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Going Beyond Social Savings

How would the British economy have developed in the absence of the railways? A case study of Brunner Mond 1882-1914.

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ABSTRACT

This paper confirms the conclusion of the social savings methodology that industrial development was not dependent on the railways. However, it finds that there would have been a significant change in the distribution of industry without rail, a point underestimated by the social savings methodology because of its flawed assumption that in the absence of the railways the cost of water transport would have remained constant.[1].

The paper uses a case study of the large industrial chemical firm Brunner Mond to demonstrate that bulk transport requirements could not be absorbed by the narrow capacity waterways that constituted 40% of the UK waterway network without significant price increases. As a result, industrial development would have been dependent on access to high capacity water transport. Some waterways could have provided such capacity inland but water supply would have limited the extension of the high capacity inland waterway network. Thus, in a non-rail economy sustained industrial development would have predominantly occurred in coastal locations.

[1] Fogel, Railroads and American Economic Growth, p.27.

Introduction

Our intuitive reaction is that the railways to a certain extent caused economic growth, a perception reinforced (and complicated) by the fact that their emergence was correlated with the unprecedented economic growth of the industrial revolution.[2] Indeed, the thesis that the railways caused economic growth seemed so intuitively obvious that for a long time it was not challenged. This thesis was encapsulated in Jenks's famous article 'Railroads as an Economic Force in American Development'. It was reinforced further by Rostow in his seminal work 'The Stages of Economic Growth' which argued that the railways were, "historically the most powerful single initiator of [industrial] take-offs".[3] However, the study of the relationship between railways and economic growth was transformed forever by Fogel in 1962 who attempted to find a causal and empirically substantiated link between the two. In his seminal work, 'Railroads and American Economic Growth' Fogel outlined a new theoretical framework for testing the contribution of the railways to economic growth called the 'social saving'. This methodology has become the default choice for economic historians who seek to calculate the impact of the railways upon economic growth.

The social savings methodology calculates, "the alternative cost of shipping exactly the same bundle of goods from the primary to the secondary markets in exactly the same pattern without the railroad" and compares this to the actual cost, with the difference between the two figures considered to be the social saving of the railways.[4] If a very large social saving is calculated then the hypothesis that the railways caused economic growth could be considered to be valid because of the extent to which they reduced transport costs.

Ville notes this methodology suffers from two key flaws which he collectively terms the 'terminal weighting problem'.[5] The first flaw is that the social savings methodology assumes the pattern of transportation in the economy would have remained the same in the absence of the railways whereas in reality the economy would have evolved to make the most efficient use of the alternative transport network.[6] However, Fogel openly admits this flaw because it also ultimately strengthens his argument. By assuming the pattern of transport would have remained the same in a non-rail economy Fogel is inflating the social savings of the railways making his conclusion their social saving was minimal even more significant.

[2] Gourvish, Railways and the British Economy 1830-1914, p.33.
[3] Rostow, The Stages of Economic Growth, p.4.
[4] Fogel, A Quantitative Approach to the Study of Railroads in American Economic History: A Report of Some Preliminary Findings, p.170.
[5] Ville, Transport ,in: The Cambridge Economic History of modern Britain: industrialisation, 1700-1860, p.329.
[6] Hawke, Railways and Economic Growth in England and Wales 1840-1870, p.10.

The second flaw in the social savings methodology is the assumption that the cost of water transport would have remained constant in the absence of the railways.[7] Fogel applies the social savings method to the United States in 1890 and states, "the water rates to be used in the second [alternative] model… must be those that actually prevailed in 1890" which is "equivalent to assuming the marginal cost of water transport was constant".[8] Fogel's conclusions, and those of all other applicants of his methodology, rest upon the validity of this assumption. As he writes,

"If the waterways could have supplied all or most of the service that the railroads were providing *without increasing unit charges*, then the presence of railroads did not substantially widen the market and their absence would not have kept it substantially narrower".[9]

In other words, if the waterways could provide the ton-miles of the railways without increasing prices then the railways could not be considered the cause of economic growth. The key part of the above assumption is 'without increasing unit charges'. Given the pivotal role of this assumption it is odd that Fogel spends only a page considering it. Fogel again claims that this assumption strengthens his position because in reality the marginal costs of operating additional boats on a waterway would have probably declined given that most costs (eg, dredging) were almost fixed relative to tonnage.[10] Fogel also notes economies of scale in boat production could have further driven the costs of water transport down in the absence of the railways.[11] It is true that the costs of maintaining a canal are almost fixed relative to its tonnage but this is not the main determinant of price. As every economic historian should know, price is determined by supply and demand. If supply is constant and demand increases - prices will rise. Fogel claims that given the existing waterways of the United States had excess capacity and assuming the construction of further waterways prices on the waterways could have remained constant in the United States in 1890. This paper seeks to not assess this claim but to raise questions as to whether this is a valid conclusion with respect to the United Kingdom.

Hawke applied the social savings methodology to England and Wales 1840-1870. Hawke uses figures from the Leeds Liverpool and the Kennet and Avon canals in an attempt to show that costs per ton mile did not rise with tons carried.[12] Whilst the waterways no doubt had some spare capacity to claim that demand could increase, supply remain fixed and prices not increase is in basic contradiction to the principles of demand and supply. As O'Brien notes, "the

[7] Fogel, Railroads and American Economic Growth, p.28.
[8] Ibid, pp.27-28.
[9] Ibid, p.13.
[10] Fogel, Railroads and American Economic Growth, p.28.
[11] Ibid.
[12] O'Brien, The New Economic History of The Railways, p.47.

diversion of output from the railways in 1865 would have increased the demand for canal capacity at a rate far beyond that implied by the increased demand that [the Leeds Liverpool and Kennet and Avon canals] coped with over a far longer period of time".[13] Indeed, the assumption that because two canals absorbed modest demand growth without significant price increases the UK waterways network could have carried all the freight the railways carried at similar prices is clearly questionable.

This paper believes the quantification of the social savings of the railway led by Fogel has "emphatically not offered a definite solution to the impact of the railways upon economic growth" because of its assumption of constant and low waterway prices in the absence of the railways.[14] Furthermore, despite extensive debate which concluded that the social savings method provided "at best" a partial and abstract analysis of the role of the railways interest in this area of economic history has dwindled and no better alternative been supplied.[15] This state of affairs led Gourvish to resignedly conclude, "a satisfactory measure of their contribution to the economy must necessarily remain elusive".[16]

[13] Ibid.
[14] O'Brien, The New Economic History of The Railways, p.14.
[15] Ville, Transport ,in: The Cambridge Economic History of modern Britain: industrialisation, 1700-1860, p.329.
[16] Gourvish, Railways and the British Economy 1830-1914, p.40.

Section 1

1.3 Methodology: Counterfactual Case Study

The extent to which the railways caused economic growth can only be properly answered by considering how large industrial firms would have operated in their absence – by posing a counterfactual question. Hawke gives the reason why he, and no doubt many other economic historians have failed to do this; namely that to construct a reasoned counterfactual economy operating in the absence of the railways is a "task mammoth in its proportions".[17] Furthermore, an inherent problem with counterfactual arguments is that they rest on unverified hypothetical situations and so it is difficult to analyse whether conclusions drawn from counterfactual reasoning are plausible.[18] Thus, the one tool which is necessary to understanding whether the railways did cause economic growth has significant flaws itself. However, O'Brien reasonably argues that counterfactuals can be, "persuasively employed where a plausible alternative can be properly specified".[19] This paper will consider 'plausible' to be defined as those alternatives which can be shown to have been actually considered by contemporaries on the basis of contemporary evidence.[20]

Thus, this paper will adopt a counterfactual case study as its basic methodological structure. This approach allows the necessary counterfactual judgements to be made but through use of a case study avoids many of the problems of this tool; unverified assumptions, inability to specify contemporary alternatives and complications introduced through scale.

To use a counterfactual case study with the intention of analysing the relationship between the railways and economic growth is unique but not totally unprecedented. Jones's paper 'A transport private saving calculation for the brewers Truman Hanbury & Buxton, 1815-63' published in 1986 examines the implications for a brewery of being forced to use alternative modes of transport in the event of closing either a waterway or a railway.[21] However, Jones's article is limited in its scope - no attempt is made to generalise from the findings and even if this had been attempted the nature of the firm studied - a brewery, limits its utility in terms of wider applicability. In contrast, this paper has deliberately chosen Brunner Mond because a case study of this firm has wider relevance to the economic growth that occurred in Britain 1882-1914.

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[17] Hawke, Railways and Economic Growth in England and Wales 1840-1870, p.32.
[18] O'Brien, The New Economic History of the Railways, p.23.
[19] Ibid.
[20] Ferguson, Virtual History, p.86.
[21] Jones, A transport private saving calculation for the Brewers Truman Hanbury & Buxton, 1815-63, Journal of Transport History, p.1.

Good economic history builds and tests hypotheses and this paper aims to fill a gap in this regard. The social savings hypothesis broadly postulates that the waterways could have substituted for the railways and facilitated continued industrial development in the process. This has not been adequately tested; Fogel constructed the hypothesis with regard to agriculture and Hawke re-wrote it for the UK but it is a clear omission that it has not been considered whether an industrial firm simply could have continued to operate without the railways. On a basic level this is what needs to happen for the social savings hypothesis to be considered valid and this paper aims to contribute to the understanding of this subject.

Section 2

2.1 Brunner Mond Background

Brunner Mond was founded in 1872 in order to produce primarily sodium carbonate (commonly known as soda ash) through the Solvay process, which was much more efficient than the original method, the LeBlanc process. Sodium carbonate is used across a wide variety of industries including glass, chemicals, pharmaceuticals and food. Changes in its price or availability would have had significant effects for the rest of the economy.

Brunner Mond grew rapidly, it produced only 838 tons of sodium carbonate in 1874 (the first year of production) and this had risen to 200,000 tons in 1900, compared to total UK consumption of around 250,000 tons.[22] By 1926 production had grown further to 650,000 tons per year and the LeBlanc process accounted for only a "few hundred tons".[23] To put this into context by 1926 the United Kingdom was consuming around 500,000 tons of sodium carbonate and this figure was growing at the rate of 3.25% per year.[24] Although Brunner Mond grew to dominate the domestic market for soda ash exports sales were a very important component of the business. Indeed, until 1884 75% of production was exported, predominantly to the USA.[25] With increasing American industrialisation from the end of the 19th century this market declined in importance for Brunner Mond and its export focus shifted to the Far East. By the mid 1920's the company was exporting around 150,000 tons of soda ash per

[22] Dick, A Hundred Years of Alkali in Cheshire, p.29.
[23] Ibid.
[24] Ibid, pp.121 - p.125.
[25] Ibid, p.61.

year to China, Japan and India which accounts for all of the soda ash produced but not domestically consumed at that time.[26]

2.2 Raw Material Requirements

Firstly, the raw material requirements of Brunner Mond will be established. Secondly, it will be shown that transport prices are the single biggest component of the price of bulk mineral cargoes and so inaccurate assumptions about transport prices do have important consequences. Thirdly, a social savings calculation will be completed and then critiqued through using a demand and supply model.

