

BRITISH ACADEMY LECTURE

The Quest for the Industrial Revolution

E. A. WRIGLEY
Fellow of the Academy

WHEN DEANE AND COLE published their pathbreaking study of the growth of the British economy between the late seventeenth and mid-twentieth centuries, they concluded, in effect, that the term ‘industrial revolution’ was meaningful and that the conventional chronology was broadly correct—that over a period of half a century or so beginning in the last decades of the eighteenth century there was a marked acceleration in the rate of growth of the national product, an acceleration so marked that, in spite of the fact that population grew faster in this period than at any earlier or subsequent time, output per head also rose more quickly than previously. ‘At the end of the century, however, there was a crucial change. After 1785, both total output and population were growing much faster than before, but the former now began to draw decisively ahead of the latter. For the first time, per capita output started to increase—at more than three times the average rate for the rest of the period under review [that is, the eighteenth century].’¹

In one sense it is almost impossible to quarrel with the use of the term ‘industrial revolution’. We live in a world in which it is difficult for people in wealthy countries to see the point of the plea in the Lord’s Prayer that we should each day be given our daily bread. Relative deprivation may be severe even in the wealthiest of countries, but few lack the ability to buy as much bread as they can eat. Yet for most people in every generation before the industrial revolution the plea made perfect

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¹ P. Deane and W. A. Cole, *British Economic Growth 1688–1959: trends and structure* (Cambridge, 1962), p. 80.

sense. When there was a poor harvest, the few with surplus grain to sell might prosper; others, with few exceptions, suffered. The industrial revolution resolved a tension which had haunted all organic economies, those economies in which almost all the material artefacts of value to man were derived from animal or vegetable products, and whose production was therefore constrained by the productivity of the land. This was the tension to which Malthus gave classical expression when he called attention to the tendency of population when unchecked to grow geometrically, while the supply of food could at best be expected to rise arithmetically.² By one of the most striking ironies of intellectual history, however, Malthus published his *Essay on Population* just at the time when, with the benefit of hindsight, it is clear that his strictures were ceasing to be applicable, and it is additionally ironical that the changes which made his analysis obsolete were happening in the country in which he was living.

Yet there is another sense in which the use of the term industrial revolution poses a severe problem. The work of Deane and Cole was path-breaking in that they made a determined effort to quantify the size and rate of growth of the national economy as a whole, to parallel earlier qualitative or partial descriptions of the industrial revolution by an exercise which would integrate estimates of growth rates in individual industries into a comprehensive account covering the economy as a whole and which would allow the relative importance of the different components of the whole to be identified.³ How significant within the overall national picture were agriculture, the cotton industry, the iron industry, and so on? Was expansion widespread and uniform, or disproportionately concentrated in a few sectors of the economy?

Deane and Cole recognised, indeed emphasised, that many of the estimates which they incorporated in their analysis were fragile because the available data were fragmentary or even completely lacking, forcing them to make assumptions which were open to question. Others following in

² 'Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio. A slight acquaintance with numbers will show the immensity of the first power in comparison of the second.' T. R. Malthus, *Essay on the Principle of Population as it affects the Future Improvement of Society* [1798], in *The Works of Thomas Robert Malthus*, ed. E. A. Wrigley and D. Souden (London, 1986), vol. 1, p. 9.

³ The radical nature of the contrast between the approach of Deane and Cole and that of their predecessors is well illustrated by comparing their *British Economic Growth* with Ashton's *An Economic History of England: the 18th century* (London, 1955), a widely acclaimed work, which had been published only seven years earlier.

the footsteps of Deane and Cole reconsidered their assumptions and were also able to take advantage of fuller or more reliable data. In particular, twenty years after the publication of Deane and Cole's *British Economic Growth*, Crafts published a book with the same short title which reviewed all that had happened in the interim and concluded that the spurt in the growth rate after *c.*1785 was an illusion. If measured per caput, the growth rate of the national economy at the end of the eighteenth century was no greater than at its beginning and any further acceleration was so modest as to call in question its reality; even if measured in aggregate, growth was only moderately faster, at least before the 1830s.⁴ Subsequent work has confirmed, even reinforced scepticism about acceleration during the classical period of the industrial revolution.⁵ Like the grin on the face of the Cheshire cat, the industrial revolution has faded from the face of the economic history of Britain in the later eighteenth and early nineteenth centuries. The term itself has not lost currency, but its traditional meaning has few remaining advocates.

How best, then, to resolve the apparent paradox posed by these two senses in which the term 'industrial revolution' is used? Is it possible either, on the one hand, to restore to it a meaning which would allow it to be located clearly in time and space once more, or, on the other, to show reason to replace it with a term or a concept which would 'save the phenomena' in a way which the old term no longer succeeds in doing?

The first step, in my view, is to consider further the implications of what for convenience may be termed the Crafts revision.⁶ Note, first, what has not changed significantly since the work of Deane and Cole. Estimates of the size of the national economy in the middle decades of the nineteenth century are little different now from those of forty years ago. In the middle of the nineteenth century, output per head and average

⁴ Crafts estimated the rate of growth of national product per head in 1700–60 as 0.31 per cent per annum; in 1780–1801 as 0.35 per cent per annum, while the comparable rates of growth in the aggregate national product were 0.69 and 1.32: Crafts, *British Economic Growth during the Industrial Revolution* (Oxford, 1985), table 2.11, p. 45.

⁵ In a measured review of recent scholarship, Deane noted, 'The results so far published now point, still tentatively, to two conclusions: first that such acceleration as occurred in the national rate of British economic growth during the late eighteenth and early nineteenth centuries represented the culmination of a long-drawn-out process, an evolutionary rather than a revolutionary development; and second that the British experience of industrialization differed in significant respects from that of any other of the countries which industrialized subsequently.' P. Deane, 'The British Industrial Revolution', in M. Teich and R. Porter (eds.), *The Industrial Revolution in National Context* (Cambridge, 1996), p. 15.

⁶ Not that it has been Crafts's work alone which has brought about the change.

real incomes were higher in Britain than in any other country.⁷ The 1851 Exhibition symbolised what all well-informed observers agreed to be the case, that Britain possessed the most productive economy to be found anywhere in the world. Pollard recently noted that Britain at that time ‘was able to produce, in a whole series of key sectors, as much as the rest of the world put together’; an astonishing, if necessarily transient, phenomenon.⁸ Those countries which had successfully challenged Britain’s position by the close of the century, such as Germany and the United States, were still adrift at the century’s midpoint. The significance of this fact, however, in the light of the Crafts revision, is arguably greater in relation to 1750 than it is to 1850. If the rate of growth of the economy during the classic period of the industrial revolution was radically slower than was once assumed and yet estimates of its size at the end of that period have not changed, it follows that its size at the beginning of the period must be markedly larger than was previously supposed. If the slope of a line inclining up to a fixed point is reduced, the point representing the other end of the line will necessarily rise higher.

