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ABSTRACT

In their different ways, both Thomas Malthus and Thomas McKeown raised fundamental questions about the relationship between food supply and the decline of mortality. Malthus argued that food supply was the most important constraint on population growth and McKeown claimed that an improvement in the population's capacity to feed itself was the most important single cause of mortality change. This paper explores the implications of these arguments for our understanding of the causes of mortality decline in Britain between 1700 and 1914. It presents new estimates showing changes in the calorific value and composition of British diets in 1700, 1750, 1800 and 1850 and compares these with the official estimates published by the Royal Society in 1917. It then considers the implications of these data in the light of new arguments about the relationship between diet, work intensity and economic growth. However the paper is not solely concerned with the analysis of food-related issues. It also considers the ways in which sanitary reform may have contributed to the decline of mortality at the end of the nineteenth century and it pays particular attention to the impact of cohort-specific factors on the pattern of mortality decline from the mid-nineteenth century onwards.

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In the *Essay on the principle of population*, Malthus famously argued that the growth of human populations was necessarily constrained either by preventive checks or positive checks. He argued that human beings had a unique capacity ‘to calculate distant consequences’ (Malthus 1803: 9), and that this enabled them to exercise voluntary control over reproduction. However, if moral restraint was abandoned and the preventive check failed, population growth would inevitably be arrested, sooner or later, by one of a large number of positive checks. These included ‘all unwholesome occupations, severe labour and exposure to the seasons, extreme poverty, bad nursing of children, great towns, excesses of all kinds, the whole train of common diseases and epidemics, wars, pestilence, plague and famine’ (Malthus 1803: 11).

Although Malthus emphasised that the positive check could take many forms, it was directly related to the problem of subsistence, and therefore the most important factor limiting the capacity for population growth was the population’s ability to feed itself. In 1803 he observed that ‘population can never actually increase beyond the lowest nourishment capable of supporting it’, so that ‘a strong check on population, from the difficulty of acquiring food, must be constantly in operation’ (Malthus 1803: 3). He then went on to describe some of the implications of this argument in the following graphic terms:

> Famine seems to be the last, the most dreadful recourse of nature. The power of population is so superior to the power in the earth to produce subsistence for man that, unless arrested by the preventive check, premature death must in some shape or other visit the human race. The vices of mankind are active and able ministers of depopulation. They are the precursors in the great army of destruction, and often finish the dreadful work themselves. But should they fail in the war of extermination, sickly seasons, epidemics, pestilence and plague advance in terrific array, and sweep of their thousands and ten thousands. Should success be still incomplete, gigantic inevitable famine stalks in the rear and, with one mighty blow, levels the population with the food of the world (Malthus 1803: 350).

Although they approached the subject from very different perspectives, it is interesting to compare Malthus’ arguments with those advanced by the medical writer, Thomas McKeown, a century and half later.[1] Whereas Malthus' main aim was to understand the limits to population growth, McKeown's aim was to explain how these limits might have been overcome. As he believed that the growth of population owed relatively little to changes in fertility, this question resolved itself into an investigation into the causes of the decline of mortality. In his most famous work, *The modern rise of population*, he argued that the most important cause of mortality decline was a decline in the level of mortality from infectious diseases, and that this in turn could be attributed to a number of different factors, including changes in the relationship between infective organisms and their human hosts, medical intervention and measures to reduce exposure, but the most important factor was an improvement in 'nutritional state'. This conclusion was summarised in the following terms:

> The most acceptable explanation of the large reduction of mortality and growth of population which preceded advances in hygiene is an improvement in nutrition due to greater food supplies. The grounds for this conclusion are twofold. (a) There was undoubtedly a great increase in food production during the eighteenth and nineteenth centuries, in England and Wales enough to support a population which trebled between 1700 and 1850 without significant food imports. (b) In the circumstances which existed prior to the agricultural and industrial revolutions, an improvement in food supplies was a necessary condition for a substantial and prolonged decline of mortality and expansion of population. The last point is in accord with present-day knowledge of the relation between malnutrition and infectious diseases (McKeown 1976: 153-4).

McKeown's account of the history of mortality decline in Britain has long been open to question. In their monumental history of *The population history of England*, Wrigley and Schofield (1981: 228) argued that McKeown had grossly underestimated the extent of fertility change during the course of the eighteenth century and that this had led him to overestimate the extent of changes in mortality before *circa* 1850 (see also Wrigley 1983). They also argued that

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[1] For McKeown's key publications, see McKeown and Brown 1955; McKeown and Record 1962; McKeown, Brown and Record 1972; McKeown 1976; 1985; 1988.

there was little, if any, evidence to support the view that improvements in diet and 'nutrition' had played any part in the decline of mortality during the second of the eighteenth century when real wages actually appeared to be declining (Wrigley and Schofield 1981: 361-5). Although their account of the chronology of mortality change was subsequently challenged by Peter Razzell (1993; 1998), he nevertheless shared their view that changes in real wages had made relatively little difference to the decline of mortality (see also Razzell 1965; 1974).

These criticisms have been strongly reinforced by Simon Szreter's critique of McKeown's account of mortality change in the nineteenth century. When McKeown examined the cause-specific nature of mortality decline in England and Wales, he argued that it was possible to draw a clear distinction between mortality from airborne infections and mortality from waterborne infections. This was one of the main foundations for his argument that the most important single cause of the decline of mortality during the second half of the nineteenth century was an improvement in the standard of 'nutrition'. However, Szreter argued that the methodology which McKeown had used to estimate the size of the contributions made by 'airborne' and 'waterborne' diseases was flawed and that he had underestimated the impact of urbanisation on the standard of public health before 1870. As a result, Szreter concluded that sanitary reform, and not dietary improvement, was the main cause of mortality change from the 1870s onwards (Szreter 1988; 1994; 1997).

As this summary suggests, one of the original weaknesses of the 'McKeown hypothesis' was the lack of correlation between movements in mortality rates and changes in real wages during the late-eighteenth and early-nineteenth centuries. The first section of this paper addresses this issue by reviewing new evidence on real wages which was not available when Wrigley and Schofield published *The population history of England* in 1981. The second part of the paper seeks to fill one of the major gaps in McKeown's account by presenting new estimates of the amount of food available for human consumption in England and Wales between 1700 and 1914, and the third compares this new evidence with existing information about changes in mortality. Section four examines some of the implications of this evidence for existing arguments about the relationship between food availability and working capacity during the eighteenth and nineteenth centuries. The final section returns to the theme of mortality change, and seeks to identify some of the other factors which also contributed to the decline of mortality during the period under review.

1. Real wages and mortality, 1770-1850

As we have already seen, one of the original criticisms of McKeown's argument was the lack of correlation between his account of mortality change and the available evidence on real wages. This criticism was summarised by Tony Wrigley (1983: 143) in the following terms:

> In the eighteenth century, as earlier, there is scant evidence of any link between living standards and mortality levels. It is probably true that the secular tendency in real wages was steadily upwards from the mid-seventeenth to the late-eighteenth century but that thereafter there was a sharp fall for about a generation before a resumption in the upward movement in the early-nineteenth century. Mortality, however, moved uncertainly between 1680 and 1730 with no decided trend in spite of rising living standards but thereafter showed a steady if not pronounced improvement, even though living standards went through a switchback period in the last decades of the eighteenth and the first decades of the nineteenth century (see also Wrigley, Davies, Oeppen and Schofield 1997: 201-6, 552).

Wrigley *et al.*'s reluctance to accept that movements in real wages were directly related to mortality changes was shared by Peter Razzell. Although he challenged their view that there was no significant reduction in mortality rates before 1750, he also argued that the reductions which did occur were more closely related to changes in personal and domestic hygiene than to changes in real wages (Razzell 1974: 12-17). In 1993, he summarised his position in the following terms:

> Real incomes probably rose for most of the population during the first half of the eighteenth century. It is thus possible that this improvement played a part in reducing mortality. Certainly, the evidence of higher mortality among husbandmen in the early-seventeenth century would suggest that economic factors were important during this early period, but the weight of evidence suggests that they were not central in bringing about the overall fall in mortality. The substantial mortality gains among all the socioeconomic groups discussed in this article indicate that noneconomic forces were of primary importance. Only further research will definitively settle this issue (Razzell 1993: 766).

Wrigley and Schofield based their findings on the estimates published by Phelps Brown and Hopkins in the mid-1950s (Phelps Brown and Hopkins 1955; 1956). Their estimates showed that real wages fell during the last two decades of the eighteenth century and did not regain their earlier level before the start of the 1820s (Wrigley and Schofield 1981: 642-4). Although later authors modified many of the details of this picture, they did not challenge its essentials. Consequently, by the early-1990s it was widely accepted that real wages rose during the first half of the eighteenth century and either stagnated or declined after 1750, with little evidence of any sustained improvement before 1800 or even 1820 (see e.g. Wrigley and Schofield 1981: 642-4; Lindert and Williamson 1983; 1985; Crafts 1985; Schwarz 1985; Floud and Harris 1997: 95).

This account of the history of real wage trends came under more radical attack in the mid-1990s. As Feinstein pointed out, changes in real wages reflect movements in both nominal wages and prices. He argued that previous attempts to estimate movements in prices had been undermined by problems associated either with the composition of the price index or the weights attached to the items within it, and that the real wage indices which were based on these price indices were also flawed (Feinstein 1995: 8-28). In 1998, he published a revised index of real wages (or, more precisely, a revised index of real earnings) which radically altered the established picture. It now appeared that real earnings increased – albeit very slowly – during the final decades of the eighteenth century, and although Feinstein also argued that previous authors had overestimated the extent of the improvement in real earnings which occurred after 1820, his figures nevertheless suggested that they increased by more than 39 per cent over the period between 1770 and 1850 as a whole (see Figure 1).

Figure 1. Real wages (1770/2-1848/52)

Notes. The data for 'Feinstein (original series)' are his estimates for real earnings adjusted for unemployment in Great Britain.

Sources: Wrigley and Schofield 1981: 642-4; Feinstein 1998: 648, 652-3.

Although Feinstein's own calculations have also been challenged, the basic picture remains unchanged (see Clark 2001; 2005; Allen 2007). Allen's (2007) latest reworking of Feinstein's figures shows very little difference in the extent of the change in real wages between 1770 and 1820, and only a small increase in the rate of improvement between 1820 and 1850 (see Figure 2). Figure 2 also compares changes in real wages with the revised estimates of life expectancy at birth which Wrigley, Davies, Oeppen and Schofield published in 1997. Although the new estimates do not remove all the inconsistency between changes in mortality and movements in real wages, they do suggest that the two sets of data were much more closely aligned, in the second half of the eighteenth century, than previous accounts have suggested.

Figure 2. Life expectancy and real wages in England and Wales, 1771-1851

2. The availability of food in England and Wales, 1700-1914

Although McKeown was unable to produce any direct evidence of changes in diet, other writers have attempted to estimate the nutritional value of the food consumed by working-class families in different parts of Britain from the late-eighteenth century onwards. Shammas (1984: 256-8; 1990: 134) examined the diets of seven northern and fifteen southern families whose household budgets were summarised by David Davies and Frederick Morton Eden in the 1780s and 1790s, and concluded that the average number of calories consumed by each individual was equal to 1734 calories per day in the south of England and 2352 calories per day in the north. Clark, Huberman and Lindert (1995: 222-3) used the same sources to examine a broader range of household budgets, and concluded that average calorie consumption was equal to just 1508 calories per day, whilst Oddy (1990: 274) suggested that average consumption among these families may have been as high as 2028 calories per day.

