'The tortoise and the economy'

Inland waterway navigation in international economic history

Gerald Crompton University of Kent

This article examines the fluctuating economic significance of inland waterway transport (IWT) in what are now the developed economies of Europe and North America. It is essentially concerned with events since the beginnings of industrialisation, and gives a high priority to such countries as Britain, Germany and the United States, where IWT was clearly important during critical phases of national economic development. It should be noted briefly, however, that not only were rivers, as might be expected, of commercial value in many pre-industrial economies, but also the basic technology of the canal was known and used in several of them. So even the artificial element in IWT, the canal, cannot be regarded as either a result or a by-product of industrialisation, or as a factor which necessarily gave a strong stimulus to it. In the ancient world, canals were employed for both irrigation and transport, especially in the Egyptian and Roman empires. The most spectacular examples of pre-industrial waterway engineering occurred in China. The 'Magic Canal' in Guangxi in the third century BC was probably the first contour transport canal. The Grand Canal of China, itself a development of the earlier Pien Canal in Henan, was greatly extended from 581 to 617, and eventually attained a length of almost 1,750 km, which made it easily the longest canal in the world. It incorporated technical features such as sluice gates, flash locks, capstans, winches, pumps, slipways round weirs, and even a version of the pound lock with vertically rising gates.[1] There is, however, evidence of decline from the thirteenth century, and despite recent attempts to restore some sections it has remained of local importance only.

Even in Europe, numerous river improvements and less frequently canals made their appearance well before any credible date for industrialisation. The Exeter Canal of 1566, designed to bypass a tricky stretch of river, was probably Britain's first deadwater canal with pound locks. A more substantial sequence of events took place in seventeenth-century France, where two major watershed canals were constructed to link river basins across intervening higher ground. The canal de Briare of 1642, which featured lock staircases and a long feeder to take water to the summit, connected the Loire and the Seine and helped to victual Paris. The Languedoc, or Midi, canal of 1681,

with three large aqueducts and curved locks, similarly joined the Garonne and the Aude (and thereby the Atlantic and the Mediterranean).[2]

But the most distinctive and comprehensive pre-industrial development of IWT in Europe occurred in the Netherlands. Here, where geography was most favourable to this mode of transport, rivers had often been connected by canals in medieval times. By the seventeenth century the strong commercial expansion of the economy had facilitated both the demand and the financial means for further transport improvement. In the 1630s and 1640s four regional networks of inter-city canals were set up, based on Bruges, The Hague, Leiden and Delft. These cities provided the necessary finance. In a second phase, from the mid-1650s to the mid-1660s, the four systems were linked. Unusually, this waterway system was used mainly for passenger transport. The bigger rivers and the Zuider Zee were important for freight, with the latter acting as a traffic interchange, and carrying large quantities of peat.[3]

None of these initiatives alters the fact that it was mainly during the eighteenth and nineteenth centuries that the principal European economies experienced the greatest growth in IWT. Until then rivers were usually the only alternative to bad roads, and therefore, along with coastal shipping, the core of the transport system for all but the shortest journeys. Even so, rivers commonly suffered from a number of hazards, such as uncontrolled currents, flooding, shallows, weirs, water mills and fishing nets. As this implies, their use by navigators was contested by various owners of riparian rights. A major non-physical deterrent to trade, especially in Germany and other Continental countries, was the right of city authorities to levy tolls. River improvements were important responses to some of these problems and to the pressures generated by the growth of towns and industries.

In Britain about forty rivers were improved between 1660 and 1750, by when the total mileage of river navigation has been estimated at almost 1,400. Improvement schemes, dependent on legislation and the investment of local capital, public or private, were normally carried out by companies entitled 'navigations', which enjoyed the sole right to impose tolls. An example was the Mersey and Irwell Navigation of 1734, which connected inland Manchester with Liverpool and the sea via the two eponymous rivers. The widespread distribution of navigable rivers, natural or improved, meant that most of lowland England was already within about fifteen miles of water transport. But by the second quarter of the eighteenth century the limits of effective river transport may have been reached. By 1830, at the end of the canal-building era, the length of navigable waterway exceeded 4,000 miles.[4]

Assessments of the significance of IWT innovation have naturally varied. One judgement was that 'the technique of channelling and controlling a large volume of moving water was . . . the first major breakthrough in the industrial revolution, and the second was the natural sequel to it, that of providing artificial navigable channels which could be made available to any point required'.[5] Some have queried the radical credentials of canal, as opposed to river, transport. The leading historian of river navigations had argued in the 1930s that the Canal Age should be seen as the natural and

inevitable outcome of a long period of river improvement rather than as a fundamental break.[6]

Claims of continuity and interdependence, both within IWT and, to some extent, with other modes of transport, were often well founded. Early canals often linked rivers, or acted as tributaries and feeders. Both rivers and canals, of course, frequently relied on road carriage for the collection or delivery of loads. The economics of both, as channels of cheap bulk transport, were essentially the same. In an age of horse or wind power the average load of a single horse might be an eighth of a ton by pack, two tons by waggon (on macadam roads only), eight tons by iron rail, thirty tons by river boat and up to fifty tons by canal barge. On both rivers and canals, greater weight did no damage to the supporting medium. Hence both had the capacity to bring about huge savings in manpower and horsepower, at the expense, especially in the case of canals, of heavy preliminary outlays of capital. These could often be justified in the light of the ability of canals to reduce the cost of overland carriage 'by at least a half'.[7]

Turnbull and others have stressed the superiority of canal to river transport, and have insisted that the former was 'far more than a single step along a logical progression of waterway technology'. Canals confined water to a purpose-built channel, usually equipped with a towpath, escaped the standard limitations of the river, and could be navigated with equal facility in each direction. The construction of canals was free 'from the tyranny of natural hydrology' and could be planned to create the most useful possible artificial links. In principle, this meant that cheap water transport could be taken to suitable manufacturing sites, rather than vice versa.[8] Topography and the water table were, however, still major constraints in many areas, even in Britain. Most canals were necessarily either of the 'contour' type, which were relatively level but circuitous, or of the 'undulating' type, which took a more direct route but were subject to more complex engineering and lockage. One basic problem – ice in winter – was naturally more an affliction of deadwater navigation than of rivers.

It should be noted that those who favour the notion of transition rather than revolution when comparing rivers with canals also emphasise in comparison with all waterways the more radical transformation precipitated by the application of steam power to transport. The railways were responsible for 'a much more fundamental and far-reaching technological advance', defined in terms of reduced dependence on the weather and animal power and of increases in the speed and volume of trade. The canal was said to be 'anything but symbolic of the Industrial Age in its continued reliance on animal traction and in its use of a natural element, water, as basic medium'.[9] Flinn regarded all IWT as essentially a 'stopgap' between the horse and cart and the coming of the railways.[10] Freeman furthermore believed that the role of the roads, obviously also non-revolutionary, during the Canal Age had been underestimated, and argued that the value of canals in the cheap supply of raw materials was not matched by any equivalent capacity for marketing and distribution to dispersed consumers.[11] It is not clear, however, that

any of these considerations are incompatible with recognition of a major role for IWT in the earlier stages of industrialisation.

