# Output and technical change in twentieth-century British agriculture*

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*Abstract*

Previous estimates of British agricultural output in the twentieth century have covered the period before the Second World War, or after it, but not both. This paper reconciles the differences between previous estimates and goes on to calculate changes in the volume of output between 1867 and 1985. As a result, it is suggested that output grew more rapidly between 1945 and 1965 than during any period before or since. Some of the reasons for this rapid growth are then examined, and it is suggested that the rapid adoption of pre-existing technology was of greater significance than the technical innovations of the period.

Many of the histories of British agriculture in the twentieth century imply, by their starting or finishing dates, that there was a discontinuity at the beginning or end of the Second World War. Thus Miss Whetham's volume in *The Agrarian History of England and Wales* ends in 1939, Dr Perren's study of *Agriculture in Depression* in 1940, and Dr Brown's account in 1947.[1] The latter two also accept, as does Dr Thirsk[2] that the years between 1900 and 1939 represent a continuation of the period beginning in the 1870s, when high levels of imports produced low levels of domestic prices. This was the age of 'dog and stick' (i.e. low input-low output) farming, with increased emphasis on milk production, except for a brief period during and shortly after the First World War. Holderness goes so far as to assert that 'Farming in 1940 was not significantly different in structure and practice from farming in 1840'.[3] In contrast, the period after the Second World War is perceived as one in which government support ('subsidy' and 'feather bedding' are alternative terms which have been used) together with extra science and technology produced dramatic increases in output with a little less land, much less labour, and much more capital. In Joan Thirsk's terminology, the period between 1939/47 and 1985 is a period of mainstream agriculture. Historians of post-war agriculture have been concerned to explain how and why the output increases and technical changes of these years came about. Thus Seddon concentrates on the technology, Blaxter and Robertson on the science behind it,

* I would like to thank Derek Shepherd, Andrew Errington, and two anonymous referees for their comments on previous drafts of this paper, and Barbara Sheaves for her assistance with the preparation of the diagram.

[1] E. H. Whetham, *The Agrarian History of England and Wales*, VIII, *1914–1939* (1978); R. Perren, *Agriculture in depression, 1870–1940* (1995); J. Brown, *Agriculture in England. A survey of farming, 1870–1947* (1987).

[2] J. Thirsk, *Alternative Agriculture. A history, from the Black Death to the present day* (1997).

[3] B. A. Holderness, 'Apropos the third Agricultural Revolution: how productive was British agriculture in the long boom, 1954–1973', in P. Mathias and J. A. Davis (eds), *Agriculture and Industrialization: from the eighteenth century to the present day* (1996), p. 69

and Collins and Holderness on productivity changes.[4] The post-war period is generally seen as a coherent whole, at least until the middle of the 1980s, when concerns over the cost of supporting agriculture, and its environmental effects, led to the first restrictions on output.

The following paper does not seek to argue that these approaches are fundamentally wrong, but that the pre-war / post-war dichotomy might be an over-simplification. This view is based upon a new attempt to produce a coherent dataset for the output of British agriculture over the period 1867–1985, details of which are given below. The consequent speculations about the reasons for the observed changes concentrate on the history of technical innovation and adoption, although the effects of labour and developments in government policy towards agriculture are not ignored.

## I

Since the beginning of the twentieth century, the output of British agriculture has increased, but not uniformly. Although the outputs of wheat, sugar beet, oilseed rape, milk, eggs, beef, pigmeat, and poultrymeat have all increased significantly, the quantity of sheepmeat produced has only increased a little and that of oats and root crops has decreased markedly.[5] To some extent, therefore, greater quantities of some products have been secured at the expense of smaller quantities of others. To measure overall output changes in physical units – tons or litres etc. – is therefore difficult and potentially misleading. This is not a new problem. It has been faced by all those attempting to measure productivity, and several approaches to overcoming it have been suggested. Campbell and Overton, for example, converted grain and potato outputs into energy equivalents.[6] Another solution is to measure all outputs in monetary rather than physical units. Not only does this render them all susceptible to addition, it also reflects the different values placed by society on various commodities. This is the approach adopted in National Product calculations, and consequently estimates of gross output, in current prices, are available for several industries, agriculture included, back to 1939. In addition, Ojala's well-known estimates of inputs and outputs cover the period from the initiation of the annual agricultural census, on which they are based, in 1866 (see Table A1). Although Ojala's figures are not directly comparable with the Ministry of Agriculture, Fisheries and Food's Departmental Net Income Calculation (DNIC), it is possible to adjust them to fit, and this has been done in the appendix to this paper.

Perhaps the main problem involved in using monetary units is their inconstancy. In order to make meaningful comparisons between different time periods, it is necessary to take account of the changing value of money. This too has been done in the appendix (Table A4). The

[4] Q. Seddon, *The silent revolution. Farming and the countryside into the twenty-first century* (1989); K. Blaxter and N. Robertson, *From dearth to plenty. The modern revolution in food production* (1995); E. J. T. Collins, 'Agricultural Revolution in a modern industrial state' (paper presented to the Economic History Society Conference at Canterbury, 1983); Holderness, 'Apropos the third Agricultural Revolution'.

[5] P. Brassley, *Agricultural economics and the CAP: an introduction* (1997), p. 38

[6] M. Overton and B. M. S. Campbell, 'Statistics of production and productivity in English agriculture 1086–1871', in B. J. P. van Bavel and E. Thoen (eds), *Land productivity and agro-systems in the North Sea area, Middle Ages-twentieth century: elements for comparison* (Turnhout, 1999), pp. 199–202.

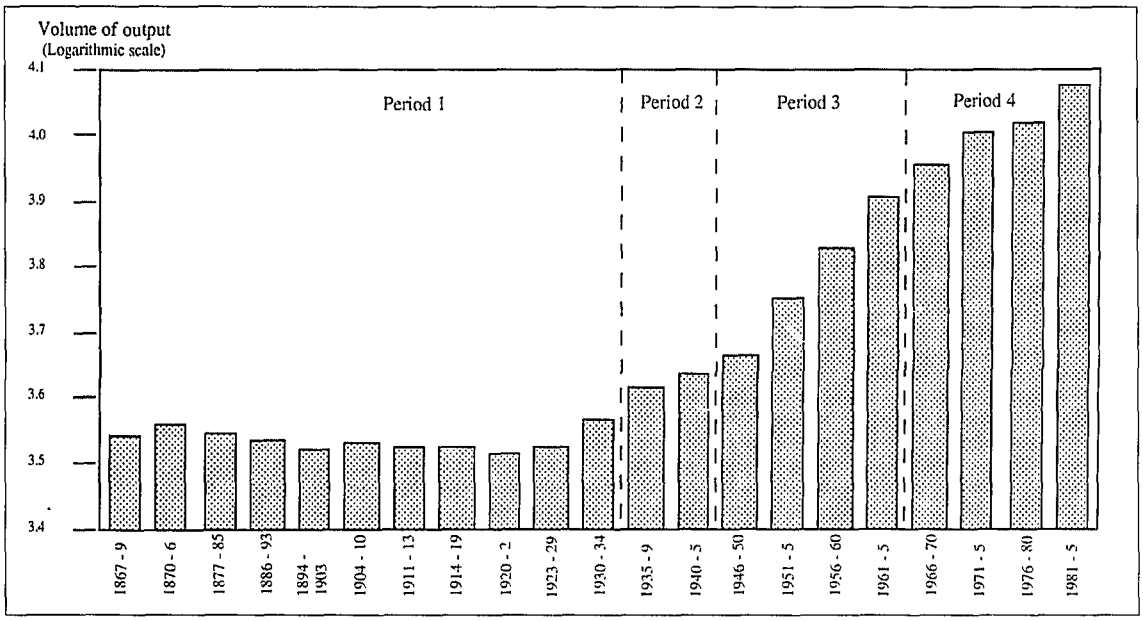


FIGURE 1. Changes in the volume of agricultural output in Britain, 1867–1985.
*Source*: See Table A4 below.

resulting figures, presented graphically in Figure 1, reveal an interesting pattern. Between 1867 and 1922, the output of British agriculture, in constant 1986 prices, was generally between £6 billion and £8 billion. Between 1924 and 1934 it fluctuated, but was always below £6 billion. Between 1935 and 1960 it rose from £6 billion to £12 billion, and thereafter remained between £12 billion and £14 billion. Thus it might be argued that there was a nineteenth-century plateau of production at the £6–8 billion level, and a late-twentieth century plateau at the £12–14 billion level. They are separated by a period of gradual decline in output, followed by a period of rapid increase in the two and a half decades between 1935 and 1960. However, a problem still remains. High levels of gross output may be produced either by high volumes of output or by high prices. Equally, volume increases may be masked if they occur at the same time as real farm price decreases. Consequently, it is also useful to calculate the volume of output, which can be done simply by deflating the gross output figures by the corresponding agricultural price indices. This in effect means that the physical output in any one period of time is multiplied by a constant price, so that the effects of increasing or decreasing prices are removed.[7]

The effect of this calculation, compared with the gross output figures, is to reduce the size of the change between 1940 and 1960, and to emphasize the continued expansion of output after 1965 (see Table A4). Nevertheless, as Table 1 demonstrates, the most rapid annual rate of output growth took place between 1946 and 1965. It therefore seems logical to divide the late nineteenth and twentieth centuries into four periods (as in Figure 1). In the first, up to the 1930s, prices declined but output was maintained as UK agriculture switched from arable to

[7] This is essentially the same as the method used by Turner for the 1867–1914 period, although the order of the calculations is different. See the discussion relating to Table A4 in the appendix, and M. Turner, 'Output and prices in UK Agriculture, 1867–1914, and the Great Agricultural Depression reconsidered', *AgHR* 40 (1992), pp. 38–51.

