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FOOD FOR THOUGHT:
COMPARING ESTIMATES OF FOOD AVAILABILITY IN ENGLAND AND WALES, 1700-1914

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Dedicated to the memory of Robert W. Fogel.

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ABSTRACT

In *The Changing Body* (Cambridge University Press and NBER, 2011), the authors presented a series of estimates showing the number of calories available for human consumption in England and Wales at various points in time between 1700 and 1909/13. The current paper corrects an error in those figures but also compares the estimates of *The Changing Body* with those published by a range of other authors. The differences reflect disagreements over a number of issues, including the amount of land under cultivation, the extraction and wastage rates for cereals and pulses and the number of animals supplying meat and dairy products. The paper considers recent attempts to achieve a compromise between these estimates and challenges claims that there was a dramatic reduction in either food availability or the average height of birth cohorts in the late-eighteenth century.

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Recent years have witnessed the publication of several efforts to estimate the number of calories available for human consumption in Britain from the thirteenth century onwards. Although these papers have often drawn on similar sources, they have sometimes reached quite divergent conclusions about both levels and trends. These disagreements have profound implications for our understanding of a range of issues, including the measurement of basic living standards, the relationship between diet and health, and the impact of food availability on economic growth, both in the British Isles and more widely.

This paper follows a number of other authors in seeking to navigate a route between these conflicting estimates and methods. The first section offers a more detailed summary of some of the major publications and their findings. The paper then offers a more detailed analysis of some of the reasons for the differences between them. The final section highlights some of the problems associated with the attempt to construct composite series and relates this discussion to the analysis of trends in real wages, height and mortality in Britain.

1. Estimating food availability

During the 1980s and 1990s, a number of authors attempted to reconstruct the dietary history of the British population using evidence from the household budgets collected by contemporary investigators such as David Davies (1795), Frederick Morton Eden (1797), William Neild (1842), Edward Smith (Parliamentary Papers 1863; 1864) and others (see Oddy 1990: 269). However, these reconstructions were marred by disagreements over the selection of relevant budgets and the representativeness of the populations from which they were drawn (Harris 2004: 386-7; Floud *et al.* 2011: 152-4). This helped to fuel a growing interest in the use of agricultural accounts to estimate the total amount of food which was produced in Britain at different points in time.

One of the earliest attempts to estimate food availability from these sources was made by Mark Overton and Bruce Campbell in a paper which was originally published (in French) in *Histoire et Mésure* in 1996 (Overton and Campbell 1996). An English-language version was presented to a session at the World Economic History Congress in Helsinki ten years later (Overton and Campbell 2006). The authors estimated the total number of calories provided by a number of different cereal crops and by potatoes for a series of years between 1300 and 1871. Based on these figures, they estimated that the total number of calories provided by these crops fell from a possible peak of around 1669 calories per head per day in 1380 to 1060 calories per head per day 491 years later. However, when these figures were added to the number of calories supplied by imported foods, the total number of calories from potatoes and grains in 1871 rose from 1060 to 1796 (Overton and Campbell 1996: 296; 2006: 45).

Although Overton and Campbell's original paper has not always received the attention it deserved (it was overlooked by Robert Fogel in *The escape from hunger* [2004] and by Floud *et al.* [2011] in *The changing body*, and was also omitted from the Bibliography of Robert Allen's unpublished but widely-cited discussion paper [Allen 2005]), it has formed the basis of the food calculations which Overton and Campbell have undertaken with Stephen Broadberry, Alexander Klein and Bas van Leeuwen for their forthcoming study of British economic growth from 1270 to 1870 (Broadberry *et al.*, forthcoming). This study incorporates a number of changes to Overton and Campbell's original estimates and combines them with estimates of the number of calories derived from non-arable sources. The most recent version (5 August 2013) suggests that aggregate consumption rose after the Black Death and reached a peak of 2467 calories per person per day during the 1380s. This level was not regained until the 1860s.

A further attempt to estimate food production and consumption levels was undertaken by Robert Allen in 2005. Allen estimated the number of calories generated by domestically-provided and imported foodstuffs in 1300, 1500, 1700, 1750, 1800 and 1850. His calculations suggested that per capita food consumption almost doubled between 1300 and 1500. It fell slightly between 1500 and 1700 and rose dramatically between 1700 and 1750. It then declined even more dramatically over the course of the next century (Allen 2005: 39).

Allen's estimates for the period after 1700 contrast quite sharply with the figures published by Robert Fogel in 2004 (Fogel 2004: 9), and by Floud, Fogel, Harris and Hong in 2011 (Floud *et al.* 2011: 160). Floud and his co-authors used different assessments of average crop yields to generate two separate estimates of the number of calories generated by the domestic production of cereals and pulses, and then combined these with data on meat and dairy production and calories from imported foodstuffs. Their published estimates incorporated a spreadsheet error (first identified by Deborah Oxley) which led them to underestimate the number of calories derived from domestic wheat production in 1750 but their corrected figures (summarised in Table 1) suggest that, despite some variations, average food consumption increased by between 210 and 243 calories between 1700 and 1800, and by between 505 and 538 calories per person per day between 1800 and the eve of the First World War.

As a number of commentators have pointed out, there are strong methodological similarities between Floud *et al.*'s work and that of Craig Muldrew. However, their results are very different. Whereas Floud and his co-authors argued that average calorie consumption rose from 2229 calories per person per day in 1700 to between 2439 and 2472 calories a century later, Muldrew (2011: 156) claimed that the number of calories supplied by grain products alone in 1700 was 2682, and that the number of calories from all foodstuffs was 3579. He also suggested that total food availability increased by more than 41 per cent between 1700 and 1770, before falling by just over 21 per cent between 1770 and 1800. Unfortunately, his figures did not extend beyond that date. However, they implied that average daily calorie consumption per head in 1800 was exactly one thousand calories greater than the figure which Floud *et al.* derived from the data published by the Royal Society for the period 1909-13 (Floud *et al.* 2011: 160).

A number of authors have attempted to steer a middle way between these conflicting estimates. Although Morgan Kelly and Cormac Ó Gráda drew on some of the work published by Fogel and Floud *et al.*, they focused most of their attention on the estimates of Broadberry *et al*. and Muldrew. After looking at the individual components of each set of estimates, they concluded that, whilst Muldrew's figures were clearly 'over-generous', those published by Broadberry and his coauthors were in need of 'upward revision' (Kelly and Ó Gráda 2012: 17; 2013a: 1150, 1153; 2013b: 2). However, even with these revisions, their own suggestions still allowed for a very wide margin of error for particular years (see Appendix 1).