The main achievement of the canals was greatly to facilitate the carriage of high bulk/low dispersion commodities, especially on short hauls. They were exceptionally well suited to the movement of the indispensable fuel of the first industrial revolution, coal. Collecting coal from pits distributed over a small area, in contrast to grain grown over a much larger region, translated into heavy loads passing along a small number of routes, instead of the opposite. The best known quotation in canal history is the Duke of Bridgewater's remark that every canal 'must have coals at the heel of it'. Coal was the principal cargo on a high proportion of the more successful British canals. Its output increased roughly sixfold from 1750 to 1830, while the real price remained stable, or slightly declined. It attracted all the manufacturing activities that needed heat or power, with the result that the industrial revolution in Britain could largely be defined geographically as the map of the coalfields. Cheap coal and good transport were the most fundamental of the characteristics shared by the industrialising areas. The contribution of canals was particularly large and obvious in south Lancashire, the West Midlands and South Wales, but was important also in the west of Scotland, Shropshire and the Potteries. The North East relied on its endowment of natural waterways and on coastal shipping.[12]

The 'Canal Age' in Britain was begun by the Sankey, opened in 1757, and the Bridgewater, built by James Brindley for the third Duke from 1759 to 1761. These short links were responses to the shortage of coal in Liverpool and Manchester respectively. The first stage of the Bridgewater allowed coal from the duke's collieries at Worsley to be delivered to Manchester, less than ten miles away, at 4*d* per ton instead of 7*d*. The Sankey similarly created access to the growing port city of Liverpool for the southern part of the Lancashire coalfield. From 1774 the longer Leeds and Liverpool Canal facilitated a rapid increase in supplies from the central part of the same coalfield. The coal-based manufacturing of the area included copper, iron, glass, salt and sugar works, breweries, distilleries and potteries. By 1800 Liverpool was the third largest city in the country and functioned as the hub of an integrated economic system incorporating almost the whole Lancashire coalfield.[13]

The British industrial revolution was essentially a regional phenomenon, and regional concentration was an important causal factor. Pollard's regional approach to the interpretation of industrialisation recognised the importance not just of coal and transport infrastructure but also of other minerals, especially iron, of technological and other interactions among various industries, of local 'styles' of production and sources of capital. He compared the region to a system of walls in which new ideas reverberated and reinforced themselves instead of being spread ineffectively around the whole country.[14] In this context canals provided major intra-regional benefits at a limited number of places – the nodes and termini and corridors of space along their routes. The impact was felt primarily at regional level, though eventually the cost-reducing and market-widening effects were extended to the national

economy. Longer-term consequences included a changed balance of population and economic growth. Before the end of the Canal Age five of England's seven largest cities were located on inland coalfields. This transformation has been described as turning the economy 'outside-in'.[15]

The regional character of this economic impact puts in perspective the valid point that Britain lacked a national canal network until industrialisation was a well established process. It is true that the diverse and poorly co-ordinated system, including large sections of 'narrow', or 7 ft, canals in the Midlands, where the typical load was no more than twenty-five tons, was not conducive to long journeys. Nevertheless the contribution of canals was high in relation to the whole category of bulky low-value goods, including food and building materials, as well as industrial supplies. National rapid transit integration was the achievement of the railways, not of IWT, and did not come until the third quarter of the nineteenth century. Railways were not, however, responsible for the formation of any major new industrial regions.[16]

In reality the principal limitation of IWT was not its failure to cater for complex, long-distance journeys, for which demand was low, but rather the inherent disadvantages of low speed, little security and greater vulnerability than the roads to extremes of weather. Yet commercial success was not in doubt. Around £20 million was invested in canals and rivers from 1760 to 1830, which was mostly a rational response to the growth of trade. Although some – mainly rural – canals never justified their construction in terms of profit, it has been estimated that the ten most lucrative in 1825 were yielding over 27 per cent on average.[17] The key variables were the size of the burden of the original capital, the availability of suitable bulk mineral traffic and the number of years of pre-railway operation.

An attempt to calculate the social savings, as opposed to private profit, attributable to canals in 1800 concluded that it was smaller than that of the railways in 1865 (4 per cent of GDP for freight), though probably 'not dissimilar' in order of magnitude. On coal traffic alone the saving was between 1.4 per cent and 3.4 per cent of GDP, depending on length of haul.[18] Another economic analysis, based on systematic comparison of Britain and France, judged that Britain experienced the first industrial revolution because it had the best transport system in the world by the late eighteenth century. During that century France made considerably slower progress in improving both roads and IWT. It was emphasised that transport improvements were the most plausible reason for the widespread shift in demand curves facing producers at micro-economic level. The crucial British advantage on this view was neither technological nor geographical but institutional. Transport investment was allegedly over-centralised in France, whereas Britain relied to better effect on local initiative, privately sponsored legislation and arbitration of land prices.[19]

There is no question that State activity was more central in French than in British IWT. Even in the British case, however, it should be noted that public-sector initiative was not absent. It came from the merchant-dominated Liverpool Corporation (the Sankey), the Dublin parliament (the Newry) and

the Westminster parliament (several Scottish canals of military significance, plus cheap Exchequer Bill loan facilities).[20] The differences between France and Britain were sharpened just as the latter was nearing the end of its Canal Age. In 1821–22 France adopted the Becquey programme, which authorised ten new canals of a total length of 2,250 km and a cost of 126 million francs. This has been described as 'the first national program for an internal waterway network ever adopted in the Western world'. Despite the prevalence of economic liberalism and preference for private action, the Becquey canals were built by the State 'because only the State could afford them', especially as there was an obvious element of building ahead of demand. There was also clearly an element of emulation of British transport. The results were substantial, although the returns were generally regarded as disappointing. From 1820 to 1850 canal mileage quadrupled and 80 per cent of the additional 3,000 km was constructed by the State. The share of IWT in national freight traffic rose from 16 per cent in 1830 to 20 per cent in 1841–44 and to a peak of 24 per cent in 1845–54. This was despite higher expenditure on both roads and railways and the absence of tolls on roads. One effect of this transport investment was to widen differences between the north and east of the country and the south and west (on each side of a line from Havre to Paris to Lyon).[21]

Many nineteenth-century canals, in contrast to their predecessors, were designed to promote specific traffic flows, or to service a large city. By the early nineteenth century Paris was receiving about 25,000 boats a year, many through the canals of Saint-Denis and Saint-Martin. The canals de la Sensée (1820), d'Aire à la Bassée (1825) and de Saint-Quentin (1828) all strengthened the market links of the northern coalfields. The last of the three allowed coal barges access to the Oise and thence to the Seine and Paris, which gradually came to rely more on the coalfields of the north than of the centre. From 1838 the Sambre–Oise canal, with some difficulty, opened the Paris market to Belgian coal from the Charleroi basin. The French State remained active in IWT throughout the nineteenth century, making good use of the highly trained engineers of the Corps des ponts et chaussées, which gained a reputation for its monumental style. Some of the implications of a high level of State support became apparent after the onset of rail competition. Here French policy again deviated widely from the British model. £56 million was invested in waterways from 1830 to 1900.[22] This was motivated by the belief that all modes of transport should contribute to economic growth and that railways should be subject to some pressure to keep their rates low.