As these figures indicate, there is a wide range of variation in the estimates constructed by different authors even when using the same sources, and these differences are compounded by the different assumptions which these authors make about the social status of the households they studied. Oddy (1990: 269) argued that the Davies-Eden surveys 'provide a cross-section of rural life in England, since the majority of Davies' families were from southern England and the largest group in Eden's were from the northern counties', but Clark, Huberman and Lindert (1995: 222, note 16) claimed that the Davies-Eden households were drawn from the poorest decile of the population, whereas Shammas (1984: 255-6; 1990: 134) implied that they were representative of the working class as a whole. However, both Oddy and Clark, Huberman and Lindert thought that diets did improve during the first half of the nineteenth century. Clark, Huberman and Lindert estimated that the nutritional value of the diets consumed by working-class families between 1837 and 1863 ranged between 1974 calories per head per day and 2395 calories, whereas Oddy (using a very similar set of sources) calculated that energy values ranged between 2300 calories in 1841 and 2600 in 1863 (Oddy 1990: 274).

Although these figures provide a useful starting-point for the study of dietary trends, they are merely snapshots, based on the household budgets of a small number of families living at different points in time in different parts of the country. However, it is possible to supplement this information by using the available evidence on food production and the import and export of different foodstuffs to construct an alternative picture of changes in the amount and nature of the food available to the population as a whole. We can then combine this information with information from other sources to provide new estimates of the amount of energy available to the British population between the end of the seventeenth century and the outbreak of the First World War.

Since the early-1980s, there have been a number of attempts to estimate British agricultural output in the eighteenth and nineteenth centuries. King (1696: 53) published figures showing the annual output of wheat, rye, barley, oats, beans and peas and these figures were reproduced by Chartres (1985: 444) in his contribution to the *Agrarian History of England*. Holderness (1989: 145) published comparable estimates of the output of cereals and pulses for 1750, 1800 and 1850, and Allen (1994: 112) combined both sets of figures in his contribution to the second edition of the *Cambridge Economic History of Britain* in 1994. However, in 2001, Turner, Beckett and Afton produced new estimates, based on the actual records of farm inventories. Their calculations suggest that the previous authors underestimated the level of output (on average) in 1750 and 1850, and overestimated output in 1800 (see Table 1).

Table 1. Agricultural output, in millions of bushels, in England and Wales, 1700-1850.

	Allen 1994				Turner, Beckett and Afton 2001			
	1700	1750	1800	1850	1700	1750	1800	1850
Wheat	21.8	32.4	53.8	100.8	n.a.	39.6	52.7	104.0
Rye	15.1	9.0	7.8	2.8	n.a.	n.a.	7.0	2.8
Barley	43.7	35.0	39.0	54.8	n.a.	34.7	38.0	54.6
Oats	29.4	56.0	56.0	80.0	n.a.	73.5	74.9	94.8
Beans and peas	26.0	28.0	28.0	30.0	n.a.	21.8	26.4	29.6

Notes:

(1) Output figures are based on the acreages used by Allen 1994: 112.

(2) Crop yields for individual years from Turner, Beckett and Afton were calculated as follows: Wheat, barley and oats: 1750: weighted average of results for 1740s and 1750s; 1800: weighted average of results for 1790s and 1800s; 1850: weighted average of results for 1840s and 1850s; Rye, beans and peas: 1750 (beans and peas only): weighted average of results for 1725/49 and 1750/74; 1800: weighted average of results for 1775/79 and 1800/24; 1850: weighted average of results for 1825/49 and 1850/74.

Sources: See Tables A1 and A2.

Although these figures enable us to estimate the total output of these crops, it is important to remember that only a proportion of the total crop was made available for human consumption, since some was retained as seed and some was used to feed livestock. We do not have precise figures for these ratios for England and Wales, but we have attempted to compensate for this using the estimates made by Gallman (1960: 52) and Towne and Rasmussen (1960: 294-304) to calculate the value of the crops entering gross product in the United States in the first half of the nineteenth century. We have also used US data to make allowances for milling losses (United States Department of Agriculture 1939: 8) and included an additional allowance of ten per cent for distribution losses. We have used information from John (1989: 1124-5) and the US Department of Agriculture (1952: 40; 1992: 11, 14) to convert bushels into Imperial pounds, and we have used McCance and Widdowson's (1960: 116-7, 138-9) data to calculate energy values. The final stage was to divide the total number of calories available for human consumption by the population to estimate the daily consumption of calories by the average person in each year.

The results of this analysis are summarised in Tables 2 and 3, and set out in more detail in the Appendices (see Tables A1 and A2). We have included separate estimates based on the initial output figures supplied by Allen (1994) and Turner, Beckett and Afton (2001) for two reasons. In the first place, Turner and his co-authors do not have figures for any crops in 1700, or for rye in 1750, and it may therefore be misleading to compare Allen's figures for 1700 with their figures for the later periods. Secondly, even though their figures are based on the direct observation of farm inventories, the number of records is quite small and may not always be representative of the entire country (see Thirsk 2002). As a result, it may be more prudent to regard the two sets of figures as upper- and lower-bound estimates of the number of calories derived from domestically-produced cereals and pulses in the years under review. Although the differences are not great in terms of the overall trend of calorie consumption, they are not insignificant. Allen's figures suggest that the number of calories obtained from these sources rose between 1750 and 1800 and fell between 1800 and 1850, whereas Turner, Beckett and Afton's figures imply that average daily consumption levels declined during both periods.

Table 2. Average number of calories per head per day derived from domestically-produced cereals and pulses in England and Wales, 1700-1850.

	Allen 1994				Turner, Beckett and Afton 2001			
	1700	1750	1800	1850	1700	1750	1800	1850
Wheat	502	430	732	706	502	526	717	729
Rye	251	131	76	14	251	131	69	14
Barley	598	421	315	227	598	418	307	227
Oats	122	205	172	101	122	269	184	120
Beans and peas	93	88	71	33	93	68	56	32
Total	1,566	1,275	1,366	1,082	1,566	1,412	1,333	1,122

Notes: We have used Allen's estimates for rye to fill the gap in Turner, Beckett and Afton's in 1750.

Sources: See Tables A1 and A2.

Table 3. Average number of calories available for consumption per capita per day from domestically-produced food sources in England and Wales, 1700-1909/13.

Source of kcal	1700	1750	1800	1850	1909-13
Cereals and pulses (1A)	1,566	1,275	1,366	1,082	217
Cereals and pulses (1B)	*1,566*	*1,412*	*1,333*	*1,122*	*217*
Meat & lard (2)	307	507	456	348	325
Dairy (3)	231	279	236	219	286
Fish (4)	24	24	24	24	24
Garden (5)	12	12	12	12	12
Fruits & nuts (6)	10	10	10	10	10
Potatoes (7)	53	79	154	255	196
Cottage produce (8)	-	-	-	-	135
Farm produce (9)	-	-	-	-	26
Poultry, game and rabbits (10)	-	-	-	-	28
Total (11A)	2,202	2,185	2,257	1,949	1,259
Total (11B)	2,202	2,323	2,224	1,990	*1,259*

Sources:

1700, 1750, 1800 & 1850: Rows 1A & 1B: Table 2; Row 2: Table A3; Row 3: Table A4; Row 4: Table A9; Rows 5-6: Table A13; Row 7: Table A14.

1909-13: Table A15.

The following two rows of Table 3 include calculations showing the number of calories obtained from domestically-produced meat and dairy products. We have estimated the calorific value of the food consumed in the form of mutton, lamb, beef, veal, pork and ham using information obtained from King (1696: 545) and Holderness (1989: 155). We do not have direct information about the consumption of lard, but have estimated this using figures showing the consumption of bacon, lard and pork in the United States at the end of the 1870s (Bennett and Pierce 1961: 114-5). We have used Holderness' (1989: 170) data to estimate the number of calories derived from cheese, butter and milk in 1750, 1800 and 1850, and extrapolated from the data on meat and dairy products in 1750 to estimate the number of calories which might have been obtained from dairy products fifty years earlier.

Table 3 also includes estimates showing the number of calories obtained from domestically-obtained fish, garden vegetables, fruit, nuts and potatoes. The figures for fish, garden vegetables, fruit and nuts are derived from the Royal Society's investigation into the food supply of the United Kingdom before the First World War, and we have assumed – in the absence of any other information – that these figures remained constant over the whole of the period (Parliamentary Papers 1917). The figures for potatoes are extrapolated from Salaman's (1949: 434, 539, 613) figures for 1600, 1775, 1795, 1814, 1838 and 1851, but we have assumed that the figure provided by Salaman for the last of these years should have been 0.70, rather than 0.07. The results illustrate the growing importance of the potato in the average British diet, as consumption rose from 53 calories per head per day at the start of our period to 255 calories per head at the beginning of the 1850s, but the total amount of energy derived from domestically-produced foodstuffs declined by between 212 and 253 calories over the same period.

The apparent inability of domestic agriculture to keep pace with the needs of an expanding population meant that Britain became increasingly reliant on imported foodstuffs. We have used information from Mitchell (1988: 221-2) and from the *Annual Accounts* (Parliamentary Papers 1849a; 1849b; 1851; 1853) to calculate the amount of energy derived from imported cereals between 1700 and 1850, after making similar allowances for losses due to milling and distribution to those made when calculating the energy derived from domestically-produced cereals. Our estimates suggest that Britain moved from being a net exporter of cereals to a net importer during the first half of the nineteenth century. Throughout the period, the main form of cereal involved in these transactions was wheat, but after 1800 Britain began to import increasing quantities of oats, barley and especially maize, which provided about one-fifth of the energy derived from imported cereals during the middle years of the nineteenth century.

The first half of the nineteenth century also saw the importation of small quantities of meat, dairy products, wines and spirits, and fruit and nuts, but the most striking development was the dramatic increase in the volume of imported sugar. According to Schumpeter (1960: 52-5), Britain imported just under 10 pounds of sugar per head at the start of the eighteenth century, but this figure increased by more than 150 per cent between 1700 and 1850, and even after allowing for re-exports, the number of calories obtained from sugar rose from 28 calories per head per day at the start of the period to 136 calories in 1850. However, the rate of increase accelerated dramatically after this date. The figures provided by the Royal Society in 1917 suggest that the average consumer derived the equivalent of 395 calories per day from sugar in the years immediately preceding the First World War.

Table 4. Average number of calories available for consumption per capita per day from imported food sources in England and Wales, 1700-1909/13.

Source of kcal	1700	1750	1800	1850	1909-13
Cereals and pulses (1)	-13	-168	86	367	788
Meat (2)	-	-	-	12	262
Dairy (3)	-	-	16	20	166
Fish (4)	-	-	-	-	8
Garden (5)	-	-	-	-	31
Fruit and nuts (6)	-	-	-	9	55
Potatoes (7)	-	-	-	-	13
Sugar (8)	28	72	95	136	395
Wine & spirits (9)	12	11	17	12	-
Total (10)	26	-85	215	555	1,718

Sources:

1700, 1750, 1800 & 1850: Row 1: Table A5; Row 2: Table A6; Row 3: Table A7; Row 4: Tables A10 & A15; Row 5: Table A11; Row 6: A12; Row 7: Table A15; Row 8: Table A8; Row 9: Table A9.

1909-13: Table A15.

When the figures for domestically-produced and imported food are taken together, they present an intriguing picture of the main trends in food consumption in Britain between 1700 and 1914. A number of authors have suggested that UK food production failed to keep pace with the growth of population during the second half of the eighteenth century and that Britain was facing a 'Malthusian crisis' before the outbreak of the Napoleonic Wars (see e.g. Komlos 1993a; 1993b), but our figures suggest that the amount of energy derived from domestically-produced food remained roughly constant during the course of the eighteenth century, and only began to decline consistently after 1800. However, the most important change was the increase in the amount of energy derived from imported foods. The combined effect of these changes was that even though energy values either fell or remained broadly constant during the first half of the eighteenth century, they rose between 1750 and 1800 and between 1800 and 1850. They then rose much more rapidly between 1850 and 1914.

Table 5. Average number of calories available for consumption per capita per day in England and Wales 1700-1909/13.