The production of soda ash requires limestone, coal, coke, lime, ammonia and salt. Salt was delivered by pipeline in the form of brine, quantities and costs of which are not documented individually as with the other inputs because this supply chain was internalised and managed by Brunner Mond itself. Ammonia was only needed in minimal quantities as it can be recycled in the Solvay process. Thus, the raw material inputs to be delivered by the rail network in significant quantity to Brunner Mond were limestone, coal, coke and lime. Brunner Mond recorded their use of these inputs on a half yearly basis in their profit and loss accounts. A complete data set is only available for 1882-1889 but this can be combined with other isolated instances of information on Brunner Mond's raw material consumption to construct an approximation of total raw material consumption 1882-1914. (See Figure 1)

The above graph shows how Brunner Mond's raw material intake grows nearly eightfold in the period 1882-1914 from around 150,000 tons per annum to more than 1.1 million tons per annum. It can be seen that limestone, coal, coke and lime were used in the ratio of 10:10:1:1 respectively.

2.3 Transport Costs Matter

This paper considers whether transport costs would have been higher in a non-rail economy and so the assumption that transport costs significantly affect the behaviour of large industrial firms needs to be tested and supported. That transport costs matter may seem intuitively obvious – but as Fogel demonstrated in 1962 sometimes quantifying the supposedly obvious can lead to surprising results.

[26] Dick, A Hundred Years of Alkali in Cheshire, pp.65-66.

The graph below breaks down the cost of 1000 tons of limestone delivered to Brunner Mond (See Figure 2 here)

Over twenty four contracts spanning a thirty five year period the railway freight rate and wagon hire averaged 73% of the average price of £20,900 per 1000 tons of limestone delivered to Brunner Mond. As can be seen in 1885 the rail rate is £14,700 per 1000 tons and had fallen to £10,200 when the fifteen year contract of 1904 was placed. Wagon hire was an average of £2364 for the whole period.

The above evidence proves that transport prices do matter and that any changes in transports costs would have had a significant effect on the total costs incurred by Brunner Mond. However, it is important to acknowledge that they are less significant for higher value goods such as finished products. For example, the average price per 1000 tons of soda ash in the UK in 1900 was £305,000 and if the above rail rates were applied they would only account for 4% that price.

Unsurprisingly, given that it accounts for such a large fraction of the total price of raw materials, the available transport infrastructure was foremost in the minds of John Brunner and Ludwig Mond when searching for a location for Brunner Mond. Indeed, in 1872 as Ludwig Mond stood in Winnington where Brunner Mond's first works would be built he noted, "It had a long frontage to the navigable River Weaver and therefore easy access to Liverpool docks and it had a railway connection with Cheshire Lines". [27] John Brunner and Ludwig Mond were clearly aware of the importance of the available transport infrastructure to the future success of their company.

2.4 Social Savings

It is worth repeating that the social savings measure calculates "the alternative cost of shipping exactly the same bundle of goods from the primary to the secondary markets in exactly the same pattern without the railroad".

However, comparing rail and waterway prices as is not an adequate test of whether the waterways could have substituted for the railways because it would be expected that, in equilibrium, they would both offer similar prices as they are selling essentially the same service. Brunner Mond, like nearly all industrial firms, is modally inert. Only those which value a factor such as smoothness of ride (eg; a pottery company), or speed (eg; a fresh food company), might

[27] Dick, A Hundred Years of Alkali in Cheshire, p.8.

value one form of transport over another, but this is not the case for most firms. Thus, it is more helpful to think of ton-mile capacity rather than railways or canals because the latter implies a false dichotomy. The railways are not fundamentally different to canals – both simply supply ton-miles to the economy.

Hawke calculated that the railways reduced freight costs on non coal minerals by 64%[28]. Hawke's conclusions are typical of those of the social savings methodology in general as they support the revisionist claim that the railways made a much more limited contribution to economic growth than first thought. However, this calculation only illustrates that the market for transport was integrated and modally indifferent; indeed in a fully integrated and competitive market for transport one would expect the social savings of the railways to be zero.

This can be illustrated through comparing the comparative costs of rail and water transport under ceteris paribus conditions. These unique conditions were established following a labour dispute at the rail served Peak District quarries which led to Brunner Mond investigating alternative sources of supply and summarising them in a report published on 25th February 1909.[29] In total Brunner Mond identify eight different possible sources of limestone and receive sample deliveries in 1907, 1909 and 1915. Of these deliveries three include the comparative cost of rail compared to water delivery. These are selected and displayed in the Figure 3 (see Appendix).

Unsurprisingly, given that all variables are held constant aside from mode of transport the prices are very similar. Indeed, in two out of the three cases rail transport is actually marginally more expensive than canal. Overall, as the average price per 1000 tons of limestone delivered from the all alternative sources identified by Brunner Mond is £26,385 by water compared to £28,325 for rail it could be said the waterways actually reduce freight costs on coal minerals by 7.3%. In the one instance where the canal price is higher it is only by a mere 2.6% of the rail cost. However, if the above average water prices are compared to the 1885-1914 average rail prices from figure two for Brunner Mond the railways reduced freight costs on non coal minerals by 26%

This is even lower than the social saving calculated by Hawke and shows that in an integrated market price differences for the same service are generally competed away. For Brunner Mond the social savings of the railways were minimal and it is not likely to be an outlier in this respect because most industrial firms were buying transport services in integrated and competitive markets – as confirmed by the macro study of Hawke.

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[28] Hawke, Railways and Economic Growth in England and Wales 1840-1870, p.178.
[29] DIC/BM 7/38. Limestone statement. P.130.

2.5 Supply Constraints in Theory

However, the equilibrium price for transport set in a market with the combined supply of the waterways and railways is not an appropriate guide for the price of transport in a market where supply would have been significantly reduced by the absence of the railways. Any reduction in the supply of transport would have led to an increase in its price, assuming demand remained constant. For example, by 1905 the waterways network was carrying 40 million tons of goods and the rail network 460 million tons.[30] Clearly, the waterways could not have carried 500 million tons of goods in the absence of the railways; they would have carried a small fraction of that figure and at far higher prices.

This is ignored not only by Hawke in his work on England and Wales 1840-70 but by most other applicants of the social savings methodology.

The diagram below highlights that as the supply of water transport was not perfectly elastic rising demand would have led to higher, rather than constant, prices:[31] (See Figure 4 in Appendix)

Supply curve S1 is the transport capacity of a canal only economy which when crossed by demand curve D1 produces a price to move goods of P1 and a quantity of Q1. The railways add to the capacity of the economy to move goods and so the supply curve shifts outwards from S1 to S2. However, given increasing industrialisation demand for transport also increases from D1 to D2. This leads to the price to move goods falling from P1 to P2, whilst quantity of goods moved increases from Q1 to Q3. This is was the actual effect of the introduction of the railways. The social savings methodology attempts to calculate the price of moving goods in a non rail economy by taking the quantity of goods moved by the economy with both the canals and the railways (Q2) and then charging this at previous canal only freight rates of P1, thus creating the fictitious market clearing point of X. The diagram shows that in reality a canal only economy supplying the S1 level of transport but faced with the D2 level of increased demand for transport would produce a price to move goods of P3 at a quantity of Q3. The economy would automatically ration scarce transport capacity through the price mechanism. Thus the social savings methodology inherently underestimates the benefit of the railways, which is not P1 – P2 but rather P3 – P2, a significantly larger benefit.

Thus, had the railways not existed Brunner Mond would have been charged far higher prices for water transport. As Atack and Passell concede the exact counterfactual prices would

[30] Royal Commission on Canals, p.52.
[31] Atack and Passell, A New Economic View Of American History, p.447.

be extremely hard to calculate but it is possible to show the principle behind this judgement, that the supply curve of water transport to Brunner Mond was fixed and inelastic, to be true.[32]

2.6 Supply Constraints in Practice

Brunner Mond seems to be well placed to operate in an economy with water transport. It operated at four sites in total, all of which had direct water access. There were two sites in Northwich, the Winnington works and the Lostock works. The former was founded by Brunner Mond and started operation in April, 1874.[33] It had a direct connection to the Weaver Navigation which ran from Winsford, through Northwich and into the Mersey estuary. The Lostock site was purchased by Brunner Mond in 1900, rebuilt and production had fully resumed by 1907.[34] This site had a direct connection to the Trent and Mersey Canal. Brunner Mond also had two other sites in the surrounding areas of Northwich, Middlewich and Sandbach. The Middlewich site was purchased in 1895, rebuilt and production had resumed by 1897. The Sandbach site was purchased in 1878 and was in full production by 1880. These sites also had direct connections with the Trent and Mersey canal.

As can be seen in Figure 5 (see Appendix) the original Winnington site was by far the largest.

The four sites together consumed approximately 496,759 tons of limestone, of which 271,648 tons or 55% was used at Winnington.[35] In addition, the Winnington site would also have been consuming another 500,000 tons of coal, coke and lime, as would the other three sites between them. All of these inputs would have had to have been delivered by the waterways in the absence of the railways.

In the absence of the railways limestone quarried in the Peak District would have been transported by tramway to the Bugsworth Basin at which it would have been loaded into narrow boats. The narrow boats would have travelled the 6.9 lock free miles of the Upper Peak Forest canal, joined the Macclesfield canal and transited its 28 miles and 13 locks before finally joining the Trent and Mersey Canal for 23 miles and 35 locks until arrival at Anderton, Northwich. Until the Anderton Boat lift was opened on 26th July 1875 there was no direct

[32] Atack and Passell, A New Economic View Of American History, p.447.
[33] Dick, A Hundred Years of Alkali in Cheshire, p.13.
[34] Ibid, p.21.
[35] DIC/BM 7/38. Limestone Deliveries.

connection between the Trent and Mersey Canal and the Weaver Navigation given the fifty foot height difference between the two waterways.[36]

Thus there are a number of potential capacity constraints on the supply of limestone to Brunner Mond by water; the canals, the Anderton boat lift and the Weaver Navigation. These constraints have to be considered in geographical order, for Brunner Mond it is irrelevant to expand the Anderton boat lift or consider the potential capacity limits of the Weaver Navigation if only a fraction of the limestone it requires can reach that point.

