4 Agriculture during the industrial revolution, 1700–1850

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INTRODUCTION

British agriculture developed in a distinctive manner that made important contributions to economic growth. By the early nineteenth century, agricultural labour productivity was one third higher in England than in France, and each British farm worker produced over twice as much as his Russian counterpart (Bairoch 1965; O'Brien and Keyder 1978; Wrigley 1985; Allen 1988, 2000). Although the yield per acre of grains was no higher in Britain than in other parts of north-western Europe, the region as a whole reaped yields twice those in most other parts of the world (Allen and O'Gráda 1988; Allen 1992.)

Most accounts of British farming link the high level of efficiency to Britain's peculiar agrarian institutions. In many parts of the continent, farms were small, operated by families without hired labour and often owned by their cultivators. Farms often consisted of strips scattered in

open fields, and animals were often grazed on commons. Peasant farming of this sort was consolidated by the French Revolution. In contrast, in Britain, the open fields were enclosed, farm size increased and tenancy became general. While this transformation had been underway since the middle ages, it reached its culmination during the industrial revolution. Furthermore, it is often claimed that the agrarian transformation made important contributions to industrialisation by increasing output and supplying the industrial economy with labour and capital.

One of the most basic questions is the timing and nature of the agricultural revolution. Toynbee (1969 [1884]), Mantoux (1905), Ernle (1961) and mostly recently Overton (1996a, 1996b) located the agricultural revolution in the eighteenth century, and their revolution comprised both institutional change and the modernisation of farm methods. In contrast, most twentieth-century historians have emphasised that much productivity growth occurred before 1700 and have tended to decouple improvements in farming from enclosure and farm size increases. Certainly by 1700 crop yields were higher than in the middle ages, labour productivity had increased, and output per worker in English farming was already 55 per cent higher than in France. The first half of the nineteenth century was also a time of sustained improvement, but a question mark hangs over the eighteenth century: some scholars see it as a period of stasis; others as a century of steady progress. The importance of enclosure and large-scale farming as bases for productivity growth is not independent of this issue since enclosure and farm amalgamation progressed so substantially during the eighteenth century. The relationships between productivity growth, rural social structure and agriculture's role in economic development remain fundamental questions of historical research.

A broad chronological and geographical perspective is needed for an assessment of British agriculture during the industrial revolution. Historians of farming concentrate on biological indicators like the yield of an acre or the weight of a fleece, but from an economic perspective the productivity of labour is a more critical variable since a larger fraction of the population can be employed off the farm if each cultivator produces more food. Figure 4.1 shows output per worker in six European countries from 1300 to 1800, and this helps put the achievements of British farming into perspective. In Italy, France and Germany agricultural labour productivity declined slowly after 1400, although France shows slight improvement in the eighteenth century. The renowned husbandry of medieval Flanders meant that productivity was exceptionally high in present-day Belgium. Population pressure in later centuries meant that output per worker slumped, but it still remained above the level on most of the continent. The well-known agricultural revolutions of the early modern period – those of the Dutch and the English – stand out in the figure. Output per worker in English farming leapt from the continental norm in 1600 to a

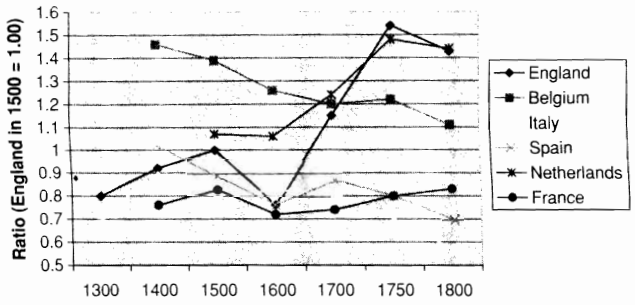

Figure 4.1 Output per worker in agriculture, 1300–1800

Source: Allen 2000: 21.

leading position in 1750. It is important that this advance occurred before the industrial revolution, and, indeed, that there was no further advance between 1750 and 1800. It is also important that England's advances did not push her efficiency above that of the Low Countries.

The modernisation of agriculture took place in the context of fluctuating farm prices. They fell during the second quarter of the eighteenth century – the so called agricultural depression – and then increased erratically until the 1790s. Corn prices doubled and tripled during the harvest years of 1795, 1799 and 1800, and the price level remained high and volatile until the end of the Napoleonic Wars. Then began a slide of prices that lasted until the middle of the nineteenth century. The pace of improvement of farm methods may have been a determinant of the price history through its impact on agricultural supply, but tariff policy and increased market integration also played a role. The fluctuations in the price level certainly affected the evolution of farming and rural society in general. Rising prices after 1750 and especially during the Napoleonic Wars accelerated enclosure; the high prices of the 1790s threatened the standard of living of the rural poor, gave rise to radicalism, and brought on changes in poor relief like the Speenhamland system; landowners who had gained from the high prices of 1795–1815 sought to preserve their rent rolls in the succeeding deflation through the corn laws, which imposed substantial duties on imported grain (Hueckel 1981).

THE RISE OF THE GREAT ESTATE

Eighty per cent of Britain's farm land lay in England and Wales, which produced 89 per cent of Britain's farm output in the mid-nineteenth century (Feinstein 1978: 635, n. 55; cf. Solar 1983 and Table 4.1). While the agriculture of the Scottish Highlands was revolutionised by the clearances, the changes that affected the largest share of British agriculture occurred mainly in England and comprised the enclosure of the open fields, the growth in farm size and the consolidation of the great

estate. Hence, discussion will focus on the English story. Many of the changes in farm methods and management affected Scottish agriculture as well.

Over half of the farm land in medieval England was organised in open fields and commons. Under this system, the land of the village was divided rigidly between arable and pasture. Holdings of arable consisted of strips scattered around the village. The strips were grouped into several large fields, which were also often units in a crop rotation. Three fields were common, in which case one was planted with wheat or rye, the second with barley, oats, beans or peas, and the third was fallow. Each year the fields shifted to the next phase in the sequence. Every farmer had to follow this communally agreed plan. The grass of the village included the meadow on which hay was cut, and the common where the sheep and cattle were pastured in a village herd. In densely settled regions, the commons were small, but in many parts of the kingdom there were great tracts of waste used as common pasture for sheep. The herd was also turned onto the fallow field, as well as the other fields after they were harvested, in order to eat weeds and manure the land.