Source of kcal	1700	1750	1800	1850	1909-13
Domestically-produced foods (A)	2,202	2,185	2,257	1,949	1,259
Domestically-produced foods (B)	2,202	2,323	2,224	1,990	*1,259*
Imported foods	26	-85	215	555	1,718
Grand total (A)	2,229	2,100	2,472	2,504	2,977
Grand total (B)	2,229	2,237	2,439	2,544	2,977

Notes: A: Based on crop-yields estimated by Chartres (1985), Holderness (1989) and Allen (1994); B: Based on crop-yields estimated by Turner, Beckett and Afton (2001).

Sources: See Tables 3 and 4.

Our estimates also enable us to calculate the ways in which the composition of the average diet changed over the course of the period. At the start of the eighteenth century, it seems likely that the average person obtained more than sixty per cent of their total calories from cereals.

This figure declined during the course of the century but the British population still obtained more than half their calories from these sources in 1850. The proportion of calories derived from meat and dairy products increased during the first half of the eighteenth century but declined between 1750 and 1850, and only regained its earlier level between 1909 and 1913. There were also small increases in the proportion of calories obtained from fruit and vegetables and a much larger increase in the proportion derived from imported sugar, but the proportion of calories derived from fish remained very low throughout the period (see Table 6).

3. The availability of food in England and Wales, 1700-1914

What do these calculations tell us about the adequacy of the diets available to the British population at the start of the eighteenth century, and about the relationship between nutrition and mortality between 1700 and 1914? Livi-Bacci (1991: 27) has claimed that 'a population which could rely on a normal consumption of 2000 calories per head would have been, in centuries past, an adequately-fed population, at least from the point of view of energy', and this figure is lower than any of the figures which we have calculated for the British population in either 1700 or 1750. However, this argument fails to take account of the impact of inequalities in the distribution of food within the population (see also Fogel 1993: 12; 1994: 373-4). Even though the new figures on food consumption are higher than some of our earlier figures, a significant proportion of the population might still have experienced a diet which fell below Livi-Bacci's measure of sufficiency.

Table 6. Sources of calories, by food group, in England and Wales, 1700-1909-13.

A. Crop yields from Chartres. Holderness and Allen

	Calories					%				
Source of kcal	1700	1750	1800	1850	1909-13	1700	1750	1800	1850	1909-13
Cereals	1,461	1,019	1,382	1,396	999	65.54	48.51	55.88	55.74	33.55
Fish	24	24	24	24	32	1.07	1.13	0.96	0.95	1.08
Fruit and vegetables	167	189	247	338	476	7.50	8.98	9.97	13.50	15.98
Meat and dairy products	538	786	708	599	1,075	24.13	37.42	28.63	23.92	36.12
Other	39	83	113	147	395	1.77	3.95	4.56	5.89	13.27
Total	2,229	2,100	2,472	2,504	2,977	100.00	100.00	100.00	100.00	100.00

B. Crop yields from Turner, Beckett and Afton

	Calories					%				
Source of kcal	1700	1750	1800	1850	1909-13	1700	1750	1800	1850	1909-13
Cereals	1,461	1,176	1,363	1,437	999	65.54	52.55	55.90	56.46	33.55
Fish	24	24	24	24	32	1.07	1.06	0.97	0.93	1.08
Fruit and vegetables	167	169	231	338	476	7.50	7.55	9.49	13.27	15.98
Meat and dairy products	538	786	708	599	1,075	24.13	35.13	29.02	23.54	36.12
Other	39	83	113	147	395	1.77	3.71	4.62	5.80	13.27
Total	2,229	2,237	2,439	2,544	2,977	100.00	100.00	100.00	100.00	100.00

Notes. We have calculated that the average daily consumption of ‘cottage produce’ in 1909-13 was equal to 135 calories per head. The Royal Society estimated that the total number of calories from this source was equivalent to one-half of the calories obtained from home-produced poultry, eggs and vegetables, and one-third of the calories obtained from home-produced fruit. We have used these figures to estimate the proportion of the calories derived from ‘cottage produce’ which may be allocated to each of the other categories. For further information, see Parliamentary Papers 1917: 7.

Sources: See Tables 3-4.

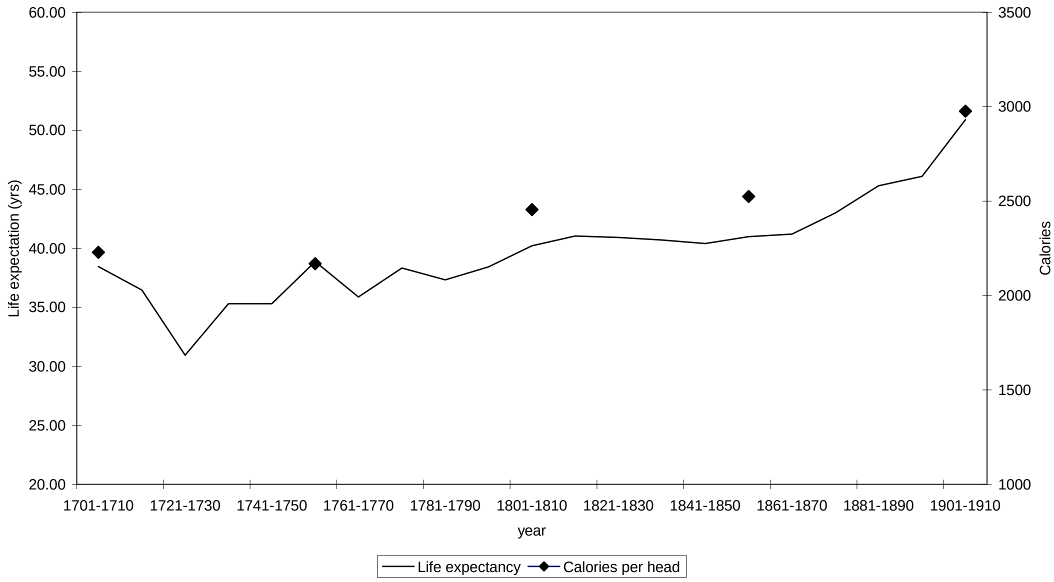
It is also important to consider the ways in which food was distributed within the household. It is now widely acknowledged that women received less pay than men during the second half of the eighteenth century, and a number of authors have argued that this imbalance was reflected in the allocation of food (see e.g. Eden 1797: 47; Oren 1974: 221; Nicholas and Oxley 1993: 737). Several nineteenth- and twentieth-century commentators also noted that women in poorer families tended to receive smaller amounts of food (Harris 1998: 418; 2008: 173, 194). These 'customs' had a damaging effect on the health of the women themselves and may also have impaired the health of their children if their mothers continued to receive inadequate diets during pregnancy (Osmani and Sen 2003: 114-8).

Recent research has also cast doubt on the extent to which it is possible to judge the adequacy of historical diets using the standards applied to well-nourished populations living under modern industrial conditions. When McKeown examined the relationship between nutrition and mortality, he was primarily concerned with the ways in which inadequate nutrition impaired resistance to infection, and he failed to consider the ways in which exposure to infection might damage 'nutrition'. It is well-known that many infections can lead to a loss of appetite and that infection increases the body's need for nutritional resources (Eveleth and Tanner 1976: 246), but infection can also have a dramatic effect on the body's ability to digest the nutrients which are consumed. Uauy (1985) found that people living in less-developed countries showed signs of sub-clinical nutrient malabsorption which meant that they were unlikely to digest more than ninety per cent of the nutrients they consumed, whilst a second study showed that undernourished individuals and individuals who had recently experienced episodes of acute diarrhoea absorbed less than eighty per cent of nutrients (Dasgupta and Ray 1990: 215).

The absorption of nutrients can also be influenced by the composition of the diet. As we have already seen, people living in preindustrial and early-industrial Britain derived a high proportion of their energy from cereals, but Dasgupta and Ray (1990: 215-6) have argued that the consumption of a high-fibre diet also leads to a significant reduction in nutrient retention. Their overall conclusion was that individuals living under preindustrial conditions in the modern world needed to increase their total consumption by more than 35 per cent to derive the same nutritional benefit from the food they consumed as people living under more favourable conditions.

In view of these arguments, it is particularly intriguing to compare our new estimates of the main trends in food consumption with the chronology of changes in height and mortality. As Floud and Harris (1997: 96, 101-2) have demonstrated, both the average height of the population and average levels of life expectancy rose between *circa* 1750 and 1820, followed by a period of stagnation or decline, and then further improvement from the 1850s onwards. These trends are broadly consistent with our new estimates of food availability (certainly for the periods 1750-1800 and 1850-1914), and help to reinforce the link between nutrition and mortality which McKeown could only infer when he attempted to account for the modern rise of population in the 1970s (see also Figure 3). However, one of the main themes of our argument has been to emphasise the *synergistic* nature of the relationship between nutrition and infection, and it would certainly not be correct to conclude that dietary change was the only reason for improvements in either height or life expectancy.

Figure 3. Food availability and life expectation at birth, 1700-1910



Notes. Estimates for 'calories per head' are based on the mean of the totals in Table 5.

Sources: For food estimates, see text. For life expectancy, see Wrigley, Davies, Oeppen and Schofield 1997: 614-5; Woods 2000: 365.

4. Food availability and work intensity

In recent years, arguments about diet and nutrition have played an increasingly important part in debates about the origins and nature of Britain's industrial revolution. Voth (2000) has examined changes in the length of the working year over the course of the eighteenth century and De Vries (2008) has incorporated these arguments into his account of an 'industrious revolution' in Britain and other parts of Europe and North America over the same period. Although these arguments are not directly concerned with either diet or nutrition, they do make important assumptions about the amount of food available to support the work involved.

Arguments about diet and nutrition have also played an important part in Allen's (2009) attempt to answer the question of why Britain became 'the first industrial nation' (Mathias 2001). He argued that the high cost of labour in Britain provided manufacturers with the necessary incentive to invest in the new technologies which defined the new industrial era. Although this argument was based primarily on comparisons of national wage rates, he also drew on nutritional data to support his claim that British workers and their families enjoyed a much higher standard of living before industrialisation than their continental counterparts.

As Allen (2009: 38) has pointed out, actual food requirements vary according to age, gender and body size. He therefore argued that it was appropriate to assume that the nutritional needs of 'a family with a father, a mother and some children' were equivalent to those of three adult males. He then used this formula to estimate the number of calories available per adult male at different income levels in 1843 (Allen 2009: 47).

Allen acknowledged that these estimates had been framed 'rather loosely' (Allen 2009: 38). However, it is possible to make the frame somewhat tighter by using current information on the dietary requirements of men and women at different ages and combining this information with data on the age- and sex-structure of the British population between 1700 and 1914. We can then use the results of this exercise to calculate the factors which should be used to convert our estimates of the number of calories available per head into new estimates of the number of calories available per adult male equivalent.

The relevant data are shown in Table 7 below. The figures in columns 1-3 show the number of calories required by males and females in each group as a fraction of the calories required by an average male between the ages of 20 and 39. These figures have then been multiplied by the percentage of the population in each age-group to estimate the total food requirements of all the individuals in that age-group in each period, and these figures have been added together to estimate the conversion factors for the population as a whole. We can then use these figures to estimate the number of calories available per adult male equivalent in each period (Table 8). The results suggest that this figure increased from just under 3000 calories per adult male equivalent (or per consuming unit) at the start of the eighteenth century to nearly 4000 calories on the eve of the First World War. Since it is obviously unreasonable to assume that all individuals consumed the same amounts of food (in relation to their physiological needs), it is also important to take some account of the likely impact of inequalities in the distribution of food on the health of different sections of the population. In a series of earlier publications, Fogel argued that 'all of the known distributions of the average daily consumption of calories for populations are … reasonably well-described by the lognormal distribution' and that it was plausible to assume that the most likely value for the coefficient of variation for the populations of both Britain and France at the end of the eighteenth century was 0.3 (Fogel 1989: 39; see also *ibid.* 1992: 268; 1993: 10-13; 1994: 374). If this assumption is applied to the current estimates of the amount of food which was available for human consumption in England and Wales, the results suggest that approximately twenty per cent of the British population is likely to have received fewer than 2500 calories per consuming unit at the start of the nineteenth century (see Table 9).