The Peak Forest canal was a narrow canal. Narrow waterways are defined as those with locks less than fourteen foot wide and thus the locks on these waterways could only accommodate an absolute maximum of two narrow boats per locking, which are usually around 7 feet in width. Such narrow boats were limited to carrying around 30 tons of cargo. In contrast, by 1892 the Weaver Navigation had locks of forty two feet in width, which could accommodate a steam flat and three barges, all together carrying 1000 tons, in a locking.[37] The table below shows how low capacity narrow waterways accounted for nearly 40% of the total mileage of waterways in England and Wales:[38] (See Figure 6 Appendix)

The tonnage conveyed by the Peak Forest Canal is included in the figure Figure 7 (see Appendix) [39]:

Of the 1905 figure a mere 15,660 tons was lime and limestone.[40] As all of Brunner Monds limestone was delivered by rail we can add their approximate 1905 requirement of 300,000 tons of limestone (see Figure 1) without fear of duplicating tonnage to give a counterfactual tonnage of 436,148. However, this figure is before the tonnage for all the other goods that would have otherwise been carried by the railways is factored in. The Royal Commission on Canals investigated the impact of the railways on twelve major waterways 1858-1905 and found that tonnage rose by 24% despite the competition from the railways.[41] Thus, it seems reasonable to assume that tonnage on the Peak Forest canal 1858-1905 would have at least stayed constant, if not increased, in the absence of the railways. Assuming constant tonnage and including Brunner Mond's limestone requirements we reach a counterfactual tonnage of 678,899 for the Peak Forest canal – 1.5x the highest previous recorded tonnage. This is a crude measure of the potential tonnage on the Peak Forest Canal in

[36] Hadfield, Canals of North West England, vol.2, p.383.
[37] Hadfield, Canals of North West England, vol.2 p.385.
[38] Ibid, vol.2, p.20 and p.23.
[39] Hadfield, Canals of North West England, vol.2, pp. 444-445.
[40] Ibid.
[41] Royal Commission on Canals, Table showing the tonnage carried on and the gross revenue of certain waterways, p.51.

the absence of the railways but given the growth in demand for transport between 1858 and 1905 it is still probably a significant understatement.

Evidence from other waterways suggests significantly increasing tonnage on the Peak Forest canal would not have been feasible, even using the above lower bound estimate. A rough measure of capacity on a waterway is traffic density or number of tons carried per mile and this calculation has been completed for the selected waterways in Figure 8 (see Appendix)

When compared to waterways of the same width such as the Trent and Mersey or Macclesfield canals the Peak Forest canal would be required to carry a traffic density 10x and 20x higher respectively. Indeed, the counterfactual Peak Forest traffic density of 98,391 tons per mile is 6x higher than the average figure which is an aggregate of twelve major waterways.[42] However, the clearest indication that the Peak Forest could not sustain the counterfactual level of traffic is found in comparison with the Weaver Navigation. The Weaver Navigation is not representative of typical water transport – it is a large, fully modernised waterway. It is consistently recognised in contemporary reports as a model waterway, indeed in British Canals: Problems and Possibilities published in 1910 it is written that "hardly any [canals] are efficient for the needs of the present time" apart from the "notable exceptions" of the Weaver Navigation and Aire and Calder Navigation.[43] In the Royal Commission on Canals 1906 the Weaver Navigation is cited as an "instance of important improvements".[44] Indeed, in 1905 the Weaver Navigation only accounted for 0.4% of the total mileage of waterways in operation in the United Kingdom but carried 5% of the total number of tons conveyed.[45] The Weaver Navigation had a traffic density of 53,829 tons per mile in 1905 and it is clearly unrealistic to claim that a narrow canal, at altitude and thus with limited water supplies could support double this traffic density. Indeed, it is known that the 442,253 tons carried by the Peak Forest canal in 1838 "put pressure on [its] water supplies", and this confirms that the significantly higher tonnage such as the 678,899 postulated would not have been feasible. Water supply would have prevented more boats being sent down the existing Peak Forest canal or the canal being significantly expanded. Thus, Brunner Mond could not have accessed limestone on a large scale from the Peak District in the absence of the railways.

The above evidence shows that the Peak Forest canal was at the limit of its supply curve and so the theoretical conclusions demonstrated in Figure 5 have been confirmed. Supply was

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[42] The twelve waterways include; Birmingham, Coventry, Grand Junction, Kennet and Avon, Leeds and Liverpool, Trent and Mersey, Oxford, Staffordshire and Worcestershire, Trent Navigation, Warwick and Birmingham, Warwick and Napton, Aire and Calder.
[43] J. Palmer, British Canals: Problems and Possibilities, pp.20-21.
[44] Royal Commission on Canals, p.69.
[45] Royal Commission on Canals, p.53.

constrained and given a significant increase in demand prices would have risen. To what extent they would have risen is not known but we can be confident that they would have done so.

In the absence of the railways high capacity waterways, not narrow canals, would have been the only way to satisfy high volume transport requirements and so industrial firms would have had to locate where such infrastructure was accessible. Brunner Mond has two main options in this regard; either centralise production at the Winnington site to eliminate dependence on narrow waterways by using the Weaver Navigation or move to a coastal location and utilise the high capacity waterway that is coastal shipping. The next section will consider the viability of these options.

Section Three: Counterfactual Alternatives

Of the three core raw materials required by Brunner Mond limestone is the most scarce and so has the greatest influence over where the company can base itself. In pure form it is found at two main locations in Britain, the Peak District and North Wales.[46] Semi pure limestone is also found in Newcastle. In a counterfactual world with Peak District limestone inaccessible on a large scale and only at much greater cost without the railways, Brunner Mond would have either transported limestone from North Wales or relocated to Newcastle. Furthermore, as Fogel recognised it is unrealistic to assume the absence of the railways and not consider any potential expansion of the waterways and so this issue will also be considered.

3.1 North Wales and the Weaver Navigation

Whether a counterfactual centralisation and expansion of production at Winnington is realistic depends on three main factors:

Is the Winnington site large enough for production to be expanded?

Is there a supply of limestone that can be accessed from the Weaver Navigation?

Could the Weaver Navigation have absorbed the increased demand?

The Winnington site is not space constrained and it is reasonable to assume that there was sufficient space to expand production there. Indeed, the Sandbach and Middlewich sites were closed in 1932 and 1962 and production transferred to Winnington in order to take

[46] Langton and Morris, Atlas of Industrializing Britain, p.115.

advantage of economies of scale.[47] Without the railways this rationalisation simply would have occurred earlier and included the Lostock site.

As written previously in Section Two, Brunner Mond had identified eight sources of limestone outside the usual Peak District quarries, of which four were in North Wales and four in the Peak District foothills of Staffordshire. In a non-rail scenario all of these locations would have been unable to supply limestone in quantity because of the limitations of narrow canals apart from the limestone quarry of Raynes & Company at Llandulas. This quarry is directly situated on the coast thereby enabling the use of high capacity barges. Indeed, the quarry is still operational today and continues to export limestone using coastal shipping. Raynes Quarry was opened in 1873 and so would have been able to supply Brunner Mond with limestone from the company's inception.

This leaves the capacity of the Weaver Navigation as the key variable for this counterfactual. The graph below compares the Weaver Navigation's known tonnage with a counterfactual tonnage. The counterfactual tonnage holds tons constant from 1882, as was done for the Peak Forest canal, and adds to this Brunner Mond's total raw material requirements. The other major input in addition to limestone is coal. Coal traffic accounted for approximately 200,000 tons of traffic on the Weaver Navigation in 1882 but was almost all lost to the railways by the end of the same decade.[48] As a result it seems reasonable to assume that had the railway not arrived in Northwich from 1863 the Weaver Navigation would have maintained its position as the most effective way to transport coal to Northwich and Brunner Mond. (See Figure 9 in Appendix)

Figure 10 (See Appendix) shows that actual tonnage was 1,516,819 tons in 1882 and it predicts this increasing by 72% to 2,608,579 tons.

The counterfactual traffic density of 1914 is 1.7x higher than the highest actual traffic density recorded of 1882, a similar magnitude of increase to the counterfactual level of traffic on the Peak Forest canal. However, such an increase is far more of a realistic proposition for the Weaver Navigation. It is a very different waterway to the Peak Forest canal; crucially it lies in a valley and has good water supplies as a result. However, the best indication that such a tonnage would have been feasible lies in comparison with the peer waterway of the Aire and Calder Navigation. The parallels are many; both navigations are of roughly similar length at under 50 miles, both flow into the major river estuaries of the Humber and Mersey and both have locks of similar dimensions at 220 foot in length by 42 foot in width for the Weaver compared to 208

[47] Dick, A Hundred Years of Alkali in Cheshire, p.55.
[48] Hadfield, Canals of North West England, vol.2, p.389.

foot in length by 22 foot for the Aire and Calder.[49] In 1905 the Aire and Calder carried 2,810,988 tons of goods – approximately 200,000 more than the counterfactual tonnage for the River Weaver.[50] This suggests that the Weaver Navigation was not at the limit of its supply curve and as a result could have absorbed an increase in demand without the substantial price increase of figure 5. To what extent this can be taken as an indication that all high capacity waterways were similarly underutilised is unclear. The Weaver Navigation was of such high capacity because it was completely rebuilt from 1871, which included doubling the dimensions of the locks to the size listed above, over two decades.[51] This reconstruction was suggested and implemented by the Navigation's Chief Engineer, Edward Williams who aimed to make the Navigation accessible to sea going vessels.[52] This expansion occurred despite tonnage being relatively stable in the decades leading up to 1871 at around 1.2 million tons.[53] Post expansion modest tonnage growth did occur up to 1.5 million tons as can be seen in the graph on Weaver Navigation Tonnage 1889-1914, but it cannot be expected that such a complete rebuilding of the Navigation was required for a mere 0.3 million tons of traffic. One benefit of the improvements was reduced time – journey duration from the Mersey estuary to Northwich was reduced by six and a half hours to four and a half hours, but ultimately with hindsight the rebuilding cannot be fully justified.[54] This issue will be returned to in the conclusion.

Thus, it has been established it is physically possible to supply Brunner Mond with the Weaver Navigation. Comparative data from 1909 for limestone indicates that to so would have been financial realistic, albeit marginally more expensive. See Figure 11 (Appendix)

As can be seen from Figure 11 limestone from Wales by water was 40% more expensive than limestone from the Peak District by rail. Brunner and Mond's profit and loss accounts are incomplete but even a limited example shows that the price increase could have been absorbed by the firm. In 1889 Brunner Mond had revenue of £21.8 million and profits of £8.8 million (2012 prices).[55] The value of limestone consumed was £1.98 million. Thus, a 40% increase in limestone costs would reduce profits by approximately £0.8 million or 9%. Brunner Mond would still have a viable and successful business in this situation.