The scale of the change implied by the Crafts revision is substantial. His estimates of growth rates between 1760 and 1831 imply that national output in 1760 must have been approximately 60 per cent larger than supposed by Deane and Cole. Similarly, whereas they estimated that output per head rose by 87 per cent over this period, he put the comparable figure at only 29 per cent.⁹ Precision is, of course, beyond reach in this connection, but what is indisputable is that the Crafts revision enforces the

⁷ Maddison offers the following estimates of GDP per caput (1990 international \$):

	1820	1870
United Kingdom	1,707	3,191
United States	1,257	2,445
France	1,230	1,876
The Netherlands	1,821	2,753

In considering these estimates, it should be borne in mind that GDP per caput was much higher in England and Wales than in the UK as a whole. Maddison offers estimates for England and Wales and for the UK as a whole for 1801. Assuming that his estimates are reliable and that the same ratio obtained later in the century, the figures for England and Wales in 1820 and 1870 would be 2,169 and 4,056. The 1801 ratio should be approximately valid for 1820 but not for 1870 since the Irish fraction of the total UK population fell precipitately in the wake of the great famine of the 1840s. A. Maddison, *The World Economy: a Millennial Perspective* (OECD, 2001), table B-13, p. 247 and table B-21, p. 264

⁸ S. Pollard, ‘The Industrial Revolution: an overview’, in M. Teich and R. Porter (eds.), *The Industrial Revolution in National Context* (Cambridge, 1996), p. 376.

⁹ The figures quoted were derived by chaining the growth rate percentages in Crafts, *British Economic Growth*, table 2.11, p. 45.

view that the economy was much larger in the mid-eighteenth century than it was once conventional to assume, and, even more important, that output per head was only modestly lower at that time than in the early years of Victoria's reign, a massive contrast with the near doubling in individual productivity per head which Deane and Cole had supposed in 1962. If it is both true that in the mid-nineteenth century the British lead was clear-cut and also true that a century earlier individual productivity was not far short of its mid-nineteenth century level, interest shifts from the classic period of the industrial revolution to the centuries which preceded it. The gap between Britain and her neighbours, which was once assumed to have been the product of an exceptional surge in growth taking place during the reigns of George III and his sons, must now appear to have opened up much earlier.¹⁰

It is one of the great strengths of Crafts's discussion of growth during the industrial revolution period that he went to much trouble to compare the British experience with that of her Continental neighbours. He had no difficulty in showing that the latter had more in common with each other than they had with Britain. At similar levels of economic advance, as measured by real income per head, Britain was much more urbanised and far less dependent upon agriculture than her neighbours, and, whereas on the Continent the value of the annual product per head of those engaged in agriculture fell far below that found elsewhere in the economy, in Britain productivity in agriculture, measured in this fashion, equalled the national average. Change was also much slower in Britain than elsewhere. Crafts estimated, for example, that Continental countries moved from average incomes per head of \$400 to average incomes of \$550 (in 1970 US dollars) in about one third of the time taken by Britain (he regarded an income level of \$550 as representing a point at which rapid change was well under way).¹¹

The comparisons made by Crafts are both valid and valuable, but the conclusion that Britain was very different from her neighbours may be as

¹⁰ It is important in this connection to distinguish clearly between the rate of growth of aggregate output and the rate of growth of output per head. Because the classic period of the industrial revolution coincided with the period in which the rate of population growth accelerated sharply in the early decades of the nineteenth century to reach a height never exceeded before or since, aggregate output could only have failed to accelerate substantially if there had been a fall in output per head, but in the context of the present discussion the key variable is output per head rather than total output, and in the light of the Crafts revision output per head was rising by only about 0.35 per cent per annum between 1760 and 1831 (Crafts gives the rate of growth in product per head during the periods 1760–80, 1780–1801, and 1801–31 as 0.01 per cent per annum, 0.35, and 0.52 respectively: Crafts, *British Economic Growth*, table 2.11, p. 45).

¹¹ *Ibid.*, p. 61.

much a matter of perspective as of substance. Viewed from the early twenty-first century, it may ring true. Viewed from the late eighteenth century by, for example, Adam Smith, it would have seemed odd to treat the British experience in this fashion. It should be remembered that by this date, in the light of the Crafts revision, output per head in Britain must be regarded as already well above the European norm. There was, in other words, already something to explain. The divergence of England did not lie in the future; it was already a fact. But the British advance was not seen by Adam Smith as out of line with experience elsewhere; on the contrary, in Smith's view, Britain was treading the path long trodden by the Netherlands. In many key respects what was happening in England, and to a lesser degree elsewhere in Britain, resembled what had happened in the Netherlands a century or so earlier. Adam Smith, in my view, was right. Consider three closely inter-related variables which illustrate the point: urbanisation, occupational structure, and real income per head.

It is one of the most remarkable, though often least remarked, paradoxes of early modern Europe that although in a Braudelian world capitalism and urbanisation are strongly linked and the capitalist system is regarded as having made great advances in the sixteenth, seventeenth, and eighteenth centuries, Continental Europe was little more urbanised in 1800 than it had been in 1600. The growth of towns and cities can be quantified with greater confidence than most other aspects of social and economic development in the early modern period. It has recently been the subject of extensive study by de Vries. His critical collation of the available evidence led him to conclude that 10.8 per cent of the total population of Europe lived in cities with 5,000 or more inhabitants in 1600 rising to 13.0 per cent in 1800. However, if England, whose urban growth was exceptionally vigorous, is removed from the European totals, the picture changes: the percentages are then 10.9 and 11.9, suggesting only marginal growth in Continental Europe.¹² At much the same time as de Vries, Bairoch undertook a similar study of urban growth in Europe over many centuries. His estimates produce a still more striking result. Using the same criterion, that a settlement counted as urban if its population was 5,000 or more, his urban percentages for Europe as a whole in 1600 and 1800 were 12.9 and 13.8, but if England is excluded from the calculation,

¹² J. de Vries, *European Urbanization 1500–1800* (Cambridge, Mass., 1984), table 3.6, pp. 36–7 and table 4.13, p. 72; E. A. Wrigley, 'Urban growth and agricultural change: England and the continent in the early modern period', in E. A. Wrigley, *People, Cities and Wealth: the Transformation of Traditional Society* (Oxford, 1987), table 7.4, p. 170.

there is a slight *fall* in the urban percentage between the two dates from 13.1 to 13.0.¹³