The Freycinet plan of 1879 set a target of an additional 2,000 km of canals, of which only about 400 km were actually built, and also promoted the long-term aim of standardisation and improvement. Almost half of French canals had achieved the desired dimensions by 1914. This suited the new standard barge, the 300 tonne *péniche*.[23] The only major new work was the canal de l'Est (Saône to Meuse), but total waterway tonnage increased by almost 60 per cent from 1885–94 to 1905–13. This consisted overwhelmingly of minerals and building materials, and was carried mainly in

areas of greatest regional density, the northern coalfields and the basin of the Seine and its tributaries. The lower Seine, between Paris and Rouen, where navigability had been 'disastrous' until the 1840s, benefited from a large-scale programme of improvements from 1879 to the early 1890s, including the raising of barrages and the enlargement of locks. It was here that steam towing, first known in 1820, expanded rapidly from the 1880s, to the point where ninety towboats were in use by 1912. Upstream trade consisted of coal, wood, wine and cereals; downstream, of building materials and agricultural products. Not only was the north-east of the country predominant in IWT, but within this segment the lower Seine was technically far more modern than the Paris–Nord links.[24] One reason for the relative backwardness of the latter was the continuing prevalence of the old artisan-owned wooden barges, which used either horses or electric haulage but which, after World War I, lost ground rapidly to motorised boats owned by navigation companies.[25]

France had a more troublesome hydrology than many of the advanced economies, requiring engineers to use 'far more sophisticated and expensive techniques to achieve far less'.[26] Many of the rivers were too wide and swift for barges but too winding and irregular for steamboats. State support for IWT was enough to keep many canals and rivers open to traffic but not to match the coherent building programme of the German government.[27]

IWT development in Germany came later than in France and followed a pattern even more different from the British. In 1850 there were only about 750 km of canals in the German states and double that length of navigable river, whereas by 1914 nearly 7,000 km of waterways were in regular use. The Rhine, with its supporting tributaries and canals, was the centrepiece of the system and Duisburg by far the biggest inland port. Its dominance was long-lasting, based on sending coal and receiving iron ore. The Rhine was proportionately even more dominant in 1914, when it claimed 60 per cent of national waterway traffic, than it had been in 1835, a trend that was closely related to the industrial development of the Ruhr. Geography was, on the whole, more favourable than in France, with several large navigable rivers flowing broadly from south-east to north-west. Many of the canals were cut east–west to connect river routes, often with high capacity and relatively few locks. An important example was the Dortmund–Ems canal of 1890, linking the Ruhr with the seaport of Emden in the north-west, carrying coal in one direction and grain and timber in the other. The 1,000 tonne Mittelland canal, built in stages from 1905, joined the Rhine and the Weser, and eventually reached the Elbe.[28]

The Berlin area came to enjoy an advantageous transport situation as the rivers Spree and Havel were reinforced by a number of linking canals. Some of these were of an earlier vintage, such as the Friedrich Wilhelm of 1669 (replaced by the Oder–Spree in the 1890s) and the Finow (modernised in the 1870s). Others, like the Ihle and the Hohenzollern, were added after 1900. The German capital became the waterway centre of a quadrilateral of cities: Hamburg, Magdeburg, Stettin and Breslau. Berlin functioned as the principal

market, Stettin and Hamburg as transshippers, and Breslau as a source of raw materials (coal and zinc).[29]

Steamboats were established on German waterways before the coming of the railways, and were organised by nearly sixty companies in 1850. Railway competition led to the decline of most of the smaller companies and of general freight and passenger services, and to the concentration of the survivors on towing barges loaded with coal, minerals and raw materials.[30]

The waterways plainly made a major contribution to German industrialisation, with traffic growing continually from the 1830s to 1914, apart from a slight dip in the late 1840s. Although a crisis attributable to railway competition can be detected in the 1850s and 1860s, water transport enjoyed a renaissance from the 1870s. The setback was fully overcome 'only in regions where the infrastructure was insufficiently modernised', which meant that the Rhine, the Elbe and, after some delay, the Oder emerged as the backbone of the modern system. Apart from the lower Rhine, a cluster of inland ports developed in the Rhine–Main area, where chemical firms received fuels and raw materials by barge.[31] Then 'between 1871 and 1918 Germany managed to build one of the – if not the – most extensive, technologically innovative, standardised and thus efficient inland waterway networks in the industrial world'.[32] In the decade 1895–1905 IWT expanded more rapidly than either coal production or rail transport. Government support was strong, especially in Prussia, where in 1905 a canal law encouraged further construction and produced, among others, the 1,500 tonne Rhine–Herne canal, connecting the Rhine and the Elbe.

The United States had some similar IWT assets to Germany's, but on a larger scale. These included the favourable geography of the eastern third of the national territory, with its long indented coastline and the 'vast dendritic drainage' of the Mississippi–Missouri–Ohio rivers and the Great Lakes.[33] Canals had an important auxiliary role here. The United States also shared with France and Germany the backing of government for water transport projects of economic significance. Four thousand miles of canals were built from 1815 to 1890, mainly in the first half of that period. In 1808 the Gallatin report had unsuccessfully attempted to establish a federal programme of integrated road and water transport. Public initiatives came, however, mainly at state or city level, and were frequently motivated by competitive considerations, as established business communities in the eastern states sought to acquire for themselves the best possible links with the Mid-west. The clear winner here was New York, where the state government under De Witt Clinton opened the Erie Canal (1825) to connect the Hudson river with the Great Lakes. This was spectacularly effective in the development of New York's hinterland, carrying cordwood, flour and wheat in one direction and manufactured goods and imported foods in the other. Within ten years the Erie had attracted over 3,000 boats and handled 1.3 million tons of cargo annually. Its example stimulated the efforts of 'growth coalitions' elsewhere, but no other single canal was so successful, and Pennsylvania's efforts to emulate New York in westward development achieved far less, even though its

waterway mileage was greater. Indeed, canal construction in the states of New York and Pennsylvania offers an extreme contrast in outcomes. The Erie and the Champlain (mainly lumber and timber) 'met conditions for success: they carried huge volumes of low-value bulky commodities to distant markets'. Pennsylvania 'faced the worst case'. 'State canals carried little traffic', had 'limited developmental impact' and 'incurred appalling financial losses that threatened the state's solvency'.[34] The canals of southern New England, the Middlesex, Blackstone and Farmington, also struggled financially and found it difficult to compete with waggons over shortish distances. Nevertheless, a number of short and relatively cheap canals in the north-east had some important effects. Anthracite coal, carried from the 1820s on the Lehigh, Schuylkill and Delaware and Hudson canals, gained access to Philadelphia and New York City, from where it could be passed on by coastal shipping to other east-coast markets.[35] This was a factor in the growing output and the location of several major industries in the 1830s and 1840s, a period associated with the beginnings of rapid industrialisation.[36] Although the cumulative impact on the national economy was considerable, America's waterways were 'divided into several distinct functioning parts' – namely the Atlantic coast and its tidal rivers, the New York canal system and the major western rivers.[37]

Public support for canals was firmly based on recognition of their widely diffused benefits. Government provided $115 million of the estimated $188 million invested in canals by 1861, and $62 million took the form of bonds bought by overseas bankers.[38] In this context 'little was heard of the argument that provision of transportation facilities was not a proper function of government'.[39] Of course, in the United States as elsewhere, these considerations led to some over-building. It has been argued that 1834, the end of the first major wave of construction, saw the completion of all the eastern canals which were subsequently heavily used. If investment had then ceased, and further expenditure been confined to improvements, 'the public and private sectors would have avoided huge losses'.[40] Canals were, nevertheless, responsible for a larger reduction in the cost of inland transport than the railways, although economic growth would have been significantly slower from the mid-nineteenth century onwards in the absence of railways. This was to a greater extent true of the United States than of any of the European economies. The development of the vast areas west of the Mississippi, and their integration into the national economy, would have been almost inconceivably difficult had dependence on IWT and the horse and cart been protracted. Few are disposed to accept Fogel's finding that the social savings attributable to the railways in 1890 were as modest as 5 per cent.[41] A distinctive feature of American IWT was the early and large-scale employment of steamboats on inland rivers and lakes. After a demonstration on the Hudson in 1807, and a first successful ascent of the Mississippi in 1816, the major expansion occurred in the Mid-west. By 1840 more than 500 steamboats served the Ohio–Mississippi system, carrying both passengers and downstream primary produce. Less effort than in continental Europe, though more

than in Britain, was made to sustain the waterway system once it had been successfully challenged by the railways. An approximate parallel with French practice was that the army's Corps of Engineers made a major contribution.[42]