TABLE 1. Annual rates of growth in the volume of agricultural output

| | *% per annum* |
|---|---|
| 1870–1935 | 0.01 |
| 1935–1945 | 0.5 |
| (1935–1965) | (2.3) |
| 1946–1965 | 2.8 |
| (1946–1985) | (2.3) |
| 1966–1985 | 1.4 |

*Source*: for output volume figures, see table A4; the calculation of annual rates uses the method described in R. Floud, *An introduction to quantitative methods for historians* (2nd edn, 1979), pp. 94–5.

pastoral products. This was Turner's conclusion for the period up to 1914, and it seems to hold equally good for the post-World War I period.[8] The second period is the ten years or so between the mid-1930s and the mid-1940s. The gradual increase in output stimulated by government subsidies to wheat production and the success in the later 1930s of the Milk Marketing Board is often swamped by the drama of the war years. Overall, however, the input changes of this period (such as labour, fertilizer use and land reclamation) were more noticeable than the changes in the volume of output. Gross output certainly increased, but largely as a result of high wartime prices. It was in the third period, between 1946 and 1965, when prices were, initially at least, higher still (see Table A4) that the volume of output rose most rapidly as both arable and livestock sectors expanded.[9] In the final period, between 1965 and 1985, output still expanded, but at a reduced rate, as labour left agriculture rapidly, and much of the extra cereal production was fed to intensive livestock (pigs and poultry) and dairy cows.

## II

A detailed explanation of the reason for these changes in the volume of output, and their timing, would take more space than is available here. Nevertheless it is possible to suggest some of the contributory factors. Those which appear to be especially important are changes in land use, changes in labour inputs, technical innovation and adoption, and agricultural policy, particularly its impact on farm prices and incomes.

Any change in the output of an individual crop can be attributed to a change either in the area devoted to the crop, or in the output per unit area. In any examination of the first of these, the cropped area, it makes sense to begin with the cereals, since these exhibited the greatest fluctuations in this period. As Table 2 demonstrates, the total cereal acreage fell between 1870 and 1930, before rising rapidly up to 1965 and rising further still until 1985. Within this

[8] Turner, 'Output and prices', p. 51

[9] The annual growth rates shown in Table 1 may be compared with the annual rates calculated for various periods between 1520 and 1850 by Overton, the greatest of which was 1.18 per cent for the period 1800–30. Mark Overton, *Agricultural Revolution in England. The transformation of the agrarian economy, 1500–1850* (1996), p. 85.

TABLE 2. Crop areas in Great Britain and the UK ('000 hectares)

| | Wheat | Barley | Oats | total cereals | Potatoes | Sugar Beet | Fruit & Veg. | Fodder Crops | Temp Grass | Perm Grass | Rough Grazing |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1870 | 1417 | 960 | 1118 | 3402 | 238 | – | n.a. | 1020 | 1825 | 4890 | n.a. |
| 1885 | 1003 | 913 | 1190 | 3251 | 222 | – | 233[a] | 959 | 1885 | 6214 | n.a. |
| 1910 | 732 | 700 | 1223 | 2811 | 219 | 2 | 265[a] | 812 | 1707 | 7066 | n.a. |
| 1930 | 567 | 456 | 1068 | 2291 | 277 | 141 | 266 | 556 | 1721 | 7389[b] | n.a. |
| 1940s | 1403 | 723 | 1490 | 3547 | 563 | 169 | 383 | 451 | 1620 | 5547 | 8683 |
| 1965 | 1025 | 2183 | 410 | 3656 | 300 | 184 | 263 | 158 | 2430 | 4912 | 7216 |
| 1985 | 1902 | 1965 | 133 | 4015 | 191 | 205 | 236 | 74 | 1700 | 5019 | 5019 |

*Notes*: [a] author's estimates; [b] 1929 figure.
*Sources*: H. F. Marks (ed. D. K. Britton), *A hundred years of British food and farming: a statistical survey* (1989), pp. 130, 158, 173–4, 179–80, 183, 187.

overall trend, though, there are considerable differences between wheat, the acreage of which increased most dramatically between 1965 and 1985, barley, which expanded most rapidly between the Second World War and the 1960s, and oats, the acreage of which remained virtually untouched by the price changes of the late nineteenth century, only to fall away rapidly and continuously after the 1940s as the farm horse disappeared. Thus some of the extra wheat and barley appeared because land was no longer needed for oats, but this is not a complete explanation, because the total cereals area roughly doubled from its low point in the inter-war years by 1985. The other main crop which took up more land was sugar beet, the area of which expanded most rapidly in the first half of the twentieth century. To some extent the extra area used by these expanding crops in the post-war years was made available by declining acreages of potatoes, fruit and vegetables, and, especially, fodder crops, the area of which declined steadily from the 1870s onwards. But these shrinkages provided only about one third of the extra land needed for the expanding crops. The bulk of the extra cropland came from the conversion and reclamation of permanent grass and rough grazing. The permanent grass area, having expanded considerably at the end of the nineteenth century as the cereal and roots acreages fell, was attacked enthusiastically at the beginning of the Second World War. Speaking in 1942, William Davies, one of the leading figures in the Plough-Up campaign, claimed that over four million acres (1.62m hectares) of the sixteen million acres identified by the pre-war Grassland Survey of England and Wales had been ploughed up.[10] This figure roughly agrees with the change in the permanent grass area between 1929 and 1942 shown in Table 2. After the war the permanent grass area declined a little further, but not in the dramatic fashion of the war years. The area of rough grazing also decreased between 1942 and 1965, and between 1965 and 1985 (Table 2). What happened before 1942 is less clear as a result of difficulties in definition and enumeration

[10] W. Davies, 'Taking the plough round the farm', a talk broadcast on the Home Service of the BBC on Thursday 12 Mar. 1942, subsequently printed in a collection of *Farming Today broadcasts* published by Littlebury & Co., Worcester (?1943), p. 17.

TABLE 3. Numbers of Agricultural Workers (excluding farmers) in Great Britain

| | ('000) | | ('000) |
|---|---|---|---|
| 1867–69 | 1450 | 1935–39 | 738 |
| 1870–76 | 1385 | 1940–45 | 815 |
| 1877–85 | 1221 | 1946–50 | 865 |
| 1886–93 | 1124 | 1951–55 | 777 |
| 1894–03 | 1047 | 1956–60 | 678 |
| 1904–10 | 1075 | 1961–65 | 567 |
| 1911–13 | 1103 | 1966–70 | 432 |
| 1914–19 | 1050 | 1971–75 | 377 |
| 1920–22 | 996 | 1976–80 | 341 |
| 1923–19 | 907 | 1981–85 | 314 |
| 1930–34 | 825 | | |

*Source*: Marks (ed. Britton), *A hundred years*, p. 138. The Marks and Britton figures before 1923 are taken from the decennial censuses. The figure for 1867–69 is calculated from the average rate of decline over the decade; those for 1870–1922 from the census years that fall in the year groups, with the exceptions of the 1904–10 period, for which the figure is the average of the 1901 and 1911 figures, and the 1914–19 period, for which the figure is the average of the 1911 and 1921 figures. For the years after 1923 annual estimates from the agricultural census are available, and these are reported for each year by Marks and Britton, and have been averaged for each year group here. The figure used here for 1914–19 may be compared with Dewey's estimate, which is slightly lower, but measured in man-units, in which young males and all females are rated as less than one unit (P. Dewey, *British Agriculture in the First World War* (1989), pp. 44–5, 248–9).

in the agricultural returns.[11] What is certain is that the change in the permanent grass area between 1930 and 1985 (2.37m ha.) was more than enough to provide for the net increase in the area of the major crops in the same period (1.19m ha.), although it should be noted that much of the expanding urban area in this period was on land which would have been classified as arable, and much of the expanding forestry area on rough grazing.[12]

To some extent, therefore, the increasing volume of agricultural output in the second half of the twentieth century can be attributed to the more intensive use of land. Rough grazing was converted to permanent grass, and permanent grass to temporary grass or arable. But this will not explain all the changes, for while the process was being reversed (i.e. cropland was being converted to permanent grass) between 1870 and 1930, the volume of output was more or less maintained. And it was not maintained by simply substituting labour for land, because the move to pastoral farming saved labour (see Table 3). Conversely, the period of most rapid output increase, in the 1940s and '50s, was the only one in which the tendency to leave the land was reversed. Apart from the impact of the Womens' Land Army and prisoners of war during

[11] These problems are discussed at length in Ministry of Agriculture, Fisheries and Food, *A century of agricultural statistics, 1866–1966* (1968), pp. 10–11, and P. Allanson and A. Moxey, 'Agricultural land use change in England and Wales, 1892–1992', *J. of Environmental Planning and Management* 39 (1996), pp. 243–54.

[12] A. G. Champion, 'Competition for agricultural land', in A. Edwards and A. Rogers (eds) *Agricultural Resources* (1974), pp. 213–44.