Enclosed farming was the antithesis of the open field system. When land was enclosed, the owners usually exchanged strips and divided commons, so that each proprietor had large, consolidated blocks of property. Communal rotations and grazing were abolished. Each owner acquired exclusive control over his property, so every farmer could cultivate as he pleased without reference to the rest of the community. In 1500, about 45 per cent of the farm land in England was already enclosed, and most of that had probably never been open. The open fields in 1500 included much of the grain growing land in the country. In 1700, 29 per cent of England remained open or common, and the proportion shrank to 5 per cent in 1914, where it remains today (Wordie 1983: 502). This phase of the enclosure movement was particularly intense in the Midlands, where over half of the farmland was enclosed in the eighteenth and nineteenth centuries (Wordie 1983: 500). Most of the remaining open land was common pasture.

In the eighteenth century, much of the enclosing was accomplished by parliamentary act. In such an enclosure the principal landowners of the village petitioned parliament for a bill to enclose their village. Unanimity of the owners was not required: in general the owners of 75 per cent to 80 per cent of the land had to be in favour in order for the bill to proceed. Since landownership was highly concentrated, an enclosure could – and often did – proceed with a majority of small proprietors opposed. In the memorable phrase of the Hammonds (1924: 25), 'the suffrages were not counted but weighed'. The bill named commissioners, who carried out the enclosure, and endorsed their award in advance. The commissioners held hearings in the village, identified the proprietors, appointed a surveyor who mapped the village and valued each holding, and finally reallocated

the land so that each proprietor (including those who opposed the enclosure) received a grant of land in proportion to the value of his or her holdings in the open fields. A total of 3,093 acts enclosed 4,487,079 acres of open field and common pasture in this manner. A further 2,172 acts were concerned exclusively with the enclosure of an additional 2,307,350 acres of common pasture and waste (Turner 1980: 26, 178).

A second major change was an increase in farm size. In the middle ages demesnes were already several hundred acres, but the farms of serfs were usually 30 acres or less (Kosminski 1956; Allen 1992). During the population decline in the fourteenth and fifteenth centuries, farm size increased. Estate surveys show that the average farm – including demesnes, copyholds and leased land – in northern England and in open field villages in southern England was 65 acres in *c.* 1700. Enclosed farms in the south were already larger, however. In the eighteenth century, small farms were amalgamated into large ones in open field villages in the south, and throughout the north. By 1800, 150 acres was the average across all types of farms in the south, and 100 acres was the average in the north (Wordie 1974; Allen 1988).

The growth in farm size was accompanied by a revolution in land tenure. Many small farms in 1700 either were owned outright by their occupiers or were held on very long term agreements like copyholds for lives or beneficial leases. During the eighteenth century, small freeholds were bought up by great estates and manorial lords stopped renewing copyholds for lives and beneficial leases. The formerly yeomen lands passed into the hands of the gentry and aristocracy. The small farms were amalgamated into large and were then leased to large-scale farmers. The result was the consolidation of the great estate and the emergence of the three-tiered social structure of rich landlord, substantial tenant farmer and poor landless labourer.

Eighteenth-century agricultural improvers regarded enclosure and the creation of large farms as prerequisites for the modernisation of agriculture, and this view has become widespread among historians. Since enclosing began on a large scale in the late fifteenth century, the defenders have argued that it led to the adoption of modern methods. Quesnay, the French physiocrat, advanced the view that higher farm output required more investment, and that only large-scale farmers had access to the requisite capital. Arthur Young adopted this view and merged it with the claim that enclosure also led to modernisation. For Young (1774: 287–8), the large 'farmer, with a greater proportional wealth than the small occupier, is able to work great improvements in his business . . . He also employs better cattle and uses better implements; he purchases more manures, and adopts more improvements.' Open fields inhibited this style of farming since they gave the small, backward farmers the power to check the initiative of the large-scale entrepreneur. Enclosure was essential to set free the process of investment and modernisation.

In the eighteenth century, there was a consensus that enclosure and large-scale farming raised output. There was, however, a deep difference of opinion about the impact of these changes on employment. One group, whose origins ran back to the earliest critics of enclosure, argued that enclosures and large farms reduced employment in agriculture. By the seventeenth century, in an ironic twist, some advocates of this view were defending enclosures on the grounds that the expulsion of people from farming created a manufacturing workforce (Fortrey 1663). This, of course, became Marx's view on the subject. The other group argued that enclosures and large farms increased agricultural employment since they led to more intensive cultivation. Young endorsed this position, and argued that, none the less, large farms and enclosures stimulated manufacturing since they increased food production, which led to a larger population, most of whom were employed off the farm. The claims that enclosure raised employment and that the industrial workforce was the result of population growth (rather than the release of labour from agriculture) have become standard views since their restatement by Chambers (1953).

The role of enclosure and large farms in raising output, the impact of these changes on employment, the contribution that agricultural change made to manufacturing development – these issues remain central questions of English history. A first step in analysing them is to consider broad trends in agricultural outputs and inputs.

OUTPUTS

Despite its importance, the rate of output growth remains a controversial issue. In the absence of agricultural censuses, estimates must be constructed from diverse data using indirect methods and strong assumptions. Alternative approaches point to different periods as those of fastest growth. Moreover, agriculture has recapitulated the experience of industry as more recent estimates of the growth rate are lower than earlier ones. There are four important approaches.

Direct aggregation is the most straightforward. In this approach, output is measured by valuing the production of the various farm products with a set of constant prices. Chartres (1985) and Holderness (1989) estimated the output of the main farm products in 1700, 1800 and 1850. Valuing them with 1815 prices implies that output grew at 0.8 per cent from 1700 to 1800 and at 0.9 per cent per year in the next half century. The similarity of the growth rate in the two periods is unique.