It had for long been an important aspect of IWT that, in strengthening communications between seaports and their hinterlands (Liverpool, New York, New Orleans), it had played a key role in stimulating both coastal and international trade. Usually, of course, this involved transhipment of goods from barge or steamboat to seagoing ships and vice versa. Some later developments eroded the distinction between internal and external water transport. The construction of a number of isthmian ship canals in the late nineteenth and early twentieth centuries did much to raise the profile of canal transport and to secure a place for it in the modern world economy. The first, and ultimately the most important, was the Suez, opened after ten years' work in 1869 by a French company which five years later became Anglo-French. At 164 km this became, and remains, the longest lockless canal, connecting Port Said with Suez. This strategic location linked the Atlantic and the Mediterranean with the Red Sea and the Indian Ocean. The obvious advantage envisaged by the promoters was in facilitating trade between West European ports and the East, especially India. The distance between Tokyo and Rotterdam was thereby shortened by 23 per cent, or, in a more extreme instance, the journey between a Red Sea and a Black Sea port was reduced by 86 per cent. The Suez originally had a bottom width of 22 m, but was widened and deepened on many occasions, and by the end of the twentieth century could accommodate vessels of 500 m in length, 70 m width and a draught of 70 ft. Before 1914 the canal captured an estimated 6.4 per cent of world seaborne trade, specialising in the primary produce of India and the Far East: jute, soya, rubber, manganese, oilseed.[43] Annual cargo tonnage first exceeded 30 million in 1928, shortly before the trade setbacks of the 1930s. It was the post-war rise of oil in the Middle East and in the world economy which raised the importance of the canal to its greatest heights. By the mid-1950s Suez carried around 13 per cent of world trade and nearly half the oil imports of Western Europe. About half of various commodities entering world trade, such as tin, tea, copra and rubber, also travelled via Suez. The canal commanded a mixture of cheap bulk oil, expensive raw materials and manufactures.[44] By the end of the century net cargo amounted to well over 600 million tons annually, and comprised about 14 per cent of world trade, 26 per cent of oil exports and over 40 per cent of the trade of the Arab Gulf ports. Many of the improvements to the canal were carried out under the auspices of the Egyptian government, which nationalised the enterprise in 1956, twelve years before the Anglo-French concession was due to expire. Contrary to the expectations of some critics in France and the United Kingdom, the company continued to be efficiently managed, to contribute substantially to national revenue and, perhaps ironically, to serve 'as a great spearhead of westernisation in Egypt'.[45]

The Panama Canal was built between 1904 and 1914 at a cost of nearly $400 million by the US government, which also obtained long-term control

(until 1979) over a ten-mile wide canal zone. It was necessarily a lock canal, as the isthmus reaches a height of 26 m above sea level, providing an 80 km link between deep water in the Atlantic and Pacific Oceans. From the beginning it was wide enough to allow two-way traffic. Following various improvements such as the widening of the Gaillard Cut in 1969, the canal now has a minimum bottom width of 152 m. The project owed much to the security concerns of the US government, whose defence department ran the canal on a break-even basis, and saw its main purpose as allowing warships swift passage between the two oceans. That is why it was originally described as 'a continental and naval canal rather than a global and commercial canal'.[46] But it was also 'an American success'[47] in commercial terms too, even if 'its trade was more inter-coastal than inter-oceanic'.[48] By the late 1930s nearly a quarter of the canal's trade was between two US ports and almost 40 per cent was either to or from a US port. Subsequently the impact of the canal on international trade patterns became more complex. The two main traffic flows have been between the east coast of the United States and the Far East, and between Europe and the west coast of the United States and Canada. The route for a coal carrier from the US east coast to Japan is around 4,800 km shorter than the nearest alternative. A ship carrying bananas from Ecuador to Europe saves about 8,000 km. The canal was transferred from US to Panamanian state ownership at the end of 1999, when total annual cargo amounted to nearly 300 million tons. The new company represents nearly 10 per cent of GDP and generates over $200 million a year for the government, out of a toll revenue of nearly $600 million. The analogy of China and Hong Kong has been invoked to describe the hand-over – of 'one country, two systems'. The implication is that 'Panama is a Third World country, while the canal remains a First World operation'.[49]

The Kiel Canal, in contrast, was very much in a First World location, but its origins shared a similar military motivation with the Panama. Originally known as the Kaiser Wilhelm Canal (later as the Nord-Ostsee Kanal in Germany), it provided a 97 km link, with four locks, between the Elbe at Brunsbuttel and the Baltic near Kiel. The scheme was completed in 1895 after eight years' work at a cost of 157 million marks by the imperial German government, which sought a facility for its navy to move between Baltic bases and the open sea without using international waters. Operators of commercial vessels also appreciated the saving of roughly 280 nautical miles, as compared with routes around the Jutland peninsula. The canal underwent the first of its widenings between 1907 and 1914, and eventually attained a size of 12 m depth and 164 m width. It plausibly claims to be the busiest artificial waterway in the world, handling over 60,000 ships a year. A two-way traffic system is operated, with the aid of a computer-assisted control system from the late 1990s.[50]

In the same period a number of non-isthmian ship canals were constructed specifically for the promotion of international trade. Prominent in this context was the Manchester Ship Canal (MSC), which was built between 1887 and 1894 on the same scale as Suez, to improve access to Manchester from

the Irish Sea, and to strengthen the connections of the Lancashire textile industry with its distant overseas markets. A prompt and powerful stimulus saw the value of Manchester's trade rise from £2.8 million in 1894 to £30.4 million by 1907. The MSC was thirty-six miles (57 km) long, with five large locks, from the Mersey estuary to almost the centre of Manchester. A unique feature of its construction was the Barton swing aqueduct, which carried the historic Bridgewater Canal over the new ship canal. Conceived as a private venture, the company had to be rescued by municipal intervention. The motive for this was clear enough, as the MSC was instrumental in making inland Manchester, from the late nineteenth century until at least the 1960s, the fourth most important port in the United Kingdom, handling usually between 4 per cent and 7 per cent of the country's imports. A strong connection was soon established with Montreal on the St Lawrence, but the MSC's links were widely dispersed. Principal imports were grain, timber, fruit, meat and raw cotton (from both Egypt and the United States). Exports included manufactured textiles, machinery, coal and salt. An oil dock at Stanlow, opened in the early 1920s, soon became second only to London as a centre for the import and distribution of oil products. The presence of the MSC was indispensable to the development of the Trafford Park industrial estate, and the two ventures had directors in common.[51]

There was also significant development of ship canals in the Low Countries. Between 1895 and 1907 a 10 km canal was completed from Bruges to a large new harbour at Zeebrugge. A notable technical feature was the use of electrically operated caissons on the sea lock. The Ghent–Terneuzen ship canal was greatly improved in several stages between the 1870s and 1910 and, along with a large new dock at Ghent, boosted the position of the latter city as an inland port. In the Netherlands the North Sea Canal from Ijmuiden to Amsterdam was opened in 1876 and the New Waterway from Hook of Holland to Rotterdam in 1872.[52]

