Tvedt, Terje. "WATER-SOCIETY SYSTEMS AND THE SUCCESS OF THE WEST."
*WATER AND SOCIETY: CHANGING PERCEPTIONS OF SOCIETAL AND HISTORICAL
DEVELOPMENT*. London: I.B. Tauris, 2021. 19–43. *Bloomsbury Collections*. Web. 26 Apr. 2023.
<<http://dx.doi.org/10.5040/9780755606511.0007>>.

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WATER-SOCIETY SYSTEMS AND THE SUCCESS OF THE WEST

Global history has long centred on the comparative economic successes and failures of different parts of the world, most often European versus Asian regions. There is general agreement that the balance changed definitely during the later eighteenth century, when a transformation began that revolutionised the power relations of the world and brought the dominance of agrarian civilisation to an end. However, there is still widespread debate as to why Europe and Britain were the first to industrialise, rather than Asia. This chapter puts forward an explanation that will shed new light on their success, by showing that analysis of the relationship between societies and water is a crucial piece that is missing from existing historical accounts of the Industrial Revolution. It argues that this great transformation was not only about modernising elites, institutions, investment capital, technological innovation, exploitation and unequal trade relations, but that a balanced, inclusive explanation also needs to consider similarities and differences in how countries and regions related to their particular waterscapes, and how they were able to exploit and change their waters for transport and to produce power for their machinery. Highlighting regional similarities and differences in complex and multifunctional water-society systems may enable us to solve some of the empirical and theoretical problems with dominant modes of explanation as to the the long-term development that ended in the Industrial Revolution.

The extensive literature on why the West ‘triumphed’, with Britain in the vanguard, can be categorised into two main competing ‘schools’ or contrasting explanatory models: ‘the European political-cultural exceptionalism school’ and the ‘European exploitation of “the other” school’ – and what is crucial in our perspective is that none of them was interested in geographical conditions or water issues.

By the middle of the nineteenth century, it was already commonplace to ascribe Europe's development in the late eighteenth century to its free, dynamic and progressive political and cultural character especially Britain. Simultaneously, Asia's lagging behind was seen as a result of its political backwardness, despotism and therefore cultural and economic stagnation. Later, an explicit religious-cultural theory became very influential, arguing that the divide could be explained by regional or continental differences in ideas and ethics. India and China did not have the cultural values that were a prerequisite for capitalism to develop while Europe had the 'entrepreneurial hero', that is, the successful businessman adhering to the Protestant worldview and ethic.¹ Others have argued that because the Islamic and Chinese civilisations did not develop modern science, they were unable to come up with the key technologies that underlay the Industrial Revolution.² Yet others emphasise how differences in law and political economy, capital and finance, education and knowledge, institutions, bureaucratic ideas, practices and markets,³ would lead to more efficient resource use and provide for greater incentives to make investments that in turn would raise *per capita* income.⁴ These explanations all reflect fundamental examples of what can be called European political-cultural exceptionalism. The essence of this school has been summarised in the one-liner: 'Culture makes all the difference'.⁵

The other dominant explanation rests fundamentally on the opposite argument: that Europe and Britain had no special cultural or institutional advantages. This school of thought interprets their success in the light of what might be called 'the European exploitation of the other' theory, arguing that it was a combination of unequal foreign trade, colonialism and the slave trade that hoisted Britain and helped fuel industrial investment and development in Europe.⁶ The view that emerges from this literature is that before the Industrial Revolution, other parts of the world, particularly regions of China and India, were quite well developed and experienced similar patterns of Smithian growth to those of Europe.⁷ In short, there were no internal social, political or cultural differences between Eurasia and Europe that were crucial enough to explain the divergence in development that eventually took place.⁸ Thus with all other variables equal, Europe's triumph can be explained by its privileged access to overseas resources and the fact that the Europeans benefited from these fruits of overseas coercion. There exists an extensive literature in support of the general thesis that the West had no internal advantages of note, but highlights the existence of different coercive or exploitive mechanisms which account for Europe's and Britain's leadership.⁹

It is necessary to investigate these two models of explanation further to increase our understanding of the importance and ontology of internal political-ideological developments and external relations, but the aim of this chapter is to argue that it will be more fruitful to look up the blind spots these perspectives have in common. The most influential explanations of the 'Great Divergence' between Europe and Asia share essential structural and reductionist problems.¹⁰

First, by underlining either only European uniqueness or European exploitation of 'the other' they can hypothetically shed light on why Europe succeeded and Asia failed, but not why Britain assumed the leading role within Europe. Recent research has added that differences in economic thinking, 'entrepreneurial spirit' and levels of scientific development were not systematic and substantial enough to be able to explain why Britain or parts of that country 'took off' instead of France or the Netherlands in the eighteenth century.¹¹ Secondly, the conclusion that there were no important differences in terms of the degree of development between Britain and China or India, or north-western Europe and Eurasia cannot be taken as evidence for a conclusion that there were no important differences of relevance for development between these areas.¹² Thirdly, the debate over the 'Rise of the West' should not be a debate only over which factor or factors in British history led Britain to diverge from pre-industrial civilisations, but should include a debate over which factor or factors made it difficult for India, China, the Ottoman Empire, Russia, France, Italy and Germany to do the same at the same time; that is, it must be able to explain both transformation and the lack of it. Thirdly, a plausible interpretation should not turn correlations into causal explanations, but rather distinguish between necessary and sufficient causes, causes and occasions, and causes and prerequisites. Such an approach should also be exogenous, in the sense that fundamental technological and economic transformations need a causal element that does not itself require an economic or technological explanation. And fourthly, a convincing explanation should also make sense of what in reality was the Industrial Revolution's gradual and regional character. Moreover, a useful account of 'the triumph of the West' must break away from an almost exclusive concern with the West, to the neglect of Asian economies and technologies. Recent findings question generally accepted assumptions about fundamental differences in economic and technological levels between Europe and 'the rest', as well as between the modern and the 'traditional' West.

COMPARATIVE STUDIES OF INTERACTIONS BETWEEN SOCIETY
AND WATER AND THE INDUSTRIAL REVOLUTION

The emphasis of this book on the fruitfulness of comparative analyses of complex, multifunctional water systems in order to understand the regional and global transformations of the late eighteenth and early nineteenth centuries is not an attempt to manufacture a single-unicausal, deterministic explanation of the Industrial Revolution. This perspective does not imply a rejection of analyses that deal with overarching trends in economic relationships between Europe and Asia, or of cultural and ideological traditions, but provides rather a new context in which also such issues can be studied comparatively. At the same time, it emphasises variables that have tended to be neglected in the literature. Without in any way claiming that the Industrial Revolution was programmed to happen when and where it did, this chapter argues that it is necessary to understand how different waterscapes and water-society systems created different possibilities for the development of trade and industries in the centuries and decades before the Industrial Revolution broke through. The emergence of a group of British industrial entrepreneurs and canal builders that managed to transform Britain was not historically inevitable, but we argue that, whatever the strengths of the market orientation, capitalist mentality, or investment capital, similar entrepreneurs could not succeed in the core economic regions of China, India or of other European countries of the time, because of the nature of their waterscapes and the established water-society relations.