Income deflation is the second approach. It relies on the accounting identity that the value of agricultural output equals value added (on the assumption of no purchased inputs), which, in turn, equals the sum of agricultural incomes (wages plus rents plus profits). For 1800–50, Deane

4.1 Agricultural output, 1700–1850

	1700–1800	1800–50
ıe and Cole	0.4%	1.5%
s	0.5%	1.2%
ɐgation of farm products	0.8%	0.9%
ılation	0.5%	1.1%
and curve I	0.3%	–
and curve II	0.2%	1.1%

and sources: Deane and Cole (1969: 78, 170) used a population-based ɔolation for 1700–1800 and deflated income for 1800–50. The figure n here for 1800–50 is their estimate for 1811/21–1841/51.
. (1985: 42) used a demand curve for 1700–1800 and deflated income e nineteenth century. The estimate for 1800–50 shown here applies to -31.
ɡation of farm products – Allen 1994: 102.
lation – Overton 1996a: 86
and curve I – Jackson 1985.
and curve II – Allen 1999.

and Cole (1969: 72–5, 164–73) deflated estimates of the latter with an index of agricultural prices to compute real agricultural production. Crafts followed the same procedure for this period. The output index, of course, is no better than the quantity and price series of labour, land and capital that go into the calculation. All of these are uncertain. Deflation is particularly difficult in the early nineteenth century when the price level was so volatile.

Population is the basis of the third approach. It assumes that per capita consumption of agricultural goods was constant, and then uses population as an index of agricultural output, making an allowance for imports and exports. Deane and Cole used this procedure for the eighteenth century, and Overton applied it to the whole period 1500–1850. These calculations show little output growth in the first half of the eighteenth century but rapid growth thereafter in line with the increase in the population.

A demand curve is posited in the fourth approach. Crafts (1976, 1985a: 38–44) effectively debunked the population method by pointing out that constant per capita consumption was inconsistent with the high income and price elasticities of demand found for developing countries as well as for eighteenth-century England. Clark, Huberman and Lindert (1995) forcefully pressed the point for the first half of the nineteenth century. Crafts specified a demand curve for farm goods in which quantity demanded depended on population, per capita income, and the price of agricultural and manufactured goods. Jackson (1985), Clark (1993), Clark *et al.* (1995) and Allen (1999) have proposed variants of this approach. All indicate slow growth in the second half of the eighteenth century: the rise in farm prices from 1750 to 1800 implies that output was growing less rapidly than population and demand.

Table 4.1 summarises the output growth rates implied by the various methods. For the eighteenth century, the aggregation of the Chartres–Holderness production figures gives distinctly the fastest growth. In all likelihood, however, farm output is underestimated in 1700. Wheat has been studied intensively by other scholars. Holderness put the yield at 16 bushels per acre *c.* 1700, and Overton (1996a: 77) concurred, although his own work on probate inventories for Norfolk, Suffolk and Lincolnshire implied an average yield of about 18.5 for the early eighteenth century (Overton 1991: 302–3). More recent scholarship points to higher values. Turner, Beckett and Afton (2001: 129), who have compiled information from farmers' account books, put the yield of wheat in excess

of 20 bushels early in the eighteenth century. Brunt (1999) arrived at a similar figure using econometric models of weather and farming methods. Turner *et al.*'s (2001: 163–4) yields for barley and beans are also considerably in excess of the yields assumed by Holderness–Chartres. The upward revisions in the yield estimates for the early eighteenth century cast considerable doubt on the production aggregation approach especially *c.* 1700.

The population-based estimates of Deane and Cole and Overton imply slower growth, but their maintained assumption of constant per capita consumption is hard to credit. Crafts's estimate based on a demand curve is superior methodologically. It implies faster output growth than the calculations of Jackson and Allen, which are also based on demand curves. The difference arises since Crafts used GDP to measure income, whereas Jackson and Allen used wages, which grew less rapidly. The latter is probably more pertinent to the food market than GDP, which also includes profits and rents. These considerations suggest that agricultural output grew at 0.2–0.3 per cent per year in the eighteenth century.

In the first half of the nineteenth century, Deane and Cole's deflation of agricultural income gives distinctly the highest estimate of output growth. There is remarkable agreement among the other procedures. The consensus is that agricultural production grew at about 1.1 per cent per year in the first half of the nineteenth century. This was markedly faster than in the eighteenth century.

INPUTS

Farm output went up for two reasons: the land, labour and capital used by agriculture increased, and those inputs generated more output owing to improvements in farm methods and organisation. As with output, there is considerable uncertainty as to the exact magnitudes of the inputs. The figures discussed here relate to England and Wales rather than Great Britain.

Land

The main sources that describe land use are contemporary estimates. As part of his social accounts for 1688, Gregory King estimated the acreage of arable, pasture, etc. W. T. Comber did the same in 1808, and his estimates agree in broad outline with B. P. Capper's figures for 1801. The noted agricultural writer James Caird produced further estimates for 1850–1. Table 4.2 applies King's, Comber's and Caird's figures to 1700, 1800 and 1850, respectively. The most remarkable development was the growth in arable, pasture and meadow, which increased from 21 million acres *c.* 1700 to 29.1 million *c.* 1800 to 30.6 million *c.* 1850. In the eighteenth

ble 4.2 Utilisation of English and Welsh Land, 1700–1850

	c. 1700	c. 1800	c. 1850
able	11	11.6	14.6
sture and meadow	10	17.5	16.0
oods and coppices	3	1.6	1.5
rest, parks, commons	3	} 6.5	} 3.0
aste	10		
uildings, water, roads	1	1.3	2.2
otal	38	38.5	37.3
otal agricultural	34	35.6	33.6
dex of land input	1.00	1.35	1.37

ource: Allen 1994: 104.

century, the growth was mainly in pasture and meadow; in the nineteenth century, it was the arable that expanded. These increases were accomplished by corresponding reductions in wood, common and waste. Some of this change was spurious: 'waste' has always been used to graze sheep, and thus has always been agricultural land. However, there was probably also a real improvement in the quality of the land – pastures were drained, fertilised and reseeded. Great tracts of land in northern and western England were developed into improved grazing in this way. In eastern England, arable was often the result. Young's (1813a: 2, 99, 100) account of Lincolnshire gives a flavour of the changes. He described the improvement of the heath near Lincoln 'which formerly was covered with heath, gorse, &c. and yielding, in fact, little or no produce, converted by enclosure, to profitable arable farms'. Much land had been improved, 'for these heaths extend near seventy miles'. On the coast, 'there spreads a great extent of lowland, much of which was once marsh and fen; but now become, by the gradual exertions of above 150 years, one of the richest tracts in the kingdom'.