TABLE 4. Crop yields, Great Britain (to 1914) / UK (tonnes per hectare)

| | *Wheat* | *Barley* | *Oats* | *Potatoes* | *Sugar Beet* |
|---|---|---|---|---|---|
| 1885–9 | 2.06 | 1.96 | 1.66 | 14.7 | |
| 1910–14 | 2.17 | 1.96 | 1.71 | 15.8 | |
| 1930–34 | 2.23 | 2.02 | 1.97 | 16.5 | 20.2 |
| 1942–46 | 2.56 | 2.37 | 2.16 | 17.8 | 26.4 |
| 1965–69 | 3.93 | 3.61 | 3.22 | 25.4 | 37.4 |
| 1985 | 6.33 | 4.95 | 4.59 | 35.8 | 38.3 |

*Source*: Marks (ed. Britton), *A hundred years*, pp. 164, 175, 180.

the war itself, returning servicemen appear to have had some effect in the five years after the Second World War when labour numbers reached a peak. Thus, as pointed out above, output can be changed by using more or less land, but also by producing more or less from any given acre of land. Other things being equal, more labour applied to a given acreage will tend to increase the output, or yield per acre, and less to decrease it. But other things were clearly not equal, for both total volumes of output and arable yields remained reasonably constant while agriculture was becoming more pastoral and labour was leaving the land between 1870 and 1930. Equally, yields increased as labour decreased after 1960 (see Table 4). Something else was affecting output and yields. Technical change is the usual suspect, and it is to the impact of technology that the discussion must now turn.

## III

The range of technical changes in twentieth-century agriculture, in the UK alone, is large. There have been new techniques for accomplishing existing activities, such as silage-making for grassland conservation and artificial insemination of animals. New crops, such as maize, oilseed rape, peas for freezing, and sugar beet, have become an important part of the industry's ouput. Although there have been no new animal enterprises (*pace* venison and ostrich meat, sheep and goats' milk and angora goats and llamas), the output of milk, pigmeat, and poultrymeat have increased significantly. In order to produce these new or increased outputs there have been new inputs, such as the change from Shorthorn to Friesian cows, underdrainage, artificial fertilizers, purchased feedingstuffs, pesticides, new varieties of crops, and the mechanization of many field and farmyard operations. This is not necessarily a complete list, but it includes most of the major changes, and it is interesting to note that many of them were originally developed before 1935, although they became widely used after 1950 or later.

This observation emphasizes the importance of distinguishing between innovation and adoption when assessing technical change. This is not to say that one is more important than the other: without innovation there is nothing to adopt; without adoption the innovation is ineffective. They work together like the blades of the scissors, but, unlike the scissors, they do not necessarily work at the same time. Some innovations have been adopted rapidly, and others much more slowly, but of all the changes listed above probably only one (peas for freezing) was totally

TABLE 5. Sugar Beet in the UK

| | *Area ('000 ha)* | *Output ('000 tonnes)* | *Yield (tonnes per ha)* |
|---|---|---|---|
| 1912 | 2 | | |
| 1925 | 23 | 497 | 21.6 |
| Pre-war | 135 | 2785 | 20.6 |
| 1946–8 | 168 | 3996 | 24.0 |
| 1959–61 | 175 | 6320 | 36.4 |
| 1983–85 | 200 | 8076 | 40.8 |

*Source*: Marks (ed. Britton), *A hundred years*, pp. 179–81.

unknown before the beginning of the First World War. Equally, few of them had been adopted on a significant scale before the Second World War. The best-known exception to this generalization was sugar beet, which could have been introduced in the nineteenth century: in the event, the first factory in England was not built until 1911, and met considerable indifference from the surrounding farmers. Following the introduction of a subsidy in 1924 the cultivated area and output increased nearly sixfold between 1925 and 1939 (See Table 5).[13] By 1960 sugar beet yields and output were approaching modern levels, but most of the modern technical developments – monogerm seed, precision drills, herbicides and harvesters – had still to be adopted. The significant point about these post-1960 developments is that they were all labour-saving rather than output-increasing.

Some new cereal varieties were also widely adopted in the inter-war period. By 1926 17 per cent of the wheat samples received by the National Institute of Agricultural Botany at Cambridge for germination testing were of Yeoman, a variety which had not been introduced until 1916.[14] Similarly, by 1939, 78 per cent of the barley samples received were of the varieties Spratt-Archer (first selected in 1908 and not grown in England on a field scale until 1920), Plumage-Archer (first produced in 1905) and Plumage (1902). The Ministry of Agriculture calculated that the average yield for the period 1922–9 was between 6 and 7 per cent higher than the average yield for the period 1912–19, which one respected (but not impartial) authority attributed largely to varietal change.[15] More detailed calculations, which attempt to distinguish between the yield increases due to varietal change and those caused by other factors such as the use of fertilizers and pesticides, reductions in harvest losses, and improvements in the standard of husbandry, are available for the period between 1947 and 1975. These suggest that 'other factors' had their major impact before the late 1960s. Between 1947 and 1967 new wheat varieties increased the national average wheat yield by 0.63 tonnes per hectare, or 26 per cent, whereas the increase due to other factors was 0.87 tonnes per hectare, or 36 per cent of the 1947 yield. In contrast, in the following decade, new varieties increased yields by a further 24 per cent, whereas other factors

[13] A. Douet, 'Some aspects of sugar beet production in England, 1945–85', *Rural Hist.* 7 (1996), pp. 221, 222.

[14] R. Biffen and F. L. Engledow, *Wheat-breeding investigations at the Plant Breeding Institute, Cambridge* (1926), pp. 61–2.

[15] H. Hunter, *The Barley crop* (1926), p. 32; E. S. Beaven, *Barley* (1947), pp. 103–5.

TABLE 6. New drainage in the UK ('000 hectares per year)

| | |
|---|---|
| 1941 | 6.1 |
| 1940–68 average | 28.4 |
| 1968 | 58.7 |
| 1970s | 100.0 |
| 1980s | 55.0 |
| 1990s | 10.0 |

*Sources:* B. D. Trafford, 'Field drainage', *JRASE* 131 (1970), pp. 132–3; B. D. Trafford, 'Recent progress in field drainage: Part 1', *JRASE* 138 (1977) p. 28; R. J. Parkinson, 'Field drainage' in R. J. Halley and R. J. Soffe (eds), *The Agricultural Notebook* (18th edn, 1988), p. 57; R. J. Parkinson, 'Soil management' in R. J. Soffe (ed.), *The Agricultural Notebook* (19th edn, 1995), p. 100.

had no effect. The story is similar for barley, although varietal change had a greater impact in the first post-war decade. The most prominent among the new varieties were Procter (a barley) and Capelle Desprez and Maris Huntsman (both winter wheats).[16]

Sugar beet was thus adopted between the wars, and cereal varieties at a greater or lesser rate over the whole century. There were other innovations which were adopted on a significant scale after 1960. There is no unequivocal test of 'adoption on a significant scale', but inspection of the available statistics reveals some clear trends. Bowers has pointed out that although the Ministry of Agriculture was successful in promoting arterial drainage schemes in the inter-war period, farmers and landowners did not follow them up with drainage schemes for individual fields.[17] Given the state of inter-war farm prices and profits, this should not be surprising. Table 6 reveals a peak in drainage activity in the 1960s and '70s which is quite clearly associated with the availability of drainage grants, which covered 65 per cent of the cost in the mid-1970s, but only 15 per cent by 1985 and after.[18]

The other principal post-1960 introductions were pesticides, silage, maize, and oilseed rape. Pesticide usage is not easy to measure using official statistics, for these do not seem to be available before about 1970. Estimates of pesticide output, which include both products used in the UK and those exported, show a much more rapid expansion after 1960 than before.[19] It might be argued that this represented relatively rapid adoption, because although sulphuric acid and copper sulphate had been used for weed control in cereals, on a small scale, since

[16] V. Silvey, 'The contribution of new varieties to increasing cereal yield in England and Wales', *J. of the National Institute of Agricultural Botany* 14 (1978), pp. 367–84; for a similar study on potato varieties, see P. M. Harris, 'Agronomic research and potato production practice', in R. G. Hurd, P. V. Biscoe and C. Dennis (eds), *Opportunities for increasing crop yield* (1980), pp. 205–17.

[17] J. Bowers, 'Inter-war land drainage and policy in England and Wales', *AgHR* 46 (1998), pp. 64–80.

[18] R. J. Parkinson, 'Field drainage', in R. J. Halley and R. J. Soffe (eds), *The Agricultural Notebook* (18th edn, 1988), pp. 56–7; R. J. Parkinson, 'Soil management', in R. J. Soffe (ed.), *The Agricultural Notebook* (19th edn, 1995), p. 100.

[19] D. Grigg, *English agriculture: an historical perspective* (1989), p. 75; Blaxter and Robertson, *From dearth to plenty*, ch. 6; K. Cowling, D. Metcalf and A. J. Rayner, *Resource structure of agriculture: an economic analysis* (1970), p. 138.