Transport and water-society systems

Transport has been widely recognised as a crucial factor in the Industrial Revolution, and there is little doubt that waterborne transport was of decisive importance for the new industries. Transport systems encouraged commercial expansion, facilitated the division of labour and linked production to markets. Until the middle of the nineteenth century, rivers and canals were essential in determining which regions and cities could trade with each other, and where industry could profitably be located, coal mined and iron refined. Most importantly, they allowed the shipment of heavy raw materials like iron and coal from their points of extraction to industrial sites.

However, comparative studies of the Industrial Revolution have paid insufficient attention to waterborne transport, even though Adam Smith, in his *The Wealth of Nations* (1776), recognised that industrial development depended on the infrastructure of water transport. Some studies have shown the importance of waterborne transport for the development of

Britain (Phillips 1803; Aldcroft and Freeman 1983; Szostak 1991; Turnbull 1987). Deane (1979: 76) put it thus: 'If Britain had had to depend on her roads to carry her heavy goods traffic the effective impact of the industrial revolution might well have been delayed until the railway age.' What this chapter will do is to compare the transport system of Britain with other countries and regions with a focus on the second half of the eighteenth century.

The importance of waterborne transport in the initial, decisive phases of the Industrial Revolution is underscored by the fact that most goods in pre-modern economies travelled by land, or on boats in coastal transport (Braudel 1990). Road transport was generally preferred when it came to transport of people and light and expensive goods, because it was more reliable than inland water transport, in spite of roads often becoming impassable due to rain. Precipitation could be a nuisance all year round in parts of England, while in China and India the monsoon rains made large parts of the road network unusable, even for small-scale commerce and transport of light goods, on a regular basis and for months on end. But even where and when roads were passable, available modes of road transport could not satisfy the emerging demands of the new industries. Only boats and barges could handle heavy raw materials like coal and metal ores in large quantities, as well as lime, sand, manure, general merchandise and agricultural produce and transport them at an acceptable cost to emerging regional and global markets. The development of the coal and iron industries and the success of the cotton industry depended upon improved transport infrastructure. Goods, whose price had been unable to justify the cost of transport, were now moved night and day on new water routes. Thus, comparative questions ought to focus on which countries or regions had a suitable physical waterscape where artificial waterways could most easily be built to serve such purposes, and entrepreneurs, engineers and politicians with the experience, competence and will to create such a transport network?

To the extent that transport systems have been compared in the literature on the Industrial Revolution and the 'great divide', the argument has been that if anybody had an edge it was the Chinese. It has been suggested that it 'seems very hard to find evidence of a European advantage in transportation' (Pomeranz 2000: 35). On the contrary, the 'remarkable development of water transport' in China has been emphasised: East Asia had an 'overall advantage in transport'.¹³ Or again, China had a 'superb system of waterways' (Pomeranz 2000: 185). As Fernand Braudel wrote, quoting Father de Magaillans, 'No country in the world [...] can equal China in navigation' (Braudel 1979, I: 421). These assessments are wrong.

Comparisons about transport development should not treat navigability as a simple binary concept, based on the extensiveness of

a canal system and the number of boats on waterways at a given time of year. When the potential and role as trade routes of the rivers and canals of different regions are compared with regard to the specific transport needs that emerged in industrialising economic sectors in the second half of the eighteenth century, many issues related to the first layer of the water-system approach need to be analysed. These include the velocity, height and frequency of rapids and cataracts of rivers, their maximum and minimum flow, tidal versus non-tidal characteristics, peak current speed, annual and seasonal variations in water level, and silt and sedimentation load. Such factors decided the cost of transport, how many times goods would have to be loaded and unloaded, the regularity of the transport system, and the extent to which goods could be shipped all year round, up- and down-stream. Furthermore, the waterscape determined the types of boats that could be used, and hence the weight and amount of goods that it was possible to transport. Other issues of significance were the relative proximity of navigable rivers and canals to new sources of raw materials, and the character of the interfaces between the sea and navigable rivers. It would also be difficult to overestimate the importance of good and stable harbours close to a navigable river mouth for the cost and efficiency of loading and unloading sea-going vessels.

The character of the second layer of the water system – river modification and canal building – was more dependent on local physical and hydrological conditions than has been acknowledged in historical writings and in the travel accounts on which they often rely. A functioning canal needed an adequate supply of water for the summit level, and open canals (all of them at that time) depended on evaporation rates and on soil types that did not leak. Ensuring a sufficient all-year water supply for the canals was the main problem in most areas, as this depended on the seasonal variability of rainfall, glacial melting and the layout of river systems. Floods also washed away embankments, covered locks and made access difficult. The work and investment needed to construct and maintain artificial waterways were, however, not only influenced by waterscapes, but also by political relationships among the various users of rivers and dominant ideas about water.

These factors combined would decide the extent to which inland water transport was possible or sensible, or indeed economically viable at all. No systematic comparison of waterscapes, hydrological cycles and transport potentials in the major regions of Europe and Eurasia has been carried out in relation to the ‘Great Divergence’ debate until now. This chapter presents some data from such a research project, but focusing mainly on Britain, China and India.

WATERSCAPES, WATER-SOCIETY RELATIONS
AND TRANSPORT IN BRITAIN

Compared to the core economic regions of China and India, Northern Italy and France, parts of England and Scotland possessed a unique system of relatively easily navigable waterways, and waterborne transport had long been more reliable than road transport. Moreover, medieval water transport was cheap, for carriage by land could cost ten times as much (Jones 2000). The rivers were fed by rain throughout the year, and there was relatively little variation in water levels. The rains that created muddy, impassable roads made rivers navigable. The rivers had few rapids, and the waters carried little sediment, and they did not normally freeze in winter. On the coasts facing the North Sea and the Irish Sea there were estuaries with tidal rivers that penetrated far inland, creating sea routes and land routes simultaneously, long before the advent of steamers being capable of moving upriver against the current. The high number of such rather short and narrow rivers became the commercial lifelines of the medieval kingdoms, encouraging early regional specialisation and urbanisation. British and especially English rivers were remarkably reliable, especially compared to those of India and China, even though Britain could also experience floods, droughts and freezing rivers that caused problems for the boatmen and for trade in general. Compared not only to India and China, but also to France, in England it was easier to dredge rivers, reinforce banks, straighten and shorten river courses and control water levels with sluices and staunches of modest size and complexity. Britain's river system and precipitation patterns were so benign that waterborne transport could largely rely on natural water routes until the 1750s.

