we assume them to be out of service, captured, or engaged in other trades, and thus were omitted for the purposes of measuring realistic trade cycles. This 7-365-day rule has been applied to the data drawn from all sources, for consistency.

*Board of Trade Crew Lists 1830-45. The National Archives.*

Oliver Dunn identified sources in The National Archives within the Board of Trade records, which were later transcribed under the supervision of Dan Bogart. Between c.1830 and c.1845, masters of coastal vessels were required to complete forms that recorded details of recent voyages and crews employed. Cargoes and vessel tonnages sometimes accompany dates of exit and entry at individual ports. Between 1830 and 1845, the forms included a field requesting information about recent voyages. The resulting detail allows detailed reconstruction of ship movements around the coast, and allows for a large dataset for journey times and routes between ports. The crew lists derive from 75 customs and member ports across England and Wales. The certificates are arranged alphabetically, by ship name, and follow the career of individual ships for up to a year. Only departures dates are recorded, and we have arranged these into consecutive voyages from between the same ports. We take these to cover the same basic operations as the cycles listed above in earlier (return voyage + x1 unloading + x1 loading = 1 trade cycle).

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Comparison of trade cycles c1650/c1689/c1830

<table>
<thead>
<tr>
<th>Source/Date</th>
<th># of observations</th>
<th>Average cycle length in days</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coast Port Books 1649-57</td>
<td>127</td>
<td>68.9</td>
<td>Newcastle/Sunderland to Colchester/Maldon = 630 miles.</td>
</tr>
<tr>
<td>St Paul’s Books 1689-95</td>
<td>1,494</td>
<td>94.5</td>
<td>Newcastle/Sunderland to London = 750 miles.</td>
</tr>
<tr>
<td>Board of Trade Crew Lists 1830-45</td>
<td>56</td>
<td>39</td>
<td></td>
</tr>
</tbody>
</table>

The three sources were used to measure the time of the average cycle durations of coasting vessels trading on either the Newcastle to London, or Newcastle to Colchester or Maldon, in 1649-57, 1689-95, and 1830-45. The Coast Trade St Paul’s Books cover periods of war, and the Crew Lists a peaceful situation. The reduction in cycle averages between 1695 and 1830, given above, seemed to result from a range of factors that go beyond any increase in sailing speeds or port infrastructure improvements. War disruption (evidenced by the c. 4000 English ships lost in the Nine Years War in home waters) seems likely to have been a factor in the high average cycle time 1689-95. We know that danger to ships, life and liberty during this time were great, and coastal shipping would sail only when risk was judged to be acceptable. Coasters waited in ports while convoys were arranged, or wartime crews could be found. Perhaps for this reason, we see a very great variation in the cycle times in the St Paul’s Book data, which brings the average to 94.5 days (the shortest cycle is 7 and the longest 365 days.)

The closest comparable voyage data available in the Coast Trade Books in c. 1650 is for Newcastle to Colchester and Maldon. Average cycle length is significantly less than 1689-95, even considering the shorter distance (120 miles shorter return). This was also a time of war. During the First Dutch War, however, there was only a small fraction of losses witnessed in 1689-1695.

For 1830-45, we have a picture of trade unaffected by war risk, and a comparatively regular 39-day average arises for this period. We believe that wartime disruption could explain the great variation in trading patterns between sources and these specific periods.

**In-port times**

Trade cycles discussed above indicate times spent in port between voyages. They do not give a breakdown of sailing or port times. However, it is possible to measure the time spent in port in 161 cases in the coast port books data (161/2,500). The method involves organising voyages by vessel name and date, and finding instances when outward followed arrival certificates from the same port and same vessel. There is some margin of error, not least because ships could sail without collecting their arrival certification, returning for the same later on. Such ‘invisible’ voyages took place, whereas it appears in the record that ships were static. It has been possible to identify and exclude most of these cases. Crew Lists are more precise as records of voyages, and did not depend so much on arduous customs processes. The times that ships spent in port are easily discernible in the intermissions between consecutive voyages as written on these forms.