TABLE 7. Estimates of silage output in Britain

| | *('000 tonnes)* |
|---|---|
| 1884–6 | 58 |
| 1887–9 | 135 |
| 1940 | 240 |
| 1947 | 350 |
| 1950–4 | 2,195 |
| 1955–7 | 3,272 |
| 1962 | 4,293 |
| 1969 | 8,294 |
| 1970–4 | 13,558 |
| 1975–9 | 21,032 |
| 1980–4 | 32,290 |
| 1985–9 | 46,286 |

*Source*: P. Brassley, 'Silage in Britain, 1880–1990: the delayed adoption of an innovation', *AgHR* 44 (1996), pp. 63–87.

the beginning of the twentieth century, it was not until the early 1940s that the first modern selective herbicides, MCPA and 2,4-D and the insecticide DDT, were developed.[20] The subsequent expansion of scientific work on pesticides was dramatic: it was claimed that more than 10,000 scientific papers were published on herbicides alone between 1953 and 1958, although it took longer for the technology to be adopted at farm level.[21] Silage took much longer still. It was first introduced in the 1880s but not widely adopted for nearly 100 years despite the efforts of its official advocates (Table 7).[22] Adoption of silage required changes to the whole farming system, which was why it took time. But as farmers learned to make better grass silage, they transferred the knowledge and machinery to maize, and in addition, by the mid-1990s, maize qualified for Arable Area Payments of up to £320 per hectare. Thus Table 8 seems to indicate rapid expansion of the maize area from the 1980s onwards. Yet the first Board of Agriculture and Fisheries leaflet on maize appeared in 1902, and claimed that maize had then been grown in England for 20 years, and definitely since 1886, although there were also claims that it had been grown earlier, in the 1860s, back to Cobbett's time, and even in the eighteenth century.[23] In 1901 trials were being conducted at the South-Eastern Agricultural College (now Wye College, University of London), and there were further trials in the 1920s and 1940s. Nevertheless, until the late 1950s only about a thousand hectares were grown each

[20] G. E. Blackman, 'Weed control in cereals by chemical methods', *Agriculture* 53 (1946), pp. 16–22; H. W. Miles, 'DDT and the Farmer', *Agriculture* 53 (1946), pp. 217–9.

[21] E. J. Russell, 'Weeds. The ancient enemy', *Agriculture* 65 (1958), p. 8.

[22] P. Brassley, 'Silage in Britain, 1880–1990. The delayed adoption of an innovation', *AgHR* 44 (1996), pp. 63–87.

[23] Board of Agriculture and Fisheries, *Cultivation of Maize for Fodder* (Leaflet No. 73, 1902) subsequently published in Board of Agriculture and Fisheries, *Leaflets (Nos. 1 to 100)* (1913).

TABLE 8. Estimate of the maize area in England and Wales

| | *('000 ha)* |
|---|---|
| late 1950s | 5.0 |
| 1960–61 | 1.0 |
| 1975–9 | 28.6 |
| 1980–84 | 17.4 |
| 1985–89 | 23.0 |
| 1990–94 | 59.2 |
| 1995 | 106.0 |

*Source*: E. Bunting, 'Maize in Europe', in E. Bunting *et al* (eds), *Forage Maize* (1977); MAFF, *UK Agricultural Statistics* (various editions).

TABLE 9. Estimates of the oilseed rape area and output in Great Britain

| | *Area ('000 ha)* | *Output ('000 tonnes)* |
|---|---|---|
| 1969 | 5 | 9[a] |
| 1970–74 | 11 | 20[a] |
| 1975–79 | 56 | 131[a] |
| 1980–84 | 176 | 541 |
| 1985 | 295 | 891 |

*Note*: [a] author's estimates
*Source*: Marks (ed. Britton), *A hundred years*, p. 172.

year.[24] Similarly, rape has been grown as a forage crop since at least the nineteenth century, and there are references to rapeseed oil in seventeenth-century Northumberland. In the twentieth century it was grown for seed in Europe and North America, but not in Britain until the late 1960s. It was then that there was a search for a combinable arable break crop as all-cereal rotations became popular, and oilseed rape proved ideal, avoiding land-damaging winter cultivations and adding little to fixed costs. The other crucial factor was the decision of United Oilseeds to handle the crop. In effect, they created a market for it; the resultant increase in output is shown in Table 9.[25]

Thus those innovations which were only adopted on a significant scale after 1960, with the possible exception of underdrainage, were not necessarily output-increasing. Pesticides have

[24] J. Darby, 'On green or fodder crops not commonly grown which have been found serviceable for stock feeding', *J. Royal Agricultural Society of England (JRASE)*, 2nd ser., 18 (1882), pp. 138–141; J. Long, 'British dairy farming', *JRASE*, 2nd ser., 23 (1887), pp. 125–34; A. Pell, 'William Cobbett', *JRASE* 63 (1902), pp. 1–26; E. Bunting, 'Maize in Europe', in E. Bunting *et al* (eds), *Forage Maize* (1978). I am grateful to Rob Dixon for these references. The maize area figures are complicated by the fact that maize might be grown for grain or silage, although most is now grown for silage.

[25] P. Brassley, 'Northumberland and Durham', in J. Thirsk (ed.) *The Agrarian History of England and Wales*, V (i), *1640–1750* (1984), p. 56; Thirsk, *Alternative Agriculture*, p. 231.

TABLE 10. Number of first inseminations in England and Wales

| | ('000) |
|---|---|
| 1944–5 | 16 |
| 1954–5 | 1497 |
| 1960–1 | 2006 |
| 1972–3 | 2528 |
| 1985–6 | 1930 |

*Source*: Milk Marketing Board, *Dairy Facts and Figures* (published annually), various editions.

obviously had some yield effects, but herbicides in particular were labour-saving, to an extent which may not be easy to measure but which is put in context by Primrose McConnell's estimate (in 1919) that 'From a third to a half of the field labour on a farm is devoted to the destruction of growing weeds'.[26] Silage, maize and oilseed rape cannot be simply characterized as either output-increasing or labour-saving: they could do both, and affected the whole system of farming. The yield of conserved fodder may have been increased by the move from silage to hay, but at the same time silage also proved easier to mechanize than the hay harvest. On the other hand, the innovations of the 1920s and '30s, especially the new varieties, tended to increase output, but their impact was limited. New crop varieties had a much bigger effect on output after the war. But it was between these two periods, from the late 1930s to the late 1960s, that the most dramatic developments occurred.

Again, the technical changes of the 1935–65 period may be divided into the output-increasing and the labour-saving. Among the former were varietal change (as discussed above), fertilizers, feedingstuffs, Friesian cows and artificial insemination (AI). Among the latter were combine harvesters, tractors, and milking machines. And, once again, most of them had been invented for some time before they were widely adopted. The only exception to this generalisation is artificial insemination, which expanded from virtually nothing in 1942 to 80 per cent of its maximum level by 1960 (see Table 10). Building on scientific work in the 1930s in Russia, Denmark, and the USA, as well as in Britain, the first two trial centres, at Cambridge and Reading, were established in late 1942 and early 1943. The Artificial Insemination (Cattle) (England and Wales) Regulations of 1943 brought the whole process under government control and by 1945 eight centres were in operation, with eight more proposed.[27] The use of artificial fertilizers expanded during the nineteenth century, but although the half million tonnes used in the 1860s had increased by nearly a million in the late 1930s, the big increase came in the following twenty years (see Table 11). In those two decades the use of artificials increased fourfold, to within sight of the peak reached in 1985. Much of the increase was in the use of nitrogenous fertilizer, which has a more direct effect on yield than the other two principal

[26] P. McConnell, *Notebook of agricultural facts and figures for farmers and farm students* (9th edn, 1919), p. 278

[27] S. Bartlett and J. Mackintosh, 'The artificial insemination of cattle', *JRASE* 105 (1944), pp. 175–189; Anon., 'Artificial insemination of cattle', *Agriculture* 51 (1945), pp. 529–532.

TABLE 11. Fertilizer use in the UK

| | *(million tonnes)* |
|---|---|
| 1867–9 | 0.51 |
| 1904–10 | 1.05 |
| 1935–9 | 1.41 |
| 1950–1 | 4.15 |
| 1960–1 | 6.27 |
| 1970–1 | 6.95 |
| 1980–1 | 6.51 |
| 1985 | 7.09 |

*Sources:* 1967–1939 figures from E. M. Ojala, *Agriculture and economic progress* (1952), p. 212; subsequent figures from Marks (ed. Britton), *A hundred years*, pp. 254–5, calculated by dividing the expenditure totals in table 27.1 by the current price index in table 27.4. Rough and ready though this method is, it gives a figure (1.04 million tons) comparable with Ojala's for the late 1930s, and one (6.94) comparable with Marks and Britton's table 27.3 figure for total fertilizer use in 1985, assuming that tons of nutrient are converted to tons of product weight using a conversion factor of 30% N for N fertilizers, 40% P for P fertilizers, and 50% K for K fertilizers (estimated from J. Nix, *Farm Management Pocketbook* (5th edn, 1972), p. 121.

TABLE 12. UK Feedingstuffs use

| | *(million tonnes)* |
|---|---|
| 1904–10 | 6.1 |
| 1935–9 | 8.8 |
| 1959–62 | 13.4 |
| 1967–9 | 13.7 |
| 1985 | 16.3 |

*Source:* Ojala, *Agriculture and economic progress*, p. 212; Marks (ed. Britton), *A hundred years*, pp. 246–7. The 1959–62 figure is estimated from data for expenditure on purchased feeds in that period, deflated by the RPI.

nutrients, phosphate and potash.[28] Similarly, if not so dramatically, the use of purchased feedingstuffs, the other principal ingredient of Thompson's Second Agricultural Revolution in the nineteenth century, increased by fifty per cent between 1935 and 1962 (Table 12), despite the fact that they were rationed for pigs and poultry between 1939 and 1953.[29] And to consume at least part of these extra feedingstuffs there was a new breed of dairy cow: the Friesian. There have been importations of Dutch cattle since the eighteenth century, and there was probably some Dutch blood in the dominant breed in 1900, the Shorthorn, which accounted for 64 per cent of the national herd in 1908. Then, just at the beginning of the First World War, the first

[28] E. M. Crowther, 'Fertilizers in the agricultural expansion programme', *Agriculture* 54 (1948), pp. 491–500. It should be pointed out that the development of shorter-strawed varieties was necessary to allow the use of extra nitrogen on cereals without increasing the danger of lodging.

[29] F. M. L. Thompson, 'The second Agricultural Revolution, 1815–80', *EcHR*, 2nd ser., 21 (1968), pp. 62–77; V. H. Beynon, 'Bacon production from some home-grown foods', *Agriculture* 60 (1953), p. 208.