England also had a crucial advantage when it came to perennial water supply for small artificial waterways for two reasons; sea-level canals in moist areas had a high water table and most of the country had year-round rainfall. While Britain had very few proper canals as late as 1759, in less than a generation the whole face of England was furrowed with navigable waterways, and bulky goods were more and more carried by boat. It has therefore been aptly stated that 'the map of English canals, is the map of industrial England' (Hartwell 1967). Canal boats could carry 30 tons pulled by a single horse, or more than ten times the load per horse drawing a cart. New technologies, notably the use of puddled clay, and new types of locks and boat lifts, also encouraged canal building.

The 'canal mania' after 1760 until about 1830 when the railway came, gave high returns to a new class of shareholders. It has been argued that the canal building ventures even created a new kind of business mentality, or the 'true beginnings of financial capitalism', utilising surpluses from agriculture and trade, and capital provided by manufacturers and other

investors (Bryer 1999: 687; Bryer 2000: 158. See also Baskin and Miranti 1997: 127; Bagwell and Lyth 2002: 12). The technological, financial and political challenges in canal building were within the reach of private entrepreneurs, while in countries like China, India and France, the state was directly involved, as the physical challenges presented by their respective waterscapes were such that they could not be solved by individual citizens or small groups of businessmen. The canal system in England was developed into an interconnected web of quite efficient waterways that could be used on a quite regular all-year basis. Very importantly, both coal and iron deposits were available within the ambit of Britain's water transport system, to a much greater extent than in any other country. This made it possible for raw material sources to be linked to the production sites as well as to the market, and every city in England, except Luton, was connected to the sea by 1800.

To summarise: England possessed 1,900 kilometres of navigable rivers in 1725 (Willan 1964: 13). By the end of the 1820s, the country had 3,400 kilometres of navigable rivers, and 3,200 kilometres of canals (Clough and Cole 1946: 446). Waterborne transport had thus become more crucial than ever, and bulk goods such as coal and iron could be transported at a much lower cost than by road (Jackman 1916; Willan 1964; Bagwell 1974).

WATER SYSTEMS AND TRANSPORT IN CHINA AND INDIA

Chinese rainfall patterns caused extreme annual and seasonal fluctuations in river discharges that were scarcely comparable with European rivers, in particular with those of Britain. Moreover, marked seasonality and long dry spells profoundly affected the availability of water for canals (Yu 2002). Extreme variations in river levels were common, as were high rates of bank erosion and sedimentation. The colossal human efforts needed to protect societies against the physical characteristics of violent rivers and monsoon climate translated into serious impediments to the development of transport infrastructure. Furthermore, run-offs from the principal river drainage basins are gathered into remarkably few main outlets to the sea in China, with only some five to six outlets for about 4,000 kilometres of main coastline to carry off enormous river discharges, fed not only by the monsoon but also by Himalayan glaciers. The characteristics of these widely separated river systems differed greatly, but they could all cause catastrophic floods, and indeed they all flooded very frequently. Commercial centres were worst affected, because they were usually located close to these rivers and on vast, fertile delta plains, partly because rivers were the main transport arteries of agricultural goods.

Large river engineering schemes, which run like a thread through Chinese history, were implemented primarily to serve agricultural production, as well as military and administrative goals. Within the same social and dynastic structure they could not easily be tailored to meet the needs of new industries and global trade. Water management traditions, or the water planners' habits of thought, had for generations been concerned first and foremost with taming water, that is, with drainage and defence against recurrent and dangerous floods and droughts. The relatively advanced multifunctionality of the Chinese river system most likely discouraged regional and local attempts to use water primarily for transport or mechanical power production. China definitely possessed the technological capacities to build canals.

The Chinese state can most aptly be described as a 'water-moving-state'. Since its very beginning the strength and legitimacy of the state depended on its ability to control and move water, and it organised great water projects that involved canal building and modifications of river systems on a grand scale. The most famous of these canals was, of course, the Grand Emperor's canal. The oldest parts of the canal date back to the fifth century BC, although the various sections were finally combined during the Sui Dynasty (581–618 AD). The total length of the Grand Canal is more than 1,700 kilometres and its greatest height is reached in the Shandong at a summit of 42 metres. It connects the Yangtze River with Beijing, passing through Tianjin and Hebei, Shandong, Jiangsu and Zhejiang provinces.

Since the most highly economically developed centres of Chinese civilisation in the seventeenth and eighteenth centuries were located in the Yangtze and Huang He basins, it is natural to compare the industrialising regions of Britain with these two river regions. The Yangtze River was China's main trade artery, and economic progress was directly connected with the intricate network of waterways (Elvin 1977). The river basin had more than 20,000 kilometres of waterways, and Marco Polo noted that thirteenth-century official reports indicated that 200,000 boats descended the river annually (Wiens 1955: 248). The many canals were one of the most characteristic features of the region. Transport by water was so much cheaper than by land that areas without water transport were usually much less developed. The difference between the two modes of transport was so pronounced that it has been seen as 'a case of premodern economic dualism' (Elvin 1973: 304).

However, the Yangtze plain was exceptional and the regional water transport network was dense. Even so, it was incapable of efficiently conveying heavy materials. Iron and coal were mostly found outside the river basin, or upstream of the Three Gorges, and were thus located in areas that could not be served efficiently by water transport. The

transport network had also clear limitations regarding even regional transport of locally produced goods. First, the layout of the canal system had not originally been to serve the exchange of goods, but mostly for drainage and flood protection. Moreover, the water level in canals fluctuated with seasonal variations in rainfall and river discharges. They were thus often not designed to move goods efficiently all year round, but to move tribute grain at certain times of the year when they were navigable. There were also huge variations in river water levels, with dangerous seasonal floods alternating with low waters. Silting of rivers and harbours and meandering tributaries on the plains made these waterways difficult to use for the transport of heavy raw materials and industrial products. Boatmen and traders in eighteenth-century England complained about the irregularity of the Severn and the Avon, but, compared to Chinese rivers, they were more like predictable highways.

As for the Huang He (Yellow River), the ‘mother of Chinese civilisation’, flooding transformed it into a raging torrent, carrying 88 times more water than in the dry season. The river had four natural flood seasons, which made regular large-scale transport extremely difficult. A detailed reconstruction of the behaviour of the Huang He from 1650 to 1850 remains to be made, but it has been estimated that between 602 BC and 1949 AD there were more than 1,500 major floods, 25 significant channel alterations and seven major changes of course. Like other mighty Chinese rivers, the Huang He originated high in the Himalayas, subsequently crossing extensive alluvial floodplains, and a massive transport of sediment contributed to the shifting of its channel. The river mouth thus moved from north to south and back again, with the most recent ‘natural’ shift occurring in 1855, when the channel mouth moved from the north side of the Shandong peninsula to the south (Zhang et al. 2010).