Urban growth in England in the second half of the eighteenth century was so notable and elsewhere so modest that about 70 per cent of all the urban growth in Europe as a whole occurred in England alone, even though the English share of the total European population was only 8 per cent.¹⁴ But the remarkable surge of urban growth in England in the seventeenth and eighteenth centuries did no more than parallel developments in the Netherlands previously. Since the Netherlands was a substantially smaller country than England, the absolute increase in urban population totals was comparatively modest, but the proportional changes were similar. Steady urban growth in the sixteenth century meant that the Netherlands in 1600 was already almost as urbanised as England in 1800 (24.7 and 27.5 per cent respectively), and a century later 33.9 per cent of the Dutch population lived cities with 5,000 or more inhabitants.¹⁵ By 1700, therefore, the Netherlands was significantly more urbanised than England a hundred years later, though during the eighteenth century the Dutch economy trod water and there was a modest decline in the urban percentage from 33.9 to 29.5 per cent. In 1800 the two countries were roughly equal in this regard.¹⁶

The extent of the contrast between the occupational structure of the labour force in England and that on the Continent in 1800 has often been stressed. At that date only about 40 per cent of the male labour force in England was employed on the land, at a time when the comparable percentage characteristically lay between 65 and 80 per cent on the Continent, a contrast which implies, of course, that a far higher percentage

¹³ P. Bairoch, J. Batou, and J. Chèvre, *La population des villes européennes. Banque de données et analyse sommaire des résultats* (Geneva, 1988), table B2, p. 255. Bairoch's definition of 'Europe', though excluding Russia in this tabulation, covers a wider area than that of de Vries, which excluded most of eastern Europe. Bairoch does not provide estimates of total population, but the table gives both urban percentages and urban totals, so that the implied total populations can be calculated with only an insignificant margin of error. The English population totals were again taken from Wrigley, 'Urban growth and agricultural change', table 7.4, p. 170.

¹⁴ *Ibid.*, table 7.7, p. 179.

¹⁵ De Vries, *European Urbanization*, table 3.6, pp. 36–7 and app. 1, p. 271; Wrigley, 'Urban growth', table 7.4, p. 170.

¹⁶ There are interesting points of similarity between London and Amsterdam, the primate cities in the two countries. Each grew roughly fourteen-fold between 1500 and 1700, and in both the growth rate declined sharply in the eighteenth century, though more markedly in Amsterdam than in London, but Amsterdam did not dominate the Dutch urban system to the astonishing, almost bizarre degree that London overshadowed other cities in England; de Vries, *European Urbanization*, app. 1, pp. 270–1.

of the English labour force was engaged in secondary or tertiary occupations.¹⁷ Here again, however, England was doing no more than mirror the position reached a century earlier in the Netherlands. In the 1670s approximately 40 per cent of the Dutch labour force was engaged in agriculture, 32 per cent in industry, and the remaining 28 per cent in service employments.¹⁸ More than a century later, in 1800, the comparable English percentage in agriculture was identical and the other two percentages were closely similar.¹⁹ The high level of output per head in English agriculture was one of the characteristics to which Crafts rightly drew attention. It was this which made possible such a considerable release of labour into activities other than agriculture. The agricultural labour force in 1800 was probably little, if any, larger than it had been in 1600 and yet in 1800 England was still largely self-sufficient in foodstuffs, even though the population was more than twice as large as it had been at the end of Elizabeth's reign.²⁰ Once again, however, the Netherlands was beforehand. Urban need created a large and expanding market for agricultural products and Dutch agriculture proved as adept as English in responding flexibly to market demand, in economising in the use of labour, in raising output per head, and in identifying where its comparative advantage lay; and it did so at an earlier date.²¹

The acid test of the productiveness of an economy is the level of real income which it will support. Few contemporaries doubted that the

¹⁷ E. A. Wrigley, 'Men on the land and men in the countryside: employment in agriculture in early nineteenth-century England', in L. Bonfield, R. M. Smith, and K. Wrightson (eds.), *The World we have gained: Histories of Population and Social Structure* (Oxford, 1986), table 11.12, p. 332; *idem*, 'Country and town: the primary, secondary, and tertiary peopling of England in the early modern period', in P. Slack and R. Ward (eds.), *The Peopling of Britain: the Shaping of a Human Landscape* (Oxford, 2002), table 7.2, p. 223 and associated discussion.

¹⁸ J. de Vries and A. M. van der Woude, *The First Modern Economy: Success, Failure, and Perseverance of the Dutch Economy, 1500–1815* (Cambridge, 1997), p. 527.

¹⁹ Deane and Cole, *British Economic Growth*, table 30, p. 142; Wrigley, 'Men on the land', table 11.12, p. 332.

²⁰ Jones estimated that British agricultural output covered 90 per cent of the country's food needs c.1800. Overton's recent discussion of this and cognate questions results in a similar or somewhat higher figure. E. L. Jones, 'Agriculture 1700–80', in R. Floud and D. McCloskey (eds.), *The Economic History of Britain since 1700* (Cambridge, 1981), I, table 4.1, p. 68; M. Overton, *Agricultural Revolution in England: the Transformation of the Agrarian Economy 1500–1850* (Cambridge, 1996), pp. 74–6.

²¹ In the sixteenth and seventeenth centuries the Dutch agricultural labour force was broadly unchanging in number: output per head roughly doubled. J. de Vries, 'Dutch economic growth in comparative historical perspective, 1500–2000', *De Economist*, 148 (2000), 456.

Netherlands led the way in this respect throughout the early modern period.²² England probably remained in arrears until well into the eighteenth century, and the same was true *a fortiori* of Britain as a whole. The estimates made by de Vries and van der Woude suggest that any crossover occurred only sometime in the third quarter of the eighteenth century. Maddison's comparative data on real incomes place England slightly ahead of the Netherlands at the end of the eighteenth century, but suggest a very marked Dutch advantage a hundred years earlier, thus paralleling the conclusions of de Vries and van der Woude.²³

When Adam Smith conducted his *An Inquiry into the Nature and Causes of the Wealth of Nations* he was clear about the Dutch advantage. 'The province of Holland, on the other hand, [that is, in contrast to France] in proportion to the extent of its territory and the number of its people, is a richer country than England.'²⁴ But it was not this bald assertion that is intriguing about Smith's use of the example of Holland, but his subsequent discussion of economic growth and its limits, for it provides a useful clue in the quest for the industrial revolution. His reference to Holland occurs in a chapter entitled 'Of the profits of stock'. He begins by noting that it is very difficult to measure what he referred to as 'the average profit of all the different trades carried on in a great kingdom',²⁵ or what might now be termed the rate of return on investment, but added: 'though it may be impossible to determine with any degree of precision, what are or were the average profits of stock, either in the present, or in ancient times, some notion may be formed of them from the

²² Though Gregory King was inclined to view the difference as relatively minor. He estimated that in 1695 income per head in England was £7. 16s. 0d., in Holland £8. 2s. 9d., and in France £5. 18s. 0d.: G. King, *Natural and Political Observations and Conclusions upon the State and Condition of England 1696 in The Earliest Classics*, with an introduction by P. Laslett (London, 1973), p. 68.