Table 7. Conversion factors for estimating calories per consuming unit in England and Wales, 1700-1919/13.

Age	Calories required as proportion of adult male (20-39) requirements			1700		1750		1800		1850		1909-13	
	Male	Female	Persons	Persons in each group as % of total population	Calories required by persons in each age-group	Persons in each group as % of total population	Calories required by persons in each age-group	Persons in each group as % of total population	Calories required by persons in each age-group	Persons in each group as % of total population	Calories required by persons in each age-group	Persons in each group as % of total population	Calories required by persons in each age-group
					(3) * (4)		(3) * (6)		(3) * (8)		(3) * (10)		(3) * (12)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
0-4	0.4413	0.4367	0.4390	12.28	0.0539	12.61	0.0554	14.32	0.0629	13.10	0.0575	10.69	0.0469
5-14	0.8050	0.7334	0.7692	19.81	0.1524	20.30	0.1561	23.09	0.1776	22.34	0.1719	19.95	0.1535
15-24	1.0084	0.7583	0.8833	16.35	0.1444	17.47	0.1543	17.73	0.1566	19.10	0.1687	18.05	0.1595
25-59	0.9400	0.6893	0.8147	42.18	0.3436	41.39	0.3372	37.60	0.3063	38.14	0.3108	43.27	0.3525
≥60	0.7500	0.5500	0.6500	9.38	0.0610	8.22	0.0534	7.26	0.0472	7.32	0.0476	8.04	0.0522
Total				100.00	0.7553	99.99	0.7564	100.00	0.7506	100.00	0.7564	100.00	0.7646

Sources: Calorie requirements: Derived from Fogel 1993: 7; Population figures: 1700, 1750 & 1800: Wrigley and Schofield 1981: 528-9; 1850 and 1909-13 (1911): Mitchell 1988: 15-16.

Table 8. Calories per consuming unit in England and Wales, 1700-1919/13.

A. Crop yields from Chartres. Holderness and Allen

	Calories				
Source of kcal	1700	1750	1800	1850	1909-13
Cereals	1,461	1,019	1,382	1,396	999
Fish	24	24	24	24	32
Fruit and vegetables	167	189	247	338	476
Meat and dairy products	538	786	708	599	1,075
Other	39	83	113	147	395
Total	2,229	2,100	2,472	2,504	2,977
Conversion factor	0.7553	0.7564	0.7506	0.7564	0.7646
Calories per consuming unit	2,951	2,776	3,293	3,311	3,893

B. Crop yields from Turner, Beckett and Afton

	Calories				
Source of kcal	1700	1750	1800	1850	1909-13
Cereals	1,461	1,176	1,363	1,437	999
Fish	24	24	24	24	32
Fruit and vegetables	167	169	231	338	476
Meat and dairy products	538	786	708	599	1,075
Other	39	83	113	147	395
Total	2,229	2,237	2,439	2,544	2,977
Conversion factor	0.7553	0.7564	0.7506	0.7564	0.7646
Calories per consuming unit	2,951	2,957	3,249	3,363	3,893

Sources: See Tables 6, 7.

Table 9. The probable distribution of calories per consuming unit per day in England and Wales in 1800 ($\overline{X}$ = 3,271)

Decile group	Daily calorie consumption	Cumulative percentage
Highest	5,244	100
9th	4,258	84
8th	3,822	71
7th	3,509	59
6th	3,251	48
5th	3,019	38
4th	2,797	29
3rd	2,568	21
2nd	2,305	13
1st	1,872	6

Note: Mean calorie consumption per consuming unit is based on the average of the estimates derived from Chartres, Holderness and Allen (3293 calories p.c.u.) and Turner, Beckett and Afton (3249 calories p.c.u.). The calculations are based on the lognormal distribution and the value of the coefficient of variation is assumed to be 0.3.

Sources and procedures: Table 8 and text.

What do these figures imply about the relationship between diet and working capacity in the eighteenth and nineteenth centuries? The World Health Organisation, in association with the Food and Agriculture Organisation of the United Nations and the United Nations University, has estimated the number of calories required by men and women of different sizes and at different ages engaged in different levels of physical activity, and we can combine this information with our knowledge of the heights and weights of British men in the nineteenth and early-twentieth centuries to estimate the calorific needs of such individuals during this period. The results are shown in Table 10. They imply that the number of calories required to enable an adult male to satisfy his basic metabolic requirements and perform a full day's work is likely to have ranged from approximately 2400 calories per day for light work to 3500 calories per day for heavy work. However, our figures suggest that the number of calories available for consumption is unlikely to have reached the latter figure before the second half of the nineteenth century.

Table 10. Calories required for different types of work, 1800-1914.

Year of birth	Age at measurement	Year of measurement	Height	Weight	BMI	BMR (kcal/hr)	Light work	Moderate work	Heavy work
1777.5	23	1800.5	168.83	59.08	20.73	65.95	2435.93	2816.27	3376.89
1827.5	23	1850.5	172.87	61.94	20.73	67.78	2503.30	2894.16	3470.28
1886-1893	20-24	1910-13	168.80	61.40	21.55	67.05	2476.44	2863.11	3433.05

Notes.

(1) The height data are based on the heights of military recruits in 1800, 1850 and 1910-14.

(2) The average weights of recruits in 1800 and 1850 have been estimated using the BMIs of men who were born in the first two decades of the nineteenth century and measured between 1826 and 1849, when they were between the ages of 26 and 30.

(3) The numbers of calories required for basal metabolism have been estimated using the following formula: BMR = 15.3W + 679, where BMR = Calories required for basal metabolism and W = weight in kilograms. The FAO/WHO/UNU Expert Consultation (1985: 178) also recommends an alternative formula, using both height and weight, but the results are almost identical when the alternative formula is applied to these data.

Sources: Floud, Wachter and Gregory 1990: 140-9; Floud 1998: 34-6; Rosenbaum 1988: 278-9, 282-4, 293; FAO/WHO/UNU Expert Consultation 1985: 71, 76-7.

These figures imply that a significant proportion of the British population may not have had access to the number of calories which they needed to undertake physically-demanding work on a regular basis at the start of the nineteenth century. The increase in the amount of food which was available for human consumption therefore helped to improve the working capacity of the population as a whole by enabling a larger proportion of the potential workforce to contribute in this way. However, there is also evidence to suggest that many families responded to this situation by transferring resources from women and children to male breadwinners. Many contemporary observers, such as the mid-nineteenth century medical officer, Dr Edward Smith, saw this as a rational response, because it enabled the male breadwinner to remain in work and therefore contribute to the wellbeing of the family as a whole (Parliamentary Papers 1864: 249). However, it also contributed to the undernutrition of other household members, and the effects of this were likely to have been reflected, not only in the poor nutritional status of working-class children, but also in the premature mortality of their mothers (Harris 1998; 2008).

5. Other factors associated with the decline of mortality

When McKeown outlined his analysis of the causes of mortality decline, he argued that some part of this decline could be attributed to changes in the relationship between infective organisms and their hosts if the organisms themselves became less virulent, or if the human population became more resistant to infection as a result of genetic selection. He acknowledged that 'scarlet fever is the outstanding example of an infection in which the relation between host and parasite is unstable, and the decline of mortality since the mid-nineteenth century can be attributed confidently to a change in the character of the disease' (McKeown 1976: 82), but he was unwilling to concede that similar factors might have contributed to declines in mortality from other diseases. Nevertheless, it is certainly possible to argue that he underestimated the overall significance of this effect in his overall schema, given the extent of the contribution made by this disease to the decline of mortality as a whole in England and Wales between 1861/70 and 1891/1900 (Harris 2004a: 398-400).

Although few historians would deny that the decline of mortality from scarlet fever was associated with changes in the virulence of the disease itself, the role played by disease virulence in the decline of tuberculosis has recently become rather more controversial. Woods (2000: 336, 340, 359) argued that mortality from phthisis, or respiratory tuberculosis, ‘appears to have declined in nearly all districts regardless of the initial rate or whether the place had urban or rural characteristics’, and that ‘the simplest explanation is that the disease became less virulent and … this was the principal reason for a reduction in the risk of disease developing and leading to early death’ (see also Woods and Shelton 1997: 143-4). However, Woods was unable to provide any direct evidence for this assertion, and his interpretation has been challenged by a number of leading authorities (see e.g. Landers 2000: 468; Szreter 2001: 563).[2] In 1976, when McKeown himself discussed this issue, he concluded that ‘there is no evidence that the virulence of the organism has changed significantly; the disease continues to have devastating effects in populations not previously exposed to it; and the virulence of the bacillus appears not to have diminished when it has been possible to assess it in the laboratory’ (McKeown 1976: 83).

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[2] Stephen Kunitz (2007: 196) has recently suggested that virulence may have declined as a result of reduced exposure. However, although he regarded this proposal as ‘conceivable’, he also acknowledged that it was ‘highly speculative’.

Although it seems unlikely that the decline in tuberculosis mortality can be attributed either to changes in the virulence of the tubercle bacillus or to any changes in the genetic susceptibility of the human population (see McKeown 1976: 83-4), it is possible that changes in the nature of infectious disease have affected patterns of mortality in other ways. As Kunitz and Engerman have argued, the main causes of premature death in the sixteenth and seventeenth centuries were epidemic or pandemic diseases, but these either became less important (in the case of plague) or more endemic (in the case of smallpox) in the eighteenth century. They argued that the transition from epidemic and pandemic diseases to endemic diseases meant that social factors, such as personal hygiene, domestic sanitary arrangements and nutritional status, played an increasingly important part in the determination of death rates as the century progressed, and this was one of the main reasons for the emergence of a 'social gradient' in health and mortality from the 1750s onwards (Kunitz and Engerman 1992: 33).

Historians of mortality change have often tended to pay particular attention to the relationship between real wages and diet, but it is also important to consider the impact of real wages on other items of consumption, including housing. During the early stages of the industrial revolution, it is widely accepted that housing conditions deteriorated in both urban and rural areas, but conditions began to improve from the 1850s onwards. These improvements were caused partly by the introduction of new bye-laws which established higher standards for the construction of new housing, but also by the increase in the value of real wages, which enabled more households to afford a higher standard of accommodation. However, it was not until 1919 that the state began to make a concerted attempt to provide subsidised housing for working-class tenants and even then it decided to concentrate on the construction of new housing at the upper end of the working-class market. The government only began to launch a direct assault on the problem of the slums following the introduction of the Greenwood Housing Act of 1930, which offered a more generous form of subsidy to local authorities that linked the construction of new housing to the demolition of slum properties and formed the basis of public housing policy for the remainder of the decade (Harris 2004b: 125-35, 245-54).