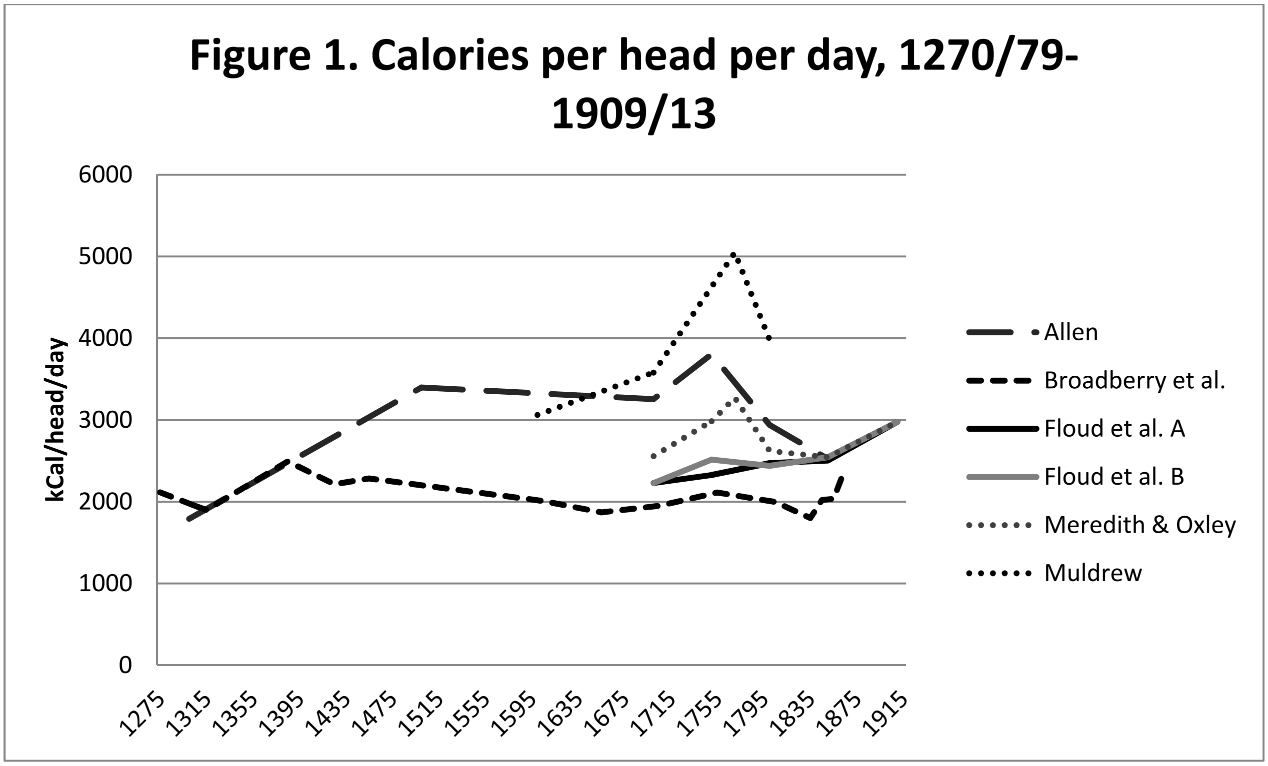
Table 1. Calories derived from domestically-produced wheat and other sources in England and Wales, 1700-1850: Published and revised estimates

	Published figures: Estimate A					Corrected figures: Estimate A				
	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories
1700	502.43	1,063.94	1,566.37	662.26	2,228.63	502.43	1,063.94	1,566.37	662.26	2,228.63
1750	430.09	845.03	1,275.12	824.84	2,099.96	657.28	845.03	1,502.32	824.84	2,327.16
1800	732.04	634.08	1,366.12	1,106.00	2,472.12	732.04	634.08	1,366.12	1,106.00	2,472.12
1850	706.28	375.22	1,081.50	1,422.58	2,504.08	706.28	375.22	1,081.50	1,422.58	2,504.08
	Published figures: Estimate B					Corrected figures: Estimate B				
	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories	Domestically-produced wheat	Other domestically-produced cereals and pulses	Total calories from domestically-produced cereals and pulses	Calories from all other sources (including imports)	Total calories
1700	502.43	1,063.94	1,566.37	662.26	2,228.63	502.43	1,063.94	1,566.37	662.26	2,228.63
1750	526.28	886.19	1,412.46	824.85	2,237.31	804.29	886.19	1,690.48	824.84	2,515.32
1800	717.77	615.12	1,332.89	1,106.00	2,438.89	717.77	615.12	1,332.89	1,106.00	2,438.89
1850	729.03	392.74	1,121.77	1,422.60	2,544.37	729.03	392.74	1,121.77	1,422.60	2,544.37

Source: Floud, Fogel, Harris and Hong 2011: Tables 4.9, D.2 and D.3.

A rather different approach has been taken by David Meredith and Deborah Oxley (2014). They compared Muldrew's estimates with those published by Floud *et al.*, and then experimented with different scenarios in which they applied the conversion ratios employed by the different authors to each other's data. They also compared the results with a reassessment of anthropometric trends and data from household budgets. They concluded that the most plausible scenario was one in which Floud *et al.*'s conversion ratios (for seeding, animal feed, processing and wastage) were applied to Muldrew's data for the eighteenth century and then merged with Floud *et al.*'s own results for the nineteenth and early-twentieth centuries. These calculations led to a substantial reduction in the size of Muldrew's eighteenth-century estimates, but still left room for a sharp fall in food availability between *circa* 1770 and 1850.