²³ De Vries and van der Woude, *First Modern Economy*, fig. 13.1, p. 707; Maddison, *The World Economy*, table B-13, p. 247 and table B-21, p. 264. De Vries and van der Woude suggest that the Dutch advantage in the later seventeenth century may have been between 30 and 40 per cent. Indeed they estimate that in the period of the Anglo-Dutch wars the gross national product of the Dutch Republic was probably 40–45 per cent of that of England, though by 1800 it was only 20 per cent of the English total: *ibid.*, p. 710. See also, de Vries, 'Dutch economic growth in comparative historical perspective'.

²⁴ A. Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*, 5th edn., ed. E. Cannan, 2 vols. (Chicago, 1976: orig. pub. 1904), I, p. 102. He added, 'The wages of labour are said to be higher in Holland than in England'. *Ibid.*, p. 102.

²⁵ *Ibid.*, p. 98.

interest of money.²⁶ He then went on to develop an argument which related the rate of interest to the scale of the opportunities for profitable investment, noting that the rate was higher in Scotland and France than in England because of their relative backwardness, but was higher in England than in Holland. In England the government was able to borrow at 3 per cent in peacetime and people of good credit at between 3½ and 4½ per cent, but in Holland the comparable rates were 2 per cent for the government and 3 per cent for private individuals.²⁷ The rate declined *pari passu* with economic success because opportunities for profitable investment were not unlimited. Present growth must always come at the cost of future deceleration, or as Smith put it:

In a country which had acquired that full complement of riches which the nature of its soil and climate, and its situation with respect to other countries, allowed it to acquire; which could, therefore, advance no further, and which was not going backwards, both the wages of labour and the profits of stock would probably be very low.²⁸

A little later he repeated the same initial phrase 'In a country which had acquired its full complement of riches' and drew out some further implications of this tendency, adding that 'The province of Holland seems to be approaching near this state.'²⁹ England was a little further from the same sad fate, but Smith saw no prospect of escape from it.

I have drawn attention to Adam Smith's views partly because doing so affords an opportunity to view the eighteenth-century world through an acute and well-informed contemporary eye, but also because his analysis is a convenient introduction to two further issues which deserve discussion in attempting to cover the range of matters relevant to the reconsideration of the industrial revolution: capitalism and the nature of the limits to growth in a pre-industrial world.

Smith was a keen advocate of the market as a vehicle for the efficient allocation of resources and for the identification of opportunities for growth. He favoured what is now conventionally referred to as the capitalist system, though his support was far from uncritical, but, as we have already seen, he did not suppose that the adoption of capitalism would prove a guarantee of indefinite growth, merely that it was the best insti-

²⁶ A. Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*, 5th edn., ed. E. Cannan, 2 vols. (Chicago, 1976: orig. pub. 1904), I, p. 99.

²⁷ *Ibid.*, pp. 100, 102.

²⁸ *Ibid.*, p. 106.

²⁹ *Ibid.*, p. 108.

tutional form to ensure that the good use was made of the opportunities offered by a country's situation and resources. His view of the possibilities of growth was, to use modern jargon, asymptotic rather than exponential. In view of this, and of his belief that the future for other countries was etched in the past experience of Holland, it is striking that in their recent study of Dutch economic history, entitled in its English version *The First Modern Economy*, de Vries and van der Woude may be said to re-express Adam Smith's views in the terminology of the late twentieth century. They offer a definition of a modern economy which, in its essentials, is one which might equally well be employed to define a capitalist economy.³⁰ The Netherlands in the early modern period, they argue, was a modern, that is a capitalist, economy. It was also an economy which, towards the end of the seventeenth century, lost momentum, reaching what might be termed a plateau of economic achievement, bearing a close resemblance to that described by Adam Smith when he referred to what would happen when a country had acquired its 'full complement of riches', a condition sometimes termed 'the stationary state'.³¹ Having analysed the reasons for the loss of growth momentum and having shown that these were characteristic of a modern economy rather than a pre-industrial economy, de Vries and van der Woude went on to make explicit what was already implicit in their analysis: 'This formulation harbors an implicit claim about modern economic growth. It is not self-sustained, exponential, and unbounded.'³² The capitalist system, in

³⁰ De Vries and van der Woude, *First Modern Economy*, p. 693. They listed the four key characteristics of a modern economy as: (1) free markets for both commodities and factors of production; (2) a sufficiently high level of agricultural productivity to sustain a complex social and economic structure with extensive division of labour; (3) a state willing and able to support property rights, freedom of movement and contract, and concerned to advance the material conditions of life of its population; (4) a level of technology and organisation able to support a sufficiently sophisticated material culture to sustain market-orientated consumer behaviour.

³¹ Even as late as the middle of the nineteenth century when the economy was greatly changed from the days of Adam Smith, John Stuart Mill, the dominant economic thinker of his day, remained troubled by this issue: 'The materials of manufacture being all drawn from the land, and many of them from agriculture, which supplies in particular the entire material of clothing; the general law of production from the land, the law of diminishing return, must in the last resort be applicable to manufacturing as well as to agricultural history. As population increases, and the power of the land to yield increased produce is strained harder and harder, any additional supply of material as well as of food, must be obtained by a more than proportionally increasing expenditure of labour.' J. S. Mill, *Principles of Political Economy with some of their Applications to Social Philosophy*, ed. J. M. Robson, 2 vols. (Toronto, 1965), I, p. 182. Mill, however, also found reasons to take a less pessimistic stand, but one of his reasons for advocating restraint upon fertility was his concern about the dangers of over-rapid population growth: *ibid.*, I, pp. 345-6.

³² De Vries and van der Woude, *First Modern Economy*, p. 720.

other words, may promote growth, but there is nothing in its nature to guarantee its long continuance.