In sum, this counterfactual scenario suggests that in the absence of the railways Brunner Mond could have continued to operate essentially unchanged. Some rationalisation but not wholesale relocation would have been required for the firm maintain production. However,

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49 Royal Commission on Canals, p.40 and Hadfield, Canals of North West England, vol.2, p.385.
50 Royal Commission on Canals, p.65.
51 Hadfield, Canals of North West England, vol.2, p.380.
52 Ibid.
53 Ibid, p.382.
54 Ibid, p.385
55 DIC/BM 4/11.

Brunner Mond and the Weaver Navigation were not completely representative of British industry as a whole. The limited impact of the absence of the railways on the firm is because it was fortunate to be sited on an underutilised high capacity waterway. This would not have been the case for all large industrial firms – 40% of the waterways in the UK were narrow capacity.[56] For those firms dependent on such waterways relocation would have been required and so this paper will consider whether Brunner Mond could have relocated as an indication of the viability of relocation for large industrial firms.

3.2 Relocation and Newcastle

Newcastle is a viable location for Brunner Mond. Indeed in 1900, with extremely few exceptions all the alkali works in Britain, either Solvay or LeBlanc process, were located either in Cheshire or Newcastle.[57] All three raw materials required for soda ash production can be supplied in Newcastle

Semi pure magnesian limestone is found in Newcastle.[58] Magnesian limestone contains only 50% calcium carbonate (the active ingredient for soda ash production) compared to pure limestone which is around 97% calcium carbonate.[59] Furthermore, the limestone deposits in Newcastle are situated on the coast and immediately north of the River Tyne. Newcastle is also endowed with ample coal supplies, indeed it was the single biggest coal producing region in England.[60] Salt could be produced at high cost in Newcastle by boiling seawater. This was done up until the 1790s until construction of the Weaver Navigation in 1732 enabled cheap Cheshire salt to be exported, which gradually outcompeted the Newcastle salt industry.

Given the presence of all three core raw materials required by Brunner Mond, Newcastle could be a viable location for the company in the absence of the railways. Furthermore, it is possible to approximately assess the extent to which Brunner Mond could have successfully operated in Newcastle because Brunner Mond itself produced a report in 1888 estimating the cost of soda ash production in Newcastle. Like the previous scenario this is not a speculative exercise but a grounded counterfactual assessment based on contemporary evidence.

[56] See: "Figure 6: Waterways in England and Wales in 1906".
[57] Langton and Morris, Atlas of Industrializing Britain, p.117.
[58] Ibid.
[59] DIC/BM, 7/38, 'Report on Limestone received from outside firms during Buxton Strike'.
[60] Langton and Morris, Atlas of Industrializing Britain, p.73.

From the report it can be calculated that in 1888 the cost per 1000 tons of limestone in Newcastle was £20,400 (2012 prices), compared to £21,800 for Brunner Mond in Cheshire at the same time.61 This is significantly cheaper than the £29,000 for limestone delivered to the Winnington site from Wales. Brunner Mond found the low cost of Newcastle limestone so surprising that a note in the report reads, "there must be an error in the Newcastle price".62 In reality, the price of Newcastle limestone is likely to be low not because of an error but because of the natural provision of a cheap means to transport it: a short distance downstream a wide and navigable river. Unfortunately, because Brunner Mond didn't record their salt costs it cannot be definitively assessed whether a Northwich or Newcastle location would have had lower costs in the absence of the railways. Admittedly, it seems likely that it would have been cheaper to be based next to coal and limestone in Newcastle and import salt than be based next to salt in Northwich and import coal and limestone but this is only an intuitive judgement. However, it is more important for this paper to demonstrate that relocation was at least a realistic option rather than cost it precisely. In a non-rail economy Brunner Mond could have operated in a Newcastle location without a significant adverse cost impact. In reality, by 1912 the alkali industry had decisively migrated to Cheshire, as with the railways easily able to supply capacity there was no cost penalty in a Cheshire location and there was access to the higher quality limestone.63 This evidence suggests that the main impact of the railways was to affect the distribution of industry, but not its viability.

3.3 Could the supply of water transport been increased?

Fogel claimed that in the absence of the railways the US economy in 1890 would have constructed 5000 extra miles of canals.[64] An indication of whether it would have been possible to achieve similar improvements in the UK is given in the 1906 Royal Commission on Canals.

Unlike Fogel's work the estimates made in the Royal Commission were actually surveyed and calculated by a civil engineering firm, Sir John Wolfe Barry and Partners, and thus can be regarded as authoritative.[65] The Royal Commission identified four main waterway trunk routes and proposed nationalising and expanding those routes to be able to accept either a 100 ton or

[61] DIC/BM, 4/3, 'Cost of making 1 ton 58% Soda Ash by LeBlanc process based upon information received from Newcastle, November 12th 1888'.
[62] Ibid.
[63] DIC/BM, 4/3, 'Cost of making 1 ton 58% Soda Ash by LeBlanc process based upon information received from Newcastle, November 12th 1888'.
[64] O'Brien, The New Economic History of The Railways, p.33.
[65] Royal Commission on Canals, p.140.

a 300 ton barge as a minimum. The four routes are shown in Figure 12 (Source: Royal Commission on Canals, p.95).

The 300 ton option was proposed by Mr. Saner who was the main engineer to the Weaver Navigation. That he was consulted on how best to expand the waterways network further reinforces the advanced nature of the Weaver Navigation.

It was estimated that the fixed costs of construction for the 300 ton scheme would be twice as high as for the 100 ton scheme, but the variable costs of operation would only be marginally higher for the 300 ton scheme.[66] The Royal Commission declined to make a decision on which scheme should adopted stating that any such decision, "must be finally decided with a view to all the circumstances, financial and other".[67] The cost estimate for expanding the above four routes and associated feeder routes to the 100 ton standard was put at £17.5 million or £35 million for the 300 ton standard.[68] With British GDP of £1.95 billion in 1905 this investment represented a substantial 1.8% of GDP.[69] However, whilst this investment is substantial it is not unrealistic when compared to the investment made in the railways. In 1845 approximately £50 million was invested in the railways to double the existing network. With British GDP of £59 million this invested accounted for a massive 118% of GDP.[70]

It is estimated the unimproved four trunk routes carried 16 million tons of goods, which would have to rise to 80 million tons to make the expansion financially viable, assuming a price of 0.2d per ton mile.[71] A five times increase in capacity on these four trunk routes is impressive but would still leave the capacity of the waterways far below that of the railways. With these improvements the waterways could have carried 104 million tons of goods in 1905, but it will be remembered that the railways carried 460 million tons of goods in the same year.

Thus, with investment of 1.8% of GDP it is possible to bring the capacity of the waterways up to around 20% of the capacity of the railways. Given that this is far lower than the investment made in the railways one might assume that further investment could increase capacity on the waterways even further. However, the ultimate constraint was not financial but water itself. Doubts were expressed in the report on the sufficiency of the water supply for the 300 ton standard, let alone a larger standard.[72]

[66] Royal Commission on Canals, p.148.
[67] Ibid, p.149.
[68] Ibid, p.156.
[69] Measuring Worth, online.
[70] Wolmar, Fire and Steam, p.88.
[71] Royal Commission on Canals, p.157.
[72] Royal Commission on Canals, p.150.

This is an important piece of evidence because it suggests that expansion of the waterways could not have compensated for the absence of the railways with regard to inland transport capacity and so relocation to coastal locations such as Newcastle would have been necessary for the continued operation of heavy industry.

Section Four

4.1 Conclusions and Generalisations

The social savings methodology postulates that industrial firms could have operated in the absence of the railways and tests this through a macro price comparison of rail and water transport. This paper believes that this is not an adequate test of whether industrial firms could have functioned without rail transport primarily because it assumes the supply of water transport was sufficient to substitute for the railways without increasing prices. In the words of Fogel,

"If the waterways could have supplied all or most of the service that the railroads were providing *without increasing unit charges*, then the presence of railroads did not substantially widen the market and their absence would not have kept it substantially narrower".[73]

As a result, this paper took a micro approach and aimed to assess whether an individual firm, Brunner Mond, could have viably operated in a non-rail economy. This would allow the impact of a large industrial firms bulk transport requirements on the waterways to be examined in detail and so actually assess whether the waterways did have such spare capacity.

The case study started by considering whether the existing pattern of supply for limestone, the key raw material for soda ash production, could have been maintained without the railways. This would have necessitated dependence on narrow canals. It was shown that the Peak Forest narrow canal could not have supplied the service that the railways were providing without increasing prices. Indeed, it was estimated that the Peak Forest narrow canal would have had to maintain a traffic density six times higher than the average waterway to supply Brunner Mond – undoubtedly unrealistic given its water supply constraints.

Counterfactual patterns of supply for Brunner Mond thereby had to be considered. Firstly, it was assessed whether Brunner Mond could have centralised production at the

[73] Railroads and American Economic Growth, p.13.

Winnington site and transported limestone from North Wales up the Weaver Navigation. Through comparison with the Aire and Calder Navigation it was concluded that the Weaver Navigation had significant additional capacity. As a result, the Weaver Navigation could have supplied the services that the railways were providing without increasing unit charges. However, whilst this evidence does directly support Fogel's argument it needs to considered whether this situation was the rule or the exception. Brunner Mond is in a unique position: not only was it sited on a high capacity waterway but that high capacity waterway was significantly underutilised. Many firms may not have found themselves in such favourable circumstances in the absence of the railways.

As a result it was then assessed whether Brunner Mond could have relocated. It was shown that Brunner Mond could have successfully relocated despite its dependence on relatively scarce supplies of limestone and so it is reasonable to assume that other large industrial firms could have also done so.

Thus, it was shown that Brunner Mond could have continued to operate in the absence of the railways either at its existing location in Northwich or in Newcastle. The relative costs of counterfactual operation at these locations would have determined which option the company chose and these could not be fully calculated. However, it is more significant that at least two locations have been identified at which a large industrial firm could have maintained production in the absence of the railways even if exactly which location cannot be established.