Although these papers cover a number of different periods, the main areas of divergence concentrate on the eighteenth and nineteenth centuries. Within this period, it is possible to identify two broad schools of thought (see Figure 1 and Appendix 1). The first school, represented particularly by Broadberry *et al.* and Floud *et al.*, suggests that food availability was generally low, and that there was relatively little change before the early-to-middle years of the nineteenth century. The second school, represented especially by Robert Allen and Craig Muldrew, argues that food availability was much greater during the first 50-70 years of the eighteenth century, and fell sharply between *circa* 1770 and 1850. In order to investigate these issues further, we begin by looking more closely at the similarities and differences between the accounts presented by Broadberry *et al.* and Floud *et al.*. We then contrast Floud *et al.*'s estimates with those published by Muldrew before looking at the compromise position proposed by Meredith and Oxley.



Sources: See Appendix 1.

2. Optimists and pessimists

Although Floud *et al.* and Broadberry *et al.* reached similar conclusions, they did not necessarily reach them in the same way, and their results were not identical. In view of this, it is appropriate to consider the different routes taken towards their final figures in more detail.

2.1. Land under cultivation

Floud *et al.* based their estimates on the amount of land under cultivation on figures originally published by Chartres (1985: 444), Allen (1994: 112) and Holderness (1989: 145). Although both Chartres (1985: 145) and Holderness (1989: 126, 139, 142; see also Allen 1994: 103) appear to have been referring to the whole of England and Wales, they reached different conclusions about the amount of land under cultivation in 1750. Floud *et al.* (2011: 205-7) followed Allen (1994: 112) in preferring Holderness' figures, partly because Chartres did not attempt to estimate the amount of land used for beans and peas, and partly to provide continuity with Holderness' figures for 1800 and 1850. However, when Allen returned to the subject in 2005, he used Chartres' figures (Allen 2005: 28). If Floud *et al.* had also used these figures, their overall estimate for the number of calories consumed per person per day in 1750 would have been between 138 calories (Estimate A) and 144 calories (Estimate B) higher.

Floud *et al.*'s figures can also be compared with those of Broadberry *et al.* in Table 2, although Broadberry *et al.*'s figures appear to refer to England only. Their figures suggest that the total amount of land devoted to the cultivation of wheat, rye, barley, oats and pulses was less than the figures published by Floud *et al.* for 1700 and 1750, but greater than Floud *et al.*'s figures for 1800. Whereas Floud *et al.* believed that the land devoted to these crops increased between 1800 and 1850, Broadberry *et al.* suggested a decline. However, they also claimed that the acreage devoted to other crops increased, so that the total amount of land under cultivation rose by just under 1.2 million acres.

2.2. Yields per acre

Floud *et al.* (2011) published two different sets of estimates for yields per acre. Their initial estimates were based on the yields reported by Chartres (1985: 444) and Allen (1994: 112) for 1700, and by Holderness (1989: 145) for 1750, 1800 and 1850. They also published a second set of estimates, based on work by Turner, Beckett and Afton (2001: 129, 153, 158, 163-4) for the period from 1750 onwards. However, Turner and his co-authors did not publish estimates for the productivity of rye in 1750, and their results may not have been entirely representative (Thirsk 2002). The corrected version of Floud *et al.*'s study suggests that the first of these two estimates may therefore provide a more appropriate guide to the general trend over the period as a whole (Floud *et al.*, forthcoming).

Table 2. Land under cultivation: Broadberry et al. *versus Floud* et al.

	1700	1750	1800	1830	1850	1871
			Broadberry *et al.*			
Wheat	1.99	1.95	2.97	2.08	-	3.31
Rye/Maslin	0.42	0.06	0.06	0.06	-	0.06
Barley/Dredge	1.82	1.50	1.62	1.82	-	1.96
Oats	1.15	1.82	1.97	1.39	-	1.45
Pulses	0.98	0.98	0.83	0.63	-	0.90
Total Cereals and Pulses	6.36	6.31	7.45	5.98	-	7.68
Potatoes	0.00	0.08	0.17	0.26	-	0.39
Other Crops	1.30	2.53	2.90	4.46	-	5.28
Total Sown	7.66	8.92	10.52	10.70	-	13.35
Fallow Arable	1.91	1.59	1.28	1.30	-	0.48
Total Arable	9.57	10.51	11.80	12.00	-	13.83
			Floud *et al.*			
Wheat	1.36	1.80	2.50	-	3.60	-
Rye/Maslin	0.89	0.50	0.30	-	0.10	-
Barley/Dredge	1.90	1.40	1.30	-	1.50	-
Oats	1.22	2.00	2.00	-	2.00	-
Pulses	1.30	1.00	1.20	-	1.00	-
Total Cereals and Pulses	6.68	6.70	7.30	-	8.20	-

Sources: Broadberry *et al.* 2011: 36; Floud *et al.* 2011: 205-7.

Broadberry *et al.* published an initial, and fuller, version of their latest estimates in 2011. This paper forms the basis of the chapter on 'Consumption' in their forthcoming volume. It is difficult to compare their estimates directly with those published by Floud *et al.* because their figures are for crop yields net of seed and it is not possible to estimate gross yields directly from the information in their paper. However, we can infer the figures for wheat, rye, barley and oats from the estimates published by Overton and Campbell in 1996. The data in Table 3 suggest that the two sets of authors reached broadly similar conclusions about the productivity of wheat, but Broadberry and his coauthors were generally more pessimistic about the productivity of barley and oats, and probably also more pessimistic about the productivity of beans and peas. They proposed higher estimates for the productivity of rye and maslin in 1700 and 1750, but lower estimates for these crops in 1800 and 1850.

Table 3. Yields per acre: Broadberry et al. *versus Floud* et al.

	Wheat		Rye/Maslin		Barley/Dredge		Oats		Beans and Peas	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
Floud *et al.* A.										
1700	16.00	-	17.00	-	23.00	-	24.00	-	20.00	-
1750	18.00	-	18.00	-	25.00	-	28.00	-	28.00	-
1800	21.50	-	26.00	-	30.00	-	35.00	-	28.00	-
1850	28.00	-	28.00	-	36.50	-	40.00	-	30.00	-
Floud *et al.* B.										
1700	16.00	-	17.00	-	23.00	-	24.00	-	20.00	-
1750	22.00	-	18.00	-	24.80	-	36.70	-	21.80	-
1800	21.10	-	23.40	-	29.20	-	37.40	-	22.00	-
1850	28.90	-	27.80	-	36.40	-	47.40	-	29.60	-
Broadberry *et al.*										
1700/09	15.40	12.90	20.45	17.95	19.75	15.75	12.73	8.73	-	9.88
1750/59	17.65	15.15	19.34	16.84	23.15	19.15	24.46	20.46	-	10.36
1800/09	18.96	16.46	22.82	20.32	26.46	22.46	26.85	22.85	-	16.13
1850/59	26.47	23.97	22.63	20.13	30.58	26.58	34.26	30.26	-	16.58

Sources: Broadberry *et al.* 2011: 36; Overton and Campbell 1996: 294; 2006: 41; Floud *et al.* 2011: 205-9.