For most of the post-war period IWT continued to lose its share of the European transport market, especially of course to the roads. Although its infrastructure was often neglected, awareness was never completely lost of the importance of the natural asset of the dense network of rivers and canals joining the basins of the major rivers emptying into Atlantic and the North Sea. These were the Seine, Rhine, Meuse, Scheldt, Elbe and Oder. From 1992 the Rhine–Main–Danube extended the network to include the Danube basin, at a substantial cost of DM 27.5 million per kilometre over 171 km (RMD website). Elsewhere in the European Union, micro-systems such as those of the Rhone, Po, Douro or the Saima canal in Finland enjoyed some regional significance, but were isolated from the principal north-west European network. In the six member countries, which include Luxembourg, with direct access to the main system, IWT still carried around 9 per cent of goods traffic at the end of the century. In the fifteen States of the Union the corresponding figure was 6.8 per cent in 1999, having declined from 11.9 per cent in 1970. Over this period the length of navigable waterways in use fell from 32,300 km to 29,500 km. In the six favoured States the modal share of IWT

varied between 2 per cent (France) and 41 per cent (Netherlands) and the other nine between nil (several) and 0.8 per cent (Finland). A process of retreat and intra-modal concentration meant that a limited number of major traffic flows became more dominant. These were the Rhine axis, the north–south route linking the Low Countries and France, the east–west axis linking north Germany with the Dutch and Belgian ports in the west and the Elbe and Oder to the east, and the south-east axis based on the Danube.[53] The latter has proved to be a major disappointment, as Danube traffic peaked at 91 million tonnes in Comecon days in 1987 before falling to just 30 million tonnes by 1998, which was prior to the damage inflicted by the Kosovo war. About 7 per cent of the Danube's capacity was in use five years later.[54]

Until the early 1990s it was largely taken for granted that the record of the IWT sector was one of 'relatively poor performance'.[55] There were even suggestions that it was 'in deep crisis',[56] and on one occasion the acting EU Commissioner of Transport defined it as 'a forgotten means of transport'.[57] Against this it could be urged that there has been some recent stabilisation, some success in limited areas, and increases in absolute volume – roughly from a base of 100 in 1970 to about 120 by the end of the century – though not in market share. It could also be argued that IWT had generally performed better than the railways in retaining its share of the freight market. It has commonly been assumed that throughout the post-war period IWT suffered more or less inevitably from a 'structural' effect related to the nature of economic development, which meant that its traditional markets, raw materials and the products of first-stage processing, were in decline. In Germany it has been estimated that 60 per cent of IWT losses were attributable to this effect, and the remaining 40 per cent to lack of competitiveness.[58] There has undoubtedly been a change in the balance of opinion in favour of IWT, with evidence of more sympathetic attitudes at governmental and EU level, though not necessarily of effective assistance.

A convenient starting point for the recent inter-modal debate is the definition by a German authority in the early 1970s which drew attention to the emergent economic characteristics of IWT. It was seen as a mode which combined high mass transport capacity with low operating costs, average predictability and good traffic safety. The principal shortcomings were perceived as very limited speed, network development potential and frequency of service.[59] The renewed effectiveness of IWT naturally owed much to the long-standing factor of low cost, to the economy with which goods could be carried once they had been loaded. The introduction of larger barges, a major trend of the last few decades, has usually implied significant gains in labour productivity. The generally high level of safety was another traditional advantage of the mode. This consideration became more relevant to both shippers and policy makers as IWT demonstrated its suitability for carrying hazardous products, especially chemicals. Flammable liquids and compressed or liquified gases have provided a growth market for IWT. Dangerous goods of all categories now account for almost a quarter of waterway freight in Germany. Modern technologies have enhanced some of these established

safety characteristics of IWT. The use of double-skinned hulls has virtually eliminated the risk of pollution, and container barges on the Rhine and elsewhere employ special computer software to ensure that boats remain stable.[60]

In current transport circumstances, several other virtues of IWT have become apparent, especially in relation to other modes, and to roads in particular. It is, of course, the very success of road transport which has eventually aroused greater awareness of various externalities, including the costs of congestion and other nuisances. In the mid-1990s the EU Green Paper *Towards Fair and Efficient Pricing in Transport* estimated the cost of road congestion at 2 per cent of GDP. Not surprisingly, waterways, which were often natural features, made much lighter demands on land use than either railways or roads. (In Germany, for a given volume of traffic, road required 290,000 ha, rail 84,000 ha and IWT 30,000 ha.) Furthermore, unlike roads, they did not encourage virtually uncontrolled urban development. In terms of air pollution, IWT in Germany produced emissions of CO_2 roughly equivalent to rail but five times less CO_2 and CH_4 than road and twenty-eight times less than air transport. IWT was also rated higher than other modes for its record on noise pollution. It has been calculated that the transfer of freight from road to water would reduce nuisance levels to those living near by by 65 per cent to 90 per cent.[61] The primary energy costs of IWT were well below those of other transport sectors. Expressed in terms of the distance travelled on the basis of using 5 l of fuel per tonne, a barge would move a given load 500 km, as against 330 km by rail, 100 km by road and 6.6 km by air.[62] Overall, it appears that IWT generates the lowest external costs of all transport modes. Studies in Germany relating to the mid-1980s (since when the advantage of IWT has increased) suggest that if external social costs are translated into a tonne per kilometre basis, and if water costs are expressed as 1, then the corresponding figure for rail is 4.2 and for road 18.9.[63]

Although it is realistic to claim that awareness of the environmental advantages of IWT has grown on a broad front, it is necessary to recognise that this change in sentiment does not translate automatically into increased use. The essential decision rests with the shippers of the relevant goods. It has been plausibly argued that 'the shipper, as an economic actor, is more or less insensitive to the natural, non-commercial benefits of transportation, such as low macro-economic cost, modest power consumption, beneficial impacts on seaport attractiveness or environmental impact'.[64] What matters to the shipper is, of course, some combination of cost and standard and reliability of service. Survey evidence of the opinions both of firms using transport services and of transport experts strongly suggests that the factor described as 'deserving support for policy reasons' was a very weak determinant of choice.[65] This obviously implies that IWT is likely to benefit in practice from its environmentally friendly character only via public policy. Whilst this has undoubtedly become more favourable, there are some inhibiting factors. These include the fragmented structure of the operators and their low level of inter-firm organisation. Accordingly they lack lobbying capacity. The relatively small numbers employed in the sector, as compared with road or rail,

also weaken its voice; an estimated 37,500 in 10,700 enterprises in the fifteen EU States in 1995, as against 5.7 million in all forms of transport.[66] The numbers remained low, even after allowing for approximately 10,000 owner-operators with between one and three vessels. An additional handicap, in the view of many, is the unattractive and old-fashioned image of the waterways, which may have persisted in part because of poor marketing and promotion of services by operators.