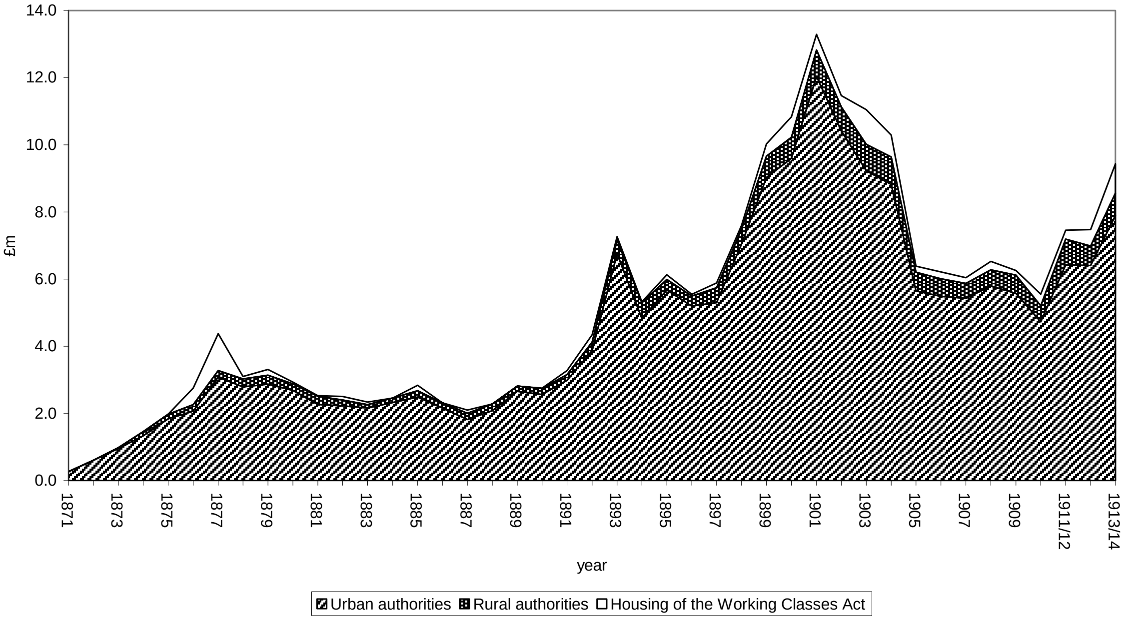
As we have already seen, the debate over the causes of mortality decline has often appeared to be polarised between those who apportion a dominant role to 'living standards' (and, by implication, diet) and those who prefer to emphasise the role of public action and, especially, sanitary intervention, but it is clear that, even during the eighteenth century, there were a number of ways in which individual communities could act collectively to reduce mortality risk. Dobson (1997) has shown how the marshland communities of Essex, Kent and Sussex were able to reduce mortality from malaria by instituting drainage schemes, and Razzell (1965; 1977: 140-58) and Mercer (1985; 1990: 46-73) have provided strong grounds for believing that the introduction of inoculation and vaccination played a major role in the decline of smallpox mortality from the 1750s onwards. These efforts were complemented by the measures taken by local bodies in the market towns of southern England and London to improve the quality of the urban environment during the same period (Jones and Falkus 1990; Porter 1991; Landers 1993). However, it is difficult to reach any categorical conclusions about the overall impact of these measures, particularly in the poorest and most rapidly-growing areas. Hennock (1957: 117) argued that the Improvement Commissioners who were primarily responsible for urban government in the late-eighteenth century 'were primarily concerned with the comfort of the wealthier citizens…. As measures of sanitary reform, their value was marginal. For the same reason, they are not conclusive evidence that there existed an effective local public opinion in favour of sanitary reform'.

Despite the best intentions of late-eighteenth and early-nineteenth century reformers, there seems little doubt that their efforts were insufficient to cope with the rapidly-expanding pace of urban growth during the first half of the nineteenth century. As Wohl (1984: 4) has shown, the period between 1800 and 1850 saw a dramatic increase in the proportion of the population who lived in towns and in the size of the towns in which they lived, and both Szreter and Mooney (1998: 104) and Woods (2000: 360-80) have argued that this led to an absolute deterioration in the standard of public health in many urban areas. Szreter (1997: 64) suggested that the rapidity of urban growth gave rise to the 'four Ds' of disruption, deprivation, disease and death, and that these features continued to blight the lives of Britain's urban citizens for much of the nineteenth century.

One of the most important aspects of early-nineteenth century urban growth was the deterioration in the quality and quantity of the water supply. As Hassan (1985: 533, 538, 543) has shown, it was already apparent by the end of the eighteenth century that many local authorities lacked the resources to maintain an adequate water supply. During the first half of the nineteenth century Parliament had encouraged them to transfer responsibility for water provision to private companies, but by 1850 'significant sections of Victorian public opinion' had come to the conclusion that it was inefficient 'to leave the profitable activities of water, gas, electricity and urban transport to unregulated private enterprise' and there was widespread support for the view that these utilities should be restored to municipal ownership. However, although there was a rapid increase in the number of municipally-owned water companies after 1850, it is difficult to say how far this may have contributed to any immediate improvement in urban health standards. This was partly because a substantial proportion of the increased supply of water was reserved for industrial use, and partly because 'the direct environmental benefits of increased water deliveries for sanitary purposes were probably limited before the whole range of water services, including sewage treatment and river conservancy, were modernised'.

In view of the close association between the improvement of water supplies and the broader concerns of sanitary engineering, it is clearly important to pay close attention to the chronology of nineteenth-century sanitary reform. As Michael Flinn and others have demonstrated, there was a significant growth of interest in the need for sanitary reform in the 1830s and 1840s, and this culminated in the passage of the Public Health Act of 1848, but this was a largely permissive piece of legislation which had relatively little impact, at least in the short term, on the largest urban centres (Flinn 1965: 18-43; Harris 2004b: 110). Szreter (1988: 22) argued that the real beginning of sanitary reform occurred in the 1870s, when local authorities began to borrow much larger sums of money from the Local Government Board for public health purposes, but Bell and Millward (1998: 232-7) have argued that local authorities only began to invest substantial amounts of money in sewerage systems during the 1890s and early-1900s. Their conclusions are reinforced by our own analysis of the Local Government Board's loan figures, which shows that the value of the loans provided to local sanitary authorities rose from £2.56 million in 1890 to a peak of just over £12 million eleven years later (Figure 4).

Figure 4. Loans for public health purposes in England and Wales, 1871-1914



Notes: The graph shows the value of the loans sanctioned by the Local Government Board for public health purposes to urban and rural sanitary authorities between 1871 and 1914. The figures for 1871 refer to the period between 19 August and 31 December only, and neither these figures, nor the figures for 1872, differentiate between loans to urban authorities and loans to rural authorities. Full details of the authorities in receipt of loans and the purposes to which they were put were given in the Appendices to the Local Government Board's reports.

Sources: *Annual Reports of the Local Government Board*, 1871-1914.

These findings have important implications for the debate about the causes and timing of the decline of mortality in England and Wales in the late-nineteenth and early-twentieth centuries. They suggest that, even though sanitary reform may have made a significant contribution to the decline of mortality before 1900, it is likely to have played an even more decisive role after that date, as the scale of public health investment increased. Recent historians of public health have tended to concentrate the bulk of their attention on the second half of the nineteenth century, but these figures reinforce the case for believing that more attention should now be paid to the early years of the twentieth century (see also Harris 2004a: 405).

The most dramatic improvements in mortality in the nineteenth century were concentrated among those between the ages of five and 44, whereas the twentieth century also witnessed substantial improvements in the survival prospects of infants and older adults (Wohl 1984: 329). It is tempting to assume that these developments must have reflected the impact of other changes which also occurred after 1900 but there is an impressive body of evidence which suggests that they should also be seen in the context of the more long-term improvement in health status which began around 1850.

In recent years, a growing number of researchers have paid increasing attention to the impact of cohort, or life-course, approaches to the study of mortality change, and such cohort factors may have played an important role in the decline of both infant mortality and older-age mortality. Baird (1974: 330, 334-5, 340; 1975: 139) suggested that women who were born during the economic recession of the late-1920s and early-1930s were more likely to give birth to low-birth-weight infants at the end of their own pregnancies, and Kramer (1987: 718) argued that 'maternal height and pre-pregnancy weight, though listed as direct determinants [of birth-weight] may themselves be affected by the mother's intrauterine and postnatal growth which depend, in part, on *her* mother's pregnancy and on subsequent nutritional and environmental influences during childhood'. However, whilst most authorities seem to agree that there is some relationship between a mother's foetal environment and the health of her own offspring, the precise nature of this relationship remains unclear. Lumey (1998: 132) argued that undernutrition of the grandmother and thus of the mother during the first trimester of her own gestation had no effect on the mother's own birth weight but did affect the birth weight of her children, whilst undernutrition in the third trimester of gestation affected the mother's birth weight but not that of her infants.

In view of these arguments, it is important to consider the extent to which changes in the health of adult females during the last thirty years of the nineteenth century may have contributed to the decline of infant mortality in the twentieth century, but the evidence for such a relationship is far from clear. Floud (1998: 11) found that there were 'insufficient observations' to draw any conclusions about trends in the heights and weights of women born during the second half of the nineteenth century, but Millward and Bell (2001) have suggested that it might be possible to infer levels of maternal nutrition from the death rate from tuberculosis among women of child-bearing age. However, even though they found that there was a close relationship between the tuberculosis mortality rate and infant mortality *before* 1900, there is little evidence to suggest that this factor can also account for the acceleration in the rate of infant mortality decline after this date.

Although it is difficult, on the basis of current knowledge, to attach too much importance to the impact of life-course effects on the decline of infant mortality, that does not mean we should ignore their effect on the decline of mortality at older ages. Since the mid-1980s, a great deal of attention has been focused on the possible impact of developments before and immediately after the time of birth on health in later life (see e.g. Barker, Eriksson, Forsén and Osmond 2002), but this research has not been accepted uncritically (see e.g. *Lancet* 2001) and it is also important to recognise the extent to which developments at older ages can also influence susceptibility to disease. Davey Smith *et al.* (2001: 113) found that 'two … conditions – stroke and stomach cancer – appear to be particularly responsive to early-life influences whilst others – coronary heart disease, chronic obstructive respiratory disease, breast cancer and suicide – appear to be influenced by socially-patterned exposures acting right across life', and a third set of conditions, such as lung cancer, 'appear to be mostly determined by … factors … in adulthood'. They concluded that ‘there is no single answer to the question … on whether deprivation in childhood or adulthood is a more important determinant of adult mortality risk’.

One of the main problems in evaluating the impact of life course factors on historical changes in adult mortality is the difficulty of finding an appropriate proxy for health in early life. If improvements in foetal and infant health were the main reason for the decline of adult mortality in the first half of the twentieth century, one might expect to find stronger evidence of a relationship between changes in infant mortality and subsequent changes in adult mortality but, as we have already seen, the infant mortality rate did not begin to decline in Britain until the decline in death rates among older children and young adults was already underway. However, there does appear to be a much more obvious relationship between changes in *child* mortality and the decline of adult mortality. In 1934, Kermack, McKendrick and McKinlay showed that when the death rate experienced by each age group was expressed as a percentage of the death rate for that age-group in the 1840s, ‘each generation after the age of five years seems to carry along with it the same relative mortality throughout adult life, and even into old age’, and this led them to conclude that the ‘care of children during their first 10-15 years of life is of supreme importance. It is at this period … that improved environment exercises its effects most promptly, and … the improved physique built up during this period would seem to be of decisive effect at all later ages’ (Kermack, McKendrick and McKinlay 1934: 699, 702).

These arguments are reinforced by evidence of changes in human stature. The average height of the population from which army recruits were drawn increased, albeit inconsistently, between the birth cohorts of the 1740s and the 1820s and declined between the birth cohorts of the 1820s and the early-1850s, before resuming its upward path from the early-1850s onwards (Floud, Wachter and Gregory 1990: 134-54). The increase in the average height of men born after *circa* 1850 coincided with the onset of the decline in child mortality, and the cohorts which experienced these improvements also experienced lower rates of age-specific mortality throughout the life-course. Although these findings do not necessarily provide unequivocal support for McKeown's view that the decline of mortality was caused by improvements in diet, they do provide further evidence of the link between improvements in child health and the subsequent decline of adult mortality (Floud, Wachter and Gregory 1990: 313-4; Harris 1994: 312; 2001: 693).