2.3. Calories from cereals and pulses

Both Broadberry *et al.* and Floud *et al.* drew on McCance and Widdowson's (1960) exhaustive account of *The composition of foods* when estimating calorie values. However, as we can see from Table 4, they nevertheless reached slightly different conclusions about the calorific value of barley and oats. Broadberry *et al.* also appear to have used slightly lower values for beans and peas.

Table 4. Calorie values: Broadberry et al. *versus Floud* et al.

	Broadberry *et al.*			Floud *et al.*
	kCal per bushel	Pounds per bushel (from Floud *et al.*)	kCal per pound	Kcal per pound
Wheat	86,667	57	1,520	1,520
Rye	83,810	55	1,524	1,520
Barley	71,429	49	1,458	1,632
Oats	63,889	38	1,681	1,824
Beans and Peas	24,000	60	400	480

Notes. These figures have been calculated from Broadberry *et al.*, forthcoming: Tables 8.1 and 8.5. The figures for wheat, rye, barley and oats are very similar to those published by Kelly and Ó Gráda (2012: 19; 2013a: 1138).

Sources: Broadberry *et al.*, forthcoming: Tables 8.1, 8.5; Floud *et al.* 2011: 205-9.

2.4. Potatoes

It is generally agreed that potatoes formed an increasingly important part of the national diet during the eighteenth and nineteenth centuries but the details of the increase remain contentious. Allen (2005: 28) argued that the amount of land devoted to potatoes increased steadily from 1700 onwards. Overton and Campbell (1996: 292; 2006: 37) did not attempt to estimate patterns of cultivation in 1750, with the result that their figures show no evidence of potato cultivation before 1800. Broadberry *et al.* (2011: 36-7) also assumed a constant rate of increase from 1700 to 1800, but at lower levels than Allen. Floud *et al.* (2011: 221) based their figures on those published by Radcliffe Salaman (1949: 61-3), but many of these figures were highly conjectural. Floud *et al.* assumed that the amount of land under cultivation by potatoes increased steadily from 1600 to 1775, whereas Salaman (149: 537) himself thought that there was little active cultivation before 1770. He derived his own estimates for 1775 and 1795 from contemporary accounts which suggested that the *consumption* of potatoes was widespread in the north of England during the 1790s; and he estimated the amount of land under cultivation in 1814 and 1838 from contemporary Scottish figures. Even the figures for 1851 had to be inferred from James Caird's (1852) attempts to estimate the total amount of land used for potatoes, turnips and mangolds (Salaman 1949: 612-3).

In order to compare the number of calories derived from these estimates, we have assumed that each pound of potatoes supplied 368 calories; that each bushel contained 60 pounds; and that each acre yielded 150 bushels throughout the period (see Table 5). We have also used Overton and Campbell's (1996: 41; 2006: 294) estimate of the difference between gross and net yields to estimate the number of calories 'lost' for seeding purposes.

The results of this exercise are shown in Table 5. The absolute values of the figures generated from each set of authors differ less dramatically than the trends. Allen's figures imply that potatoes already accounted for a significant proportion of total consumption at the start of the eighteenth century, and that their significance increased between 1700 and 1750. They also suggest that per capita consumption peaked during the second half of the eighteenth century and declined between 1800 and 1850. Broadberry *et al.* imply that potato consumption increased from a minimal level in 1700 to around 113 calories per head in 1750. They also suggest that potato consumption continued to rise, albeit at a lower rate, between 1750 and 1800 and remained at much the same level between 1800 and 1830, before declining between 1830 and 1871. Floud *et al.* suggest that consumption rose quite slowly between 1700 and 1750, and more rapidly between 1750 and 1800. Their figures suggest that the rate of increase continued to accelerate between 1800 and 1850.

2.5. Extraction rates

In order to estimate the proportion of the total crop which became available for human consumption, it is necessary to make allowances for seeding, the consumption of grain by animals, processing, distribution and wastage. Floud *et al.* (2011: 205-9) used data from the United States to estimate the proportion of cereals and pulses 'lost' as a result of seeding, animal consumption and processing, and allowed an extra ten per cent for wastage. They assumed that the gross extraction rate (the amount of food available for human consumption as a proportion of the gross yield of each crop) remained constant over the whole of the period from 1700 to 1850.

Table 5. Potato consumption: Allen, Floud et al. *and Broadberry* et al.

	Acres (mn)	Bushels per acre	Calories per bushel	Total yield (billion calories)		Population (mn)	Calories per head per day	
				Gross	Net		Gross	Net
				Allen (2005)				
1700	0.10	150	22,080	331.20	297.20	5.44	166.67	149.56
1750	0.20	150	22,080	662.40	594.40	6.19	293.08	263.00
1800	0.30	150	22,080	993.60	891.60	9.22	295.14	264.84
1850	0.40	150	22,080	1,324.80	1,188.80	17.93	202.45	181.67
				Broadberry *et al.* (2011)				
1700	0.00	150	22,080	0.00	0.00	5.03	0.00	0.00
1750	0.08	150	22,080	264.96	237.76	5.73	126.48	113.50
1800	0.17	150	22,080	563.04	505.24	8.61	179.24	160.84
1830	0.26	150	22,080	861.12	772.72	13.11	180.02	161.54
1871	0.39	150	22,080	1,291.68	1,159.08	21.50	164.59	147.70
				Floud *et al.* (2011)				
1700	-	-	-	-	-	5.44	-	52.57
1750	-	-	-	-	-	6.19	-	78.86
1800	-	-	-	-	-	9.22	-	153.98
1850	-	-	-	-	-	17.93	-	255.34

Notes. Bushels per acre are based on Overton and Campbell (1996: 37; 2006: 292). The difference between gross and net yields is based on Overton and Campbell 1996: 41; 2006: 294. English population figures are taken from Wrigley and Schofield 1981: 533-5. It is worth noting that, although the figures published by Overton and Campbell are consistent with the idea that each bushel contained approximately 60 lbs in 1800 and 1830, their figures for 1871 suggested that the number of pounds per bushel in that year was closer to 76.