TABLE 13. Percentage of Friesian cows in the dairy herd (England and Wales)

| | |
|---|---|
| 1955 | 40.6 |
| 1965 | 64.2 |
| 1973–4 | 81.0 |
| 1985–6 | 85.8 |

*Source*: Milk Marketing Board, *Dairy facts and figures 1959*, p. 32; and subsequent editions for 1966, 1976, and 1986.

modern Friesians were imported. But again, they did not achieve their present dominance until after the Second World War (see Table 13).[30]

If the replacement of Shorthorns by Friesians increased milk yields, which it undoubtedly did, the labour required to extract the extra milk was reduced by the replacement of hand-milking by milking machines. Again, these were a nineteenth-century invention adopted in the 1940s and '50s. There were 237 patents for milking machines between 1860 and 1915, most of them of dubious worth. But the Struthers and Weir pulsator of 1892 and the Gillies teat cup of 1902 solved the major technical problems, so that by the late 1920s, according to Professor Collins, effective milking machines were available.[31] Nevertheless, ninety per cent of herds were still hand-milked in 1939. Between 1944 and 1961 the machine-milked proportion rose from ten to eighty five per cent. The delay in adoption was caused by cheap labour, high capital costs of machinery, small herds, and the association with the change from cowshed to parlour milking. As Collins points out, the eventual rapid uptake was 'part of a broader pattern of change affecting output, organisation, and the farm production function'.[32]

This broader pattern of change was also apparent in other aspects of farm mechanisation. It was eventually a labour-saving development, but not always initially. Roland Dudley of Linkenholt in Hampshire, who farmed a thousand acres of Hampshire cereal land, claimed in 1942 that '... on that same farm on which I employed three men and a boy just before the war I was employing thirty people as a result of mechanisation and today I haven't got enough cottages'. Geoffrey Tawell, a Bedfordshire market gardener, agreed with him: '... up-to-date equipment ... increases your gross output and so you become an employer of more labour rather than less'.[33] Mechanisation also contributed indirectly to output increases because not only human labour, but horse labour too, was saved. As horse numbers fell, so did the quantity of hay, oats and beans that had to be fed to them rather than to meat and milk producers. As Table 14 demonstrates, horse numbers were decreasing from the beginning of the twentieth

[30] Board of Agriculture and Fisheries, *The Agricultural Output of Great Britain* (Cd. 6277, 1912) (in BPP 1912–13, X, p. 529) table 11 p. 57; G. E. Mingay, *British Friesians. An epic of progress* (1982), pp. 34, 47.

[31] E. J. T. Collins, 'The uptake of the milking machine in England and Wales', in *Vom 'Fleissigen' zum 'Produktiven' Bauern. Aspekte zum Wandel der Europaischen Landwirtschaft des 19./20. Jahrhunderts* (Ostfolden: Scripta Mercaturae Verlag, 1996), pp. 2–7. I am most grateful to Professor Collins and John Creasey for providing a copy of this paper.

[32] *Ibid.*, p. 13.

[33] 'Machinery on the farm', a talk broadcast on the Home Service of the BBC on 3 Dec. 1942, in *Farming Today broadcasts*, p. 76.

TABLE 14. Tractors and Horses in Great Britain

| | *Horses ('000)* | *Tractors ('000)* |
|---|---|---|
| 1909 | 1132 | 0.05 |
| 1921 | 962 | 20 |
| 1940 | 642 | 66 |
| 1946 | 545 | 204 |
| 1950 | 347 | 332 |
| 1960 | 54 | 476 |
| 1971 | | 477 |
| 1980 | | 481 |
| 1985 | | 491 |

*Source*: C. Cawood, *Vintage tractors* (1980), p. 3; Marks (ed. Britton), *A hundred years*, p. 146.

century, although before 1940 some at least of the decrease reflected the fall in the arable acreage. Once again, it was during the 1940–60 period that the replacement of the horse by the tractor was at its most dramatic. And once again, the tractor was a nineteenth-century invention. There were tractors in the USA in the 1890s, the first British tractor was produced in 1902, and enough Fordsons were imported in the First World War to bring the numbers up to 7,000 by 1918. But, as Table 14 shows, adoption was at first slow, hampered by capital cost and steel wheels (for there were no rubber tractor tyres before the 1930s). Then a combination of wartime labour shortages and the major technical changes of weight transfer and live power take-off embodied in the Ferguson TE20 of 1948 made a difference: numbers increased sevenfold between 1940 and 1961. It should also be remembered that tractors increased in power and capability, and their drivers in expertise.[34] In 1942 it appeared to one speaker that '... farmers of the last generation had the knack of horsemanship ... It will take a few more generations of mechanical power before farmers have the same instinct for tractors and tractor implements'.[35] Presumably the implication of comments such as this is that Table 14 understates the increase in effective tractor power after 1960.

Combine harvesters, too, like the reaper-binders which preceded them, were an American invention which were adopted much more quickly in the United States than in Britain. There were combines in the USA by the 1840s, and two thirds of the Californian wheat crop was said to be combined in the 1880s. Internal combustion engines were added after the First World War, and by 1926 over 5000 combines in Kansas cut 30 per cent of the crop.[36] The first combines in Britain were imported only in 1928, and they were soon followed by home-produced competitors: Clayton and Shuttleworth, long-established as threshing machine manufacturers in

[34] C. Cawood, *Vintage tractors* (1980); K. Cowling *et al*, *Resource structure of agriculture*, pp. 96–9.

[35] S. J. Wright, 'More power to the land', a talk broadcast on the Home Service of the BBC on 12 Feb. 1942 in *Farming Today broadcasts*, p. 80.

[36] P. Fearon, 'Mechanisation and risk. Kansas wheat growers, 1915–1930', *Rural Hist.* 6 (1995), p. 232.

TABLE 15. Changes in cereal harvesting machinery in the United Kingdom, 1942–80

| | *Binders ('000)* | *Combines ('000)* | *Balers ('000)* |
|---|---|---|---|
| 1942 | 102 | 1 | nd |
| 1946 | 119 | 3 | nd |
| 1950 | 120 | 10 | 16 |
| 1960 | 75 | 48 | 58 |
| 1971 | | 57 | 70 |
| 1980 | | 47 | 74 |

*Source*: Marks (ed. Britton), *A hundred years*, p. 146; MAFF, *Agricultural Statistics 1954/5: England and Wales Agricultural Censuses and Production* (1956), p. 89; *Agricultural Statistics 1960/1: England and Wales Agricultural Censuses and Production* (1962), p. 102; *Agricultural Statistics England and Wales 1976–7: Agricultural Censuses and Production* (1980), pp. 138–9.

Lincoln, exhibited a 'combined harvester and thresher' with a 12 foot cut at the Manchester Royal Show in 1930. In 1936 Allis-Chalmers had a small (5 foot cut) combine, powered by the tractor power take-off, which was said by the judges at the Bristol Royal Show in 1936 to be 'a distinct advance towards a combine suited to British conditions', on sale for £230.[37] Nevertheless, by 1939 there were only one hundred machines in the country. Their adoption was delayed by lower labour costs, smaller fields and farm sizes, the need for driers, the absence of balers to deal with the straw, and the capital cost involved. Consequently it came a little later than that of the tractor, and it was in the 1950s that it occurred most rapidly (Table 15).

## IV

This is not a complete survey of the technical changes which have affected British agriculture in the twentieth century, but simply a selection of some of those which are judged to be both important and capable of quantification. There are obviously others which may be one or the other but not both. The intensification of pig and poultry production has clearly had a major impact on the output of eggs, pigmeat, and poultrymeat, but it is not easy to find figures which illustrate the change from hens running around the orchard and pigs in sties to battery cages and sow stalls over a long period of time. It might also be suggested that the identification of some quantifiable development as a technical change, which, in theoretical terms, produces a shift in the supply curve, as opposed to an increase or decrease in the use of inputs which produces a movement up or down along the supply curve, is, to some extent, a matter of judgement. The example of fertilizer use illustrates this admirably. It is not difficult to identify the introduction of artificial fertilizers in the nineteenth century as a technical change, but the impact of a few thousand tons of guano then may not have had as much effect on total agricultural output as the rapid increase in the use of ammonium sulphate in the 1940s and

[37] R. Borlase Matthews, 'Report on new implements at the Manchester Show, 1930', *JRASE* 91 (1930), pp. 247–8; T. Close, 'Report on new implements at the Bristol Show, 1936', *JRASE* 97 (1936), pp. 405–6.

'50s. Yet that was existing technology, which farmers were employing in response to increased wartime demand and guaranteed prices.