What was it that constrained growth, which promised at best asymptotic growth in the early modern world? Why did there appear to be limits to growth? Gaining clearer understanding of this issue is of great consequence in the quest for the industrial revolution because it serves to make clear why England, having followed the Dutch example so closely for so long, did not lose the momentum of growth, but made a successful transition from an asymptotic to an exponential growth curve. The answer was given starkly and trenchantly by the third of the triumvirate of the great economists of the era later generations have labelled the industrial revolution, David Ricardo. It was Ricardo who gave clearest expression to what is usually termed the law of diminishing returns.³³

Whilst the land yields abundantly, wages may temporarily rise, and the producers may consume more than their accustomed proportion; but the stimulus which will thus be given to population will speedily reduce the labourers to their usual proportion. But when poor lands are taken into cultivation, or when more capital and labour are expended on the old land, with a less return of produce, the effect must be permanent.

Ricardo then went on to draw out the implications of this assertion for labour and capital, both of which must ultimately suffer in an expanding economy from the fact that the supply of land was limited. He concluded, significantly: ‘This [that is the reduced reward both to labour and to capital] will necessarily be rendered permanent by the laws of nature, which have limited the productive powers of the land.’³⁴

Ricardo’s essential insight can be restated in a manner which helps to explain how, at the very time when Smith, Ricardo, and Malthus were writing, the problem which all three viewed as ineluctable, was slowly ceasing to trouble the English economy. Ricardo referred to the laws of nature, and was right to do so, since it was a combination of physical, chemical, and biological processes which formed the key constraint. Both the sustenance of life and the production of all the material artefacts of value to man must involve the consumption of energy. Food is the fuel of

³³ Though Malthus expressed the same idea at much the same time in *An Inquiry into the Nature and Progress of Rent, and the Principles by which it is Regulated* [1815] in *The Works of Thomas Robert Malthus*, ed. E. A. Wrigley and D. Souden, vol. 7 (London, 1986).

³⁴ D. Ricardo, *On the Principles of Political Economy and Taxation* [1817] in *The Works and Correspondence of David Ricardo*, ed. P. Sraffa with the collaboration of M. H. Dobb (Cambridge, 1951), I, pp. 125–6.

all living organisms, but man, unlike other animals, was also a voracious consumer of energy for other purposes. At some point in the sequence of activities which converts raw materials into finished products for human consumption or use, both heat energy and mechanical energy must be expended. The ultimate source of almost all energy available on the surface of the earth is the sun. The scale of energy transfer from the sun in the form of insolation in the course of a year is enormous, but organic societies could only hope to tap a tiny fraction of this inflow of energy. Overwhelmingly the most important energy source for such societies was the process of photosynthesis by which plants use sunlight to generate the vegetable growth which in turn forms the base of the food pyramid sustaining all forms of life. But photosynthesis did not only provide food; it provided the heat energy used by organic societies in the form of wood, and most of the mechanical energy which they used in the form of human or animal muscle power.³⁵ Photosynthesis also provided communities with most of their raw materials, of which the great bulk used in production processes were either vegetable or animal. Even in the production of metals, although the raw materials were mineral, their smelting meant the expenditure of heat energy on a large scale, and this energy came from the burning of wood or charcoal.

Unhappily for the inhabitants of the pre-industrial world, photosynthesis is not an efficient process. The conversion efficiency of natural vegetation has been variously estimated at between one and four parts in one thousand. The natural plant cover, in other words, captures only a tiny fraction of what is potentially available. Cultivated plants have a slightly higher conversion ratio on average, but remain within the same range. Thus, to indicate the severity of the constraint which is inherent in this situation, although the annual solar energy receipt of the United Kingdom has been estimated at more than 22 billion tons of coal equivalent a year, a truly colossal total,³⁶ the theoretical maximum available to the country in a pre-industrial era via the process of photosynthesis was only about 40 million tons of coal equivalent at best. Of this, however, a very substantial fraction was unavailable for human use because of the energy loss in moving up the food chain and because of the claims of other forms of

³⁵ The inflow of solar energy also provided an additional source of mechanical power because of the energy potential of moving wind and water, but this was of minor importance compared with muscle power.

³⁶ At its peak in 1913 the coal output of British collieries was 287 million tons, or only about 1.5 per cent of the solar energy receipt.

life.³⁷ All pre-industrial societies were organic economies in the sense that they were dependent upon animal and vegetable resources for almost all their energy, whether expressed as food for men and women, as fodder for draught animals, or as fuel for heating a house, baking bread, making bricks, boiling dyes, brewing beer, smelting metal, or heating salt pans. All such societies had to work within an energy budget which made many of the activities and processes which became basic to economic life in later centuries physically impossible. It would be impossible, for example, within the constraints of an organic economy to produce iron and steel on a scale sufficient to construct a modern rail network or an oil tanker, still less the tens of millions of cars which are manufactured every year. Symbolically, one might describe the change wrought by the lifting of the energy constraint as the difference between a Toledo blade and a battle tank.

Stating the problem in this fashion points to the developments which made escape from these constraints feasible. Only by finding a way round the energy barrier which had always limited growth could poverty cease to be an inescapable element in the human condition and become problematic for the first time in human history. Nothing could be done to alter the flow of energy from the sun, nor to change the nature of the process of photosynthesis. The annual quantum of available useful energy could not be enlarged. But in certain circumstances the annual quantum was, so to speak, stored and might be tapped to meet human needs. The possibility was already familiar to those living within the confines of an organic economy, if only on a small scale. Mature standing timber represents the product of a century of photosynthesis, where a hayfield represents the product only of a year. Little wonder that reckless eldest sons on inheriting an estate would sell off the oaks their great grandfathers had planted, thus realising instantly a credit line which had been accumulating over several generations. Nothing else on an estate had this character.³⁸

In favourable circumstances, however, the annual quantum of energy secured by photosynthesis can be stored over far more than a century. One reason for the outstanding success of the Dutch economy during its

³⁷ See L. P. White and L. G. Plaskett, *Biomass as Fuel* (London, 1981), pp. 2, 12; D. Pimentel, 'Energy flow in the food system', in D. Pimentel and C. W. Hall, *Food and Energy Resources* (London, 1984), p. 2.

³⁸ In 1870, at the time when the United States was about to replace Britain as the world's leading economy, it has been estimated that more than half its total energy consumption still consisted of the use of fuel wood. The early days of settlement in a new country may permit energy consumption per head from organic sources to balloon well above the level which could be sustained in the country of origin: J. C. Fisher, *Energy Crises in Perspective* (New York, 1974), table A2.2, pp. 160–1.

golden age in the sixteenth and seventeenth centuries was the presence of large and accessible supplies of peat. Many of the industries which flourished in the Netherlands in this period were energy-intensive activities: salt and sugar refineries, breweries, distilleries, brick kilns, tanneries, and so on. Peat represents the product of photosynthesis accumulated over thousands of years, where a mature forest is limited to a single century of accumulation. The potential of peat, however, is dwarfed in turn by the energy potential of coal seams where energy accumulated over millions of years rather than millennia is stored. Other energy sources could offer only a temporary escape from the constraints of an organic economy. Coal held out the promise of a solution which might prove long lasting, at least on the time-scale of human history.