Sources: Allen 2005: 28; Broadberry *et al.* 2011: 36-7; forthcoming: Table 8.5 ; Floud *et al.* 2011: 221; Wrigley and Schofield 1981: 533-5.

These assumptions have not escaped criticism. Kelly and Ó Gráda (2012: 31; 2013b: 2) argued that 'Floud *et al.*'s assumed proportions of wheat, barley and rye entering gross product … seem to be on the low side' and that 'the assumed losses from processing and distribution may be too high except, perhaps, in the case of barley'. Meredith and Oxley (2014: 180) also thought that Floud *et al.*'s 'assumptions regarding loss … are arguably very high' although, as we shall see, this did not prevent them from accepting the same rates when performing their final calculations.

It is difficult to compare the impact of these assumptions directly with those made by Broadberry *et al.* because Broadberry and his co-authors only showed the proportion of the total crop which remained available for human consumption *after* making an initial allowance for seeding. However, we can address this for some crops using the figures on gross and net yields in Overton and Campbell's paper (1996: 292-5; 2006: 37-44). Their figures enable us to make separate calculations for the proportions of the original crop which were 'lost' in the form of seeds, animal consumption, wastage and processing for wheat, rye, barley and oats.

The results of this exercise are shown in Table 6. As we have already explained, Floud *et al.* assumed that the proportion of each crop which entered gross production remained constant throughout the period, as did the proportions lost through processing and wastage. Overton and Campbell suggested that the extraction rates of wheat and rye both increased between 1700 and 1830. This was because the amount of grain which was used for seeding remained constant at 2.5 bushels per acre, with the result that the proportion fell as the total yield increased. Floud *et al.* also suggested that the extraction rates for these two crops were consistently lower than the figures suggested by Overton and Campbell throughout the period, but their figures for barley were greater, and their figures for oats became greater as the period progressed. When the extraction rates for all four crops are combined, Floud *et al.*'s figures are also lower, but not excessively so. Floud *et al.* estimated a combined extraction rate of between 30 and 33 per cent, whereas Overton and Campbell's figure was around 36 per cent.

2.6. Meat and dairy products

Floud *et al.* and Broadberry *et al.* derived their estimates of the numbers of calories from meat and dairy products from different sources. Broadberry *et al.* derived their information from studies by John (1989: 1042-6), Clark (1991: 216) and Allen (2005: 29, 33). Floud *et al.* drew their information from King (1696: 54-5) and Holderness (1989: 155, 170). They also sought to estimate the number of calories derived from lard with information from US sources (Bennett and Pierce 1961: 114-5).

Although meat and dairy products only accounted for a minority of total calories between 1700 and 1850, the differences between the two sets of estimates are noticeable. Broadberry *et al.* (2011: 59; forthcoming: Table 8.7) increased the total value of 'non-arable' foods by adding 200 calories per person per day for fish and poultry, whereas Floud *et al.* (2011: 156) only allowed 24 extra calories from fish and made no allowances for poultry, game or rabbits before the twentieth century. However, Broadberry *et al.*'s other estimates were much lower. They suggested that the number of calories derived from beef, mutton, pork and dairy products accounted for no more than 380 calories per day between 1700/09 and 1850/59, whereas Floud *et al.*'s estimates ranged from 538 calories to 786.

Table 6. Food extraction rates: Floud et al. *versus Overton and Campbell*

							Overton and Campbell							Floud et al. A	
				Millions of acres	Gross output (tn calories)	Total output (tn calories, net of seed)	Proportion fed to livestock	% entering gross product	Losses due to wastage	Losses due to processing	Proportion net of milling and distribution losses	Gross extraction rate (including allowance for seed)	% entering gross product	Proportion net of milling and distribution	Gross extraction rate (including allowance for seed)
			O & C, Tab. 12	O & C, Tab. 5	O & C, Tabs. 5 & 9	O & C, Tabs. 5 & 9	O & C, Tab. 12								
1700	Wheat		-	1.60	2.22	1.87	0.020	0.825	0.10	0.20	0.70	0.5774	0.855	0.6189	0.5292
	Rye		-	0.52	0.57	0.46	0.000	0.807	0.10	0.20	0.70	0.5651	0.737	0.5345	0.3939
	Barley	As bread	0.30	-	-	-	-	-	0.10	0.22	0.68		-	-	-
	Barley	Brewed	0.68	-	-	-	-	-	0.10	0.70	0.20		-	-	-
	Barley		-	2.04	2.61	2.04	0.020	0.766	0.10	0.55	0.35	0.2656	0.850	0.4000	0.3400
	Oats		-	1.06	1.48	1.22	0.600	0.329	0.10	0.44	0.46	0.1511	0.280	0.4263	0.1194
	Total		-	5.22	6.89	5.59	0.143	0.694				0.3663	0.701	0.4733	0.3318
1750	Wheat		-	-	-	-	-	-	-	-	-	-	0.855	0.6189	0.5292
	Rye		-	-	-	-	-	-	-	-	-	-	0.737	0.5345	0.3939
	Barley	As bread	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barley	Brewed	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barley		-	-	-	-	-	-	-	-	-	-	0.850	0.4000	0.3400
	Oats		-	-		-	-	-	-	-	-	-	0.280	0.4263	0.1194
	Total		-	-	-	-	-	-	-	-	-	-	0.627	0.4799	0.3009
1800	Wheat		-	2.44	4.66	4.12	0.020	0.867	0.10	0.20	0.70	0.6070	0.855	0.6189	0.5292
	Rye		-	0.06	0.11	0.10	0.000	0.886	0.10	0.20	0.70	0.6201	0.737	0.5345	0.3939
	Barley	As bread	0.20	-	-	-	-	-	0.10	0.22	0.68	-	-	-	-
	Barley	Brewed	0.78	-	-	-	-	-	0.10	0.70	0.20	-	-	-	-
	Barley		-	1.38	2.84	2.46	0.020	0.847	0.10	0.60	0.30	0.2523	0.850	0.4000	0.3400
	Oats		-	1.93	3.94	3.44	0.700	0.262	0.10	0.44	0.46	0.1204	0.280	0.4263	0.1194
	Total		-	5.81	11.55	10.11	0.252	0.656				0.3540	0.638	0.4930	0.3145
1830	Wheat		-	3.40	6.39	5.64	0.020	0.865	0.10	0.20	0.70	0.6057	-	-	-
	Rye		-	0.06	0.11	0.10	0.000	0.886	0.10	0.20	0.70	0.6201	-	-	-