The relative slowness of IWT had been a modal weakness ever since other forms of transport acquired the ability to move goods faster than walking speed. It was a limiting factor which clearly excluded IWT altogether from the freight market for certain types of goods, most obviously perishables, and which imposed a serious handicap in the case of higher value/lower bulk commodities. But within the framework of existing IWT markets, speed has become, on balance, a less salient factor than in the past. This is attributable in part to the increased average length of haul, especially on international journeys. In the extreme case, where IWT handled goods which also made long sea voyages, low inland speed was of little relevance. Furthermore when IWT was supplying materials to firms which had carefully programmed regular supply schedules, sometimes based on the 'just in time' principle, what was crucial was not speed but predictability.[67]

Within the European Union IWT came to be regarded as 'a greatly underused option'.[68] An official objective was 'to build up a network of consistent, interoperable and economically and ecologically sound inland waterways on the basis of existing waterways which will enable these to be used to an optimum extent as a cheap, safe and environmentally friendly mode of transport'.[69] There was a perception that the fulfilment of the comprehensive wish list was dependent on increased efficiency and profitability, which were considered essential to induce shippers to switch traffic away from overcrowded roads. The belief 'that it is in fact vital to make river transport a profitable option' lay behind a number of measures from the 1990s. An attempt to make the market work involved measures of liberalisation and harmonisation and an attack on overcapacity in the sector. This was calculated in the early 1990s to be around 15 per cent by the EU Commission, which sought a solution through a scrapping programme.[70]

Fleet obsolescence had long been considered a problem, especially in France and Belgium, and was particularly associated with owner-operators. The relatively long life of their craft was thought to have encouraged subsistence policies, with neglect of depreciation, and living on capital.[71] Financial aid for scrapping, which had previously been practised on a national basis, was expected to achieve several desirable objectives. One was to persuade small owners to accept compensation to leave the industry. A new scrapping initiative to this effect cost €129 million between 1996 and 1998 for the industry, member States and European Union, and was claimed to have reduced capacity by about 15 per cent.[72] An 'old for new' scheme which was in force from 1989 to 2003 required operators who increased their capacity by introducing new vessels to either scrap a proportion of their old tonnage

or to pay a fine. Entry to the industry was regulated through a series of directives harmonising conditions for obtaining boatmasters' certificates. Not surprisingly, it proved difficult to combine through such measures the desired combination of capacity reduction, modernisation and social justice.[73]

The problems of the roster system and price fixing were also targets of the EU liberalisation strategy. The roster, or 'chartering by rotation', or 'alternating turn', system had long been prevalent on some trade routes in France and the Low Countries. It meant essentially that charges were fixed by national authorities and barge operators took their turn in loading consignments, rather like taxis in a rank. This was increasingly criticised as a crude system which encouraged the maintenance of excess capacity, prevented any vessel from obtaining optimal utilisation of either tonnage or time and constrained the development of own-account transport.[74] It also prevented shippers from establishing desirable long-term relations of trust with particular operators. Under an EU directive of 1996 (96/75) the rotation system was abolished and the market declared 'completely free' from the beginning of 2000. Belgium and the Netherlands had anticipated this by liberalising their markets from late 1998.[75]

These policies have not all been successful or consistent with each other. Scrapping was less effective than expected in reducing capacity and therefore in encouraging a rise in charges, which had been quite stable. An increase had been thought essential to raise profits and facilitate self-sustaining modernisation.[76] It now seems more likely that making the market work will imply lower prices, which might attract more traffic, and which will require higher productivity and lower costs. From 2003 the 'old for new' scheme was suspended and new vessels could be introduced at will. One of the last exceptions in EU regulations to the general strategy of freeing the market was that member States were allowed to pay subsidies of up to half the cost of investment in IWT terminals and loading equipment.[77] Even here, the underlying EU position was that 'public authorities should not interfere with decisions on the siting of ports and logistical centres', as 'this type of investment should remain in the hands of the private sector, which is in a better position to decide whether multimodal facilities . . . should be set up'.[78]

This indirect encouragement of investment in terminals was founded on appreciation of some existing major successes of IWT and also of a serious limitation. The latter was the relatively high cost of transhipment, which could be lowered only by investment in equipment and by the cultivation of improved long-term relations between shippers and operators. The former was the flourishing condition of container transport on the Rhine, which depended on container terminals. Between the late 1970s and the early 1990s these grew to thirty-two in number. Over the same period the share of IWT in the container flow (which itself doubled) between Rotterdam and Germany expanded from 5 per cent to almost 35 per cent. Frequent regular services were established to connect the terminals in the hinterland with seaport terminals in Amsterdam, Rotterdam and Antwerp. Most of this traffic was in the hands of about a dozen barge operators using around sixty ships,

including motor vessel/push-barge combinations with a capacity of up to 350 TEU (20 ft equivalent units). Operations were inter-modal, as road or rail was usually necessary to reach final destinations. This container traffic included some relatively high-value electronic and chemical products, machine parts and foodstuffs.[79]

Recent trends in IWT in the United States show many parallels with Europe. Geographical concentration on the broadest, high-capacity waterways and the restriction of traffic to large-scale bulk commodities were even more pronounced characteristics of the American system. By the end of the twentieth century only a handful of canals survived, if a canal was defined as a complete and strictly artificial waterway. These included the Erie in its later incarnation as the New York Barge Canal. But if artificial waterways linking natural waterways, such as the connections between the east and west coasts of Florida, were added, and also, most important, canalised river navigations, the United States still had more than 6,000 miles of canal-type waterways. But the total navigable IWT mileage was almost 26,000, of which perhaps 12,000 were commercially significant, serving a hinterland population of 80 million people, and carrying at least 660 million short tons annually. The core of the system was the Great Lakes, the Atlantic and Gulf Intercoastal Waterways, and the river basins of the Mississippi–Missouri, the Ohio, Illinois, Arkansas and Tennessee. Its central claim to continuing value to the national economy was the 15 per cent share of freight ton mileage, and only 5 per cent share of the annual freight bill. IWT allegedly saved $7 million per million tons shipped. Important commodities included iron ore for the steel industry, coal for energy production, petroleum, fertiliser, chemicals, grain and feedstock. A recent document summarising its principal modal advantages unsurprisingly mentioned moderate capital cost, low operating cost, good environmental hospitality and suitability for bulk cargoes whether dry or liquid. Observers in most other countries might, however, have been taken aback by the figure of 1,500 tons as the minimum shipment size.[80]

Distinctive methods have been adopted for handling large consignments. A linehaul canal tow consisted of three to five barges, with a 1,400 h.p. to 1,900 h.p. towboat. Linehaul river tows were much longer, with typically ten to twenty-five barges and a 3,000 h.p. to 5,600 h.p. towboat. It resembled a railway freight train in that it could pick up and drop off barges as it made its way up or down stream. The American market generated not just large line-haul tows but also some giant operating companies. One alone, specialising in liquid chemicals, owned over 850 inland tank barges and over 200 towing vessels.[81] Another, after a series of mergers, controlled over 160 boats and over 4,000 barges.[82] Complex information and computer systems were used to co-ordinate the movement of company fleets and to assist the navigation of individual towboats. The latter included electronic charting, using differential global positioning systems and radar integration technology.[83] One particularly flourishing area of the American IWT system was the Great Lakes, with its sixteen US ports. Between 1991 and 2000 tonnage expanded from 123.8 million to 192 million (of which 8.8 million was international

cargo moving to or from the St Lawrence Seaway). The principal commodities were iron ore and steel, coal, grain, cement, stone and aggregates and salt. The Lakes IWT system was estimated to provide $1.2 billion of cost saving to the relevant industries and to be responsible wholly or in part for 152,000 jobs.[84]