This paper has highlighted that it is important to draw a distinction between different types of waterway. Narrow canals would not have been able to substitute for the railways without increasing prices. This is an important finding, 40% of the waterways in the UK were narrow canals and it is very unlikely that they could have supplied adequate transport capacity for large scale industrial production. In contrast, this study suggests that high capacity waterways could have substituted for the railways without increasing prices, although there are question marks over the wider applicability of this judgement. Furthermore, the Royal Commission shows that it was unlikely that the network of high capacity waterways could have been significantly expanded. It believed with an investment of £35 million or 1.8% of GDP the waterways could have been expanded to a 300 ton standard on key routes and feeder branches. This was predicted to allow an additional 60 million tons of goods to be carried on the waterways to a total of 100 million tons. This is still significantly below the 460 million tons of goods carried by the railways in 1905. It is untenable to argue, as Hawke does, that with a water transport network with limited capacity and limited scope for expansion over a large portion of the network that prices would have been unchanged while freight volume increased nearly 12x to 500 million tons annually.

Thus, the conclusion confirms the core of the social savings methodology - that industrial development was not dependent on the railways. The study has also assessed the claim that the waterways could have substituted for the railways without increasing prices and found that this holds true for only part of the network in the UK. For just under half of the waterways were narrow canals where prices would have been likely to rise reflecting a large increase in demand coming up against a capacity constraint. The other half of the waterways were high capacity, and here prices were likely to be broadly constant. This suggests that the pattern of industrial development would have changed in the absence of the railways as firms would have had a strong incentive to locate where their transport requirements were not constrained by the capacity of internal waterways, indeed continued large scale industrial production for these firms would only be possible if this constraint could be avoided.

On the basis of this evidence it seems likely that large scale industrial activity would still have been possible in the absence of the railways, but in fewer locations and only in those with access to high capacity waterways. The main advantage of the railways was that they supplied high capacity transport away from water supplies and with a greater tolerance of gradients than the waterways. In doing so they enabled industrial development to be sustained in many more locations than ever before, but crucially the bulk of industrial activity probably could have successfully mitigated their absence either through existing using high capacity waterways or through relocating to a high capacity waterway. The railways primarily affected the distribution of industry rather than the existence of industry.

In sum, this paper sought to investigate how Brunner Mond would have reacted to the absence of the railways with the aim of gaining a deeper understanding into how large industrial firms would have operated in a non-rail economy. It also sought to assess the assumption of constant water prices in the absence of the railways. Brunner Mond would have been able to adjust to the absence of the railways at its existing location albeit at the cost of a 9% reduction in profits. Relocation was a viable and possibly less costly alternative to this. Together, these two scenarios confirm that industrial activity could have been maintained without the railways. However, constant water prices would not have been seen across the waterways network in the absence of the railways due to capacity constraints on narrow canals. This would have prompted a significant change in the economic geography of the United Kingdom, if not the overall level of output.

Bibliography

Primary Sources

Cheshire Record Office (CRO). Brunner Mond Profit and Loss Account. DIC/BM 4/11.

CRO. Letter from T. Ryan to Brunner Mond dated December 11th 1907. DIC/BM 7/38.

CRO. Limestone Deliveries. DIC/BM 7/38.

CRO. Report on Limestone received from outside firms during Buxton Strike. DIC/BM 7/38.

CRO. Cost of making 1 ton 58% Soda Ash by LeBlanc process based upon information received from Newcastle, November 12th 1888. DIC/BM 4/3.

Online sources

Royal Commission: The Canals and Inland Navigations of the United Kingdom: Volume VII, Fourth and Final Report, Command 4979. [WWW document]. URL http://parlipapers.chadwyck.co.uk/fullrec/fullrec.do?area=hcpp&resultNum=1&entries=1&source=config.cfg&queryId=../session/1333203192_26947. [Accessed on March 2012].

Measuring Worth: What was the UK GDP then? [WWW document]. URL http://www.measuringworth.com/datasets/ukgdp/result.php. [Accessed on April 2012].

Secondary Sources

Atack, J, Passell, P and Lee, Susan. A new economic view of American history: from colonial times to 1940. (New York, 1994).

Dick, W. *A hundred years of alkali in Cheshire*. (Runcorn, 1973).

Ellis, J. '*Decline and Fall of the Tyneside Salt Industry, 1660-1790: A Re-examination*'. Economic History Review. Volume 33, number 1 (1980). pp.45-58.

Ferguson, N. *Virtual History: Alternatives and Counterfactuals*. (1997).

Fogel, R. '*A Quantitative Approach to the Study of Railroads in American Economic History: A Report of Some Preliminary Findings*'. Journal of Economic History. Volume 22, number 2 (1962). pp.163-197.

Fogel, *R. Railroads and American Economic Growth: Essays in Econometric History*. (Baltimore, 1970).

Gourvish, T. Railways and the British economy, 1830-1914. (1980).

Hadfield, C and Biddle, G. The canals of North West England, 2 vols. (Newton Abbot, 1970).

Hawke, G. Railways and economic growth in England and Wales 1840 - 1870. (Oxford, 1970).

Jenks, L. 'Railroads as an economic force in American Development'. Journal of Economic History. Volume 4, number 1 (1944). pp.1-20.

Jones, Edgar. 'A transport private saving calculation for the Brewers Truman Hanbury & Buxton, 1815-63'. Journal of Transport History. Volume 8 (1986). pp.1-17.

Langton, J. Atlas of industrializing Britain, 1780-1914. (1986).

Mokyr, J. The lever of riches: technological creativity and economic progress. (New York, 1990).

Mokyr, J. The gifts of Athena: historical origins of the knowledge economy. (Princeton, 2002).

O'Brien, P. The New Economic History Of The Railways. (New York, 1977).

Palmer, J. British canals: problems and possibilities. (1910).

Rostow, W. The stages of economic growth, a non-Communist manifesto. (Cambridge, 1960).

Ville, S. 'Transport', in Roderick Floud and Paul Johnson, eds., The Cambridge economic history of modern Britain. Vol. 1: Industrialisation, 1700-1860. (Cambridge, 2004). pp.295-331.

Wolmar, C. Fire and Steam: How the railways transformed Britain. (London, 2008).

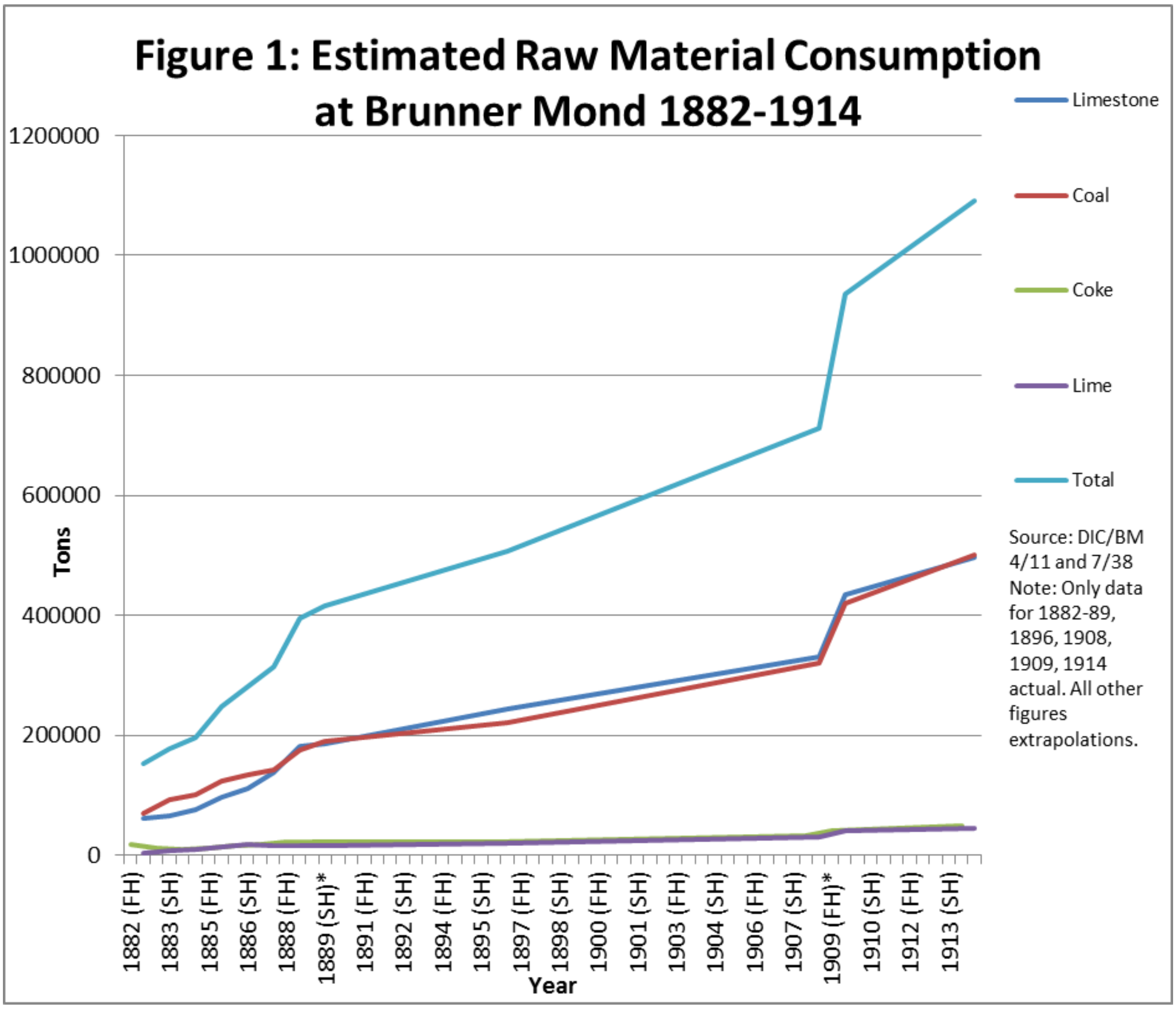

Figure 1: Estimated Raw Material Consumption at Brunner Mond 1882-1914
Limestone
Coal
Coke
Lime
Total
Source: DIC/BM 4/11 and 7/38
Note: Only data for 1882-89, 1896, 1908, 1909, 1914 actual. All other figures extrapolations.
Tons
1200000
1000000
800000
600000
400000
200000
0
1882 (FH)
1883 (SH)
1885 (FH)
1886 (SH)
1888 (FH)
1889 (SH)*
1891 (FH)
1892 (SH)
1894 (FH)
1895 (SH)
1897 (FH)
1898 (SH)
1900 (FH)
1901 (SH)
1903 (FH)
1904 (SH)
1906 (FH)
1907 (SH)
1909 (FH)*
1910 (SH)
1912 (FH)
1913 (SH)
Year