The interface between rivers and sea was much less conducive to trade in China than in Western Europe. China’s flat coastal landscapes were formed by the deposition of fine river sediments and the river mouths were often choked with silt, and time and time again their outlets to the sea would shift. There was a lack of tidal rivers, and riverbanks were frequently sandy and shifting. Access to the sea from the Yangtze was not usually a great problem, but one major channel to the sea did not constitute a dynamic inter-regional transport network, similar to the one that could be developed in England. Although maritime trade was substantial, and the Chinese had the technological capability to develop seaborne transport, the hazards of the maritime route were both natural and societal, including the problem of piracy. Beijing thus prioritised the Grand Canal and inland water routes.

Clichés about the inward-looking, conservative ‘oriental mind’ or ‘stagnant’ Chinese civilisation are highly misleading where canal building is concerned. The Chinese carried out many major projects from the third century BC onwards, developing sluice and lock technologies and constructing a myriad of canals, the most famous of which was the Grand Canal, which was more technologically sophisticated, administratively challenging and managerially complex than ever by 1800 (Dodgen 2001).¹⁴ Use of the canal was limited, however, due to silt and water level problems, and by its narrowness, which made it unsuitable for heavy loads. Indeed, the Grand Canal complex collapsed in the nineteenth century, as it silted up from the mid-eighteenth century. Despite the experience of Qing engineers, the state did not have the resources to control the canal when changes in climate altered the amount of water carried by the Huang He (Leonard 1996). Nor was there sufficient relatively silt-free water at a suitable altitude in Shandong to keep the canal functioning throughout the year.¹⁵

Moreover, the navigable rivers and the existing canal system were far from where the most important coal and iron deposits were to be found. China’s vast river system, characterised by river basins whose water runs more or less uni-directionally from west to east, turned rivers into barriers to north–south trade in general and to the transport of heavy goods in particular. The huge rivers were often difficult to cross by boat due to their highly variable patterns of discharge and high flow speeds and, unlike the many small rivers in Britain, they were also impossible to cross on foot or with wagons, since bridges could not be built due to their enormous width. Those features, which for hundreds of years had made the rivers quite efficient seasonal highways for the downstream transport of agricultural products grown along their banks, became a drawback when a regular, perennial and gentle flow was necessary for the shipment of heavy goods.

In India, monsoon rains were the most important negative physical factor, influencing navigability, reliability and opportunities for port establishment. The monsoon limited inland navigation to a seasonal activity in some areas (for an overview, see Jain et al. 2007). The major Indian rivers had been harnessed and exploited for generations, and they encouraged the development of a very productive agricultural civilisation, but as transport highways they suffered from some of the same hydrological problems as Chinese rivers. The Sanskrit word for the Indus River, *Sindhu*, means ‘ocean’, but in the winter season, when the melt water from the Himalayan glaciers was radically reduced, the river resembled rather a series of pools connected by narrow and shallow channels. On the Ganges, and even on parts of the Brahmaputra system, it was possible to move goods in the dry months from November to

January, but in the spring, many river branches became too shallow for even very small boats (see, for example, Forrest 1824). On the other hand, during the monsoon, the rivers flooded and became dangerous for navigation. In spite of these drawbacks, rivers played a very important role in traditional transport, because water transport was still more efficient than transport by land, which in many areas came to a standstill during the monsoon. In Bengal, for example, about 80 per cent of trade goods were carried by river.

However, while rivers were crucial as local transport routes, they were not conducive to growth in national and international trade. One author concluded that rivers in India 'are not considered fit for navigation' (Bharati 2004: x; see also Hart 1956). This problem can be illustrated in another way. One-sixth of the area of modern India is drought-prone, and one-eighth of the area is flood-prone, with floods rendering an average of 33 million people a year temporarily homeless (Verghese 1990: 8–9). Although the number of affected people was less at the beginning of the nineteenth century, floods and droughts could strike much harder, since there were insufficient dykes and storage facilities for flood water for use in the dry season.

India is probably the country with most river migration and 'disappearing' waterways. Indeed, the mythical and famous River Saraswati can be seen as a religious expression of this predicament (Jain et al. 2007: 870–913). A distinguishing feature of South Asia is changing riverbeds and cities left high and dry. This is mainly due to the fact that the Himalayan courses of these rivers are extremely torturous, while on the plains, due to heavy sediment loads and strong flows during the flood season, they meander across the floodplain, frequently shifting course (see, for example, Khan 2005). It is safe to say that there is no river in the Indo-Gangetic Plain that has not changed its course a hundred times, mostly due to factors that outwit humans' control. Human settlements from the earliest times had followed the rivers, which meant that every deserted river implied a disturbance of settlements, and the abandoning of villages, towns or even great cities. These phenomena removed the water supply to an inconvenient distance, destroying strategic advantages and established trade routes. Larger changes of course have had proportionately more serious consequences. Lines of mounds marking abandoned villages along the line of a former river are sufficiently common in the Punjab to have a name: *thes* (Wood 1924: 3). In India, the monsoon brought heavy rainfall during the monsoon season, producing natural reservoirs in depressions even far from the main rivers. They were replenished annually by the rains and some of the earliest settlements were established along these depressions as well as along the riverbanks. But in some regions, such depressions might not

be replenished by rainfall for several years. This led to many settlement shifts throughout history.

During the first phase of the Industrial Revolution in Britain, India experienced a number of radical changes in its waterways. At the end of the eighteenth century, the Beas River was 'captured' by the Sutlej, a tributary of the Indus, and its old bed became a dry ravine. The Brahmaputra also changed course. Until 1787 it had flowed through Mymensing, but then it started to move west, while the Teesta in turn formed the easternmost branch of the Ganges (Michel 1967: 48; Bernstein 1960: 14–16). In times of flood large changes in the courses of the rivers were particularly likely to occur. The Damodar River had formerly joined the Hooghly about 50 kilometres upstream of Calcutta, but in the great flood of 1770 it left its old channel altogether, and joined the Hooghly about 50 kilometres below Calcutta. The consequence was a marked deterioration in the channel of the Upper Hooghly, and a silting-up of the old channel. This lack of river stability was acknowledged by the British as one of the major obstacles to transport improvements when, several decades later, they tried to develop steamboat traffic on the Ganges (Bernstein 1960).