Although these findings continue to provide strong support for a life-course approach to the understanding of mortality change, they also suggest that researchers need to look beyond a straightforward focus on the health and nutrition of the future child in the womb. Bengtsson and Lindström (2000) found that there was a close relationship between infant mortality in four Swedish parishes and the mortality rates experienced by the survivors of these cohorts between the ages of 55 and eighty, and suggested that this was a consequence not so much of access to nutrients (either in the womb or during infancy), but exposure to infection. There are obvious problems in applying this directly to England and Wales in the absence of any similar relationship between infant mortality and mortality at older ages, but their emphasis on the relationship between childhood infection and later-life mortality may still have an important part to play in enhancing our understanding of the relationship between the decline of child mortality and the decline of adult mortality during the first half of the twentieth century (see also Finch and Crimmins 2004).

6. Conclusions

As this paper has demonstrated, the relationship between food, income and health has continued to be the subject of considerable controversy. Although Thomas McKeown argued that improvements in the quality and quantity of the human diet were primarily responsible for the decline of mortality in Britain from the beginning of the eighteenth century, several writers have criticised this view. One of the major sources of objection was the lack of correlation between movements in real wages and life expectancy and the absence of direct information about food availability.

This paper has sought to address these issues in two ways. In the first place, we have summarised the new evidence on changes in real wages which has come to light since McKeown's findings were originally published. Although these findings do not remove all the inconsistencies between the movement of real wages and changes in life expectancy, they do suggest that the two series were much more closely aligned, during the second half of the eighteenth century, than previous accounts have suggested.

The second aim of the paper was to present new estimates regarding the availability of food in England and Wales between 1700 and 1914. Although some of the results are mixed, our overall conclusion is that the number of calories available for human consumption per head per day increased by between 200 and 250 calories over the course of the eighteenth century and by between thirty and one hundred calories between 1800 and 1850. This was followed by a much larger increase in food availability between 1850 and 1914.

Our evidence also shows that there were significant changes in the composition of the British diet over this period. At the beginning of the eighteenth century, about two-thirds of the calories consumed by the average Briton were likely to have been derived from cereals. However, by the early years of the twentieth century, the proportion of calories derived from cereals had halved and the proportions derived from fruit and vegetables, and from meat and dairy products, had increased substantially. Although some authors have recently highlighted the increased importance of the role played by processed foods in British diets during the course of the nineteenth century (see Clayton and Rowbotham 2008a; 2008b; 2008c), the potentially negative aspects of this change may still have been outweighed by the improvement in the nutritional composition of the average diet and the overall increase in the number of calories.

The nutritional adequacy of a diet depends on the size of the body which the diet is required to sustain and on the amount of work which the same body is required to perform. In order to estimate the adequacy of the diet which was available in Britain at different points in time, we have also calculated the number of calories available per 'consuming unit' or 'adult male equivalent' and compared this with the available information about the average heights and weights of British men in the eighteenth and nineteenth centuries. This exercise demonstrated that the average number of calories per consuming unit was well below the level needed to enable an 18-30 year old man to perform a full day's worth of physically-demanding labour during much of the period under review. However, it is also important to recognise that the costs of any shortfall may not have been shared equally – either within the household or within society as a whole. During the nineteenth and early-twentieth centuries, many contemporary observers noted that adult women and children regularly consumed a smaller share of the available food than their husbands and fathers. Even if it were possible to justify this on the grounds that it was essential to maintain the strength of the primary breadwinner, it may still have contributed to the stunted bodies of many working-class children and the high mortality rates of their mothers.

Although we have paid particular attention to the importance of diet and the estimation of food availability, this paper has not been designed to offer a monocausal explanation for mortality change. In the first place, it is important to recognise that a diet which may prove adequate under one set of environmental circumstances may prove wholly inadequate under a different set of circumstances, and therefore it is essential to take full account of what Nevin Scrimshaw and others have called the 'synergistic' relationship between infection and nutrition (see e.g. Scrimshaw, Taylor and Gordon 1968; Scrimshaw and SanGiovanni 1997; Scrimshaw 2000). Secondly, it is also important to recognise the wide range of additional factors which also influenced changes in mortality during our period.

Although we have identified a range of such 'additional factors', two are of particular importance. In the first place, it is important to recognise the impact of environmental degradation in general, and urbanisation in particular, on the history of public health in Britain during the first three-quarters of the nineteenth century. The rising tide of urbanisation was associated with a reduction in the average heights of men who were born during the second quarter of the nineteenth century and was at least partly responsible for the absence of any further progress in aggregate life-expectancy rates over the course of the same period. As a result, it is also important to acknowledge the vital contribution made by sanitary reform to the decline of mortality after *circa* 1870. However, our findings suggest that the greatest increases in spending on the sanitary infrastructure only became apparent at the very end of the nineteenth century and during the early years of the twentieth century. A lot of attention has been paid in recent years to the impact of sanitary reform before 1900 but our evidence suggests that it was likely to have played an even greater role after that date.

The second key factor is the importance of a cohort-based or life-course approach to the understanding of mortality decline. As Kermack, McKendrick and McKinlay pointed out in 1934, the first generation to experience declining mortality in the second half of the nineteenth century were the men and women who were born towards the end of the 1840s. The decline in mortality began when these individuals were between the ages of five and nine and then started to affect each succeeding age-group as the century progressed, but there was little improvement in the scale of older-age mortality before the start of the twentieth century. This pattern of age-specific mortality decline suggests that, in order to understand at least some of the causes of the decline of mortality at older ages, we still need to pay more attention to the factors which contributed to an improvement in the life-chances of these individuals during their earlier years.

Appendices

Table A1. Energy derived from domestically-produced cereals and pulses, 1700-1850 (based on crop yields estimated by Chartres, Holderness and Allen).

		Millions of acres	Yields per acre	Gross output	% entering gross product	Millions of bushels as food	Lbs per bushel	Ounces of food (000,000s)	kCal per ounce	Proportion net of milling and distribution losses	Total kCal net of milling and distribution losses (000,000s)	Population (England and Wales)	Kcal per cap. Available for consumption per day
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
								(5)*(6)*16			(7)*(8)*(9)		(10)/(11)
1700	Wheat	1.361	16.0	21.8	0.855	18.6	57	16,980	95	0.6189	998,427	5,444,426	502.43
	Rye	0.890	17.0	15.1	0.737	11.2	55	9,813	95	0.5345	498,307	5,444,426	250.76
	Barley	1.901	23.0	43.7	0.850	37.2	49	29,137	102	0.4000	1,188,790	5,444,426	598.22
	Oats	1.223	24.0	29.4	0.280	8.2	38	4,997	114	0.4263	242,824	5,444,426	122.19
	Beans & peas	1.3	20.0	26.0	0.600	15.6	60	14,976	30	0.4050	184,371	5,444,426	92.78
	Total												1,566.37
1750	Wheat	1.8	18.0	32.4	0.855	27.7	57	25,264	95	0.6189	972,041	6,192,091	430.09
	Rye	0.5	18.0	9.0	0.737	6.6	55	5,837	95	0.5345	296,416	6,192,091	131.15
	Barley	1.4	25.0	35.0	0.850	29.8	49	23,324	102	0.4000	951,619	6,192,091	421.05
	Oats	2.0	28.0	56.0	0.280	15.7	38	9,533	114	0.4263	463,278	6,192,091	204.98
	Beans & peas	1.0	28.0	28.0	0.600	16.8	60	16,128	30	0.4050	198,553	6,192,091	87.85
	Total												1,275.12
1800	Wheat	2.5	21.5	53.8	0.855	46.0	57	41,912	95	0.6189	2,464,431	9,223,320	732.04
	Rye	0.3	26.0	7.8	0.737	5.7	55	5,059	95	0.5345	256,893	9,223,320	76.31
	Barley	1.3	30.0	39.0	0.850	33.2	49	25,990	102	0.4000	1,060,376	9,223,320	314.98
	Oats	2.0	35.0	70.0	0.280	19.6	38	11,917	114	0.4263	579,097	9,223,320	172.02
	Beans & peas	1.2	28.0	33.6	0.600	20.2	60	19,354	30	0.4050	238,264	9,223,320	70.77
	Total												1,366.12
1850	Wheat	3.6	28.0	100.8	0.855	86.2	57	78,600	95	0.6189	4,621,669	17,928,000	706.28
	Rye	0.1	28.0	2.8	0.737	2.1	55	1,816	95	0.5345	92,218	17,928,000	14.09
	Barley	1.5	36.5	54.8	0.850	46.5	49	36,485	102	0.4000	1,488,604	17,928,000	227.49
	Oats	2.0	40.0	80.0	0.280	22.4	38	13,619	114	0.4263	661,826	17,928,000	101.14
	Beans & peas	1.0	30.0	30.0	0.600	18.0	60	17,280	30	0.4050	212,735	17,928,000	32.51
	Total												1,081.50

Sources:

Col. 1. 1700: Figures for wheat, rye, barley and oats from Chartres 1985: 444; figures for bean and peas from Allen 1994: 112; 1750-1850: Holderness 1989: 145.

Col. 2. As for column 1.

Col. 4. Figures for wheat, oats, barley, and beans and peas, from Towne and Rasmussen 1960: 294, 298, 304; for rye, see Gallman 1960: 52.

Col. 6. Conversion rates for wheat, barley, rye and oats from John 1989: 1124-5. Conversion rates for wheat, barley, rye and oats from John 1989: 1124-5. Figures for beans and peas from United States Department of Agriculture1992: 11, 14.

Col. 8. Energy values for wheat, rye, barley and oats from McCance and Widdowson 1960: 116-7; and for beans and peas from Parliamentary Papers 1917: Appendix 1A.

Col. 10. Allowances for milling losses derived from United States Department of Agriculture 1939: 8. An additional ten per cent has been allowed for losses associated with distribution.

Col. 11. 1700-1800: England (figures for 1701, 1751 and 1801): Wrigley and Schofield 1981: 533-4; Wales (1701, 1751 and 1801): Deane and Cole 1967: 103; 1850 (1851): Mitchell 1988: 9.

Table A2. Energy derived from domestically-produced cereals and pulses, 1700-1850 (based on crop yields estimated by Turner, Beckett and Afton).

		Millions of acres	Yields per acre	Gross output	% entering gross product	Millions of bushels as food	Lbs per bushel	Ounces of food (000,000s)	kCal per ounce	Proportion net of milling and distribution losses	Total kCal net of milling and distribution losses (000,000s)	Population (England and Wales)	Kcal per cap. Available for consumption per day
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
								(5)*(6)*16			(7)*(8)*(9)		(10)/(11)
1700	Wheat	1.361	16.0	21.8	0.855	18.6	57	16,980	95	0.6189	998,427	5,444,426	502.43
	Rye	0.890	17.0	15.1	0.737	11.2	55	9,813	95	0.5345	498,307	5,444,426	250.76
	Barley	1.901	23.0	43.7	0.850	37.2	49	29,137	102	0.4000	1,188,790	5,444,426	598.22
	Oats	1.223	24.0	29.4	0.280	8.2	38	4,997	114	0.4263	242,824	5,444,426	122.19
	Beans & peas	1.3	20.0	26.0	0.600	15.6	60	14,976	30	0.4050	184,371	5,444,426	92.78
	Total												1,566.37
1750	Wheat	1.8	22.0	39.6	0.855	33.9	57	30,915	95	0.6189	1,189,448	6,192,091	526.28
	Rye	0.5	18.0	9.0	0.737	6.6	55	5,837	95	0.5345	296,416	6,192,091	131.15
	Barley	1.4	24.8	34.7	0.850	29.5	49	23,137	102	0.4000	943,980	6,192,091	417.67
	Oats	2.0	36.7	73.5	0.280	20.6	38	12,511	114	0.4263	607,968	6,192,091	269.00
	Beans & peas	1.0	21.8	21.8	0.600	13.1	60	12,551	30	0.4050	154,519	6,192,091	68.37
	Total												1,412.46
1800	Wheat	2.5	21.1	52.7	0.855	45.1	57	41,095	95	0.6189	2,416,388	9,223,320	717.77
	Rye	0.3	23.4	7.0	0.737	5.2	55	4,558	95	0.5345	231,451	9,223,320	68.75
	Barley	1.3	29.2	38.0	0.850	32.3	49	25,311	102	0.4000	1,032,676	9,223,320	306.75
	Oats	2.0	37.4	74.9	0.280	21.0	38	12,742	114	0.4263	619,221	9,223,320	183.94
	Beans & peas	1.2	22.0	26.4	0.600	15.9	60	15,225	30	0.4050	187,442	9,223,320	55.68
	Total												1,332.89
1850	Wheat	3.6	28.9	104.0	0.855	89.0	57	81,132	95	0.6189	4,770,543	17,928,000	729.03
	Rye	0.1	27.8	2.8	0.737	2.1	55	1,805	95	0.5345	91,674	17,928,000	14.01
	Barley	1.5	36.4	54.6	0.850	46.4	49	36,376	102	0.4000	1,484,143	17,928,000	226.80
	Oats	2.0	47.4	94.8	0.280	26.6	38	16,143	114	0.4263	784,473	17,928,000	119.88
	Beans & peas	1.0	29.6	29.6	0.600	17.7	60	17,037	30	0.4050	209,742	17,928,000	32.05
	Total												1,121.77

Sources:

Col. 1. See Table A1

Col. 2. 1700 (all crops): see Table A1; 1750 (rye): see Table A1; 1750 (all other crops): Turner, Beckett and Afton 2001: 129, 153, 158, 163-4; 1800 & 1850 (all crops): Turner, Beckett and Afton 2001: 129, 153, 158, 163-4.