	Barley	As bread	0.10	-	-	-	-	-	0.10	0.22	0.68	-	-	-	-
	Barley	Brewed	0.86	-	-	-	-	-	0.10	0.70	0.20	-	-	-	-
	Barley		-	2.00	4.36	3.80	0.040	0.837	0.10	0.65	0.25	0.2092	-	-	-
	Oats		-	1.60	3.44	3.02	0.800	0.176	0.10	0.44	0.46	0.0809	-	-	-
	Total		-	7.06	14.30	12.57	0.214	0.691	-	-	-	0.3587	-	-	-
1850	Wheat		-	-	-	-	-	-	-	-	-	-	0.855	0.6189	0.5292
	Rye		-	-	-	-	-	-	-	-	-	-	0.737	0.5345	0.3939
	Barley	As bread	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barley	Brewed	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barley		-	-	-	-	-	-	-	-	-	-	0.850	0.4000	0.3400
	Oats		-	-	-	-	-	-	-	-	-	-	0.280	0.4263	0.1194
	Total		-	-	-	-	-	-	-	-	-	-	0.651	0.4973	0.3236
1871	Wheat	-	-	3.32	8.57	7.80	0.020	0.893	0.10	0.20	0.70	0.6248	-	-	-
	Rye	-	-	0.06	0.11	0.10	0.000	0.886	0.10	0.20	0.70	0.6201	-	-	-
	Barley	As bread	0.00	-	-	-	-	-	0.10	0.22	0.68	-	-	-	-
	Barley	Brewed	0.95	-	-	-	-	-	0.10	0.70	0.20	-	-	-	-
	Barley	-	-	1.96	4.84	4.27	0.050	0.838	0.10	0.70	0.20	0.1677	-	-	-
	Oats	-	-	1.45	4.03	3.65	0.900	0.091	0.10	0.44	0.46	0.0417	-	-	-
	Total	-	-	6.79	17.55	15.83	0.230	0.693				0.3647	-	-	-

Notes. Overton and Campbell (1996: 294; 2006: 41) did not include estimates of the gross and net numbers of calories from rye in 1871. However, their estimates for the amount of land under cultivation were the same as for 1800 and 1830. Changes in the 'total' extraction rate for Floud *et al.* reflect changes in the proportion of land under cultivation for each crop and in the gross yields per crop. The 'total' figures for Floud *et al.*'s Estimate B would therefore be as follows: 1750: 0.2909; 1800: 0.3072; 1850: 0.3120.

Sources: Overton and Campbell 1996: 292-5; 2006: 37-44; Floud *et al.* 2011: 205-9.

Table 7. Meat and dairy products: Broadberry et al. *versus Floud* et al.

	Broadberry *et al.*					Floud *et al.*				
	Calories per unit	1700/09	1750/59	1800/09	1850/59	Calories per unit	1700	1750	1800	1850
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Milk (gallon)	3,185	25.58	59.33	52.56	76.52	3,256	-	87.23	52.34	90.14
Cheese (lb)	1,032	13.81	33.20	39.37	26.40	1,757	-	78.46	70.62	51.79
Butter (lb)	2,270	21.27	51.63	66.89	41.90	3,612	-	112.89	112.89	77.41
All dairy	-	60.66	144.16	158.82	144.83	-	230.75	278.58	235.84	219.33
Beef (lb)	1,035	16.91	23.70	35.77	31.93	-	-	-	-	-
Veal (lb)	681	1.93	2.60	3.76	3.08	-	-	-	-	-
Beef and veal (lb)		18.84	26.30	39.53	35.01	1,318	137.97	166.57	143.32	121.38
Mutton (lb)	1,039	101.96	111.28	130.17	99.28	1,472	75.86	141.53	137.90	105.32
Pork (lb)	1,003	25.50	34.93	50.82	44.51	-	-	-	-	-
Pork and ham (lb)	-	-	-	-	-	2,041	61.42	146.65	128.37	89.08
Lard	-	-	-	-	-	4,040	21.99	52.50	45.70	31.89
Others	-	-	-	-	-	1,215	9.65	-	-	-
Total meat and dairy	-	206.97	316.66	379.34	323.63	-	537.64	785.83	691.13	567.00

Notes. In column 1, the figure for veal is from Bennett and Pierce 1961: 116-7; all other figures are from Broadberry *et al.,* forthcoming, Table 8.5. In columns 2-5, figures for milk, cheese and butter are derived from Broadberry *et al.*, forthcoming: Table 8.6; all other figures have been calculated from the figures in Broadberry *et al.* 2011: Tables 7 and 23. The figures in the final row of columns 2-5 differ from Broadberry *et al.*'s published figures because they use information from a different source to calculate the number of calories derived from veal and because they combine data from Broadberry *et al.*'s two publications. The published totals are as follows: Broadberry *et al.* 2011: 1700/09: 236; 1750/59: 292; 1800/09: 379; 1850/59: 328; Broadberry *et al.*, forthcoming: 1700/09: 210; 1750/59: 319; 1800/09: 385; 1850/59: 328.

Sources: Col. 1: Broadberry *et al.*, forthcoming: Table 8.5; Bennett and Pierce 1961: 116-7; Cols. 2-5: Broadberry *et al.* 2011: Table 7; Broadberry *et al.*, forthcoming: Table 8.6; Cols. 6-10: Floud *et al.* 2011: Tables D5 and D5.

There appear to be two main reasons for these differences. In the first place, Broadberry *et al.* used much lower calorific values to estimate the amount of energy derived from pork, cheese and butter. As we can see from Table 7, much of the difference between their estimates of the number of calories derived from these sources and Floud *et al.*'s estimates can be attributed to this cause. The second source of variation is the amount of meat derived from cattle, but the ultimate cause of this difference is unclear. Broadberry *et al.* suggest that they derived their estimates of the numbers of animals from Allen (2005) and John (1989: 1042-6), but their figures are much closer to the latter (see Table 8). This may help to explain why their overall estimates are so much lower than the figures which Allen himself proposed (Appendix 1).