The following histograms presents the spread of in-port times derived from the coast port books c. 1650 and the crew lists c. 1830. The first is mix of home and away stops, and the second only destination stops. A wide range of ports is involved in both analyses, including London, Colchester, and Newcastle. The most salient result of this evidence is that regularity of in-port times appears to improve greatly by c1830. The average in-port time for 1650 time-slice is 39.23 days (after including a corrective value of 2.5 days to account for the certificate process not measured here); the 1830 average is 10.4 days. This change is mainly attributable to the numerous and lengthy periods of delay in c.1650 compared with 1830 when there are no
significant delays recorded. The 1650 data shows that 69 out of the 161 recorded stops were completed within one day, but the issue was that ships seemed to cease operations for long periods, thus greatly increasing the average. Disruption related to the First Dutch War seems to be a feasible explanation for cessations and the great discrepancies in regularity between 1650 and 1830 records, although there may be other explanations. In some cases, ships might have been employed in other trades for those periods, for example in foreign trade.
Seasonality

Both the crew lists and coast trade books date voyages accurately enough to generate the frequency of voyages throughout the year. The coasting trade continued all year round in both the seventeenth and nineteenth centuries. Although there were less than half the number of voyages in December compared to July in the seventeenth century. In nineteenth century, surprisingly, this ratio is slightly larger, indicating more downtime in winter, not less. The sail coasting trade was somewhat seasonal, but trade did not cease in winter months, even when dangerous storms were more frequent. Moreover, the trade did not become less seasonal over time. One assumption has been that technological and other improvements to coasting shipping might have led to general improvement in this situation, but the evidence presented here indicates continuity rather than change.
Sailing Speeds between the seventeenth and nineteenth centuries

Measuring the sailing speeds of coasting ships is difficult because it demands precision that the sources do not often provide. Moreover, actual sailing speed was probably less important than arriving safely at a destination. For the purposes of creating a functioning model of coastal transportation in GIS some comprehension of speeds coasting vessels travelled, and how these changed is important. It is an open question whether sail ships employed in coasting trades became faster over time. However, we find no evidence that sailing ships got significantly faster in the coasting trade. Real cabotage sailing speeds can be assessed by transcribing original and rare surviving ships’ logs. One such is the Log the Sancho, a brig that traded coal between Newcastle and London in the 1840s. The crew left record of voyages that includes detail of port times, winds and weather and other voyage events, all marked by the hour of the clock. This has allowed for a detailed reconstruction of this brig’s voyages:

One can observe a leisurely pace of business in the voyages undertaken in January 1848 (above), with a long 27-days period in London moored alongside another ship when coal was sold on city market days. Its crew maintained the Sancho during this time, moving it short distances along the river when necessary. By isolating hours spent at sea when the Sancho sailed (both night and day) when winds were adequate, we measure an average speed of just under 3mph. This speed could be increased fractionally by removing periods without winds. The Log of the Sancho indicates that for this brig, 4-5 days was a typical journey time between Newcastle and London. Interestingly, the first steam collier to traverse this route took about half this time (5 days return) in 1852. However, it took the Sancho around a month to complete this trade cycle (return plus port time at each end) due to long periods in port. This unscheduled-delay-free cycle supports the trade cycle average taken from the crew lists of 39 days, which obviously includes longer stays being a much wider sample.

For the seventeenth century, it is possible to use the fastest voyages recorded between given ports in the coast port books, and for the nineteenth century, the crew lists, to obtain a larger sample of coasting shipping speeds along a similar route to the Sancho along the English coast of the North Sea. In the case of port books, unfortunately, we also capture the time taken between the entrance of ships and entry of their detail into customs books. In the fastest cases, we presume this to take less than one day, however (the average for this process when involving port books is 2.5 days, per available data). For one-way voyages between Newcastle and Colchester/Maldon (315 miles) the minimum time is 6 days, the average 18.25, and the maximum 30 days. 6 days is one day more than the Sancho’s voyage between Newcastle and London – about 60 miles further. In the crew lists, we have generated observations for only 16 journeys between Newcastle and Aldeburgh in Suffolk, about 40 miles north of Colchester. The fastest journey is 12 days, the average 25.8 and the longest 77 days. This evidence is inconclusive, but does not suggest increasing sailing speeds.