Cols. 4, 6, 10 & 11: See Table A1

Table A3. Energy derived from domestically-farmed animals.

1700	Oz (000,000)	Population	Oz/head/day	kCal/oz	kCal/head
Mutton & lamb	1,638.40	5,444,426	0.82	92.01	75.86
Beef & veal	3,328.00	5,444,426	1.67	82.39	137.97
Pork & ham	956.80	5,444,426	0.48	127.56	61.42
Others	446.24	5,444,426	0.22	42.96	9.65
Lard	173.42	5,444,426	0.09	252.53	21.99
Total					306.88
1750					
Mutton & lamb	3,476.48	6,192,091	1.54	92.01	141.53
Beef & veal	4,569.60	6,192,091	2.02	82.39	166.57
Pork & ham	2,598.40	6,192,091	1.15	127.56	146.65
Lard	470.96	6,192,091	0.21	252.53	52.50
Total					507.25
1800					
Mutton & lamb	5,017.60	9,223,320	1.49	92.01	137.90
Beef & veal	5,824.00	9,223,320	1.73	82.39	143.32
Pork & ham	3,368.96	9,223,320	1.00	127.56	128.37
Lard	610.62	9,223,320	0.18	252.53	45.70
Total					453.01
1850					
Mutton & lamb	7,490.56	17,928,000	1.14	92.01	105.32
Beef & veal	9,640.96	17,928,000	1.47	82.39	121.38
Pork & ham	4,569.60	17,928,000	0.70	127.56	89.08
Lard	828.24	17,928,000	0.13	252.53	31.89
Total					347.67

Sources:

Meat production

1700: King 1696: 54-5

1750-1850: Holderness 1989: 155.

Lard

Derived from the ratio of lard to bacon and pork production in Bennett and Pierce 1961: 114-5.

Energy values

Parliamentary Papers 1917: Appendix 1A.

Table A4. Energy derived from domestically-produced dairy products

	Consumption per head per week		oz/day	kCal/oz	kCal/day
	oz	Pints			
1700					
Cheese					
Butter					
Milk					
Total					230.75
1750					
Cheese	5.00		0.71	109.85	78.46
Butter	3.50		0.50	225.78	112.89
Milk	30.00	1.50	4.29	20.35	87.23
Total					278.58
1800					
Cheese	4.50		0.64	109.85	70.62
Butter	3.50		0.50	225.78	112.89
Milk	18.00	0.90	2.57	20.35	52.34
Total					235.84
1850					
Cheese	3.30		0.47	109.85	51.79
Butter	2.40		0.34	225.78	77.41
Milk	31.00	1.55	4.43	20.35	90.14
Total					219.33

Notes.

Figure for total consumption of energy from dairy products in 1700 derived from the ratio of beef and cattle production in 1700 to beef and cattle production in 1750 (roughly 1.67:2.02). For sources, see Table A1.

Sources: Holderness 1989: 170. Energy values derived from Parliamentary Papers 1917: Appendix 1A.

Table A5. Energy derived from imported cereals and pulses.

	Net imports (Cwt, 000s)	Quantity as food (Ozs, 000s)	Kcal/oz	Net of milling losses (35% of grain)	Net of distribution losses (10% of grain & flour/meal)	kCal/head/day for consumption (constant losses)
1700 (GB)						
wheat	-157.94	-283,028	95	-17,476,975	-15,729,278	-6.59
wheat flour	-41.56	-74,476	95	-7,075,225	-6,367,703	-2.67
Total	-199.50	-357,504	95	-24,552,201	-22,096,981	-9.25
Barley	-115.50	-206,968	102	-13,721,995	-12,349,795	-5.17
barley meal	0.00	-8	102	-791	-712	0.00
Total	-115.50	-206,976	102	-13,722,786	-12,350,507	-5.17
Oats	29.99	53,742	114	3,982,259	3,584,033	1.50
Oatmeal	0.11	195	114	22,282	20,053	0.01
Total	30.10	53,937	114	4,004,541	3,604,087	1.51
Maize	0.00	0	104	0	0	0.00
Cornmeal	0.00	0	104	0	0	0.00
Total	0.00	0	104	0	0	0.00
Grand total	-284.90	-510,542.86	415.00	-34,270,445.56	-30,843,401.01	-12.91
1750 (GB)						
wheat	-3,062.10	-5,487,276	95	-338,839,321	-304,955,389	-111.52
wheat flour	-805.76	-1,443,924	95	-137,172,737	-123,455,463	-45.15
Total	-3,867.86	-6,931,200	95	-476,012,058	-428,410,852	-156.66
Barley	-335.99	-602,089	102	-39,918,530	-35,926,677	-13.14
barley meal	-0.01	-23	102	-2,300	-2,070	0.00
Total	-336.00	-602,112	102	-39,920,831	-35,928,748	-13.14
Oats	29.75	53,310	114	3,950,280	3,555,252	1.30
Oatmeal	0.11	194	114	22,103	19,892	0.01
Total	29.86	53,504	114	3,972,382	3,575,144	1.31
Maize	0.00	0	104	0	0	0.00
Cornmeal	0.00	0	104	0	0	0.00
Total	0.00	0	104	0	0	0.00
Grand total	-4,174.00	-7,479,808.00	415.00	-511,960,506.30	-460,764,455.67	-168.50

1798-1802 (UK)						
wheat	2,532.38	4,538,033	95	280,223,542	252,201,188	43.01
wheat flour	666.37	1,194,139	95	113,443,240	102,098,916	17.41
Total	3,198.76	5,732,172	95	393,666,782	354,300,104	60.43
Barley	234.48	420,188	102	27,858,477	25,072,629	4.28
barley meal	0.01	16	102	1,605	1,445	0.00
Total	234.49	420,204	102	27,860,082	25,074,074	4.29
Oats	1,046.73	1,875,741	114	138,992,386	125,093,147	21.33
Oatmeal	3.81	6,822	114	777,692	699,923	0.12
Total	1,050.54	1,882,563	114	139,770,078	125,793,070	21.45
Maize	0.00	0	104	0	0	0.00
Cornmeal	0.00	0	104	0	0	0.00
Total	0.00	0	104	0	0	0.00
Grand total	4,483.78	8,034,938.93	415.00	561,296,942.50	505,167,248.25	86.17
1848-1852 (UK)						
wheat	13,892.78	24,895,853	95	1,537,318,944	1,383,587,049	138.66
wheat flour	3,655.75	6,551,102	95	622,354,710	560,119,239	56.13
Total	17,548.52	31,446,956	95	2,159,673,653	1,943,706,288	194.79
Barley	3,406.84	6,105,054	102	404,765,108	364,288,597	36.51
barley meal	0.13	229	102	23,323	20,991	0.00
Total	3,406.97	6,105,283	102	404,788,431	364,309,588	36.51
Oats	3,052.88	5,470,767	114	405,383,869	364,845,482	36.56
Oatmeal	11.10	19,897	114	2,268,210	2,041,389	0.20
Total	3,063.99	5,490,664	114	407,652,079	366,886,871	36.77
Maize	6,732.28	12,064,250	104	815,543,304	733,988,974	73.56
Cornmeal	71.50	128,129	104	13,325,387	11,992,848	1.20
Total	6,803.78	12,192,379	104	828,868,691	745,981,822	74.76
Rye	340.80	610,710	104	41,284,006	37,155,605	3.72
Ryemeal	12.56	22,515	104	2,341,528	2,107,375	0.21
Total	353.36	633,225	104	43,625,533	39,262,980	3.93
Peas	722.63	1,294,949	78	65,653,933	59,088,540	5.92
pea meal	0.16	279	78	21,777	19,599	0.00
Total	722.78	1,295,229	78	65,675,710	59,108,139	5.92

Beans	1,783.76	3,196,493	73	151,673,583	136,506,225	13.68
bean meal	0.01	11	73	785	706	0.00
Total	1,783.76	3,196,504	73	151,674,368	136,506,931	13.68
buckwheat	7.11	12,743	97	805,402	724,862	0.07
buckwheat meal	0.29	528	97	51,300	46,170	0.00
Total	7.41	13,270	97	856,702	771,032	0.08
beer or bigg	2.56	4,579	102	303,606	273,245	0.03
Malt	0.00	0	102	303,606	273,245	0.03
Grand total	33,693.13	60,378,087.88	971.58	4,063,422,379.35	3,657,080,141.41	366.50

Sources

Grain imports

1700 & 1750: Mitchell 1988: 221-2.

1798-1802: Parliamentary Papers 1849a.

1848-52: Parliamentary Papers 1849b; 1851; 1853.

Quarters were converted into hundredweights using the conversion factors in Table A1. Conversion factors for maize were derived from United States Department of Agriculture 1952: 40, and for buckwheat, beer, bigg and malt from United States Department of Agriculture 1992: 12, 14.

Energy values

Wheat, barley (including beer or bigg), oats, rye, peas and beans: McCance and Widdowson 1960: 116-7.

Maize (yellow corn), buckwheat and malt: United States Department of Agriculture, National Nutrient Database (http://www.nal.usda.gov/fnic/foodcomp/search/).

Losses due to milling and distribution

See Table A1.

Population

1700-1800: England (figures for 1701, 1751 and 1801): Wrigley and Schofield 1981: 533-4; Wales (1701, 1751 and 1801): Deane and Cole 1967: 103; 1850 (1851): England and Wales 1851: Mitchell 1988: 11; Scotland: 1700 & 1750: Schofield 1994: 93; Scotland & Ireland (1801 and 1851): Mitchell 1988: 11-12.

Table A6. Energy derived from imported meat.

	Cwt (000s)	Oz/head/day	kCal/oz	kCal/head/day
1850	699	0.13	93.48	11.74

Sources:

Meat imports: Mitchell 1988: 233. Energy values derived from estimates of total meat consumption and total calories derived from consumption of meat products in Table A3.

Table A7. Energy derived from imported dairy products

	1800	1850
Butter (oz)	206,312,960	593,393,920
Cheese (oz)	222,510,848	623,209,216
kCal per ounce (butter)	225.96	225.96
kCal per ounce (cheese)	110.97	110.97
Population (Great Britain)	10,686,000	-
Population (United Kingdom)	-	27,524,000
kCal per day (butter)	11.94	13.33
kCal per day (cheese)	4.25	6.88
kCal per day (total)	16.20	20.22

Sources:

Imports of dairy products: 1800 (1801): John 1989: 1027-9; 1850: Parliamentary Papers 1851: 2; Population: Mitchell 1988: 11; Energy values: Parliamentary Papers 1917: Appendix 1A.