2.7. Imports and exports

Of the various authors whose work has been considered in this paper, only Overton and Campbell (1996: 45; 2006: 296, Allen (2005: 39), Broadberry *et al.* (2011: 59; forthcoming: Table 8.7) and Floud *et al.* (2011) framed their own estimates of the number of calories derived from imported foodstuffs. Meredith and Oxley (2014: 169-70) made no allowance for imports or exports in 1770, but used Floud *et al.*'s figures for 1700, 1800 and 1850. However, Floud *et al.* were the only authors who attempted to go beyond the production of estimates for arable, meat and dairy products, and only Floud *et al.* and Broadberry *et al.* provided much information about the sources of their figures. Broadberry *et al.* (forthcoming: section 8.2.1) derived their figures from those published by Mitchell (1988), whereas Floud *et al.* derived their figures for 1800 and 1850 from the Parliamentary Papers (see Floud *et al.* 2011: 212-19 for further details).

However, although this enabled them to supplement Mitchell's figures with imports of other cereals and pulses (including maize, rye, peas, beans, buckwheat, beer or bigg and malt) their calorie totals were lower. This may have been because they applied the same allowances for losses due to milling and distribution as they applied to domestic cereals.

Overall, Broadberry *et al.*'s estimates differ from those published by Floud *et al.* in two important respects (see Table 9). In the first place, they argued that the calorific value of imported grain products increased steadily from the 1750s onwards. Floud *et al.* argued that Britain was a net exporter of grain calories in 1700 and 1750, and – as we have already noted – they believed that the calorific value of imported grains in 1800 and 1850 was below the level suggested by Broadberry *et al.* for 1800/09 and 1850/59. The second major difference arises from the fact that Floud *et al.* also estimated the calorific value of other imported foods. Broadberry *et al.* (forthcoming: Table 8.10) acknowledged the importance of sugar and other imported items when they discussed the per capita consumption of imported luxury foodstuffs (including tobacco!) but failed to incorporate these figures in their estimation of food values.

3. Food availability in a high-wage economy?

Despite the similarity between Broadberry *et al.* and Floud *et al.*'s overall figures, there are also some important differences in the ways they have been constructed. By comparing these approaches, it would doubtless be possible to exchange some of the assumptions made by each set of authors in order to bring their final conclusions even closer together. However, they would still differ substantially from the 'high wage' estimates preferred by Allen (2005) and Muldrew (2011).

Table 8. Numbers of animals and their yields: Allen versus Broadberry et al.

	Allen 2005								Broadberry *et al.* 2011							
	Millions of animals				Gallons or pounds per animal				Numbers of non-working animals in England (millions)				English yields per animal			
	1700	1750	1800	1850	1700	1750	1800	1850	1700/09	1750/59	1800/09	1850/59	1700/09	1750/59	1800/09	1850/59
Cows	1.55	1.55	1.21	1.44	300	330	380	440	0.36	0.46	0.83	1.15	272.01	316.69	368.72	429.29
Calves/veal	1.55	1.55	1.21	1.44	39	45	75	105	0.36	0.46	0.83	1.15	67.12	76.84	87.96	100.69
Beef cattle	1.40	1.40	1.09	1.30	260	400	500	700	0.32	0.42	0.75	1.04	384.98	440.22	503.37	575.59
Total cattle	4.50	4.50	3.51	4.18	198	254	312	405	1.04	1.34	2.41	3.34	235.85	273.07	313.93	361.70
Sheep	16.60	16.60	20.00	26.70	30	52	60	70	15.40	14.86	19.82	22.62	46.39	52.53	59.49	67.36
Hoggs/swine	1.30	1.70	1.90	2.30	64	95	110	125	0.95	1.10	1.75	2.20	86.56	98.78	112.72	128.63

Notes. The notes to Broadberry *et al.*'s table also refer to estimates published by A.H. John (1989: 1042-6). He proposed the following figures for the numbers of different types of animal in 1770 and 1854: 1770: cows: 0.74 million; young cattle: 0.91 million; fatting cattle: 0.51 million; sheep: 22.19 million; swine: 1.71 million; 1854: milch cows: 1.38 million; calves: 0.71 million; other cattle: 1.34 million; sheep: 12.12 million; swine: 2.36 million. As with Allen's figures, these estimates refer to the whole of England and Wales.

Sources: John 1989: 1042-6; Allen 2005: 29, 33; Broadberry *et al.* 2011: 41-2.

Table 9. Calories from imported foodstuffs: Broadberry et al. *versus Floud* et al.

	Broadberry *et al.*			Floud *et al.*						
	Grain	Meat	Total	Cereals and pulses	Meat	Dairy	Fruit and nuts	Sugar	Wine and spirits	Total
1700 (1700/09)	0	0	0	-13	0	0	0	28	12	27
1750 (1750/59)	20	0	20	-168	0	0	0	72	11	-85
1800 (1800/09)	168	0	168	86	0	16	0	95	17	214
1850 (1850/59)	524	10	534	366	12	20	9	136	12	555

Notes: The figures attributed to Broadberry *et al.* for grain imports in 1800/09 and 1850/59 differ slightly from those published in 2011. Their earlier figures (Broadberry *et al.* 2011: 59) were as follows: 1800/09: grain imports: 166 calories; 1850/59: grain imports: 537 calories.

Sources : Broadberry *et al.* 2011 : 59 ; forthcoming : Table 8.7 ; Floud *et al.* 2011 : 159.

In view of this, it may be more profitable to compare both sets of estimates – and especially those of Floud *et al.* – with those published by the other authors. However, it is much easier to compare Floud *et al.*'s estimates with Muldrew's. This is partly because we have already used some of Allen's figures in the previous section but mainly because Muldrew provided a great deal more information about the foundations on which his figures were built.

Although Muldrew's overall figures were much higher than Floud *et al.*'s, they were actually based on a somewhat narrower range of comestibles. Muldrew's eighteenth-century consumers derived 29.9 calories from poultry (including chickens, turkeys, geese and ducks) and deer in 1700 and 42.1 calories in 1770, but they obtained nothing from either potatoes or fish. Using information from Devon in the mid-eighteenth century, he estimated that the average person derived 191.2 calories per day from cider in 1700, but nothing in 1770, and he did not include any calories from fruit sources in his final figures (Muldrew 2011: 154-7).