Throughout the early modern period the British economy was gradually reducing its dependence upon organic energy sources. Coal displaced wood as a source of heat energy in a steadily widening range of industries, initially those, like the boiling of salt, where the source of heat and the object to be heated were separated by a physical barrier which prevented chemical contamination, or in the heating of houses where pollution was tolerated because coal was cheap, but extending in time across many other industries—brickmaking, pottery manufacture, glassmaking, and brewing, for example—and culminating in finding a solution to the use of coal in the smelting of iron, the development which has rightly attracted the greatest subsequent attention. Coal output and consumption in Britain were on a different scale from the Continent. As late as the early decades of the nineteenth century, British coal output, which was already over 20 million metric tons per annum, exceeded the output of the whole of Continental Europe by a factor of seven.³⁹ The benefit gained from the substitution of coal for traditional energy sources was to be seen in many facets of life in England. For example, the possibility of substituting brick for wood as the most important structural material in the building of houses and the fact that windows were glazed in the houses not just of the elite but of a broad swathe of society in contrast to what was true of, say, France, depended upon the existence of a cheap source of heat energy.⁴⁰ But the benefits created by the increasing use of coal

³⁹ E. A. Wrigley, *Continuity, Chance and Change: the Character of the Industrial Revolution in England* (Cambridge, 1988), p. 29, n. 38.

⁴⁰ Arthur Young's comments about the absence of window glass as he journeyed through France in the years immediately before the Revolution are instructive: A. Young, *Travels in France and Italy during the Years 1787, 1788 and 1789* (London and Toronto, n.d.), pp. 22, 25, 30, 101, 103, 105, 208, 213.

were not simply those of conferring a competitive advantage on a growing range of industries. More fundamental was the erosion of the organic constraint.

In the past expansion had always brought about its own nemesis. Each successive step taken made the next step harder to take. If land were devoted to forest cover to supply wood for fuel and for construction, it could not also be used as arable to meet the food needs of a growing population. An expanding iron industry implied securing the wood cut from a rising acreage, at the expense, at least symbolically, of the food supply of the iron workers. If a growing economy was built upon the division of labour, the process which Adam Smith described in his secular parable about the pinmakers, it must, among other things, increase the demand for transport by increasing the separation between producer and consumer, and this must, by the same token, exacerbate the problem that land given over to the feeding of draught animals could not also be used to produce milk and cheese. One by one such constraints were reduced or eliminated as coal use suffused an increasing proportion of the productive economy. The laws of nature to which Ricardo referred were not contravened, but they were circumvented. The land was the source of a steadily declining proportion of the raw materials used in the English economy as mineral raw materials increasingly supplemented or displaced vegetable and animal raw materials, but the disappearance of the energy constraint was the key development. Whereas organic economies were dominated by negative feedback, escape from the energy constraint carried with it the possibility of positive feedback as growth continued in England.

The use of coal provided an obvious solution to the heat energy problem but not, initially, to that of mechanical energy. It was at first simply a cheap and dirty substitute for wood but not for horses or oxen. Hence the immense importance of the development of the steam engine as a prime mover. Although initially only a tiny proportion of the energy in the steam was converted into useful power, the coal-fired steam engine, allied to suitable machinery could increase individual productivity dramatically. Furthermore, an increasing proportion of the material needs of mankind could be satisfied without increasing the consumption of organic raw materials. Inorganic raw materials were disproportionately important in the new mineral-based energy-intensive economy which was developing. Inside the chrysalis of an organic economy a new and very different economy was slowly taking shape in England in the seventeenth and eighteenth centuries.

I noted earlier that the best estimates now available suggest no acceleration in the rate of growth of national product per head in the later eighteenth and early nineteenth centuries, and that one of the implications of this revision of the previous orthodoxy is that the English economy, indeed presumptively the economy of Britain as a whole, was much more productive in the middle of the eighteenth century than was once supposed. It is not yet possible to attempt a convincing estimate of the comparable situation in Elizabethan times, but it is unlikely that England enjoyed any advantage over her neighbours in this regard in the sixteenth century. It would be a major surprise, therefore, if the revised view of the situation *c.*1750 did not imply that the rate of growth of national product per head for a century or more before 1750 was as high as, or higher than, it was in the century next following.

This turns the spotlight on agriculture, whose centrality to all organic economies is clear by definition. It must figure prominently in any quest for the industrial revolution, despite its apparent exclusion by the oddities of nomenclature. Before 1750, and indeed for many decades thereafter, progress in the organic sector of the economy, which was, of course, largely underpinned by agriculture, was far more important than any developments in the inorganic sector in determining the level of output per head. Until well into the nineteenth century agriculture was much the largest single industry and the largest employer of labour. Productivity trends in agriculture were, therefore, the single most important influence on overall productivity trends. The fact that a steadily increasing proportion of the labour force could find a living outside agriculture was made possible only because output per head in agriculture was rising *pari passu*.⁴¹ England was probably the only country in western Europe, other than the Netherlands, in which the number of men working on the land scarcely changed in the course of the seventeenth and eighteenth centuries, even though the population, and hence the labour force, was growing faster than in any other large country in western Europe. Elsewhere numbers in agriculture rose, if not as rapidly as the overall increase in population, then nevertheless substantially. The result was the remarkable contrast emphasised by Crafts between output per head in agriculture in England where it was close to the average for the economy as a whole and the comparable

⁴¹ As Deane recently remarked, 'In the last analysis, then, the most distinctive feature of British agriculture's role in the development of the first industrial revolution stemmed from its ability to meet all or most of the food needs of a fast-growing and urbanizing population using a steadily diminishing proportion of the national workforce.' Deane, 'The British Industrial Revolution', p. 31.

ratio in Continental countries. In nineteenth-century France, for example, the average worker in agriculture contributed only half as much to national income as the average worker in the rest of the economy.⁴²

In a peasant society it is normally the case that people leave the land with great reluctance. Individuals may remain on the family plot even though they are contributing less to the output of the farm than they are receiving from it. Development economists are familiar with the generalisation, which is perhaps over-simple, that in an archetypal peasant society an individual will leave the family holding only when his or her presence causes the *average* level of income to fall below some conventionally accepted minimum, whereas in a capitalist, market-orientated society, this will happen as soon as the *marginal* individual's contribution falls below this level. English agriculture became increasingly capitalist in nature in the early modern period.

Ill fares the land, to hastening ills a prey,
Where wealth accumulates, and men decay:
Princes and lords may flourish, or may fade;
A breath can make them, as a breath hath made;
But a bold peasantry, their country's pride,
When once destroyed, can never be supplied.