Clearly this brings the argument back to the question of innovation and adoption. The futility of trying to decide which of these is the more important has already been discussed. On the other hand, the desirability of identifying the factors which promote either or both of them is obvious. There is a long list of potential influences: output price changes; input price changes and relative movements of different input prices; the impact of inflation on the *perception* of cost and price changes; state control of farm rents and the increase in owner-occupation which allowed farmers to retain a bigger proportion of their profits; state promotion of agricultural research and extension services; changes in the business objectives of farmers from survival to profit maximisation as they came to assume that government support would continue; successful implementation of agricultural policy (especially the 1947 Agriculture Act); a patriotic response to a perceived national need; and a combination of several of these. They could all be important. It would require at least one (and probably more than one) further paper of the length of the present one to place them in order of precedence. However, it seems clear that the greatest expansion in output took place when prices, in real terms, had returned almost to nineteenth-century levels, which was also the point at which state propaganda and policy was encouraging output maximisation at almost any cost (see Table A4).[38] The preamble to the 1947 Agriculture Act declared the purpose of British agriculture to be the production of 'such part of the nation's food and other agricultural produce as in the national interest it is desirable to produce in the United Kingdom', and in the 1940s and '50s that seemed to mean as much as possible.[39] Consequently, not only was money made available for research, and for a National Agricultural Advisory Service to put the fruits of the research into the hands and minds of the farmers, but something also encouraged farmers to believe that attempts to increase output would not be met by a return to pre-war low price conditions, as they had been after the First World War. The 1947 Act is an obvious candidate.[40]

Several conclusions thus emerge from this examination of the relationship between price, output, and technical change. First, the output figures suggest that the development of British agriculture in the late nineteenth and twentieth centuries should be considered in four periods: from the 1860s to the 1930s; from between 1930–35 to 1945; from 1945 to 1965; and the twenty

[38] Although it should be noted that the figures in Table A4 would obviously not support the contention that the volume of output was directly and closely related to the price level over the whole period 1867–1985.

[39] Agriculture Act, 1947, section 1(1), quoted in P. Self and H. J. Storing, *The state and the farmer* (1962), p. 23; Lord Williams of Barnburgh, *Digging for Britain* (1965), pp. 152–63.

[40] *The Economist* in 1950 called the 1947 Act 'the comprehensive measure of support British Agriculture has always wanted', and Lord Williams devoted an appendix of his autobiography to demonstrating the great increase in output between 1939 and 1959 (Williams, *Digging for Britain*, pp. 179 and 191–5). Tony Harman, who farmed in Buckinghamshire between 1931 and the 1980s felt that '. . . we made no *real* [his italics] progress until after the war ... when the war ended and farmers weren't immediately dropped ... but continued to be supported by the government, my confidence increased still further.' (T. Harman, *Seventy summers* (1986), pp. 186–7, 203). The impact of agricultural policy on producer expectations and consequent investment is discussed, in a different context, in A. Buckwell, 'Economic signals, farmers' response and environmental change', *J. Rural Studies*, 5 (1989), pp. 149–160. I am most grateful to Matt Lobley for this reference.

[41] Turner, 'Output and prices', p. 51.

years after 1965. Secondly, before 1935 the volume of output appears to vary little, as Turner suggested was the case before 1914.[41] There were only a few examples of technical adoption, and they did not change output very much one way or the other. In contrast, after 1965 both prices and labour inputs fell, but the impact of technology ensured that output continued to expand by increasing both land and labour productivities, probably at the expense of capital productivity. The crucial periods were the intervening years. The volume of output did not increase all that much in the Second World War, because the emphasis had to be placed on maximising self-sufficiency. Thus the changes in land use were dramatic, but the resultant increases in arable output were balanced by restrictions in livestock output needed to minimize the use of purchased feedstuffs. Once these restrictions were removed, from the late 1940s to the early 1960s, high prices, increasing labour, and the rapid adoption of what was mostly *existing* technology all combined to raise the volume of output more rapidly than ever before or since. This emphasis on adoption certainly attracted academic attention at the time.[42] Scientific breakthroughs and innovations, which have also attracted their share of academic interest,[43] could have had little influence on output in the absence of adopting producers. Thus, having identified the importance of the 1945–65 period, and made a case for the output increases depending on existing technology, the obvious next stage of research should be on the reasons for adoption. Given the prevalence of theories of technical change that claim the predominant influence of input prices,[44] the suggestion made here of the significance of high output prices is interesting. Detailed work on relative input price changes and other factors affecting labour and capital use is beyond the scope of the present paper,[45] but it would clearly be worthwhile. Further work is also needed to explain which of the other factors listed in the previous paragraph led farmers to become adopters. Whatever the reason for them, the dramatic output increases perhaps explain why farmers became so popular during the 1940s and '50s: extra output was required and farmers produced it. In other times and places it might have been called a Great Leap Forward.

## Appendix
## Calculation of gross output, prices and volume of output

This appendix explains the way in which gross output and price data have been brought together to form consistent series covering the period 1867–1985. First, a gross output series in current prices is constructed, then a retail price index (RPI) is produced and used to convert the gross output series to constant (1986) price terms. An agricultural price index (API) is also constructed, and deflated by the same RPI. Since no consistent data sets covering the whole of this period have been found, each of these series have been constructed from several sources. The deflated agricultural price index is then used to convert the gross output figures to a volume of output series.

[42] G. E. Jones, 'The diffusion of agricultural innovations', *J. Agricultural Economics* 15 (1963), pp. 387–409; E. H. Whetham, 'The mechanisation of British farming, 1910–1945', *J. Agricultural Economics*, 21 (1970), pp. 317–31. See also E. M. Rogers, *Diffusion of innovations* (1962).

[43] See, for example, Blaxter and Robertson, *From dearth to plenty.*

[44] These are summarized in B. M. Koppel (ed.), *Induced innovation theory and international agricultural development: a reassessment* (1995).

[45] Discussed to some extent in Holderness, 'Apropos the third Agricultural Revolution'

*(i) Gross Output for UK Agriculture, 1867–1985.*

Turner has discussed output and prices in UK agriculture, but only for the period 1867–1914. He concludes, after discussing previous estimates by Ojala, Dewey and Bellerby, that 'there are no reasonable estimates which we can use, but ... we should face up to the fact that a completely fresh approach to the problem of estimating output will be no guarantee of better results'.[1] Nevertheless, since the differences that he identifies between the various estimates are usually of the order of three or four per cent, and always less than ten per cent, it might be argued that for the purposes of the present study they are nugatory. The estimates used here are those produced by Ojala, adjusted to render them compatible with the Ministry of Agriculture, Fisheries and Food's Departmental Net Income Calculation (DNIC).[2] Once these two series can be put together, they produce a consistent data set covering the period from 1867 to the present day (although this study ends at 1985).

Although some of the categories used by Ojala and the DNIC are different (e.g. Ojala's 'horses' become 'other livestock' in the DNIC), their totals are the same except for Sundry Output, which is the annual value of own-account capital formation, such as the construction of glasshouses, silos, or pig and poultry houses. This is included in the DNIC but not in Ojala, so Ojala's figures need to be adjusted thus:

Ojala total output + sundry output = DNIC gross output.

Tasker uses Feinstein and Pollard's estimate of fixed capital formation.[3] Since these two sources use different year groupings, the Feinstein and Pollard figures are converted by assuming that the figure for each year is the same as the average for the group of years, and then adding the appropriate years for the Ojala year groupings. In addition, Ojala (p. 215) takes account of the impact of government subsidies on the gross output figures for 1930–4 and 1935–9 by adding £5 million and £10 million respectively. Having done this, he then concluded (pp. 207, 210) that the figures produced by MAFF for the 1935–9 period were better than his, and so in his final gross output estimate he used a figure of £279m. Adjusting this as above for sundry output (£4m) and subsidies (£10m) gives a gross output of £293m for 1935–9, which is in reasonable agreement with the figures reported by Britton and Marks for 1938 (£300m) and 1939 (£342m).[4]

Turner compares various output estimates for 1909–13, and Ojala's modified estimates are of the same order of magnitude.[5] There are certainly differences between Ojala and other estimators, but they are reasonably consistent, and, given the need for compatibility with the later MAFF DNIC figures to produce a data set covering the whole period under discussion, and the greater importance of relative changes as opposed to absolute levels of output, it seems permissible to use them here.

Two major problems remain. The first is that Ojala omits any estimate for the period of the

[1] Turner, 'Output and prices', p. 43.

[2] E. M. Ojala, *Agriculture and economic progress* (1952), pp. 208, 215; J. C. Tasker, 'An Investigation of Farm Income 1867 to 1939' (unpublished BSc (Hons) dissertation, University of Plymouth, 1994), pp. 43, 66; the MAFF DNIC figures are reported in H. F. Marks (ed. D. K. Britton), *A hundred years of British food and farming: a statistical survey* (1989), p. 149.

[3] Tasker, 'Farm Income', p. 42, app. C; C. H. Feinstein and S. Pollard (eds), *Studies in capital formation in the United Kingdom, 1750–1920* (1988), p. 269.

[4] Ojala, *Agriculture and economic progress*, p. 215; Marks (ed. Britton), *A hundred years*, p. 149.

[5] Turner, 'Output and prices', pp. 42–3.

First World War. One way of dealing with this problem would be to produce a new estimate of output for 1914–19 using Ojala's methods. Unfortunately, many of the figures required are not easily available. A cruder approach was therefore adopted, in which Ojala's estimate for 1911–13 output was increased by the proportion in which the API rose between 1911–13 and 1914–19, giving a figure of £399.41 million. This method obviously takes no account of the changes in the pattern of agricultural production which occurred in 1914–19. However, it can be checked against Dewey's detailed calculation for the First World War years and Ojala's estimate for the 1920–22 period.[6] Dewey does not in fact estimate an output for 1919, so if his 1918 estimate is raised to 1919 prices, and all his figures for the whole 1914–19 period are then averaged, an estimated average gross output for the period of £286.5 million is produced. But this applies to Great Britain only, whereas Ojala's figures are for the United Kingdom, so the Irish output (from Turner[7]) needs to be added in. Taking Turner's 1911–13 Irish output figures, again raised by the proportionate increase in the API, gives an Irish 1914–19 output estimate of £87.4m, which, added to Dewey's figure for Great Britain, gives an estimate for the UK of £373.9m, which is only 6.4 per cent less than the crude estimate derived from proportionately increasing Ojala. Incidentally, using the API-proportionate method to go from Ojala's 1911–13 figure to 1920–22 produces agreement with Ojala's original figure to within 3 per cent. Therefore, despite their methodological simplicity, these figures have been incorporated into the output series reported below.