Not only were the rivers and water availability in China and India much less conducive to the rapid development of water transport and facilities than in Britain, but large-scale canal construction was technologically impossible at the time. This was due to the huge seasonal and annual variations in potential sources of water supply for artificial waterways, and the enormous sedimentation problems that threatened to destroy canals and embankments in the course of only a few years. Furthermore, the permanent need to protect land and people from floods and droughts made it dangerous to establish transportation canals, while there were serious conflicts of interest between the irrigation and transport sectors regarding the type of water control works envisaged for various economic activities. The canals that existed in some regions of both countries were not suited to the transport of goods like coal and iron, since they had not been built with that purpose in mind. Nor were their rivers suitable as arteries for global trade, due to their strong seasonality and the sediment problem where they met the ocean. The boat-building technology available at the time made it almost impossible to build boats that could carry heavy goods on such seasonal, violent rivers. Large areas of both countries had no navigable waterways whatsoever, and those that they had did not run close enough to where coal and iron were found in sufficient quantities.

Trade, the instrument of any developing economy, had been hampered for centuries by transport, which was invariably slow, inadequate, irregular and, not least, very expensive. As Paul Valéry remarked: 'Napoleon moved no faster than Julius Caesar.' The water transport system that developed in

Britain during the late eighteenth century signalled a transport revolution. No other country in the world possessed such a highly developed network of waterways. Although transport was still slow, trade in heavy goods could be quite reliable. It could be carried out on an all-year basis, and boats on the small rivers and canals could carry iron, coal and sand from where they were found to where they were to be used. Only in Britain could an efficient and reliable transport system be established at the time, bringing the different regions together, and linking them to regional and global trade routes.

MANUFACTURING AND WATER-SOCIETY SYSTEMS

Whatever definition of the Industrial Revolution we use, all emphasise the centrality of the rise of the modern factory in England in the last third of the eighteenth century. Even if this is not in itself a sufficient explanation, the use of machinery remains the principal aspect relative to which every other issue is studied. Before the steam engine came into widespread use in the mid-nineteenth century, only two types of inanimate power were available: wind and water (Watts 2005: 53).

While windmills were not sufficiently reliable for the new production processes, water power made large mechanical workshops feasible, fostering industrial discipline among a modern working class. Water was the main power source in the initial phase of the Industrial Revolution. All-important industries, such as textiles, iron, paper, pottery and a myriad of less important ones were dependent upon water power of this type. A number of writers have shown that water power continued to be the most important source of industrial energy well into the nineteenth century (Von Tunzelmann 1978; Pounds 1973: 38; Kanefsky 1979). It is therefore essential to understand and analyse from a comparative perspective the role of water power, notably the reasons for its dominance in Britain and for its marginality in China, India and other European countries at the time. While this chapter deals with the role of water in the Industrial Revolution in general, the discussion focuses on the water-powered mechanisation of the textile industry, due to this industry's particular importance in analyses of why Britain succeeded and India and China did not.

While water remained the main and sole reliable source of inanimate power, the waterwheel was the key technological factor in all the basic and new industrial processes. Seen from a perspective of about 2,000 years, the first phase of the Industrial Revolution saw the zenith of the societal and economic importance of the waterwheel, which most new factories utilised to drive their machinery. For the more efficient vertical

waterwheels that had been developed, the overshot wheel almost always required an aqueduct, often elevated, leading water to the top of the wheel where it poured into the buckets. The wheel was rotated by the weight of the water in these buckets. Aqueducts could be artificially made by constructing small dams and millraces. The waters needed to satisfy three conditions: a year-round supply, not too much silt and adequate stream power capable of turning the waterwheel 24 hours a day throughout the year. This particular relationship between economic activity and natural resources meant that the new factories had to be located where there was running and falling water.

Thus the fundamental question became where one could find sources of water that could easily be adapted to the need of the new industries, and that were located close enough to both sources of raw materials and national and global trading routes. In spite of the importance of this form of inanimate power in the first phase of the Industrial Revolution, no systematic comparison of water-society relations has been made.

Water-powered industry in Great Britain

Parts of England, as well as parts of Wales and Scotland, had waterscapes conducive to this type of industrial power. The great number of relatively small perennial rivers fed by all-year precipitation, such as the Derwent, Irwell and tributaries of the Severn, with modest currents and silt-free water, were perfect for existing waterwheel technology and for developing new technologies (Baines 1835: 55–83; Robson 1957: 1). For centuries, the prevailing conditions in various areas of England had made it an ideal workshop for practical engineering and experiments, which encouraged a wide variety of water-driven inventions. This disparate economic-technological milieu grew in size and importance, and, in the final decades of the eighteenth century, it turned out a number of new inventions, such as the water frame, Crompton's mule and Henry Cort's grooved rolling process and puddling furnace. It was relatively easy to channel sufficient water to where the waterwheel was situated, thanks to the wealth of experience of making minor modifications to river embankments and canal construction, and the existence of a decentralised, bottom-up water management system. But why did the water-powered mechanisation and technology flourish so much more richly in Britain in the period 1760–1820 than in what might be called its European birthplaces: parts of northern Italy and eastern France? To explain this, many factors must be considered, but one of the main reasons was the great discharge variations of the Alpine rivers; the force of the peak currents and the turbulent, flood-prone rivers such as the Rhône and the Po made it difficult to operate modern factories all year round at that time.

The textile industry was the leading sector in the Industrial Revolution, and the first to adopt new forms of industrial organisation. The most spectacular growth took place in the cotton industry between 1750 and 1800, by which time Britain had become the world's leading exporter of cotton textiles (Ellison 1968: 57–70, Robson 1957: 1–3). This power shift was made possible by many factors, political, cultural and imperial, but without the development of new factory technology, such as new spinning and weaving machinery in England, it would not have happened. When multiple spindles began to be mounted on frames, it became evident that human power was inadequate, and as long as water power was the only available substitute for human and animal energy at the time, the waterscape attained a new and fundamental social and economic importance. Indeed, yarn made this way was known as 'water-spun' as opposed to 'hand-spun'. Cotton could not be grown in England, for climatic and water-related reasons, but it could be processed there, thanks to the same features of the climate and water systems.

It is therefore symbolic that the location of the first modern factory in history, a cotton mill in Cromford near Derby that was established in 1771, was on the banks of the Bonsall Brook, a tributary of the River Derwent. Arkwright's 'water-frame' was installed here to be powered by large waterwheels. The mill swiftly grew to house several thousand spindles and 300 workers. A disadvantage of the Cromford site was poor communications, so Arkwright had the Cromford Canal built to transport raw materials and finished goods to and from the site. In 1780, the owner bought land for a yet bigger factory complex and a larger mill, and moved to a more powerful river, the Derwent itself. Fifteen years later some 140 similar water-powered mills were spinning cotton. By 1800, there were about 900 cotton-spinning factories, most of them in the North and the Midlands, 300 of which employed more than 50 workers. In the late eighteenth century, there were nearly 100 cotton mills within a 10-mile radius of Ashton-under-Lyne, all on the River Tame, and all powered by water. By 1816, the average number of workers employed in 42 Manchester textile factories was already as high as 300 (Redford 1960: 19, 27). More efficient technologies increased productivity and quality. Crompton's mule gradually overtook Arkwright's water-frame as the preferred machinery. But this was also set in motion by waterwheels, fitted with as many as three or four hundred spindles. In 1835, there were 109,626 power looms in the United Kingdom in the cotton industry (Aspin 2003; see also Bowden 1925; Daniell and Ayton 1814; Hills 1970). The cotton mill became one of the defining symbols of the Industrial Revolution, signifying material progress and the growth of industrial spirit and identity. Wool-spinning and weaving were mechanised during the same period, using water at crucial stages of the production process.