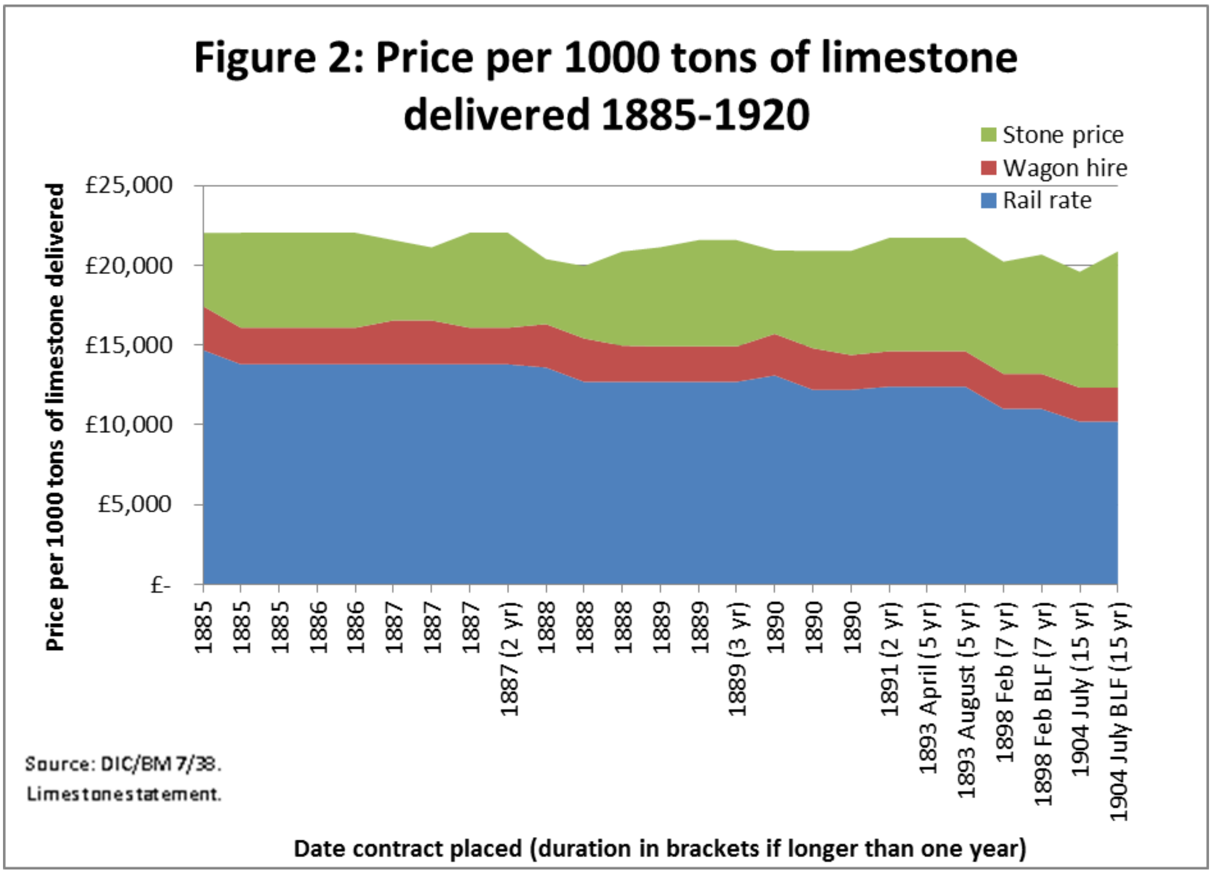

Figure 2: Price per 1000 tons of limestone delivered 1885-1920
Stone price
Wagon hire
Rail rate
Price per 1000 tons of limestone delivered
£25,000
£20,000
£15,000
£10,000
£5,000
£-
1885
1885
1885
1886
1886
1887
1887
1887
1887 (2 yr)
1888
1888
1888
1889
1889
1889 (3 yr)
1890
1890
1890
1891 (2 yr)
1893 April (5 yr)
1893 August (5 yr)
1898 Feb (7 yr)
1898 Feb BLF (7 yr)
1904 July (15 yr)
1904 July BLF (15 yr)
Source: DIC/BM 7/38.
Limestonestatement.
Date contract placed (duration in brackets if longer than one year)

Figure 3: Canal vs. Rail freight rates per 1000 tons of Limestone delivered

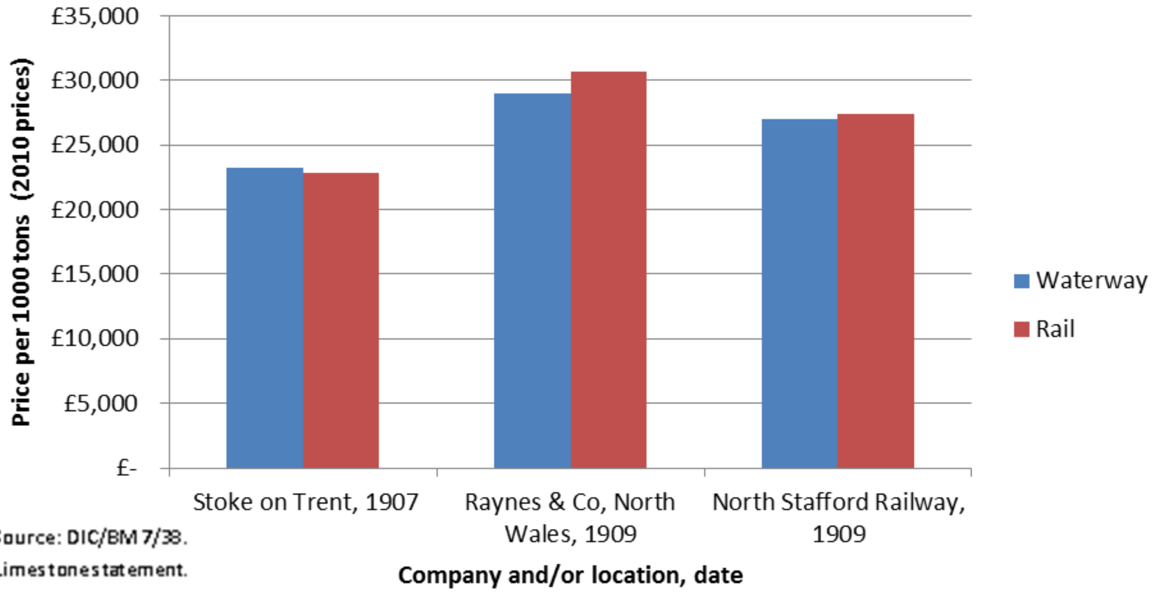

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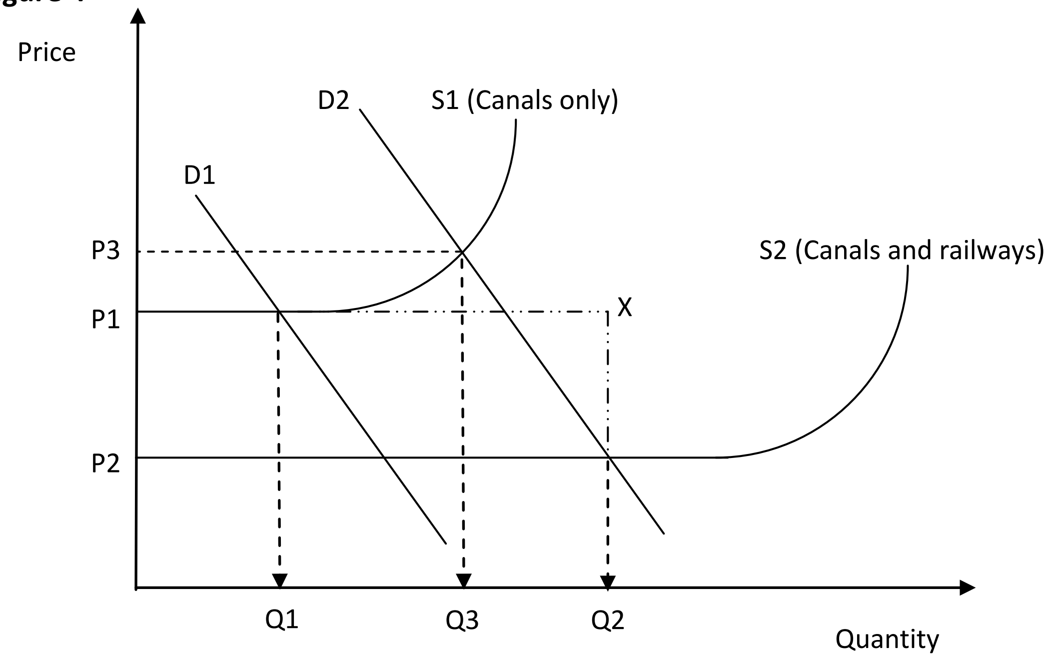
Figure 4


Price
D2
S1 (Canals only)
D1
P3
S2 (Canals and railways)
P1
X
P2
Q1
Q3
Q2
Quantity

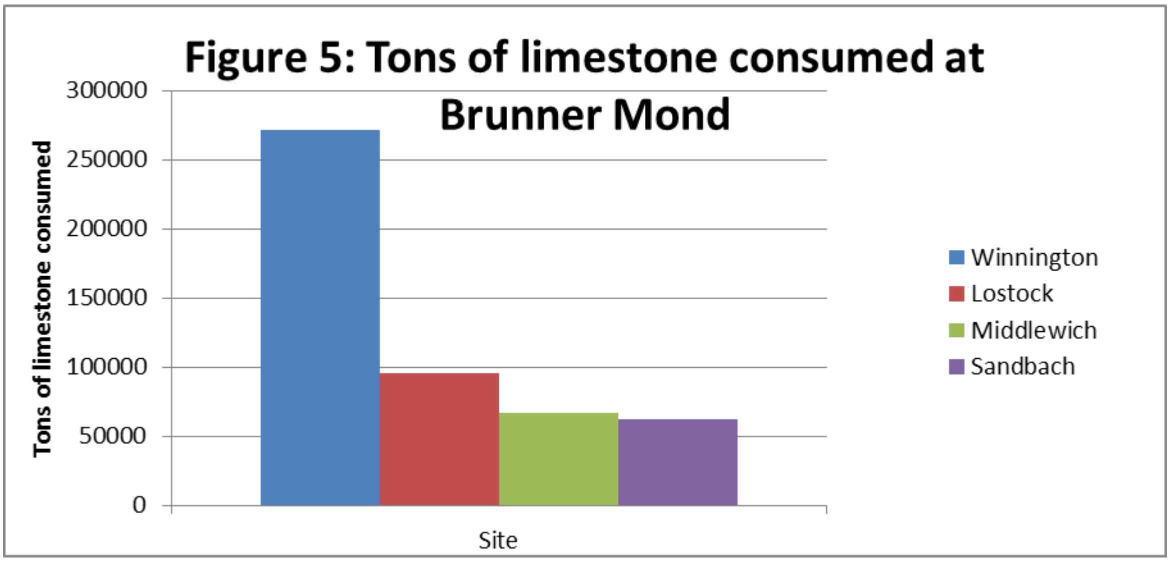


Figure 5: Tons of limestone consumed at Brunner Mond
Tons of limestone consumed
300000
250000
200000
150000
100000
50000
0
Site
Winnington
Lostock
Middlewich
Sandbach