Table A8. Energy derived from retained sugar imports.

	cwt	population	lbs/head/year	oz/head/year	cal/oz	cal/head/day
1700	442,800	5,444,426	5.68	90.84	112	27.87
1750	913,080	6,192,091	14.72	235.55	112	72.28
1800			19.45	311.12	112	95.47
1850			27.69	442.96	112	135.92

Sources:

Sugar: 1700 & 1750: Sheridan 1973: 22; 1800 & 1850: Mokyr 1988: 75.

Energy values: McCance and Widdowson 1960: 142.

Population: 1700 & 1750: Deane and Cole 1967: 103; Wrigley and Schofield 1981: 533-4.

Table A9. Wine and spirits

	1700	1750	1800	1850
Total wine	914,739,840	621,532,800	1,225,042,560	1,482,811,680
Total spirits	380,480	138,317,120	577,401,280	1,242,124,640
kCal per oz of wine	25	25	25	25
kCal per oz of spirits	63	63	63	63
Population	5,444,426	6,192,091	10,686,000	27,393,000
kCal/oz/head/day (wine)	11.51	6.88	7.85	3.71
kCal/oz/head/day (spirits)	0.01	3.86	9.33	7.83
kCal/oz/head/day (total)	11.52	10.73	17.18	11.53

Notes.

Imported wine was normally measured in tuns, and imported spirits in tuns and/or gallons. These figures have been converted into ounces on the basis that each tun contained 252 gallons, and that each gallon contains 160 fluid ounces.

Sources:

Imported wines and spirits: 1700-1800: Schumpeter 1960: 52-9; 1850: Parliamentary Papers 1851.

Population: England and Wales 1700 (1701) and 1750 (1751): Wrigley and Schofield 1981: 533-4; Deane and Cole 1967: 103; Great Britain: 1800 (1801): Mitchell 1988: 11; United Kingdom: 1850 (1851): 12.

Table A10. Energy derived from fish.

		Herrings	Other fish, fresh	Shell fish (without shell)	Canned and salted fish	Total
Metric tons (000s)	Home	99.00	606.00	10.50	0.00	715.50
	Imported	63.00	30.00	1.90	38.00	132.90
	Total	162.00	636.00	12.40	38.00	848.40
Calories (000,000,000s)	Home	82.00	306.00	4.00	0.00	392.00
	Imported	57.00	12.00	*	70.00	139.00
	Total	139.00	318.00	4.00	70.00	531.00
Calories per head per day	Home	4.97	18.55	0.24	0.00	23.76
	Imported	3.45	0.73	0.00	4.24	8.43
	Total	8.43	19.28	0.24	4.24	32.19

Sources: Parliamentary Papers 1917: Appendix 1A. The population was taken as 45.2 million.

Table A11. Energy derived from garden vegetables.

		Beans, peas and lentils	Other vegetables (including tomatoes)	Preserved vegetables	Total
Metric tons (000s)	Home	0.00	700.00	0.00	700.00
	Imported	116.00	295.00	21.00	432.00
	Total	116.00	995.00	21.00	1,132.00
Calories (000,000,000s)	Home	0.00	191.00	0.00	191.00
	Imported	421.00	83.00	8.00	512.00
	Total	421.00	274.00	8.00	703.00
Calories per head per day	Home	0.00	11.58	0.00	11.58
	Imported	25.52	5.03	0.48	31.03
	Total	25.52	16.61	0.48	42.61

Source: Parliamentary Papers 1917: Appendix 1A. The population was taken as 45.2 million.

Table A12. Energy derived from imported fruit and nuts, 1850

	Cwt	Oz	kCal/oz	Population (UK)	Kcal/head/day
Currants	405,388	726,455,296	69	27,524,000	4.99
Figs	33,499	60,030,208	61	27,524,000	0.36
Lemons & oranges	537,960	964,024,927	7	27,524,000	0.67
Raisins	218,982	392,415,744	70	27,524,000	2.73
Total					8.76

Parliamentary Papers 1851: 3. The figure for oranges and lemons has been estimated using the ratio of the amount of duty paid to the volume of fruit imported for currants, figs and raisins. The energy obtained from these fruits has been calculated on the assumption that equal quantities of oranges and lemons were imported.

Table A13. Energy derived from fruit & nuts, 1909-13.

		Apples	Bananas	Nuts	Fresh fruit	Preserved fruit (without sugar)	Total
Metric tons (000s)	Home	127.00	0.00	0.00	214.00	0.00	341.00
	Imported	163.00	150.00	38.00	430.00	149.00	930.00
	Total	290.00	150.00	38.00	627.00	149.00	1,271.00
Calories (000,000,000s)	Home	57.00	0.00	0.00	111.00	0.00	168.00
	Imported	74.00	99.00	100.00	231.00	405.00	909.00
	Total	131.00	99.00	100.00	442.00	405.00	1,077.00
Total	Home	3.45	0.00	0.00	6.73	0.00	10.18
	Imported	4.49	6.00	6.06	14.00	24.55	55.10
	Total	7.94	6.00	6.06	20.73	24.55	65.28

Source: Parliamentary Papers 1917: Appendix 1A. The population was taken as 45.2 million.

Table A14. Energy derived from potatoes

	lbs/head/day	oz/head/day	kCal/oz	kCal/person/day
1700	0.14	2.29	23	52.57
1750	0.21	3.43	23	78.86
1800	0.42	6.69	23	153.98
1850	0.69	11.10	23	255.34

Sources:

<u>Potatoes</u>

Figures for 1700, 1750, 1800 and 1850 derived from Salaman 1949: 434, 539, 613, assuming that consumption was zero before 1600, and grew at a linear rate between 1600 and 1775, 1795 and 1814, and 1838 and 1851, and that the figure quoted in the text for 1851 (0.07 lbs per head per day) should be 0.70.

<u>Energy value:</u>

McCance and Widdowson 1960: 140.

Table A15. Energy derived from domestically-produced and imported foods, 1909-13.

	Metric tons (000s)			Calories per ounce			Calories per head per day		
	Home	Imported	Total	Home	Imported	Total	Home	Imported	Total
Wheat flour, shredded wheat, etc.	840.00	3,485.00	4,325.00	95	95	95	170.26	706.38	876.64
Oatmeal	145.00	55.00	200.00	114	114	114	35.27	13.38	48.65
Barley meal	25.00	25.00	50.00	102	102	102	5.44	5.44	10.88
Tapioca, sago, arrowroot, etc.		100.00	100.00		100.28	100.28		21.40	21.40
Maize meal		50.00	50.00	104	104	104		11.09	11.09
Rice		140.00	140.00		100.65	100.65		30.06	30.06
Cereals	1,010.00	3,855.00	4,865.00	104.21	103.22	103.43	210.97	787.75	998.72
Beef and veal	820.00	491.00	1,311.00	82.39	64.92	75.84	144.14	68.01	212.15
Mutton	294.80	182.20	477.00	95.02	79.21	88.98	59.76	30.79	90.56
Lamb	36.20	83.80	120.00	67.49	67.12	67.23	5.21	12.00	17.21
Bacon	80.00	228.00	308.00	170.10	169.96	169.99	29.03	82.68	111.71
Hams	20.00	44.00	64.00	109.38	105.89	106.98	4.67	9.94	14.61
Other pig meat	304.00	41.00	345.00	117.56	114.33	117.18	76.25	10.00	86.25
Meat offals	60.00		60.00	49.72		49.72	6.36	0.00	6.36
Meat	1,615.00	1,070.00	2,685.00	94.44	93.48	94.06	325.43	213.42	538.85
Poultry (and game)	41.00	14.00	55.00	42.96	36.53	41.32	3.76	1.09	4.85
Eggs (at 2 oz)	129.00	129.00	258.00	38.10	38.10	38.10	10.49	10.49	20.97
Rabbits (excl. skins)		18.00	18.00		55.24	55.24		2.12	2.12
Poultry, eggs etc.	170.00	161.00	331.00	39.27	39.88	39.57	14.24	13.70	27.94
Herrings	99.00	63.00	162.00	23.53	25.70	24.38	4.97	3.45	8.43
Other fish, fresh	606.00	30.00	636.00	14.35	11.36	14.20	18.55	0.73	19.28
Shell fish (without shell)	10.50	1.90	12.40	10.82	0.00	9.16	0.24	0.00	0.24
Canned and salted fish		38.00	38.00		52.33	52.33		4.24	4.24
Fish	715.50	132.90	848.40	15.56	29.71	17.78	23.76	8.43	32.19

Milk (inc. cream)	4,500.00		4,500.00	20.35	#DIV/0!	20.35	195.42	0.00	195.42
Butter	114.00	207.00	321.00	225.78	225.76	225.77	54.92	99.71	154.62
Cheese	30.00	117.00	147.00	109.85	110.97	110.74	7.03	27.70	34.73
Condensed milk		2.20	2.20						
Sweetened condensed milk		53.00	53.00		94.34	94.34		10.67	10.67
Margarine	60.00	58.60	118.60	222.06	223.01	222.53	28.43	27.88	56.31
Lard		90.00	90.00	#DIV/0!	252.53	252.53		48.49	48.49
Dairy produce	4,704.00	527.80	5,231.80	28.48	190.43	44.81	285.79	214.45	500.24
Apples	127.00	163.00	290.00	12.75	12.90	12.83	3.45	4.49	7.94
Bananas		150.00	150.00		18.75	18.75		6.00	6.00
Nuts		38.00	38.00		74.76	74.76		6.06	6.06
Fruits, fresh	214.00	430.00	644.00	14.74	15.26	15.09	6.73	14.00	20.73
Fruits, preserved (without sugar)		149.00	149.00		77.22	77.22	0.00	24.55	24.55
Fruit	341.00	930.00	1,271.00	14.00	27.77	24.07	10.18	55.10	65.28
Potatoes	3,988.00	262.00	4,250.00	23	23	23	195.70	12.86	208.56
Beans, peas and lentils		116.00	116.00		103.11	103.11	0.00	25.52	25.52
Green peas and broad beans (shelled)	100.00		100.00	30.40		30.40	6.49	0.00	6.49
Other vegetables (inc. tomatoes)	700.00	295.00	995.00	7.75	7.99	7.82	11.58	5.03	16.61
Preserved vegetables		21.00	21.00		10.82	10.82	0.00	0.48	0.48
Vegetables	4,788.00	694.00	5,482.00	24.05	31.03	24.94	213.76	43.89	257.66
Cocoa and chocolate		36.00	36.00		177.56	177.56		13.64	13.64
Sugar taken as refined		1,525.00	1,525.00	112	112	112		364.42	364.42
Molasses		33.00	33.00		63.71	63.71		4.49	4.49
Glucose, solid		18.00	18.00		96.28	96.28		3.70	3.70
Glucose, liquid		45.00	45.00		90.28	90.28		8.67	8.67
Sugar, cocoa etc.	0.00	1,657.00	1,657.00		113.72	113.72		394.91	394.91
Cottage produce			0.00				134.99		134.99
Farm produce (consumed by producers)			0.00				25.94		25.94
Totals	13,343.50	9,027.70	22,371.20	43.73	89.90	62.36	1,245.08	1,731.64	2,976.72

Notes. Energy values have been calculated using the original figures, with the following exceptions: wheat: 95 calories per ounce (rather than 103 calories); oats: 114 calories per ounce (rather than 109); maize: 104 calories per ounce (rather than 97); sugar: 112 calories per ounce (rather than 114); potatoes: 23 calories per ounce (rather than 27). The population has been taken to be 45.2 million (in accordance with the original estimates).

Sources: Parliamentary Papers 1917: Appendix 1A. For alternative energy values, see Tables A1, A5, A8 and A14.

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