The other problem is Irish output. Ojala, in his output tables (pp. 208–9) simply points out that the UK excludes Eire after 1922. Since this paper attempts to trace changes in output in the long run, this approach is not ideal. The ideal would involve adjusting UK output to remove all of the Irish output, except for that produced in Northern Ireland, for the period before 1922, but Turner's estimate of Irish agricultural output deals with the whole island. Again, adopting the simplest possible procedure, Northern Ireland accounts for a little less than 20 per cent of the area of the whole of Ireland, so assuming that it produces roughly 20 per cent of the total Irish output should produce an estimate of the right order of magnitude, and there are sufficient sources of error in other parts of the calculation to render the pursuit of pinpoint accuracy, in this point, redundant.[8] Therefore eighty per cent of the Turner's Irish output figures have been deducted from Ojala's estimates, as modified by Tasker, for the years before 1922. For the years after 1940, the MAFF DNIC figures, reported by Britton and Marks, have been used, and the whole output series is shown in Table A1. However, since table A1 is reported in current price terms, and inflation, especially in the second half of the twentieth century, has not been insignificant, it is necessary to convert these estimates to constant price terms. This process requires a retail price index covering the whole period, which has had to be constructed.

[6] P. Dewey, *British agriculture in the First World War* (1989), pp. 244–8.

[7] M. Turner, *After the Famine. Irish agriculture 1850–1914* (1996), p. 108.

[8] *Ibid.*, table 4.2, p. 108. O'Grada has produced a different set of output estimates for Irish agriculture in 1912 (see C. O'Grada, 'Irish agriculture north and south since 1900', in B. M. S. Campbell and M. Overton (eds) *Land, labour and livestock. Historical studies in European agricultural productivity* (1991), pp. 439–456). He reports figures for all Ireland, and also the south and the north separately. His estimates are higher than Turner's, but he calculates the output of the six counties of the north to be 21.3 per cent of the total for all Ireland. Clearly, since Turner's figures are the only ones covering the whole period back to 1850 they have to be used here, but assuming a Northern Ireland output of 20 per cent of the total is not in violent disagreement with O'Grada.

TABLE A1. Gross output estimates for UK agriculture in current prices

| | *Ojala's Gross Output (£m)* | *Ojala adjusted to DNIC (£m)* | *Irish output x 0.8 (£m)* | *Adjusted Ojala minus adjusted Irish output* |
|---|---|---|---|---|
| 1867–69 | 229.83 | 236.43 | 31.94 | 204.49 |
| 1870–76 | 247.18 | 254.29 | 35.46 | 218.83 |
| 1877–85 | 219.20 | 225.62 | 31.61 | 194.01 |
| 1886–93 | 187.80 | 192.96 | 28.64 | 164.32 |
| 1894–03 | 182.78 | 186.94 | 29.81 | 157.13 |
| 1904–10 | 200.75 | 205.05 | 34.50 | 170.55 |
| 1911–13 | 222.12 | 226.92 | 38.87 | 188.05 |
| 1914–19 | no data | 404.21 | 69.92 | 334.29 |
| 1920–22 | 489.97 | 493.97 | 84.62 | 409.35 |
| 1923–19 | 279.67 | 283.67 | | 283.67 |
| 1930–34 | 236.46 | 245.47 | | 245.47 |
| 1935–39 | 244.53 | 293.00 | | 293.00 |
| 1940–45 | | | | 556.33 |
| 1946–50 | | | | 818.40 |
| 1951–55 | | | | 1258.60 |
| 1956–60 | | | | 1541.40 |
| 1961–65 | | | | 1817.20 |
| 1966–70 | | | | 2213.20 |
| 1971–75 | | | | 3735.60 |
| 1976–80 | | | | 7498.40 |
| 1981–85 | | | | 11454.40 |

*Sources*: E. M. Ojala, *Agriculture and economic progress* (1952), pp. 208, 215; J. C. Tasker, 'An Investigation of Farm Income 1867 to 1939' (unpublished BSc (Hons) dissertation, University of Plymouth, 1994), pp. 43, 66; M. Turner, *After the Famine. Irish Agriculture, 1850–1914* (1996), p. 108; Marks (ed. Britton), *A hundred years*, p. 149.

*(ii) A Retail Price Index for 1867–1986.*

Feinstein's retail price index covers most of this period, but stops short in 1965.[9] Britton and Marks report gross output in both current and constant price terms back to 1938, thus implying a price index.[10] The two therefore overlap, and in fact bear a virtually constant relationship to each other. The Feinstein index has therefore been rebased on the 1986 base of the Britton and Marks index by means of a simple proportional calculation, and the results are shown in Table A2.

[9] C. H. Feinstein, *Statistical tables of national income, expenditure and output of the UK 1855–1965* (1972), table 61.
[10] Marks (ed. Britton), *A hundred years*, pp. 149–50.

TABLE A2. A retail price index, 1867–1986 (1986 = 100)

| *Year* | *RPI* | *Year* | *RPI* | *Year* | *RPI* | *Year* | *RPI* |
|---|---|---|---|---|---|---|---|
| 1867 | 2.58 | 1897 | 2.38 | 1927 | 4.95 | 1957 | 12.32 |
| 1868 | 2.58 | 1898 | 2.39 | 1928 | 4.94 | 1958 | 12.64 |
| 1869 | 2.58 | 1899 | 2.40 | 1929 | 4.89 | 1959 | 12.72 |
| 1870 | 2.59 | 1900 | 2.53 | 1930 | 4.76 | 1960 | 12.85 |
| 1871 | 2.64 | 1901 | 2.54 | 1931 | 4.55 | 1961 | 13.21 |
| 1872 | 2.76 | 1902 | 2.54 | 1932 | 4.44 | 1962 | 13.74 |
| 1873 | 2.84 | 1903 | 2.55 | 1933 | 4.34 | 1963 | 14.01 |
| 1874 | 2.75 | 1904 | 2.54 | 1934 | 4.34 | 1964 | 14.47 |
| 1875 | 2.69 | 1905 | 2.55 | 1935 | 4.37 | 1965 | 15.13 |
| 1876 | 2.69 | 1906 | 2.55 | 1936 | 4.40 | 1966 | 15.72 |
| 1877 | 2.67 | 1907 | 2.58 | 1937 | 4.55 | 1967 | 16.16 |
| 1878 | 2.61 | 1908 | 2.59 | 1938 | 4.62 | 1968 | 16.89 |
| 1879 | 2.49 | 1909 | 2.61 | 1939 | 4.92 | 1969 | 17.79 |
| 1880 | 2.57 | 1910 | 2.63 | 1940 | 5.46 | 1970 | 18.94 |
| 1881 | 2.54 | 1911 | 2.63 | 1941 | 6.58 | 1971 | 20.75 |
| 1882 | 2.57 | 1912 | 2.71 | 1942 | 7.04 | 1972 | 22.22 |
| 1883 | 2.56 | 1913 | 2.70 | 1943 | 7.26 | 1973 | 24.21 |
| 1884 | 2.48 | 1914 | 2.69 | 1944 | 7.40 | 1974 | 28.09 |
| 1885 | 2.41 | 1915 | 3.03 | 1945 | 7.53 | 1975 | 34.97 |
| 1886 | 2.38 | 1916 | 3.58 | 1946 | 7.62 | 1976 | 40.65 |
| 1887 | 2.36 | 1917 | 4.48 | 1947 | 8.14 | 1977 | 47.17 |
| 1888 | 2.38 | 1918 | 5.47 | 1948 | 8.76 | 1978 | 51.02 |
| 1889 | 2.41 | 1919 | 6.02 | 1949 | 8.97 | 1979 | 57.80 |
| 1890 | 2.41 | 1920 | 6.94 | 1950 | 9.23 | 1980 | 68.49 |
| 1891 | 2.41 | 1921 | 6.35 | 1951 | 10.06 | 1981 | 76.34 |
| 1892 | 2.42 | 1922 | 5.46 | 1952 | 10.68 | 1982 | 83.34 |
| 1893 | 2.38 | 1923 | 5.13 | 1953 | 10.86 | 1983 | 86.96 |
| 1894 | 2.38 | 1924 | 5.09 | 1954 | 11.04 | 1984 | 90.91 |
| 1895 | 2.35 | 1925 | 5.11 | 1955 | 11.43 | 1985 | 97.07 |
| 1896 | 2.35 | 1926 | 5.07 | 1956 | 11.92 | | |

*Source*: see appendix text

*(iii) An Agricultural Price Index for 1867–1986.*

Once a retail price index is available, it can be used to express the index of prices of agricultural products in constant price terms. The most recent published agricultural price index for the UK is the one produced by Turner covering the period 1867–1914.[11] This overlaps with the MAFF estimates for 1906–66 reported in *A Century of Agricultural Statistics*, which are part of the same series as that used by Britton and Marks.[12] Thus it is possible to produce a consistent API, based on 1986 = 100 (this base being chosen as the one used by Britton and Marks and the same base as the RPI calculated above.) The annual API is shown in Table A3, which also shows the effect of deflating this index by the RPI.