By the time Oliver Goldsmith wrote *The Deserted Village* as a heartfelt protest against enclosure and the grasping landlord, the picture which he drew, though moving, was already archaic, the product of a charming, but unconvincing nostalgia. But it was what he went on to say which gives the game away.

A time there was, ere England's griefs began,
When every rood of ground maintained its man;
For him light labour spread her wholesome store,
Just gave what life required, but gave no more:
His blest companions, innocence and health;
And his best riches, ignorance of wealth.

Goldsmith's peasants would have fitted well into what de Vries termed his 'peasant model', men who 'strive to avoid market dependence',⁴³ resulting in a situation which frustrated the development of mutually beneficial links between town and country of the type which Adam Smith

⁴² This is implied by the estimate that in 1870 50.6 per cent of the male labour force was in agriculture, but agriculture contributed only 33.5 per cent of national income: Crafts, *British Economic Growth*, table 3.4, p. 57.

⁴³ J. de Vries, *The Dutch Rural Economy in the Golden Age* (New Haven and London, 1974), p. 6.

regarded as fundamental to growth and prosperity.⁴⁴ The peasants of the northern Netherlands transformed themselves into market-orientated specialist producers of those products which yielded the highest return on their capital. Their enhanced income and changed life-style made them a significant market for urban products. In England events took a different turn. In many areas the characteristic agrarian structure of landlord, capitalist farmer, and landless labourer became dominant, but the upshot in economic terms was not dissimilar. Specialisation progressed; new crops, breeds of livestock, tools, and working practices were widely adopted; and the mutual dependence of town and country deepened and extended. In both Holland and England labour left the land readily and was largely successful in finding employment in secondary and tertiary occupations both in urban areas and in the countryside.

‘When Henry VIII died, full of years and sin, some of the main characteristics, which were to distinguish it till the advent of steam-power and machinery, could already, though faintly, be descried’, Tawney remarked.⁴⁵ Whether the changes which took place in English rural society in the early modern period should be welcomed or deplored will depend upon the set of values of the observer. But the peasant society of which Goldsmith wrote, though having all the virtues which he claimed for it, could never have been a suitable launch pad for a society seeking to break free from the constraints of an organic economy. The doubling of output per head in agriculture which took place in England between 1600 and 1800 was a necessary, though not a sufficient cause of the complex of changes which gave birth to the modern world. An economy whose rural sector conformed to the ‘peasant model’ sketched by de Vries,⁴⁶ as many did in Europe in the centuries before the French revolution, stood no chance of achieving such a notable feat. Indeed, in an era in which population was rising, productivity per head in agriculture was more likely to fall than to rise.

The quest for the industrial revolution should lead, in my view, to the following conclusions about the nature of the changes taking place in England between the sixteenth and nineteenth centuries:

⁴⁴ See, for example, the chapter ‘How the commerce of towns contributed to the improvement of the country’ in Smith, *Wealth of Nations*; also E. A. Wrigley, ‘“The great commerce of every civilised society”’: urban growth in early modern Europe’ *Scottish Economic and Social History*, 12 (1992), 5–23.

⁴⁵ R. H. Tawney, *Religion and the Rise of Capitalism: a Historical Study* (London, 1926), pp. 70–1.

⁴⁶ The peasant model is described in de Vries, *Dutch Rural Economy*, pp. 4–7.

1 In seeking to understand what occurred, it is just as important to pay attention to the period prior to 1750 as to the classic period of the industrial revolution. It is unlikely that the rate of growth of production per head changed much between a date which might provisionally be located in the early seventeenth century and the mid-nineteenth century. It may even have been higher before *c.*1750 than thereafter until the middle decades of the nineteenth century.

2 What was extraordinary about the rate of growth of product per head in the century between 1750 and 1850 was not that it was so low but that it did not turn negative. An increase in the rate of population growth as great as that experienced in this period might have been expected in the light of earlier experience to have reduced output per head and depressed living standards substantially.⁴⁷ In the later seventeenth century the intrinsic growth rate of the English population was zero. By the early decades of the nineteenth century it had reached about 1.7 per cent per annum, sufficient to cause the population to double in only just over 40 years, a rate almost without precedent in European experience.⁴⁸ That output per head did not turn negative in a land long fully settled, in these circumstances, is persuasive evidence that remarkable developments were in train.

3 Before the later eighteenth century growth in England strongly resembled what had already occurred in the Netherlands. As in the Netherlands it may be viewed as the product of establishing a 'modern', 'capitalist', or 'market-orientated' economy which facilitated making optimum use of the possibilities afforded by an advanced organic economy with an increasingly productive agriculture.

4 Growth of this sort, however well conducted, could not continue indefinitely. If it had not been for the emergence of some radically new features in the economy, the example of the Netherlands would in all probability have been followed by England in this respect also, as Adam Smith expected, because of the necessary constraints upon growth in all organic economies, constraints which, as Ricardo noted, were imposed, as he put it, by the laws of nature.

5 To escape from this danger, to avoid the growth curve becoming asymptotic, it was essential to break free from the constraint imposed by

⁴⁷ E. A. Wrigley and R. S. Schofield, *The Population History of England 1541–1871: a Reconstruction* (London, 1981), figure 10.4, p. 410 and associated discussion.

⁴⁸ E. A. Wrigley, R. S. Davies, J. E. Oeppen, and R. S. Schofield, *English Population History from Family Reconstitution 1580–1837* (Cambridge, 1997), table A9.1, pp. 614–15. Growth rates reached a peak during the period 1806–25.

the energy budgets of organic economies, which depended almost exclusively upon annexing as much as possible of the annual inflow of energy from the sun trapped by plants through photosynthesis. Such economies were incapable of sustaining prolonged growth since the maximum quantity of heat and mechanical energy which could be secured in this fashion was modest.

6 Escape was possible because of the circumstances of plant life during the Carboniferous era which resulted in a part of the photosynthetic products of hundreds of millions of years of plant growth being 'frozen' in geological strata.⁴⁹ Some of these strata were relatively readily accessible in England, and began to be exploited on an increasingly significant scale from the sixteenth century onwards. A succession of technical innovations made coal applicable in a widening range of applications where heat energy was needed, and at a later stage, because of the ingenuity and perseverance of men such as Newcomen and Watt, the burning of coal could be made to overcome bottlenecks in the use of mechanical energy also.