Labour

The agricultural workforce is much more difficult to count than the acreage of farm land or even the volume of production. The subject is bedevilled by the problems of part-time work, unpaid family work, and people dividing their time between farming and proto-industry. Perhaps for these reasons, King tallied much of the population as 'labourers' and 'cottagers' without assigning them to agriculture, commerce or manufacturing. Massie did the same with his social table for 1759 (Lindert and Williamson 1982). Estimates of the agricultural workforce must be erected on a basis other than contemporary estimates.

The oldest view about the size of the agricultural workforce – and one that appeals to common sense – is that it declined during the industrial revolution. This view is supported by the long-standing notion that enclosures were driving people off the land into the factories. Both of these positions have been called into question by historians. In particular, Deane and Cole (1969: 142–3) have used the occupational information in the nineteenth-century censuses to argue that farm employment in Great Britain increased from 1.7 million in 1801 to 2.1 million in 1851. Although they describe their 1801 employment estimates as 'little more than guesses', the idea that agricultural employment expanded during the

industrial revolution (albeit at a slower rate than manufacturing employment) has become the standard view.

While the 1851 census does provide an acceptable basis for calculating the agricultural workforce at the end of the industrial revolution, the early censuses are not nearly so reliable, and, in any event, cannot be used to push the estimates back before 1800. Indirect methods are necessary. One procedure is to combine information from estate surveys with the returns collected by Arthur Young on his English tours (Allen 1988). Young was a noted agricultural improver and prolific writer. He travelled through most English counties in the 1760s and reported the details of several hundred farms. Since the information includes the size and land use pattern of the farm as well as the number of regularly employed men, women and boys, equations can be estimated that correlate employment with variables like farm size. Applying those relationships to the distribution of farm sizes shown by estate surveys allows estimates of the agricultural labour force. The estimates encompass only those steadily employed: additional labour was hired during peak periods like the harvest. While important, the total number of hours worked by the additional labourers was small compared to the contribution of the regularly employed.

Table 4.3 Employment in English and Welsh agriculture, 1700–1850 (thousands)

	1700	1800	1850
Men	612	643	985
Women	488	411	395
Boys	453	351	144
Total	1553	1405	1524
Index of labour input	1.00	0.95	1.16

Source: Allen 1994: 107.

Table 4.3 shows that there was little long-run change in the English agricultural workforce. The total number employed fell between 1700 and 1800, then rebounded to 1851 when the total was still less than it had been in 1700. Weighting the employment of men, women and boys by the wage rates recorded by Young produces an index of the quantity of labour. It increased marginally over the period. Since the acreage of improved farm land was also rising, employment per acre (as measured by the ratio of the index of labour to the index of land) fell from a value of 1.00 in 1700 to 0.70 in 1800 and then returned to 0.85 in 1850. Even though farm employment was roughly constant, employment per acre declined, especially in the eighteenth century.

The composition of the agricultural workforce also changed significantly from 1700 to 1850. First, the share of adult males increased from 39 per cent of the workforce to 64 per cent. Second, more of these men were employees rather than farmers since the number of farms was probably falling. Third, most of the hired men in 1851 were day labourers while most had been servants hired by the year in 1700 (Kussmaul 1981). Fourth, while the servants in 1700 had been continuously employed over the year, about one third of the male labourers in 1851 were only employed in peak periods like the harvest. The contrast between 1700 and 1851 is far reaching: in 1700, the agricultural workforce had been built

around family labour supplemented by young adults in their late teens and early twenties hired on annual contracts as servants. These categories were still present in 1851, but the workforce had become much older, more male and more erratically employed.

Wrigley (1985, 1986) has also analysed the agricultural labour force over the eighteenth and nineteenth centuries. He estimated that the 'agricultural population' was about 3 million people over the eighteenth century. This figure includes non-working children and retired people. Assuming that the average household had 4.5 members, 3 million people corresponds to 667,000 households – a figure close to the 612,000 and 643,000 adult men shown in Table 4.3. An exact match is not expected, since male servants did not head households and since some women did. Nevertheless, the correspondence confirms the order of magnitude of both calculations. Wrigley's procedure does not permit a separate examination of the employment histories of men, women and children, and so does not pick up the falls in the employment of women and boys.

Wrigley (1986) has also estimated the growth of the adult male agricultural labour force in the first half of the nineteenth century. He found it grew about 10 per cent from 1811 to 1851 when it equalled 1 million, a figure that includes men who only worked in peak periods as well as those steadily employed. Wrigley's estimate of the rate of growth is the right order of magnitude for the growth rate of the total, regularly employed agricultural labour force over the period. However, the number of steadily employed men grew more rapidly than Wrigley's estimate, as men displaced women and boys in farm labour.

Capital

The provision of capital was divided between landlords and tenants. Landlords financed most of the permanent improvements to the property – structures, roads, fences and enclosures. Tenants financed implements and livestock. Tenants also financed a few improvements to the soil such as marling or draining. Their benefits lasted a decade or two and were worthwhile from the tenant's point of view only if the tenant had adequate security. The tenants also had to pay wages, rent, taxes, etc. in advance of the sale of the crops. These expenses did not result in capital formation, strictly speaking, since they did not create assets that lasted longer than one year.