*(iv) Gross output, prices, and the volume of output.*

The data available in tables A1–3 make it possible to express the two series of gross output data, originally produced by Ojala and MAFF, but now modified to be consistent with each other over the whole period 1867–1986, in constant price terms, and to compare them with the constant-price agricultural price index. The data so produced are shown in Table A4. The final stage of the calculation requires the gross output figures, now expressed in constant price terms, to be converted into volume terms. The decline, in constant price terms, of the API, implies that a greater volume of farm products had to be sold in the latter years of the century to generate the same revenue (in real terms) as in earlier years. For example, the API in Table A4 shows that agricultural products that were sold for £100 in 1986 would have realized £206 in 1951–5. Since the argument in this paper is concerned with the factors which produced more tons of wheat, gallons of milk, dozens of eggs, and so on from UK agriculture – in other words, with the *volume* of production – it is necessary to allow for the changes in the real farm prices. This can be done using the following formula:

$$\text{volume (£m)} = \text{gross output} \times \frac{100}{\text{API}(1986=100)}$$

This operation obviously has little impact when the API is close to 100, and increasingly more as the API increases. It is essentially the same as Turner's method (although he calculates the figures on an annual basis, expresses them as an index, and reports them as a graph) and, unsurprisingly, produces similar results for the period up to 1914.[13] These, together with those for subsequent years, are also shown in Table A4.

[11] Turner, 'Output and prices', p. 47.

[12] MAFF, *A century of agricultural statistics*, p. 85.

[13] Turner, 'Output and prices', p. 48.

TABLE A3. (1) an agricultural price index (1986 = 100) (2) deflated by the RPI (1986 = 100)

| | (1) | (2) | | (1) | (2) | | (1) | (2) |
|---|---|---|---|---|---|---|---|---|
| 1867 | 5.90 | 228.7 | 1907 | 5.15 | 199.6 | 1947 | 17.24 | 212.2 |
| 1868 | 6.03 | 233.7 | 1908 | 4.94 | 190.7 | 1948 | 17.85 | 203.8 |
| 1869 | 5.71 | 221.3 | 1909 | 5.07 | 194.3 | 1949 | 18.62 | 207.6 |
| 1870 | 5.54 | 213.9 | 1910 | 5.18 | 197.0 | 1950 | 19.33 | 209.4 |
| 1871 | 5.88 | 222.7 | 1911 | 5.42 | 206.1 | 1951 | 21.21 | 210.8 |
| 1872 | 6.10 | 221.0 | 1912 | 5.74 | 211.8 | 1952 | 21.92 | 205.2 |
| 1873 | 6.50 | 228.9 | 1913 | 5.67 | 210.0 | 1953 | 22.33 | 205.6 |
| 1874 | 6.23 | 226.5 | 1914 | 5.65 | 210.0 | 1954 | 22.23 | 201.4 |
| 1875 | 6.14 | 228.3 | 1915 | 7.12 | 235.0 | 1955 | 23.65 | 206.9 |
| 1876 | 6.02 | 223.8 | 1916 | 8.95 | 250.0 | 1956 | 23.14 | 194.1 |
| 1877 | 6.04 | 226.2 | 1917 | 11.24 | 250.9 | 1957 | 23.14 | 187.8 |
| 1878 | 5.90 | 226.1 | 1918 | 12.97 | 237.1 | 1958 | 23.35 | 184.7 |
| 1879 | 5.39 | 216.5 | 1919 | 14.45 | 240.0 | 1959 | 22.90 | 180.0 |
| 1880 | 5.69 | 221.4 | 1920 | 16.33 | 235.3 | 1960 | 21.72 | 169.0 |
| 1881 | 5.49 | 216.1 | 1921 | 12.26 | 193.1 | 1961 | 22.13 | 167.4 |
| 1882 | 5.72 | 222.6 | 1922 | 9.46 | 173.3 | 1962 | 22.33 | 162.5 |
| 1883 | 5.52 | 215.6 | 1923 | 8.80 | 171.5 | 1963 | 22.38 | 159.7 |
| 1884 | 5.20 | 209.7 | 1924 | 9.00 | 176.8 | 1964 | 22.69 | 156.8 |
| 1885 | 4.97 | 206.2 | 1925 | 8.90 | 174.2 | 1965 | 22.94 | 151.6 |
| 1886 | 4.82 | 202.5 | 1926 | 8.44 | 166.5 | 1966 | 23.45 | 149.2 |
| 1887 | 4.61 | 195.3 | 1927 | 8.04 | 162.4 | 1967 | 23.71 | 146.7 |
| 1888 | 4.76 | 200.0 | 1928 | 8.29 | 167.8 | 1968 | 24.14 | 142.9 |
| 1889 | 4.78 | 198.3 | 1929 | 8.04 | 164.4 | 1969 | 25.00 | 140.5 |
| 1890 | 4.82 | 200.0 | 1930 | 7.38 | 155.0 | 1970 | 26.3 | 138.9 |
| 1891 | 4.86 | 201.7 | 1931 | 6.82 | 149.9 | 1971 | 27.6 | 133.0 |
| 1892 | 4.85 | 200.4 | 1932 | 6.56 | 147.7 | 1972 | 30.4 | 136.8 |
| 1893 | 4.78 | 200.8 | 1933 | 6.27 | 144.5 | 1973 | 36.0 | 148.7 |
| 1894 | 4.71 | 197.9 | 1934 | 6.31 | 145.4 | 1974 | 41.3 | 147.0 |
| 1895 | 4.47 | 190.2 | 1935 | 6.66 | 152.4 | 1975 | 50.0 | 143.0 |
| 1896 | 4.28 | 182.1 | 1936 | 6.71 | 152.5 | 1976 | 65.5 | 161.1 |
| 1897 | 4.66 | 195.8 | 1937 | 7.38 | 162.2 | 1977 | 67.1 | 142.3 |
| 1898 | 4.84 | 202.5 | 1938 | 7.32 | 158.4 | 1978 | 68.6 | 134.5 |
| 1899 | 4.57 | 190.4 | 1939 | 7.38 | 150.0 | 1979 | 75.6 | 130.8 |
| 1900 | 4.88 | 192.9 | 1940 | 10.22 | 187.2 | 1980 | 79.6 | 116.2 |
| 1901 | 4.91 | 193.3 | 1941 | 12.31 | 187.1 | 1981 | 88.3 | 115.7 |
| 1902 | 5.22 | 205.5 | 1942 | 13.12 | 186.4 | 1982 | 95.2 | 114.2 |
| 1903 | 4.88 | 191.4 | 1943 | 13.38 | 184.3 | 1983 | 100.2 | 115.2 |
| 1904 | 4.79 | 188.6 | 1944 | 13.63 | 184.2 | 1984 | 100.3 | 110.3 |
| 1905 | 4.86 | 190.6 | 1945 | 14.04 | 186.5 | 1985 | 98.7 | 101.7 |
| 1906 | 5.10 | 200.0 | 1946 | 14.85 | 194.9 | 1986 | 100.0 | 100.0 |

*Source*: Turner, 'Output and prices', p. 47 (using the values for yearly weights); MAFF, *A Century of Agricultural Statistics*, p. 85; Central Statistical Office, *Annual Abstract of Statistics* (various years); Marks (ed. Britton), *A hundred years*, p. 150.

TABLE A4. Gross output, prices and the volume of output.

| | *Gross Output £m (Current Prices)* | *RPI 1986=100* | *Gross Output £m (Constant Prices)* | *API 1986=100* | *Volume of Output (£m)* |
|---|---|---|---|---|---|
| 1867–69 | 204.49 | 2.58 | 7926.0 | 227.9 | 3477.84 |
| 1870–76 | 218.83 | 2.71 | 8075.0 | 223.6 | 3611.36 |
| 1877–85 | 194.01 | 2.54 | 7638.2 | 217.8 | 3506.99 |
| 1886–93 | 164.32 | 2.39 | 6875.3 | 199.9 | 3439.37 |
| 1894–03 | 157.13 | 2.44 | 6439.8 | 194.2 | 3316.07 |
| 1904–10 | 170.55 | 2.58 | 6610.5 | 194.4 | 3400.46 |
| 1911–13 | 188.05 | 2.68 | 7016.8 | 209.3 | 3352.51 |
| 1914–19 | 334.29 | 4.21 | 7940.4 | 237.2 | 3347.55 |
| 1920–22 | 409.35 | 6.25 | 6549.6 | 200.6 | 3265.01 |
| 1923–29 | 283.67 | 5.03 | 5639.6 | 169.1 | 3335.07 |
| 1930–34 | 245.47 | 4.49 | 5467.0 | 148.5 | 3681.48 |
| 1935–39 | 293.00 | 4.57 | 6411.4 | 155.1 | 4133.72 |
| 1940–45 | 556.33 | 6.88 | 8080.8 | 186.0 | 4344.52 |
| 1946–50 | 818.40 | 8.54 | 9526.6 | 205.6 | 4633.56 |
| 1951–55 | 1258.60 | 10.81 | 11617.2 | 206.0 | 5639.42 |
| 1956–60 | 1541.40 | 12.49 | 12337.6 | 183.1 | 6738.18 |
| 1961–65 | 1817.20 | 14.11 | 12871.8 | 159.6 | 8065.04 |
| 1966–70 | 2213.20 | 17.10 | 12943.8 | 143.6 | 9013.79 |
| 1971–75 | 3735.60 | 26.05 | 14255.4 | 141.7 | 10060.27 |
| 1976–80 | 7498.40 | 53.03 | 14248.6 | 137.0 | 10400.44 |
| 1981–85 | 11454.40 | 86.93 | 13185.2 | 111.4 | 11835.91 |

*Sources*: Tables A1-A3 above. Note small discrepancies due to rounding errors in the RPI and constant price figures after 1940. These arise because the figures for gross output at constant prices after 1940 have been calculated on an annual basis, and the annual series has then been averaged into year groups.