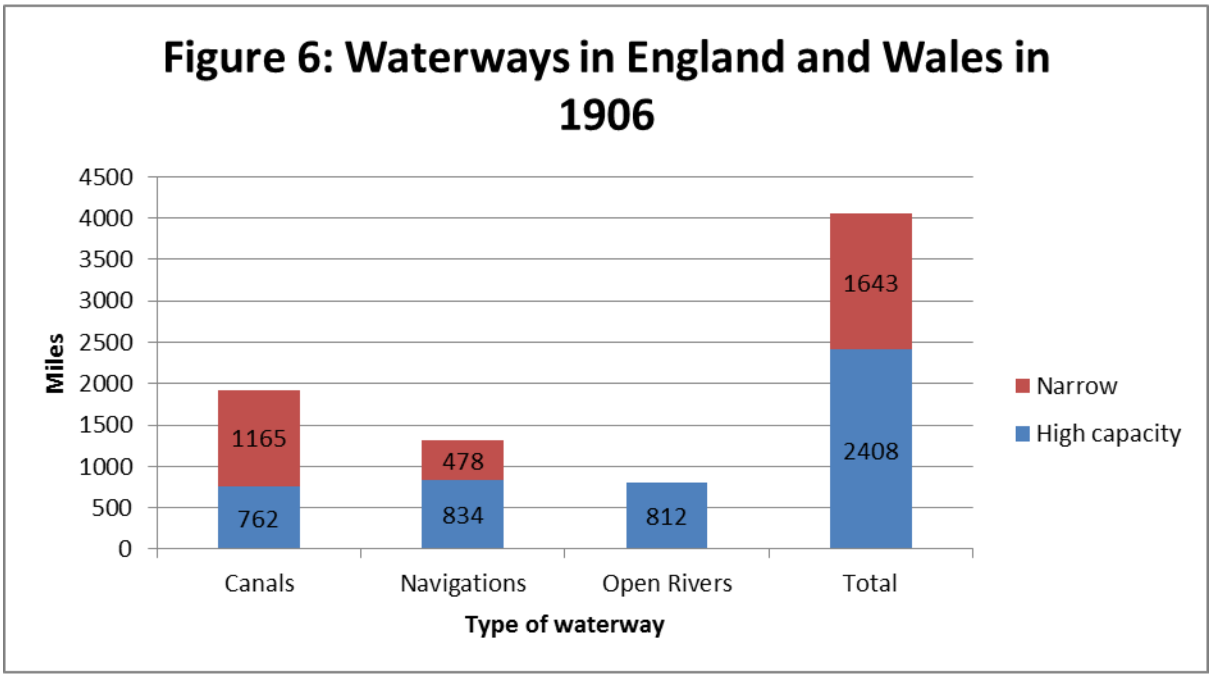


Figure 6: Waterways in England and Wales in 1906
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Miles
1165
762
478
834
812
1643
2408
Canals
Navigations
Open Rivers
Total
Type of waterway
Narrow
High capacity

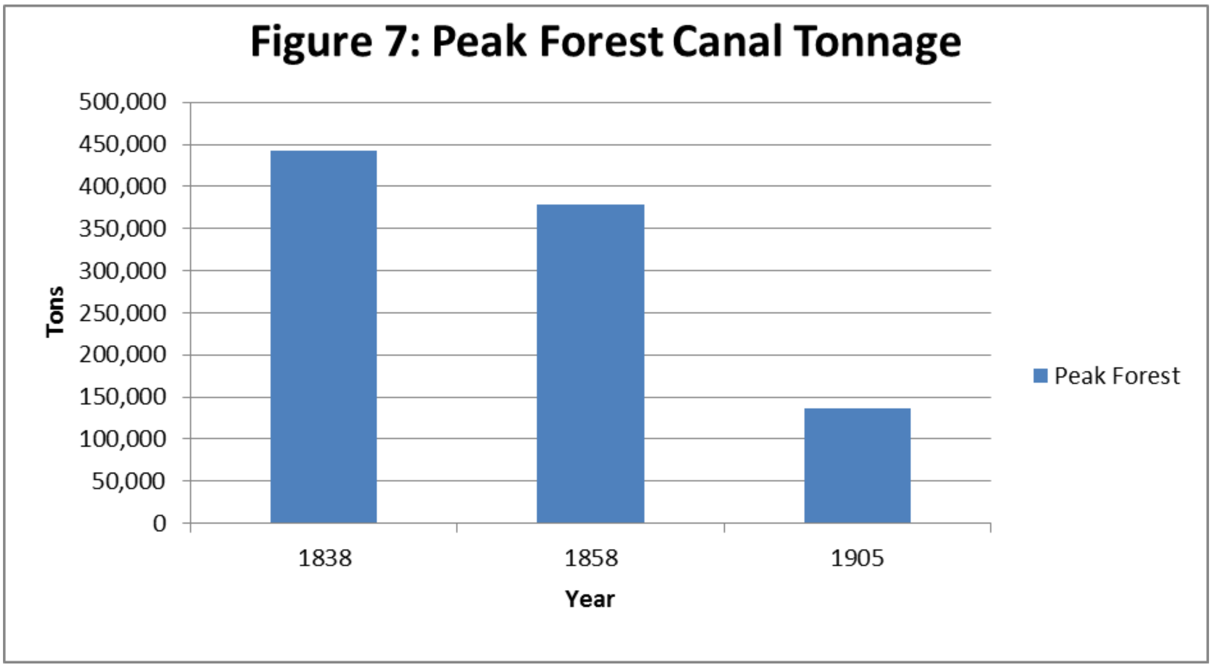


Figure 7: Peak Forest Canal Tonnage
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Tons
1838
1858
1905
Year
Peak Forest

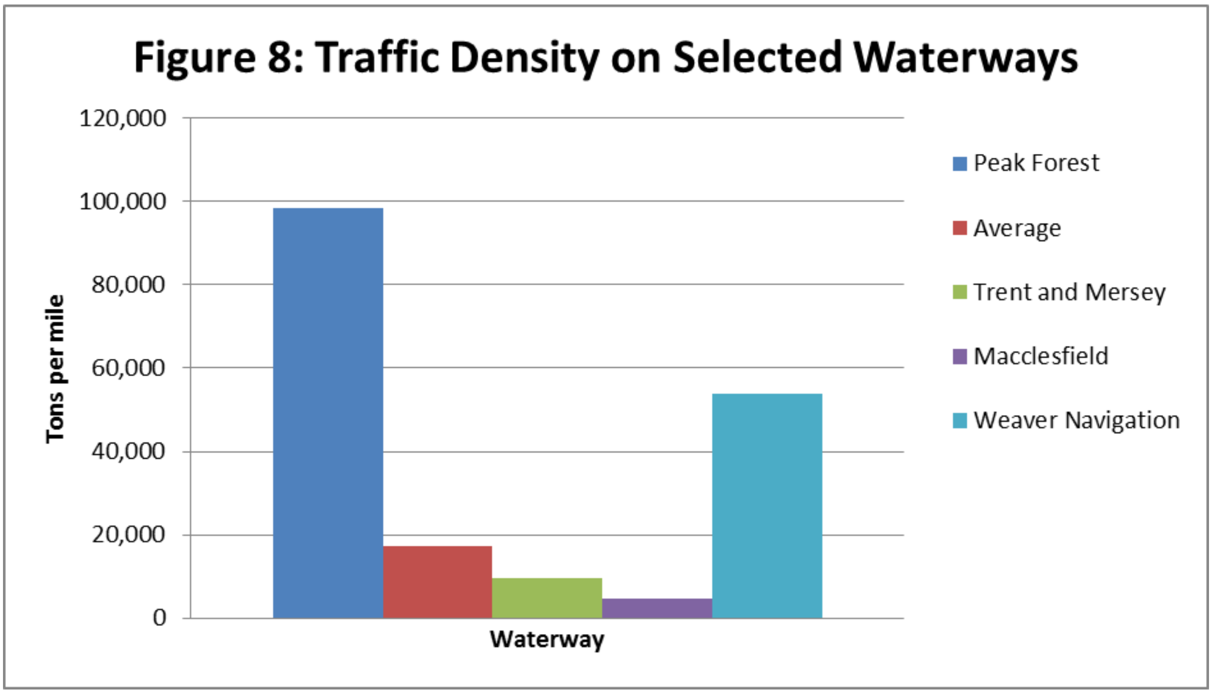


Figure 8: Traffic Density on Selected Waterways
120,000
100,000
80,000
60,000
40,000
20,000
0
Tons per mile
Waterway
Peak Forest
Average
Trent and Mersey
Macclesfield
Weaver Navigation

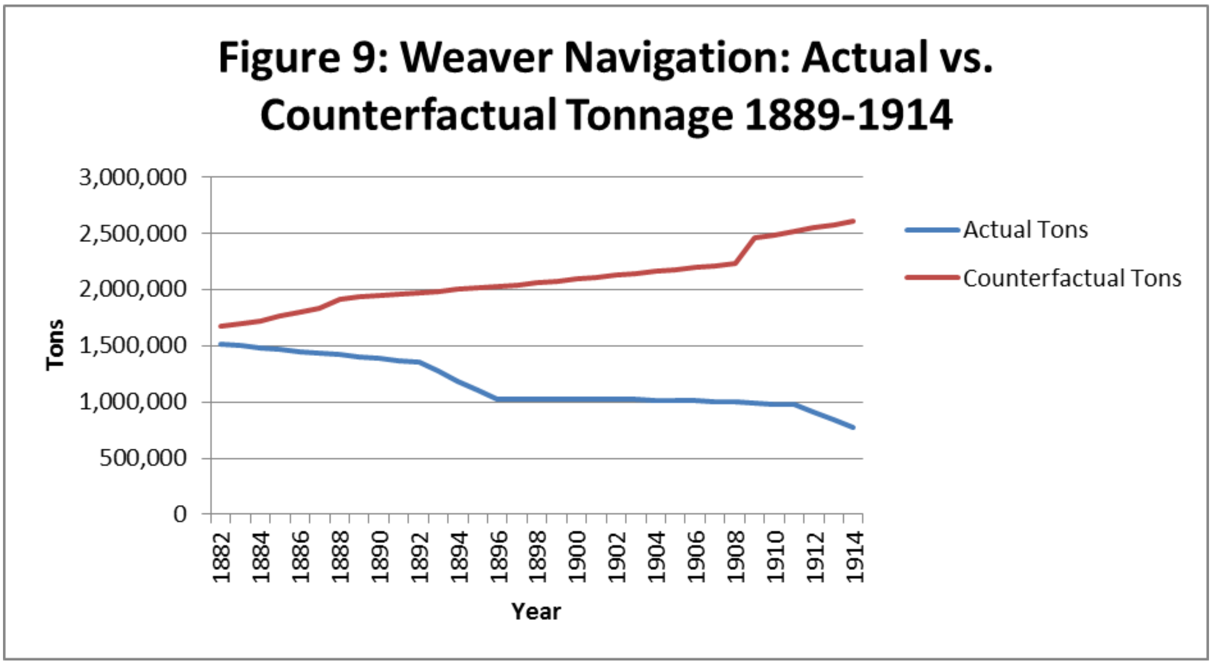


Figure 9: Weaver Navigation: Actual vs. Counterfactual Tonnage 1889-1914
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Tons
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908
1910
1912
1914
Year
Actual Tons
Counterfactual Tons