Landowners could finance their investments by mortgaging their property. Tenants obtained their capital in more diverse ways. At the outset, most farmers took over their parents' farms and secured their livestock and implements in that way. Thereafter, they bred their animals. Cash to pay wages and rents was saved from the sale of the previous year's output. Sometimes landlords provided their tenants with capital, for instance when drains were installed. 'At Marston, much draining has been performed on a farm of Mr. Foster's, who pays all of the bushes [to line the drains], except what could be obtained from the farm, and the tenant is to allow interest for the money thus sunk by the landlord' (Batchelor 1808: 476). Money could be borrowed from relatives and other villagers (Holderness 1976). Corn merchants often bought the crop while it was still standing in the fields. According to Defoe (1727: II, part II, 36), 'These Corn-Factors in the Country ride about among the Farmers, and buy the Corn, even in the Barn before it is thresh'd, nay, sometimes they buy it in the Field standing, not only before it is reap'd but before it is ripe.' Whether or not the factors were 'cunningly taking advantage of the farmers by letting them have Money before-hand, which they, poor Men, often want', credit was being extended.

Table 4.4 Capital in English and Welsh agriculture, 1700–1850

	1700	1750	1800	1850
Landlords				
structures, etc.	112	114	143	232
tenants				
implements	10	8	10	14
farm horses	20	20	18	22
other livestock	41	53	71	85
Total	183	195	242	353

Source: Allen 1994: 109.

Feinstein (1978, 1988) and Holderness (1988) have estimated the growth of capital supplied by farmers and landlords. Their results are shown in Table 4.4. Between 1700 and 1850, both components of capital approximately doubled. During the eighteenth century, capital grew at the same rate as improved farm land, so capital per acre remained constant. From 1800 to 1850, capital per acre rose 40 per cent. Capital was the fastest-growing input.

PRODUCTIVITY GROWTH

The history of outputs and inputs implies that productivity grew from 1700 to 1850. Over that period, land grew 37 per cent, labour 16 per cent and capital 93 per cent. Giving equal weight to each input implies that inputs *in toto* grew by a factor of 1.45 from 1700 to 1850. Output grew by a factor of 2.2 according to the demand curve approach. Total factor productivity increased by 50 per cent (1.52 = 2.2/1.45) or about 0.3 per cent per year over the whole period. In the eighteenth century, inputs grew at 0.2 per cent per year. According to Allen's and Jackson's demand curve estimates, output grew at 0.2–0.3 per cent per year, implying negligible productivity growth (0.0–0.1 per cent per year). From 1800–50, input growth increased to 0.4 per cent per year, but output grew much faster by all measures. Accepting output growth of 1.1 per cent per annum implies TFP growth of 0.7 per cent per year – a much better performance.

Other estimates of output growth, of course, imply other estimates of productivity growth. One can side-step the difficulties in measuring the *quantities* of inputs and outputs by inferring productivity from their *prices*. If efficiency rises, then a farmer can cut his price and still cover his costs.

Hence, a fall in product prices with respect to input prices indicates productivity growth. McCloskey (1981: 114, 126) used this reasoning to compute productivity growth of 0.5 per cent per year for the first half of the nineteenth century. In contrast, Turner, Beckett and Afton's (1997) rents imply higher productivity growth, while Clark (1993: 247; 1998b: 208) has calculated rates ranging from nil to about 0.5 per cent per annum from 1700 to 1850.

The lack of consensus indicates that the price approach is not a quick fix to the productivity measurement problems. Not only does this method require good information on product and factor prices, but it presumes that they equalled marginal costs and the values of marginal products. This condition was probably not satisfied for many inputs, in particular land. Rents, for instance, were not adjusted annually and so could fall behind changes in land values (Allen 1982). In such cases price calculations can give spurious measures of productivity change. The measurement of both prices and quantities needs to be refined to pin down the chronology of the agricultural revolution.

Farm methods and productivity growth

Agricultural productivity rose because output increased and employment per acre declined. No single innovation or institutional change explains these increases. Many reinforcing changes were involved.

Corn output increased because of changes in yields and acreage. In the case of wheat, the yield rose from perhaps 10 bushels per acre – certainly more in Norfolk (Campbell 1983) – at the end of the middle ages to 20 bushels or more in the early eighteenth century (Rogers 1866: I, 38–45; Salzman 1938: II, 60–1; Titow 1972: 121–35; Clark 1991b; Overton 1991; Allen 1992, 1999; Brunt 1997, 1999; Turner *et al.* 2001: 129). Between 1700 and 1850, yields rose little, and output increased because more land was planted as fallow was reduced. The yields of barley, oats and beans also increased in the early modern period; they continued to rise after 1700 so the increase in the production of these crops was not simply due to greater acreage.

The causes of the rise in corn yields are diffuse. First, there were improvements in seed. Farmers collected the seeds from the best plants and grew them separately to isolate high-yielding and disease resistant strains. This practice, which began in the seventeenth century and was responsible for some of the pre-1700 advance of yields over medieval levels, was carried on by enterprising farmers through the eighteenth and probably into the nineteenth centuries (Plot 1677: 151; Marshall 1788: II, 4). Second, heavier manuring may have raised fertility, although Brunt (2000) has called this into question. Third, the cultivation of legumes (beans, peas, clover) increased during the eighteenth century. These crops fixed atmospheric nitrogen and thereby raised soil fertility (Chorley

1981). Fourth, soils were improved by marling and draining. During the Napoleonic Wars, the high price of corn relative to labour made it profitable to install bush drains on heavy clays. By the 1840s, the price of drain tiles fell enough to precipitate another round of drainage investment. Other investments that improved the quality of the soil included paring and burning and the application of lime. Fifth, the diffusion of seed drills and other improved farm machinery resulted in a better seed bed. Historians have not yet been able to pin down the relative importance of these factors, but together they were responsible for the rise in corn output (Brunt 1997). Sixth, regional specialisation increased, so that crops were grown where the natural conditions were most favourable.