7 The significance of the gradual circumventing of the energy bottleneck was not that it suddenly produced a marked acceleration in the rate of the growth of the economy or in the level of individual productivity. It was that it removed a barrier which would otherwise have tended slowly to constrict growth. Only at a much later stage in the process by which the organic economy gave way to a mineral-based energy-intensive economy did the full benefit emerge in the form of a significantly higher rate of economic growth both in aggregate and per head. In England this occurred during the middle decades of the nineteenth century, and then only because of a series of technological advances which enabled the new possibilities to begin to be realised. An abrupt acceleration in the early stages of the process was never a plausible possibility.⁵⁰

⁴⁹ Siefertle illustrated this idea elegantly when he entitled his monograph about the characteristics of historical energy systems and the significance of the advent of coal as a dominant energy source, *The Subterranean Forest* (its title in the original German edition was *Der unterirdische Wald*). He provides a handy ready reckoner of the land saving effect of the use of coal by noting that 'an annual use of 1 ton of coal makes 1 hectare of land available that would otherwise have been required as fuel plantation': R. P. Siefertle, *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge, 2001), p. 103.

⁵⁰ That the process was, in effect, certain to be gradual is well illustrated by a calculation which Mokyr made for a somewhat similar purpose. He pointed out that if there were a sector of an economy which was growing at 4 per cent per annum but which initially comprised only 10 per cent of the whole (the 'modern' sector), and another sector comprising the remaining 90 per cent of the economy growing at 1 per cent per annum (the 'traditional' sector), it would take 74 years for the two sectors to become equal in size and that even then the overall growth rate would be

The manner in which a question is posed determines the kind of answer which can be offered. Since it is possible to define what is meant by the industrial revolution in innumerable, different ways, and the question posed often includes or implies a particular definition, it is not surprising that so many differing opinions have been proposed concerning its nature, origins, and timing, often plausible enough in their own terms. At one extreme, it has been argued that the term is vacuous and should no longer be given currency.⁵¹ At another, it is asserted that the industrial revolution was the culmination of a comparatively simple cumulative process which had been in train for a millennium before reaching fruition.⁵² My case is no different. I have expounded the nature of the problem in a manner which foreshadowed the type of discussion which ensued. In concluding, therefore, it may be appropriate to say a few words about the logical status of this essay. Its prime purpose was not to attempt to explain why or how the industrial revolution occurred, though some aspects of these issues are covered directly or by implication. It was to identify the *explicandum*. I revert to the paradox with which I began. On the one hand, it is impossible to doubt the fundamental nature of the difference between the ease with which modern economies can flood the world with material goods and a host of related services and the desperate difficulty experienced by most communities in earlier centuries in meeting the most basic needs of their inhabitants for food, shelter, clothing, and fuel. It is absurd not to accord this change a title which symbolises its significance. On the other hand, inasmuch as the term revolution connotes abrupt change, it seems bizarre to apply it to a period in which there is little reason to think that change, as measured by the yardsticks commonly employed to describe economic activity, was unusually rapid.

To be paradoxical in turn, one might say that the revolution was not economic so much as physical, chemical, and biological, or at least that viewing it principally as an economic phenomenon and neglecting other attributes of production processes, and above all their energy requirements, will result in an incomplete and unbalanced picture. Although the

no more than 2.5 per cent per annum. J. Mokyr, 'Editor's introduction: the new economic history and the Industrial Revolution', in J. Mokyr (ed.), *The British Industrial Revolution: an Economic Perspective* (Boulder, San Francisco, Oxford, 1993), p. 12.

⁵¹ R. Cameron, 'The Industrial Revolution: a misnomer' in J. Schneider (ed.), *Wirtschaftskräfte und Wirtschaftswege* (Stuttgart, 1981), V, pp. 367–76.

⁵² G. D. Snooks, 'Great waves of economic change: the Industrial Revolution in historical perspective, 1000 to 2000' in G. D. Snooks (ed.), *Was the Industrial Revolution necessary?* (London and New York, 1994), pp. 43–78.

industrial revolution involved a profound economic transformation, the conventional tools of economic description and analysis fail to expose much that was fundamental to its character. The analytic framework erected by Adam Smith works splendidly in explaining the growth process which characterised the Dutch Republic in its golden age and England a little later. The accumulation of capital, the division of labour, symbolised in the pinmaker parable, and such linked developments as improved transport facilities and the creation of mutually beneficial exchange between town and country; what is often, indeed, referred to simply as 'Smithian' growth, accounts satisfactorily for the changes associated with the suffusion of Dutch and later English society by capitalist practices and a market economy. But neither classical nor neo-classical economics accounts well for what came later unless reference is made to other developments which played no part in the thinking of the classical economists and have often been ignored subsequently. The classical economists expected growth to grind to a halt. Capital and labour might both increase virtually without limit in favourable circumstances but the third of the trinity of factors needed to secure material output, land, was in fixed supply. Hence, even allowing for human ingenuity in squeezing an increased output from a given area, there was no prospect of exponential growth. But their gloomy prognostications, though logical, proved unfounded. In the quest for the industrial revolution, both the growth which took place in the early modern period, and its failure to die away thereafter must be taken into account. Coupled with a 'Smithian' analysis of early success, there must be a satisfactory explanation of why growth did not die away, why the stationary state did not supervene.

If England had remained, as all countries previously had remained, an organic economy, the comparative paucity of energy supplies would have exercised the same restraining influence on growth which it had always done. But a means of escape was found, by happenstance rather than conscious design initially, and once the nature of the escape route became clear, it proved, of course, irresistibly attractive, whatever the pains of the initial transition. The industrial revolution was not a unitary process. If it had been, the pessimistic forebodings of the classical economists would have proved justified. Its nature was essentially dual. In parallel with 'Smithian' growth, there was a slow transformation of what had previously been a purely organic economy into one which was less and less dependent on the products of the earth, on the current yield of photosynthesis. The economy became capitalist not only in the sense which is reflected in Adam Smith's writings, but also in a second sense.

An expanding economy necessarily requires a rising expenditure of energy, broadly in parallel with the curve of growth. No organic economy could meet a rising demand of this sort indefinitely. It was essential to begin to tap the energy capital which had been locked up in coal deposits 300 million years previously. The annual *flow* of solar energy could not sustain continued growth; only by tapping a vast capital *stock* of energy could it be sustained and enhanced. The current inflow of energy from the sun was insufficient to permit exponential growth, but a way was found to tap the inflow which had reached the land surface of Britain geological ages before there were first men on earth.

Viewed in this light the key feature of the industrial revolution consisted less in an acceleration in growth than in the absence of any deceleration. What might seem an exaggerated claim to the title of a revolution if judged using the conventional tools of economic measurement, was nonetheless one of the most momentous of all changes in human affairs when viewed in a wider context. Perhaps, in short, the apparent paradox is not beyond resolution.