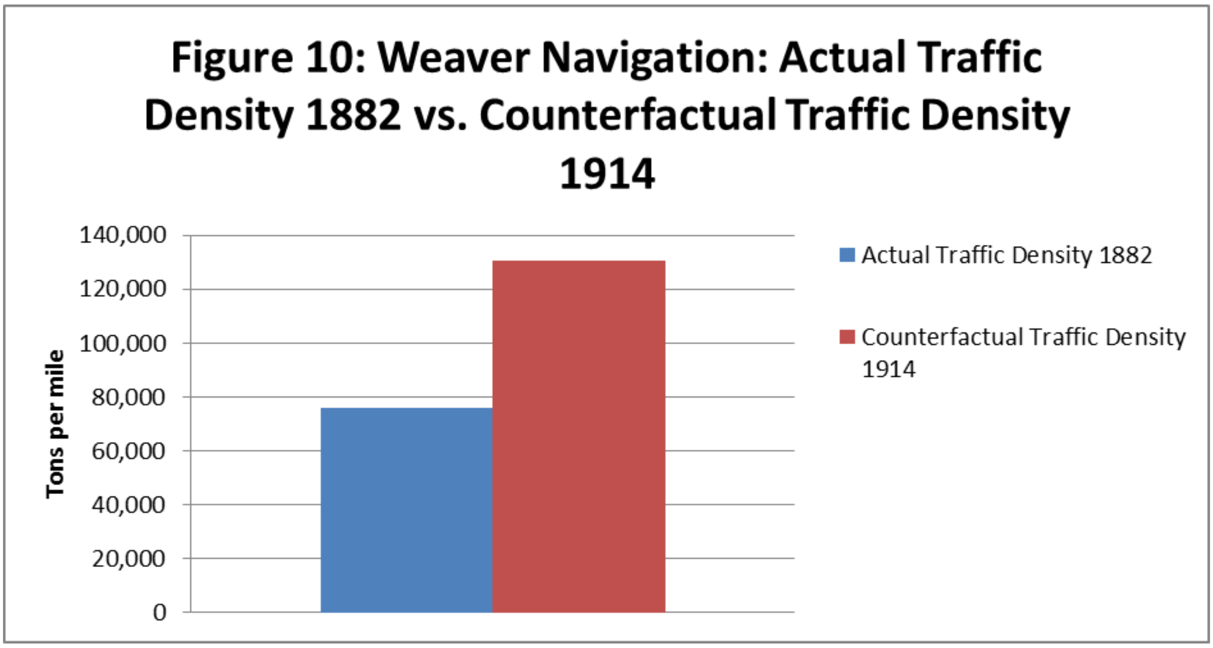


Figure 10: Weaver Navigation: Actual Traffic Density 1882 vs. Counterfactual Traffic Density 1914
Tons per mile
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Actual Traffic Density 1882
Counterfactual Traffic Density 1914

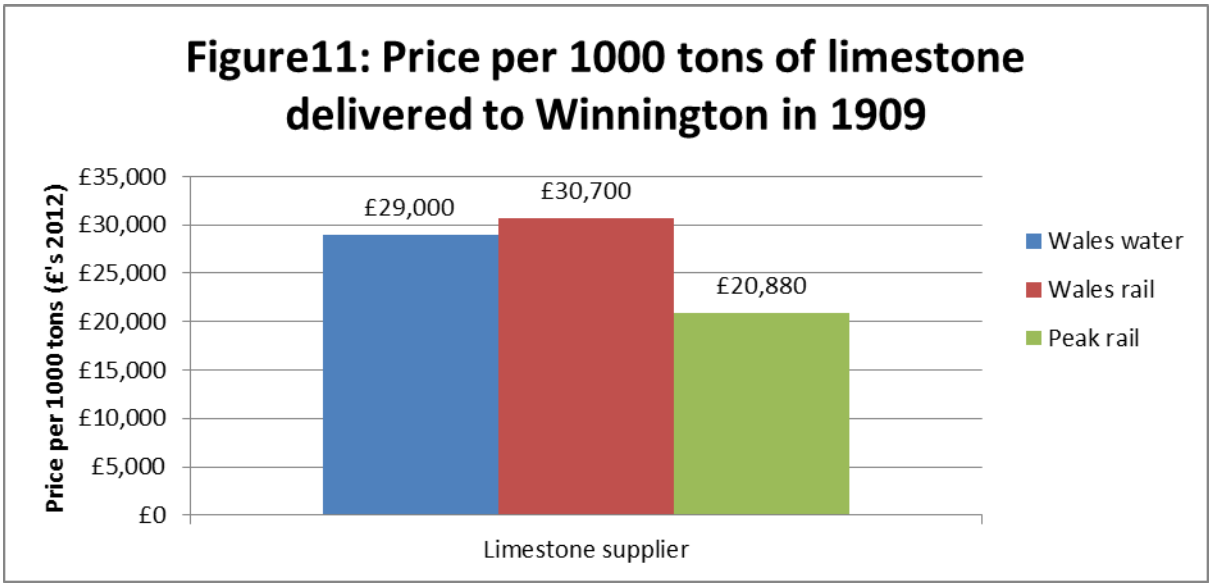


Figure11: Price per 1000 tons of limestone delivered to Winnington in 1909
Price per 1000 tons (£'s 2012)
£35,000
£30,000
£25,000
£20,000
£15,000
£10,000
£5,000
£0
£29,000
£30,700
£20,880
Limestone supplier
Wales water
Wales rail
Peak rail

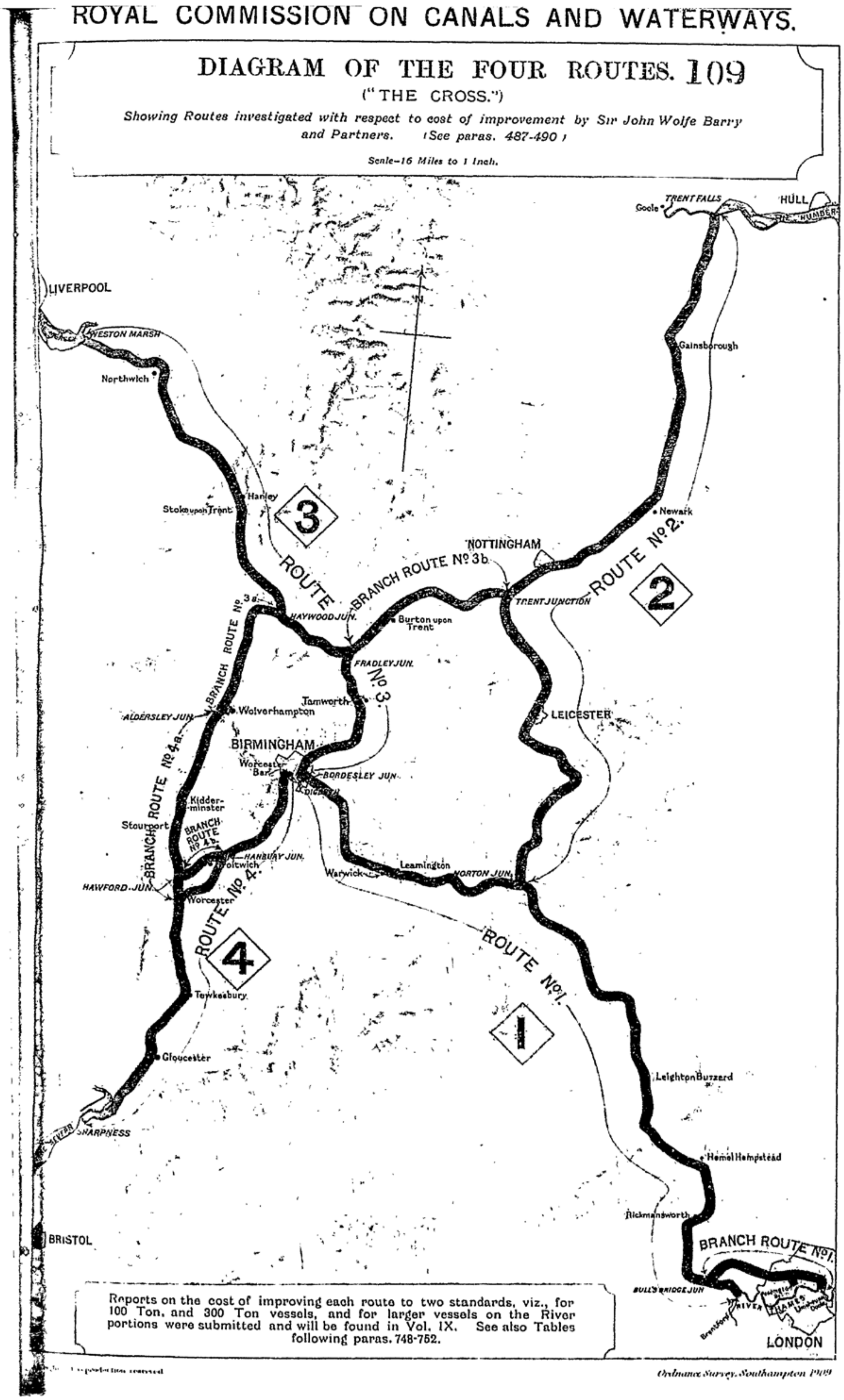


Figure 12 (Source: Royal Commission on Canals, p.95).

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