Livestock output increased because the herds and flocks became more productive rather than because there were more animals. The number of cattle probably fell from about 4.5 million at the end of the seventeenth century to 3.9 million in the middle of the nineteenth, but the share of productive animals (i.e. dairy cows and those slaughtered) increased. Moreover, the weight of a carcass and the product of a cow rose. Likewise, the number of swine scarcely increased, so the main reason for the rise in pork output was a much greater rate of slaughtering and a very sharp rise in meat per carcass. In the case of sheep, the stock doubled between 1700 and 1850, but the weight of a fleece and the meat per carcass both increased (King 1696: 430; Holderness 1988: 32; 1989: 147–159, 169–70).

Meat per carcass increased for several reasons; improvements in the breed and increases in feed consumption were the main factors. A shift in tastes away from veal and young lamb towards the meat of older animals may have played a minor role as well (Holderness 1989: 155). Stockbreeders created new varieties of sheep, pigs and cattle in an effort to increase the rate of weight again. The earliest and most famous breakthrough was the development of the New Leicester sheep by Robert Bakewell in the mid-eighteenth century. It reached a large size at a younger age than other breeds and it had a higher proportion of flesh to bone. Ellman's subsequent creation of the Southdown had a similar objective. Cattle breeds were also improved. Bakewell and Robert Fowler improved the Longhorn in the mid-eighteenth century, and it had a vogue for fifty years. After 1800 the Shorthorn gained popularity in the north and east as it was improved by Robert and Charles Colling, and by Thomas, John and Richard Booth. In the first half of the nineteenth century, the Hereford emerged as an important fattening breed. Likewise, pigs were improved through the introduction of foreign, particularly Chinese, breeds. Rapid weight gain was the objective of most of these improvements.

The quantity of feed consumed by British livestock was increased by upgrading commons and waste into improved pasture and by cultivating animal feed in the arable rotations. Feed had always been grown by farmers. Much of the oat crop, for instance, was consumed by the farm horses, and

peas and beans were often eaten by livestock. In the seventeenth century, the production of feed was increased with the cultivation of turnips and clover on a large scale. By the mid-eighteenth century, the classic Norfolk rotation (turnips–barley–clover–wheat) had emerged. The fallow was eliminated, and the clover and turnips provided winter fodder for animals. Other fodder crops like sainfoin and roots like swedes and mangolds were also introduced into British rotations and fed to livestock. A big reason that sheep and cattle weighed more when they were slaughtered in 1850 than they had in 1750 was because they were eating better.

Farm size and productivity growth

The second reason that agricultural productivity increased during the industrial revolution was because labour per acre declined. The employment of women and boys fell. The employment of men grew slightly but much less than the growth of improved land. The drop in labour per acre resulted from the growth in farm size.

Higher rent was the motive behind the creation of large farms. Big farms could afford to pay a higher rent since their costs were less – in particular, their labour costs. Large farms employed fewer boys per acre than small farms since boys were hard to supervise. The employment of women was also curtailed since their work was often tied to dairying and large mixed farms kept fewer cows per acre. There were also economies in the employment of men. Specialists replaced the ordinary labourer in tasks like tending hedges and caring for sheep. Activities like transporting grain and manure were carried out more efficiently when they were performed by groups of workers than when they were done by individuals. 'In harvest; two drivers, two loaders, two pitchers, two rakers, and the rest at the rick, or in the barn, will dispatch double the work that the same number of hands would do if divided into different gangs on different farms' (Arbuthnot 1773: 8). The growth in the average size of farms was the reason that the total employment of women and boys declined in the eighteenth century, and the employment of men remained constant even as the improved acreage expanded.

Enclosure and productivity growth

The most long-standing explanation for the rise in efficiency is enclosure. Eighteenth-century commentators regarded it as a prerequisite for improvement since the open field system was supposed to have blocked advance. The rigid division of lands into arable and pasture precluded convertible husbandry, which involved alternating lands between the two uses. Collective management of the fields inhibited the adoption of new crops since a consensus was necessary among the farmers in order for change to occur. Pasturing the village livestock in a single herd led to

overgrazing, the spread of animal diseases, and the inability to control breeding. According to the critics, 'open-field farmers were impervious to new methods' (Ernle 1961: 199).

Enclosure is supposed to have rectified these problems by bringing land under exclusive private control. Communal controls were abolished, so that each owner – and thus each farmer – had exclusive control over his or her property. The scene was set for the enterprising farmers to take the lead in adopting new crops and improving the quality and care of their animals.

The case for the backwardness of the open fields and the modernity of the enclosures has rested mainly on eighteenth-century commentaries. In an extravagant phrase, for instance, Arthur Young (1813b: 35–6) contrasted 'the Goths and Vandals of open fields' with 'the civilisation of enclosures'. There is some truth to this opinion, but inquiries by historians have shown that open fields were not nearly as backward as has been claimed. Havinden (1961) was one of the first to question the conventional indictment of open fields. He showed that such villages in Oxfordshire did indeed adopt new crops – in this case sainfoin. Yelling (1977: 146–232) strengthened the case with additional local comparisons, but remained unconvinced that open fields were really as flexible as enclosures. Allen (1989) has refined the assessment with a series of regional studies. These show that open field villages adopted new crops and increased the share of grass when these innovations were profitable. However, enclosed villages always adopted the new methods more fully than did open field villages.

Enclosure also led to greater output, but the increase was much less than the growth in production that occurred between 1700 and 1850. Chronology suggests this conclusion: much of the enclosure took place in the second half of the eighteenth century, when agricultural output stopped growing. Comparisons of corn yields in open and enclosed villages buttress the case. The data collected by Arthur Young on his tours of the 1760s show that yields of the main crops were 7–12 per cent higher in enclosed villages (Allen and O'Gráda 1988: 98). Turner (1986: 691) found a larger increment – 11 per cent to 23 per cent – in his sample drawn from the 1801 crop returns. A limitation common to both of these studies is that they did not standardise the comparisons by soil type. Allen (1989: 72) used data drawn mainly from Board of Agriculture county reports prepared between 1794 and 1816 and divided them into districts with relatively uniform environments. On the boulder clays of Cambridgeshire, Bedfordshire and Huntingdonshire, enclosure resulted in yield increases of 10–39 per cent for beans, barley and oats (but only 3 per cent for wheat) because the consolidation of property facilitated the installation of drains in the furrows that had formerly divided the open field strips. In other regions, the yield increases were generally less than 10 per cent. While enclosure did have some impact on yields, the

boost was only a small part of the doubling that took place between the middle ages and the nineteenth century.