The mill and all that came with it thus marked the dawn of a new era. It was not until 1783 that the steam engine was first used in a factory, and then only indirectly (Arkwright's Manchester mill used a Newcomen engine to pump water to drive the machines in the dry season when the water pressure was insufficient to turn the waterwheel).

At the beginning of the nineteenth century, in brooks and streams all over England, waterwheels were set up, effectively powering not only the textile industry, but also the metallurgical industry. Indeed, steam engines could not have been built in the first place without waterwheels to drive the equipment that was needed to smelt the iron and form the cylinders and other metal parts of the steam engine. The development of the iron industry was crucial because it allowed the production of most of the machinery required by other industrial activities, whereas earlier machines had been made of wood. The key factors in the iron industry were the heating process and the hammering of smelted iron, both of which depended wholly upon water power. Without water-powered bellows it would simply not have been possible to produce temperatures in the blast furnaces sufficiently high to produce cast iron economically. This water-aided furnace technology was an essential element of the iron industry and its high output. The iron industry depended on water power to produce the new machines of the new industries, such as rolling mills, metal lathes, hydraulic hammers and so on, which also required water power. It is therefore safe to assert that the increase in productivity was dependent upon the more efficient use of water, in this industrial sector as in other emerging industrial sectors.

The success of waterwheel technology in parts of England cannot be sufficiently explained by European political-ideological exceptionalism, or by European colonialism and unfair global trade regimes. The fundamental technology itself was not a European invention, but was first developed in Asia, probably in India or China. It was introduced to England by the Roman conquerors. From its earliest days, the technology spread quickly throughout England. At the time of the Domesday Book, compiled for William I in 1086, more than 6,000 watermills were registered, all using the small brooks and streams that were full of water at the time of the corn harvest. The waterwheel was then primarily used for grain milling but was gradually adopted for other purposes. The mechanical fulling-mills that cleaned woollen textiles were especially important. Around 1200, water-powered hammers were brought into use in many small rural forges for beating hot metal into shape. The Wealden iron industry was located close to streams because these were where it was possible to accumulate the head of water needed to drive the hammers. Great improvements in watermill technology took place in the sixteenth and seventeenth centuries (Unwin, Hulme and Taylor 1924: 27). However,

the development of the overshot system was crucial for the industrial breakthrough (Reynolds 1983). In technological terms, the equipment in itself was not revolutionary, and it would probably not have puzzled or surprised a millwright from medieval China or the Ottoman Empire. Many of the early water-powered cotton factories were converted silk mills (Lewis 1848: 95), which themselves were often converted medieval corn mills, an indication of the long and varied history of water-powered technologies.

By the end of the eighteenth century, entrepreneurs and businessmen in much of England had wide experience of using waterwheels for productive purposes. The role of and dependence on water can also explain the distinct regional pattern of England's transformation in the late eighteenth century, for industries, which often were clustered in combinations of textiles, iron and engineering, had to localise along streams and brooks. No such transformations took place in parts of England that lacked rivers and brooks with sufficient force to power waterwheels, or where it was not possible to build dams, reservoirs and man-made waterfalls that could drive these 'water engines'. For example, it mattered that about 250 kilometres of year-round, ice-free and stable rivers, streams and canals flowed within 15 kilometres of Manchester city centre. Some waterways, such as the Dene, Tib and Corn Brook, important in previous centuries, have now been forced underground, while four rivers still flow visibly through the city: the Irk, Irwell, Medlock and Mersey. It also mattered that the water ran down gentle hills, carrying sufficient energy to drive the waterwheels. After all, the Romans called this area Mamucium, the place of the breast-shaped hill, from which the word Manchester later derived, due to the contours of the landscape.

WATER-POWERED MECHANISATION IN THE CORE ECONOMIC REGIONS OF CHINA

Explanations of the success of Britain based on assumptions about European technological supremacy are not very convincing when it comes to water control, for water power had already been an important source of energy in ancient Chinese civilisation. In fact, China led the West in this respect. Large rotary mills for grinding grain appeared in China in about the second century BC. The typical Chinese waterwheels were of the horizontal type, although the vertical wheel was known and was used to operate trip-hammers for hulling rice and crushing ore. The edge-runner mill appeared in China in the fifth century AD. The trip-hammer was in use in China perhaps as early as eight centuries before it was used in Europe, and China invented the first water-powered blast furnace. China

had factory-like establishments, and iron works that employed 1,000 men (Elvin 1973: 307–8. See also Wagner 1984: 95–104). Some historians argue that iron output in the eighteenth century was greater than ever, possibly exceeding 200,000 tonnes per year (Eastman 1988: 137–47). The Chinese were certainly familiar with milling technology, as the earliest paper mills date from around 1570, the earliest sawmills from 1627, and mills for winding silk from cocoons from 1708 (Needham 1996: 4, 404, 394, 405).

It has been documented that the Chinese were using a water-powered, multi-spindle spinning machine in northern China by the end of the thirteenth century.¹⁶ We do not know why such early Chinese machine-spinning disappeared, but a reasonable hypothesis is that it was related to changes in the waterscape (either natural or man-made) and the limited diffusion of them was restricted by a general shortage of suitable rivers and streams for this type of industrial activity. What we do know is that water continued to be used as a power source in various places in China where such water was available. The Chinese were well aware of the benefits of water power. In Hunan, water was lifted with stream-driven norias, and a contemporary poem praised how much easier this was than pedalling (Elvin 1998: 113–200, 136–7).

The Chinese knew the technology and definitely had the scientific and engineering capability to build reservoirs and dams, but the waterscape was in general difficult to regulate for this purpose, given the extremely variable flow in most of their rivers and the fact that the most important ones in the populous cotton industrial areas crossed extremely flat flood plains. Furthermore, such reservoirs would soon be filled up with silt. The Chinese rivers were extremely difficult to use for regular industrial production given the technology of the time. Chinese factories could therefore not get the regular power supply that could transform them into modern machinery-based factories. The rate of invention and application of iron instruments was much slower than in Western Europe (Elvin 1972: 137–72). A main reason was that there were very few exploitable water resources close to where iron was found and made, which affected negatively the heat of the smelters and thus the quality of the products.