However, the three Sancho voyages were very regular and rapid compared to those plying the same route in the seventeenth century, judging by the messy data of the coast port books and the limited information drawn from the crew lists, which indicate even slower proceedings. It may transpire with further research that sailing ships engaged in coasting trades became slightly faster as they changed in size and design. We have not yet found evidence that sailing ships became significantly faster in the water between 1650 and 1845. The coasting trades operated in a fundamentally different context by the nineteenth century, and safe seas combined with zero state taxation and a hollowed-out internal customs administration were likely the primary causes of change, evidenced by the faster turn-around times in the crew lists compared with the port books. It is also true that lighthouses proliferated from around 1800, which must have made sailing

21 Quoted in Hausman 1987, p. 595.
easier and faster, but it is also unclear whether port infrastructure changed fundamentally in the coasting trade before 1845.22

Conclusion
This research paper presents some early findings drawn from recent research by authors and as such is subject to change. It does indicate the effectiveness of our coastal network GIS when applied with historical sources to research key aspects of Britain's historical coasting network. This is more important considering the economic impact of cheap bulk coastal transportation to industrial development and demographic change in Britain, and the relative lack of surviving information about Britain’s large historical coastal trades.

Our analysis of total transport costs of coast transport based on coal price distribution between 1700 and 1843 indicates significant total productivity gains. The TFP growth rates are different depending on whether we take war or peace years c.1700 as the baseline. Using war as the baseline, the TFP growth rate is 0.508% per year. Using peace as the baseline, the TFP growth rate is 0.237% per year. Thus, the peace dividend accounts for about half of the productivity change in coastal shipping from 1700 to 1843. Alongside losses at sea, delays and input costs were clearly higher during war periods. Moreover, disruption of trade during war is evidenced in voyage data in which it appears that ships were delayed more often, as is evidenced by our in-port waiting times and trade cycle analyses above. There were lesser advances indicated in our data for periods of peace. Although state taxation on coal transported fell dramatically in 1831, and this may have filtered through to become a significant peace saving by 1843. Moreover, the cumbersome Tudor-era customs administration featuring fees, port books and physical searches was scrapped by 1799, and the removal of this national customs system should have reduced costs to internal coastal transportation.

Our analysis of trade cycles indicates a similar rate of change to that shown by coal price integration between c1700 and c1843. In fact, the ratio between reducing transport costs and declining trade cycle times is similar for both war and peace years (exact ratios of change pertaining to time and costs to follow). Symbiotic decline in monetary and time costs in coastal transportation may reflect the direct link between times at sea and the overall cost of moving coal in ships. The faster coal could be loaded on ships transported, unloaded and sold at market, the cheaper it could be sold. These ratios seem to be self-supporting as evidence of single phenomenon of increasing regularity and speed of turnaround plus reducing monetary costs of moving coal under sail in Britain during this period.

Seasonality remained a constant factor between 1650 and 1845, meaning technology nor had working practices changed to confront winter climatic conditions. The evidence presented by the seventeenth century coast port books indicates a great variation in port waiting times, with some ships waiting over a year before setting off. Ships could face serious damage when left docked for long periods, and income could not be generated at all, meaning such delays were very costly in all respects. The crew lists from 1830-45 indicate that coasting vessels were far more regularly employed by this time. More regularised sailing patterns of the nineteenth century indicate shipping was more productive by 1830, even if technology and infrastructure had been mechanised or greatly expanded or improved.

In contrast to Simon Ville and John Armstrong, we question whether technological advancement in sail ships and infrastructure were the primary agents of change before the advent of steam ships. Whereas, like those authors, and unlike Hausman, we posit there were significant gains at this, the closing of the age of sail. We are left with organisational more than technological explanations, which aligns us more with Douglas North's study of trans-Atlantic freight costs. Our evidence indicates better protection of coastal shipping in times of war in the eighteenth century, and the shifting areas of conflict, buoyed by abolition of most customs bureaucracy by 1799 and state taxation in 1831.

22 Gordon Jackson, The history and archaeology of ports, (Tadworth, 1983)