Both Turner (1986) and Allen (1992) have combined their findings on yields with estimates of the impact of enclosure on cropping to measure the overall effect on output. Turner found that enclosure had little effect on total corn production, although declines were more frequent than advances. Allen found that enclosure increased corn production on the boulder clays where yields went up substantially, lowered output marginally on light soils where turnip cultivation was introduced, and substantially reduced output where there was large-scale conversion of arable to pasture. Allen also included animal products in his comparison. He found that enclosure raised real farm output 12 per cent on the boulder clays in the East Midlands and by 20 per cent on high-grade fattening pastures. Otherwise, eighteenth-century enclosures led to only minor increases or even reductions. As with the results on yields, the important finding is that the output increases that followed enclosure were small, as was the growth in output that occurred in English and Welsh agriculture during the industrial revolution.

Enclosure affected the inputs in English agriculture as well as the output. The acreage of improved land increased substantially between 1700 and 1850. Enclosure was fundamental to this upgrading. In 1700, the waste that was later improved was legally common land. Only when it was enclosed and brought under individual control was it worthwhile for anyone to improve it.

Enclosure had a small impact on capital formation. The stock of fixed capital increased as landlords paid for the hedging, ditching, road building, etc. that accompanied enclosure. The capital supplied by farmers also increased as flocks were expanded and livestock upgraded to take advantage of the improved pastures and greater production of winter forage. However, Table 4.4 suggests that the total effect was not substantial during the eighteenth century – agricultural capital did not rise greatly before 1800.

The most hotly debated issue is the impact of enclosure on employment. In this regard, one must distinguish the charge that enclosure led to the expropriation of peasant lands from the impact of enclosure on labour demand *per se*. It is probable that many fifteenth-century enclosures did involve lords' usurping the land of small farmers and the destruction and depopulation of the villages concerned (Beresford 1954; Allen 1992). Such extreme results did not occur in the eighteenth and nineteenth centuries, since legal titles were protected in both parliamentary and non-parliamentary enclosures. There were still people at risk of losing property, however – principally cottagers who pastured stock on commons without a legal right to do so. They lost that privilege at enclosure. Moreover, even cottagers with legal common rights may have been worse off after enclosure since their land grants may not have generated

as much income as their grazing right had previously. The losses were particularly serious for women (Neeson 1989; Humphries 1990).

There are strongly divergent views on the effect of enclosure on the demand for labour. Critics of enclosure have generally charged that people were put out of work, while defenders have claimed that enclosure created new jobs. In the modern literature, Chambers (1953) has championed the latter view and argued that the improved agriculture required more labour to hoe the turnips, thresh the additional corn, trim the hedges and scour the ditches. Recently, this view has been challenged. Snell (1985) has used poor law evidence to argue that enclosure led to increased seasonal unemployment rather than the greater stability in employment expected by Chambers. Allen (1988) used Young's survey data to measure the impact of enclosure on employment. He found that enclosures had little effect on farm employment unless they led to the conversion of arable to pasture, in which case employment declined. In some regions, eighteenth-century enclosures did have this result. However, the total arable acreage increased slightly in this century (Table 4.2), so enclosure did not lead to a general decline in agricultural employment.

This review of the evidence about the impact of enclosure on agricultural outputs and inputs suggests that it had a positive but small effect on productivity. This conjecture is confirmed by measurements of total factor productivity. McCloskey (1972, 1975, 1989) suggested that the impact of enclosure on productivity could be inferred from the movement of rents. Indeed, a rise in rent was the landlord's incentive to enclose, and, in the eighteenth century, the conventional expectation was a doubling from 10s. to 20s. per acre. A stylised example shows how this increase might have arisen and its relationship to total factor productivity. In an eighteenth-century open field village, output, as measured by farm revenue, was about £3.5 per acre. The cost of the labour, capital and materials applied to the land (including the opportunity cost of the labour and capital of the farmer and his family) was about £3 per acre. The difference, or Ricardian surplus, was £5 or 10s. If the market for farm tenancies were competitive, then rents would have been bid to equal this level. Suppose that enclosure involved no change in employment or capital per acre but resulted in an increase in output to £4 per acre. With costs the same, Ricardian surplus and rent would have risen to £1 (= £4 – £3). In this example, the doubling of rent that followed enclosure was a consequence of the accompanying output increase.

While rents doubled, total factor productivity also increased but by a smaller proportion. Total factor productivity rises when output rises with respect to the 'bundle of inputs' used in production. In both the open and the enclosed village in this example, the 'bundle' is the same – namely £3 of labour, capital and materials per acre of land. Output, however, increased from £3.5 to £4, i.e. by 14 per cent. That is the rise in total factor productivity.

The overall impact of the enclosure of open fields on the growth in productivity in English agriculture was less than 14 per cent for four reasons. First, the rent increase following enclosure was probably less than a doubling (Allen 1992; Clark 1998a). Second, the assumption that rental markets were always in competitive equilibrium so rents always equalled Ricardian surplus has been questioned – the rise in surplus may, in fact, have been less than the rise in rent (Allen 1982). Third, only 21 per cent of the farm land of England and Wales was enclosed between 1700 and 1850. Setting aside the first and second points, the enclosure of the open fields raised the total factor productivity of English and Welsh agriculture only 3 per cent (= 14 per cent × 0.21). This is an inconsequential amount compared to the 50 per cent increase that took place over the period.