The question of the Chinese cotton textile industry has been thoroughly discussed. The Chinese had the technological capacity, enough raw cotton and sufficient demand for cotton textiles to develop modern cotton textile factories, but no such factories were established before the latter part of the nineteenth century, after the steam engine had been introduced. China's textile industry was overwhelmingly located in the populous Lower Yangtze region, for long the core area of the Chinese economy, where large merchants established considerable control over the production process of better grades of cloth (Nishijima 1984: 17–79). The Ming cotton industry demonstrates that the idea of the stagnant

Chinese society is misplaced, since a family-based rural industry, with hundreds of thousands of people working in the weaving and spinning industry, had developed in the eighteenth century, stimulating important changes in production and marketing. Spinning and weaving were done by every family in the many small villages dotting the area around Shanghai (Lindsay and Gützlaff 1833: 188). Although the Chinese were aware of the watermill technology, and acknowledged its advantages, they still did not use it in cotton-producing regions. All scholars seem to agree that a critical weakness of the industry was the relative absence of mechanisation.

My argument is that the Chinese were unable to copy English textile machinery, even if all other cultural and political factors had been equal, because they did not have the rivers, streams and brooks that could power the new industry that the British had. The river control works in China of the past had, moreover, been engineered to solve other tasks and served water interests and waterworks that would compete with projects to tame rivers in order to harvest their industrial potential. On the extremely flat Yangtze plain, crossed by a violent, silt-laden river that drained 70–80 per cent of the country's precipitation, there were very few places that were suitable for exploiting the flow of water for driving waterwheels, especially overshot vertical wheels. The Yangtze and its main tributaries could not be used for producing power through waterwheels like the much smaller and more modest English rivers, streams and brooks. In major cotton-producing regions, the head of water was not sufficient to drive hydraulic machinery. Frequent flooding also functioned as a major disturbance influencing the dynamics of the river-land interface. The Huang He could not be used either, not only because of its irregularity and the fact that it broke through the levees almost every year, causing floods and displacements, but because of the amount of silt transported by the river which would damage or destroy the vulnerable waterwheels.

The fact that China did not modernise its textile industries has again and again been described as a 'great puzzle' (Chao 1977), but what has been shown here, by integrating water-system relations in the analyses, is that it is no longer a puzzle. Explaining the lack of suitable channels and waterfalls as a function of a lack of entrepreneurship, capital or competence, is misleading and confusing. Dominant explanations have focused only on various social variables and have thus overlooked a fundamental geographical constraint in China: the sheer lack of relevant inanimate power sources to power machinery.

WATER-POWERED MECHANISATION IN THE
CORE ECONOMIC REGIONS OF INDIA

Until the second half of the eighteenth century, India was the most important cotton textile producer in the world (Parthasarathi 2001). According to some estimates, it accounted for 25 per cent of global manufactures in 1750 (Bairoch 1982: 296). The key to this production process was the pit loom, a technology that endeavoured to mechanise work previously performed entirely by human labour. This horizontal loom was lightweight, consisting of only a few pieces of wood that could easily be dismantled, transported and reassembled. In the late eighteenth century, it was not unusual to see an individual weaver moving house, carrying on his back everything he needed to start weaving the moment he arrived in his new home. The pit loom's mobility was an advantage for weavers, since they could compete with other weavers at local level. However, it was at a technological disadvantage compared to the efficient factory system that was being established in England. This type of loom, however, was also totally dependent upon water, but for a quite different reason, and with far-reaching implications. The hole under the loom where the weaver sat and worked the pedals (hence the name 'pit loom'), created the humidity necessary for the cotton to be woven. In parts of South India, however, even hand-weaving itself came to a standstill for about a month because of the heavy rains. In some areas, high winds were a regular annual problem, breaking 'the warp yarns that were fixed in the loom'. In Kongunad, the work schedule was reflected in concentrating festivals for the left-handed caste, of which weavers were an integral part, in the months of the monsoon. During the rains, yarn preparation, which was done outdoors, could not be performed (Parthasarathi 2001: 12, 19).

India did not possess the necessary power sources to develop a modern factory system, before the steam engine liberated industries from the riverbanks, due to the difficulty of exploiting rivers in both the rainy and the dry seasons.¹⁷ Moreover, the large rivers crossing the northern plains had very few places with a sufficient head of water. The Ganges, for example, falls only 215 metres on its 1,600-kilometre journey from Delhi to the sea. The extreme monsoon pattern in India brings 90 per cent of the annual rainfall between June and September, resulting in swollen, violent rivers. During the rest of the year, rivers are shallow and slow-flowing, and some even dry up completely. To use these rivers for year-round power production was virtually impossible at the time. Moreover, they ran through flat plains, whose only relief was flood-plain bluffs and belts of ravines and badlands formed by gully erosion along the larger streams. The steady or sudden migration of rivers and riverbeds made factory building on riverbanks a very risky business. In Bengal, where the

textile industry was strongest, rivers meandered through the slopeless plain of the Ganges–Brahmaputra delta. About 80 per cent of present-day Bangladesh is less than 10 metres above sea level, and in the flood season almost half the country is normally under water. The rivers in the southern parts of the sub-continent depended almost completely on the monsoon and were generally more irregular than the Himalayan rivers.

In India, therefore, inanimate power was mostly used only in a few places where watermills could be established. There were watermills along some of the streams of the Deccan plateau, where Panchakki took its name from a seventeenth-century watermill, which used to grind grain for the pilgrims and troops of the garrison. A mountain spring provided the water which powered the mill. Water power was also used in the north-western district of Hazara ‘to manoeuvre a wooden trip-hammer for milling rice’. The vertical wheel was also found in a water-driven cotton gin in another part of the same district. The latter, it has been argued, was a local invention (Raychaudhuri 1982: 261–308, 292–3). Hazara, unlike the rivers on the plains and in the Deccan, had sufficient water to drive a mill, to a great extent on a perennial basis. These few pockets of water power make it clear that the technology was known, and they indicate that the problem was the diffusion of this technology to the very different water regimes that dominated in the central economic regions of India.

A NEW INTERPRETATION OF THE ‘GREAT DIVERGENCE’

This chapter has shown that an inclusive explanation of why certain regions of Britain were the first to industrialise must consider and analyse the complex, multifunctional water systems within which these developments took place. The reason is that before the dominance of the steam engine, the revolution in transport systems and the development of the modern factory system that transformed much of Britain from the 1760s to the 1820s were linked to changes in how the British related to and used their particular waterscape. It has also described how the central economic and political regions of India and China did not have water systems that could be used or developed as easily and profitably as they could be in parts of Europe. Variations in hydraulic designs can thus not only be interpreted in social terms or reduced to social variables.