The success of IWT in the Great Lakes was not matched farther east, in the rest of the St Lawrence Seaway route, which experienced decline after 1980. The Seaway, which was eventually realised between 1954 and 1959, after a belated agreement by the US and Canadian governments, had a lengthy prehistory. The potential of a deep-draught waterway from Thunder Bay at the head of Lake Superior to Montreal on the St Lawrence estuary had been apparent in the nineteenth century. The distance was around 3,700 km and there were many obstacles apart from political difficulties. The short connection from Lake Erie to Lake Ontario required four Welland Canals between 1829 and 1933, and the fourth needed a by-pass in 1973. The difference in height was 100 m, and the modern canal featured the longest lock in the world at Port Colborne. At the peak of its success in the 1960s and 1970s the Seaway handled more than half of Canada's grain exports and also enjoyed a large trade in iron and coal. In 1983 the seaway carried its billionth tonne of cargo. The fading of its prosperity in the 1980s and 1990s was due to a combination of factors: the loss of grain exports to west-coast ports, aided by rail subsidies, inability to accommodate the increased size of container ships used on transatlantic routes, falling demand for grain in Europe, the raising of tolls because of financial pressures, and more effective competition from ice-free or toll-free Atlantic or Gulf of Mexico ports.[85]

It is apparent that IWT is no longer of any commercial consequence in the country where it once had a major energising impact. Its decline in Britain has been the result of the increasingly inadequate size and excessive lockage of the once effective waterways. A major contributory factor has been the unsympathetic attitude of government, which was indifferent to the subordination of IWT to the interests of the railways. In France, where the State was far more benign and active, IWT continued to make a substantial contribution for much longer, but decline to minor status was rapid after World War II as most of the network became outdated. Germany, the Netherlands and the United States provided the best modern examples of commercial success and technical best practice, based mainly on large rivers. In both Germany and the United States, although populous and economically important regions were served, the direct benefits were confined to a minority of the national territory. On the other hand, IWT impacts have become more dispersed from the originating source of goods as length of haul has increased, and the stimulus to international trade has become stronger.

In the age of wind and horse power it had not been difficult for IWT to be competitive. A horse could pull far larger loads by barge along the towpath of a deadwater canal than it could haul by cart on mainly poor roads. But in the age of the steam and internal combustion engines, when road and rail had boosted their speed and capacity, IWT seemed condemned to be the tortoise

of the transport world. The broad effect of this disadvantage was, of course, to intensify the original characteristics of the mode and to confine it more rigidly to the carriage of non-perishable, low-value goods whose journey time was not crucial. The search for economies of scale meant concentration on a smaller network of higher-quality routes, mostly rivers or high-capacity, low-lockage canals.

The other response was to bring technology to bear on operations from which it had previously been virtually absent. The introduction of steamboats from the early nineteenth century was an important stage in the evolution of IWT vessels from the small barge to the massive, high-powered towed or self-propelled multiple unit of today. Technology has now been applied from advanced areas of the modern economy, as computers are used in loading, balancing, navigation and logistical planning. Despite generally modest market shares, there has been some upgrading of the types of freight carried. Freight is no longer confined to primary minerals, building materials and raw foodstuffs but includes more processed and manufactured goods, such as chemicals. Some modal characteristics have proved persistent. Backward linkages have been limited, especially by comparison with railways. Both the numbers employed in the sector and the average size of firm have remained low, with constraining consequences for investment, management development and political lobbying.

The fortunes of IWT have been more dependent on State support than those of other transport modes, even the railways, where intervention often occurred at a somewhat later stage in the growth of national systems. This had much to do with the fact that canals, in particular, had high initial capital costs, even though they were cheap to operate. The only significant exception is Britain, where the State was relatively and consistently inactive both during the creation of the network and in its premature decline. The United States emphatically did not conform to the British model, as public authorities, mainly at state and local level, were much involved in the promotion of the system before the Civil War, and in recent decades have been much involved, at federal level, in infrastructural improvement. The governments of France (from the early nineteenth century) and Germany (from a few decades later) could probably claim to have made the greatest policy contribution to IWT and to national transport development. The latter was probably ultimately more successful. Since 1945 national governments in Europe have periodically shown awareness of the need for practical assistance. The European Commission, however, over the past thirty years has promoted a much more market-oriented approach. A 1973 memorandum set out its policy goal as 'the development of a common transport market based on the principle of the free play of market forces subject to correction only in exceptional circumstances'.[86] EC strategy since then, although favourable to mobility, has inevitably done little to challenge the dominance of roads or to promote more environmentally friendly alternatives. The IWT sector has been congratulated for its modal virtues, but has been offered little more than advocacy of greater efficiency by operators and market

liberalisation. It has not flourished in such circumstances in the past, and is unlikely to do so in the future.

Notes

1 J. N. Jackson, *The Welland Canals and their Communities: Engineering, Industrial and Urban Transformation* (Buffalo NY, 1997), Introduction.
2 S. P. Ville, *Transport and the Development of the European Economy, 1750–1918* (1990).
3 *Ibid*. J. de Vries, *Barges and Capitalism: Passenger Transportation in the Dutch Economy, 1632–1839* (Utrecht, 1981).
4 B. F. Duckham, 'Canals and river navigations', in D. H. Aldcroft and M. J. Freeman (eds), *Transport in the Industrial Revolution* (Manchester, 1983).
5 H. J. Dyos and D. H. Aldcroft, *British Transport: an Economic Survey from the Seventeenth Century to the Twentieth* (Harmondsworth, 1974).
6 T. S. Willan, *River Navigation in England* (Manchester, 1936).
7 Aldcroft and Dyos, *British Transport*.
8 G. L. Turnbull, 'Canals, coal and regional growth during the industrial revolution', *Economic History Review* 40, 4 (1987), pp. 539–40.
9 M. J. Freeman, 'Transport', in J. Langton and R. J. Morris (eds), *Atlas of Industrialising Britain, 1780–1914* (1986), p. 84.
10 M. J. Freeman, 'Road transport in the English industrial revolution: an interim assessment', *Journal of Historical Geography* 6 (1980), p. 21.
11 M. W. Flinn, *History of the British Coal Industry* II, *1700–1830* (Oxford, 1984), pp. 188–9.
12 G. W. Crompton, 'Canals and the industrial revolution', *Journal of Transport History* 14, 2 (1993), pp. 99–102.
13 J. Langton, *Geographical Change and the Industrial Revolution* (Cambridge, 1979), especially pp. 161–75, 234–42.
14 S. Pollard, *Peaceful Conquest* (Oxford, 1981), pp. 3–19.
15 G. L. Turnbull, 'Canals in the Industrial Revolution: an Economy turned "Outside-in"?' University of Leeds School of Economic Studies Discussion Paper Series (n.d.).
16 J. Langton, 'The industrial revolution and the regional geography of England', *Transactions of the Institute of British Geographers* 9, 2 (1984), pp. 163–4.
17 Duckham, 'Canals and river navigations', p. 123.
18 G. R. Hawke and J. P. P. Higgins, 'Transport and social overhead capital', in R. C. Floud and D. McCloskey (eds), *The Economic History of Britain since 1700* I (Cambridge, 1981), pp. 243–9.
19 R. Szostak, *The Role of Transportation in the Industrial Revolution: a Comparison of England and France* (Montreal and Kingston, Ont., 1991).
20 Duckham, 'Canals and river navigations', pp. 121–2.
21 R. G. Geiger, *Planning the French Canals: Bureaucracy, Politics and Enterprise under the Restoration* (Newark NJ, London and Toronto, 1994).
22 Ville, *Transport and the Development of the European Economy*, pp. 32–9.
23 M. Merger, 'The navigable waterways of France under the Second Empire, 1851–1870', *Journal of Transport History* 18, 2 (1997), pp. 93–115.
24 M. Merger, 'The economic performance of inland navigation in France', in A. Kunz and J. Armstrong (eds), *Inland Navigation and Economic Development in Nineteenth Century Europe* (Mainz, 1995), pp. 182–210.
25 J. Jones, *The Politics of Transport in Twentieth Century France* (Montreal and Kingston, Ont., 1984), especially pp. 46–8.
26 Geiger, *Planning the French Canals*, p. 255
27 Jones, *The Politics of Transport*, p. 45.
28 A. Kunz, 'The economic performance of inland navigation in Germany, 1835–1935: a reassessment of traffic flows', in A. Kunz and J. Armstrong (eds), *Inland Navigation and Economic Development in Nineteenth Century Europe* (Mainz, 1995).
29 *Ibid*., p. 74.
30 A. Kunz, 'Steamship companies in industrialising Germany: a contribution to a sectoral analysis of the German inland shipping industry during the nineteenth century', in L. Andersson-Skog and O. Krantz (eds), *Institutions in the Transport and Communications Industries* (Canton MA, 1998).