Enclosure did make another contribution to productivity growth in the same period – namely the reclamation of waste. This contribution can be analysed similarly using Gregory King's figures. In the eighteenth century, about 3 million acres of 'forest, parks, and commons' were enclosed and improved as well as 3 million acres of waste. According to King, the rental value of the first type of land was 3.5s. per acre *c.* 1700 and the latter was worth 1s. per acre. If the annual value of these lands was raised to 9s., the value of enclosed pasture, then the total value of English agricultural land, increased from £8.75 million to £10.025 million – a gain of 23 per cent. Such a rent gain translates into a total factor productivity increase of about 7 per cent. This increase may well be an overstatement of the efficiency gains of the enclosure of waste since it values the improved land at a rent equal to the most productive land in King's account. The overall conclusion must be that the enclosure movement made little contribution to agricultural productivity growth during the industrial revolution.

AGRARIAN CHANGE AND ECONOMIC GROWTH

Even if enclosure was not of great importance in boosting output or efficiency, it is possible that agricultural change *in toto* made an important contribution to economic development. The potential linkages include:

1. increasing output
2. providing a home market for manufactures
3. generating new capital by increasing the savings from the agricultural surplus
4. releasing capital by reducing the agricultural demand for investment
5. releasing labour by reducing the agricultural demand for workers.

Most of these functions were not performed by British agriculture during the industrial revolution.

1. Output grew less rapidly than the population during the industrial revolution. Production and consumption per head declined, and the drop in consumption would have been much greater had imports not expanded to meet demand. Prices rose to allocate the limited supply of food. The result was downward pressure on working-class living standards and a deterioration in stature during the first half of the nineteenth century. If one asks how British agriculture fed the expanding population during the industrial revolution, the answer is – badly.

2. Agriculture did not provide a home market for manufactures. O'Brien (1985: 780) and Crafts (1985a: 133–4) independently estimated that the consumption of manufactures by agriculturalists increased about one third between 1700 and 1800 – a century when industrial production increased more than threefold (Crafts 1985a: 32). After 1800, the importance of the agricultural market became even less important. Exports and the urban economy absorbed the manufacturing output – not agriculture.

3. Industrial and commercial capital formation were not financed by tapping the agricultural surplus. Landlords received the bulk of the surplus – that is, the value of production less the consumption needs of farmers and labourers – in Britain as rent. While some landlords invested in urban and commercial activities, many borrowed instead. Crouzet (1972: 56) endorsed Postan's (1935: 2) 'view that "surprisingly little" of the wealth of rural England "found its way into the new industrial enterprises"'. Crafts (1985a: 122–5) has calculated that agricultural savings financed little non-agricultural investment.

4. Agriculture did not release capital by reducing its demand for investment. Instead, as Table 4.4 indicates, agricultural capital increased. Any other result would be surprising in view of the eighteenth-century emphasis on rising investment as the source of rising agricultural output.

5. One way in which British agriculture may have contributed to economic growth was through the release of labour. Here the conclusion depends on the definition adopted. The most straightforward meaning of 'labour release' is that farm employment declined. Male employment in agriculture was constant in the eighteenth century and rose in the first half of the nineteenth. The employment of women and children declined throughout. If these 'freed' workers were re-employed in industry, then the resulting rise in manufacturing output would have been an indirect contribution of agrarian change to economic development. But this is a big 'if'. Most of the boys and women did not leave their villages. Only if employment were found in rural industry would it have been found at all. Throughout the industrial revolution, the employment prospects of women in the rural textile industries, their biggest employer, were declining in the face of mounting competition from factories. In 1724, Defoe wrote, 'The Farmers' Wives can get no Diary-Maids . . . truly the Wenches Answer, they won't go to Service at 12*d.* or 18*d.* a week, while they can get 7*s.* to 8*s.* a Week at Spinning' (Pinchbeck 1969 [1930]: 140). By

the 1830s, if not by 1800, these jobs had disappeared. Agricultural redundancies then resulted in structural unemployment rather than increased manufacturing output.

The problem of structural unemployment was greatest in southern England. Williamson (1990: 178–218) has shown that southern urban wages were much higher than rural wages, even allowing for the higher living costs and lower quality of life in the cities. There was no comparable disequilibrium in the north. Despite the fact that a large share of children born in rural England moved to cities when they reached adulthood, migration was not enough to equalise wages. This failure to allocate labour efficiently reduced the national income several per centage points, according to Williamson (1990: 211). The fact that enclosures ceased to be depopulating during the industrial revolution may have meant – ironically – that agrarian change was less significant in raising the national income than traditional accounts suggest.

A LONGER-TERM PERSPECTIVE

This is a dreary assessment. Did agrarian change really contribute so little to the industrial revolution? The answer depends critically on the time period. One reason why the industrial revolution could proceed in the face of a largely static agriculture was that agriculture had already revolutionised itself between 1600 and 1750, as Figure 4.1 shows. In that period, yields, output and labour productivity all increased sharply. Crafts (1985c) has urged that declining farm employment is not the appropriate definition of labour release; instead, he proposes that a rise in output per worker that allows a decline of the fraction of the workforce in agriculture is a more revealing concept. In Crafts's terms, labour was released from British agriculture between 1500 and 1750 when the agricultural share of the population dropped from 74 per cent to 45 per cent and agricultural labour productivity rose 54 per cent (Allen 2000). The agricultural revolution did not run concurrently with the industrial revolution but rather preceded it.

5 Industrialisation and technological change

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Contents

INTRODUCTION

Technological change was a central component in the industrialisation process of the late eighteenth and early nineteenth centuries, and thus in the making of the modern world economy. Nevertheless, more than two centuries after the beginnings of industrialisation, our understanding of the factors that impelled and shaped the development, diffusion and impact of the new technologies of early industrialisation remains far from complete. As a consequence, important questions concerning the place and interpretation of technological change in industrialisation remain unresolved.

The idea that we know relatively little about the sources and outcomes of innovation in the industrial revolution may seem strange, since there is a large historical literature organised explicitly or implicitly around the idea that technological change and industrialisation are intimately linked. Indeed there are many writers for whom new technologies *are* industrialisation, and so the emergence of new techniques is implicitly