Water-society systems affected other important variables relevant to growth and development that have not been specifically dealt with here, for example management practices and ideas about water. In the latter half of the eighteenth century, Chinese water management traditions could be categorised into four main activities: drainage, flood control,

irrigation and transport. Drainage had been an important activity on the flood plains, due to the combined impact of the monsoon, melting ice in the Himalayas, and the flatness of the land. Even Chinese creation myths were connected to mythical stories about drainage; the Emperor Yu became mythical because he managed to drain the lowlands in the mythical past. Flood control has been a key task throughout Chinese history, particularly on the lower reaches of the major rivers. In some cases, therefore, navigation canals were a sort of fringe benefit of proper levee maintenance. The gradual development of a system of drainage canals, and the water management system that was established to oversee their maintenance, was more a hindrance than a benefit to building canals for transport of goods and for turning the rivers into power sources for machinery. The density of irrigation canals in both the Yellow River and the Yangtze basins also slowed the development of water transport and the use of water for power production, because these needs collided. During the Ming and Qing dynasties, the Director General of Waterways was responsible for management of the Grand Canal and the lower Yellow River basin, and his main task was, and this is significant, to prevent damage to the impressive Grand Canal. This very powerful state agency has been described as an adjunct of the Grain Transport Administration, and the staff there was therefore not interested in building canals for transport of other goods from other places, or in building dams and ponds for mechanical water power production, also because such projects would have made management of the Grand Canal even more complex and difficult.

In England, management traditions and ideas about how water should be used were much more pluralistic and neither the state nor the financial elite had strong vested interests in a particular type of water management of the past. There were of course conflicts between different water usages also in England, but since irrigation and irrigation canals were of marginal importance, the conflicts arose more within the modernising sectors of the economy – between those who wanted to develop the waterways for transport and those who wanted to develop them for power production. Since the waterscape was so diverse and the rivers had been of marginal economic and political importance for other sectors of society, water entrepreneurs could emerge and operate quite unhindered by state intervention and, in fact, usually supported by the state.

The issue of cultural constructions of water was also important and requires more research to be understood. The transformation of the rivers into a form of natural capital and a source of profit for individual entrepreneurs, as happened in England, did not occur in India, where the cultural construction of water or water resources was not concerned with how to put them to work in the construction of a new social and economic

order. On the contrary, water had been recognised as a primordial spiritual symbol since Vedic times (Baartmans 1990), and the seven major rivers, especially the Ganges, were pivots of regional sacred geography. Thus, all over the country temples, holy tanks and important places of ritual were to be found on the banks of rivers, a cultural practice often merged with economic activities that most likely influenced the early drive for water engineering works for purely economic purposes.

The climatic history of these countries in the eighteenth century also needs to be studied in much greater detail. For example, during the very same decades in which England prospered, terrible floods and droughts devastated parts of both India and China.¹⁸ These rapid and partly uncontrollable changes in the behaviour of their main rivers obviously contributed to dynastic decline, but nothing has yet been published on how this affected the economic development of these during these decades. Water systems also had a fundamental impact on health, living standards, population growth and thus labour productivity and labour costs. In India, for example, malaria was rampant, and it has been called 'Killer no 1' in the sub-continent. Nobody has so far presented a systematic comparative study of the consequences of waterborne diseases on productivity levels in the eighteenth century.

With its focus on the period from the 1760s to the 1820s, this chapter has argued for the fruitfulness of a broader research project on the Industrial Revolution that would locate it within a deeper history of technological change, waterscapes and water control.¹⁹ There is general agreement that the mixture of large rivers, fertile soil created by the same rivers and irrigation was a precondition for the first riverine irrigation civilisations to develop in Asia and the Middle East about 5,000 years ago. The erratic character of the rainfall and the intense seasonality and silt loads of the rivers were turned into advantages by human intervention. Large and prosperous agricultural civilisations were established with the aid of artificial irrigation. From the Indus to the Yellow Rivers, great civilisations rose from the life-giving waters of these turbid, violent river systems and, especially in China, there emerged a strong water management tradition, geared to control and defence. This chapter has suggested that the very conditions that had given Asian irrigation economies their comparative advantage for millennia had become a disadvantage by the eighteenth century. The system that was conducive to agriculture made it extremely difficult to establish modern factories based on water power along British lines, and stifled the establishment of an efficient system of all-year waterways for transport.

Many factors must be considered in explanations of why parts of north-western Europe were at a disadvantage compared to Asian and Middle Eastern irrigation civilisations during the long period when agriculture

dominated. But these different development trajectories cannot be grasped without bringing into the analytical picture the fact that rain-fed agriculture was far from being as productive as cropping benefiting from artificial irrigation and fertile silt-laden soils. The long, snowy winters additionally reduced the cropping period and the possibility of multiple harvests, making overall yield much less in north-western Europe than on the banks of the Nile, the Indus, the Yellow River or the Euphrates. The Eurasian raincoast states did also develop a water management bureaucracy, but it was much smaller and less powerful than in the river basins further east and in the eastern Eurasian monsoon states. Moreover, here the habits of thought or the ideas about water were not geared to exploiting rivers for canalisation and agriculture, but had for centuries been concerned with how to handle conflicts between millers or transporters, or between the mill and the lock.

Then, in the later eighteenth century, during the first phase of the Industrial Revolution, those hydrological conditions, which had worked against radical productivity gains in the earlier phases of the agricultural age, gave this part of Europe a decisive advantage over Eurasia. The waterscape of much of England, and to a lesser extent of parts of Western Europe, was relatively easy to exploit, control and develop into transport routes and sources of power, thanks to its abundance of medium-sized, perennial rivers and brooks, which could be exploited all year round. The rapid economic development of the latter part of the eighteenth century had been in the making for generations, as thousands of millers, engineers and boatmen had experimented with and improved technologies and machinery capable of exploiting countless small, silt-free, benign brooks and streams. Even if the Chinese and the Ottomans had had the same entrepreneurial ideas and political culture as some of the British modernisers, they could not have pushed their country through an industrial revolution at that time because they did not have either the transport routes or the power sources. This chapter has shown that in order to give a more complete and thorough understanding of why Britain and the West could lead the world into one of its most fundamental transformation processes one also has to make variations in water-society relations a central part of the whole story, and that it is not sufficient to focus only on European exploitation and unequal trade relationships or on institutional traditions and cultural and scientific ideas. By including both social and natural factors in the narrative, this non-reductionist analysis of the Industrial Revolution helps to explain the gradual and regional character of its development and the emergence of the 'Great Divergence', and it does so by distinguishing between necessary and sufficient causes and between causes and prerequisites.