31 Kunz, 'Economic performance', p. 74.
32 A. Kunz, 'La modernisation d'un transport encore préindustriel : le cas des voies navigables de l'Allemagne imperiale de 1871 à 1918', *Histoire, économie et société* 11, 1 (1992), p. 19.
33 D. W. Meinig, *The Shaping of America: a Geographical Perspective on 500 Years of History* II, *Continental America*, *1800–1867* (New Haven CT, 1993), p. 311.
34 D. R. Meyer, *The Roots of American Industrialization* (Baltimore MD, 2003), pp. 148–50.
35 *Ibid*., p. 154.
36 A. D. Chandler, 'Anthracite coal and the beginnings of the industrial revolution in the United States', *Business History Review* 46 (1972), pp. 141–81.
37 Meinig, *The Shaping of America*, p. 322.
38 J. E. Held, 'The Canal Age', *Archaeology*, 1 July 1998, p. 3.
39 C. Goodrich *et al*., *Canals and American Economic Development* (New York, 1961), p. 252.
40 Meyer, *The Roots of American Industrialization*, p. 142.
41 R. W. Fogel, *Railroads and American Economic Growth* (Baltimore MD, 1964). P. A. David, 'Transport innovation and economic growth: Professor Fogel on and off the rails', *Economic History Review* 22, 3 (1969), pp. 506–25.
42 Meinig, *The Shaping of America*, p. 323.
43 D. A. Farnie, *East and West of Suez: the Suez Canal in History* (Oxford, 1969), p. 511. Suez Canal Web site, www.sis.gov.eg and www.economic.idsc.gov.eg.
44 Farnie, *East and West of Suez*, p. 688.
45 *Ibid*., p. 744.
46 *Ibid*., derived from L. Hutchinson, 'The Panama Canal and trade competition in Latin America, the Orient and Australasia', *Journal of the Royal Statistical Society* (1913).
47 C. Hadfield, *World Canals* (Newton Abbot, 1986), p. 357.
48 Farnie, *East and West of Suez*, p. 576.
49 *Financial Times*, 22 March 2003. Panama Canal Commission Web site, www.orbi.net /pancanal.
50 Hadfield, *World Canals*, pp. 158–9. United Canal Agency Web site, www.Kiel-canal.de.
51 D. A. Farnie, *The Manchester Ship Canal and the Rise of the Port of Manchester* (Manchester, 1980). Web site, www.penninewaterways.co.uk.
52 Hadfield, *World Canals*, pp. 149–55.
53 M. Kraan, 'Inland waterways in Europe: at what level do we want to play?' European Conference of Ministers of Transport seminar 'The Inland Waterways of Tomorrow on the European Continent' (Paris, 2002), pp. 7–13. EU *Energy and Transport in Figures*, 'Goods transport', europa.eu.int/comm/energy_transport/etif (2001).
54 *Financial Times*, 24 February, 18 July 2003.
55 Round Table 108, 'What Markets are there for Inland Waterways?' European Conference of Ministers of Transport, 'Conclusions' (Paris, 1997), p. 2.
56 I. Valkar, 'Investment in inland waterways? Infrastructure needs', 'The Inland Waterways of Tomorrow on the European Continent', p. 2.
57 Quoted in *ibid*., p. 2.
58 Round Table 108, 'Conclusions', p. 2.
59 F. Voigt, *Verkehr* I, *Die Theorie der Verkehrswirtschaft* (Berlin, 1973).
60 Round Table 108, 'France', pp. 109–13.
61 *Ibid*.
62 Inland Navigation Europe, *Sustainable Transport: Transport by Waterway in Europe* (Brussels, 2001).
63 Round Table 108, 'France', p. 110.
64 Round Table 108, 'Netherlands', p. 189.
65 Survey by Baum and Lankes, Institute for Traffic Science (Cologne, 1978). Report of Forty-ninth Round Table on Transport Economics, *Competitive Position and Future of Inland Waterway Transport* (Paris, 1980), p. 68.
66 *EU Energy and Transport in Figures*. Europa.eu.int/comm/energy_transport/etif (2001). Turnover per employee was, however, almost three times as high in IWT as on either rail or roads. Company size was also low in road haulage, but road transport was supported by powerful interests such as car manufacturers and construction companies.
67 Round Table 108, 'Germany', p. 31.
68 European Commission, *Land transport*, Web site, europa.eu.int/comm/transport/themes /land/english/lt (1999).

69 *Ibid*.
70 *Ibid*.
71 Round Table 49, *Competitive Position and Future of Inland Waterway Transport*, p. 87.
72 European Commission Web site, europa.eu.int/comm/transport/themes/land/english/lt (1999).
73 *Ibid*.
74 Round Table 49, *Competitive Position and Future of Inland Waterway Transport*, p. 65.
75 European Commission Web site, europa.eu.int/comm/transport/themes/land/english/lt (1999).
76 Round Table 108, 'Conclusions', pp. 3–4.
77 European Commission Web site, europa.eu.int/comm/transport/themes/land/english/lt (1999).
78 Round Table 108, 'Conclusions', p. 4.
79 Round Table 108, 'Netherlands', pp. 208–9.
80 M. E. Stevens, *Review of Inland Navigation Needs: Shipper and Carrier Perspectives* (Transportation Research Board, 2002).
81 Kirby Inland Marine Web site, www.kmtc.com/inland (2001).
82 Ingram Barge Company, *Company History*, www.ingrambarge.com (2003).
83 *Ibid*.
84 US St Lawrence Seaway Development Corporation, *Economic Impact Study of the Great Lakes St Lawrence Seaway System* (Lancaster PA, 2001).
85 Jackson, *The Welland Canals*, pp. 7–8, 359–63, 389–93.
86 N. Robinson, *The Politics of Agenda Setting: the Car and the Shaping of Public Policy* (Aldershot, 2000). A recent Round Table on transport economics judged that the belief that 'investment in transport infrastructure promotes economic development . . . is not borne out by scientific analysis' and queried whether road congestion was 'a genuine problem'. European Conference of Ministers of Transport, Round Table 119, *Transport and Economic Development*, 'Conclusions'.

Address for correspondence

Kent Business School, University of Kent, Canterbury, Kent CT2 7PE.
E-mail g.w.crompton@kent.ac.uk