In order to compare Muldrew's estimates directly with those of Floud *et al.*, we can begin by identifying the areas of greatest agreement. Table 10 compares the figures used by the different authors to convert bushels into pounds and to estimate the energy derived from the same amounts of cereals and pulses. It shows that Floud *et al.* and Muldrew made very similar assumptions about the weight of each bushel and the calorific value of the main cereal crops. However, Muldrew attached a much higher value to the calorific value of beans and peas. If he had used the same conversion factor as Floud *et al.*, the estimated value of the number of calories derived from these sources would have fallen by 119.64 calories in 1700, 137.56 calories in 1770, and 111.16 calories per person per day in 1800.

Table 10. Pounds per bushel and calories per pound of cereals and pulses: Muldrew versus Floud et al.

	Pounds per bushel		Calories per pound	
	Floud *et al.*	Muldrew	Floud *et al.*	Muldrew
Wheat	57	56	1,520	1,431
Rye	55	56	1,520	1,508
Barley	48	48	1,632	1,650
Oats	38	38	1,824	1,805
Beans and Peas	56	56	480	1,290

Notes. The calorie figures differ from those published by Kelly and Ó Gráda (2012: 33 [Table A5]; 2013b: 3 [Appendix Table 2]). In his book, Muldrew published different figures for the number of calories per pound of each crop in the text and in Table 3.14 (Muldrew 2011: 140-9). The figures in Table 3.14 reflect the number of calories per pound *after* allowing for milling (so, for example, the number of calories per pound of wheat is given as 1,431 in the text and 1,324 calories in the table). Kelly and Ó Gráda's figures appear to have been derived from the figures in Muldrew's table. However, it is still not clear how they estimated the number of calories per ounce of oats.

Sources: Floud *et al.* 2011: 205-7; Muldrew 2011: 140-9; Kelly and Ó Gráda 2012: 33 [Table A5]; 2013b: 3 [Appendix Table 2].

As we have already seen, Floud *et al.* generated two different sets of figures for the average productivity of each crop, based on estimates derived from Chartres (1985) and Holderness (1989) in the first instance, and from Chartres, Holderness and Turner, Beckett and Afton (2001) in the second. The differences between the two sets of estimates were minimal in the case of barley, but the figures derived from Chartres and Holderness generated lower estimates for wheat in 1750 and rye in 1800, and for oats in both 1750 and 1800. On the other hand, they generated higher estimates for the productivity of beans and peas in both years. Muldrew's estimates were based more closely on the figures published by Turner, Beckett and Afton, and this is reflected in

Table 11. However, his figures for wheat in 1750 were closer to Floud *et al.*'s Estimate A than their Estimate B.

Table 11. Crop yields per acre: Muldrew versus Floud et al.

	Floud *et al.* 2011 (Estimate A)				Floud *et al.* 2011 (Estimate B)				Muldrew 2011			
	1700	1750	1770	1800	1700	1750	1770	1800	1700	1750	1770	1800
Wheat	16.0	18.0	19.4	21.5	16.0	22.0	21.6	21.1	17.0	19.1	20.0	20.5
Rye	17.0	18.0	21.2	26.0	17.0	18.0	20.2	23.4	15.0	20.0	22.0	25.5
Barley	23.0	25.0	27.0	30.0	23.0	24.8	26.6	29.2	20.0	27.1	30.0	28.0
Oats	24.0	28.0	30.8	35.0	24.0	36.7	37.0	37.4	22.0	33.4	38.0	38.0
Beans and Peas	20.0	28.0	28.0	28.0	20.0	21.8	21.9	22.0	17.0	19.1	20.0	23.5

Notes. In order to make the two sets of figures more directly comparable, we have interpolated between Floud *et al.*'s figures for 1750 and 1800 to generate a set of estimates for 1770, and between Muldrew's estimates for 1700 and 1770 to generate an estimate for 1750. Muldrew explained his allowances for seeding in his text, and these have been added to the figures in Table 3.14 of his study to generate the figures for *gross* yields in this table.

Sources: Floud *et al.* 2011: 205-9; Muldrew 2011: 140-9.

Disagreements over the calorific value of different crops and average yields per acre are much less important than the different authors' attempts to estimate the amount of land under cultivation and the conversion of total yields into edible foodstuffs. In order to estimate the total amount of land under cultivation, it is important to recognise that Muldrew's figures were only partially based on direct information. Although they were derived from Overton's (1996: 76) study, Muldrew estimated the total amount of land under cultivation in 1770 by interpolating between Overton's figures for 1700 and 1800 and then reallocated some of the land from barley to wheat in order to generate new figures for each crop (Muldrew 2011: 144, 148).

It may also be helpful to compare both sets of estimates with those published by other authors. Although Floud *et al.*'s figures for the amount of land devoted to wheat are generally towards the lower end of the range of published estimates, their estimate of the total amount of land under cultivation by cereals and pulses was closer to the centre (see Table 12). By contrast, Muldrew's figures suggest that the amount of land devoted to wheat in 1770 was 860,000 acres greater than the highest estimate for 1750, and his figure for 1800 was 130,000 acres greater than the next highest figure for the same year. Overall, he suggested that the amount of land devoted to all cereals and pulses in 1770 was 980,000 acres greater than the highest figure for 1750, and also greater than any of the other published estimates for 1800. His own figure for 1800 was nearly 1.2 million acres higher than the next published figure.

Muldrew's figures also raise three further questions. As we have already seen, Muldrew derived his figures for the total amount of land under cultivation from Overton's 1996 study. However, although Overton (1996: 76) argued that these figures applied to the whole of England and Wales, Muldrew (2011: 142-3) appears to have divided the total amount of food produced from this land among the population of England alone. The second problem is that Overton himself argued that these figures had been superseded by the work he published with Bruce Campbell in the same year (Overton and Campbell 1996: 282; 2006: 29). The third problem is that Muldrew also assumed that the total amount of land under cultivation grew at a consistent rate between 1700 and 1800, but this assumption is called into question by the figures which Overton published with Broadberry, Campbell, Klein and van Leeuwen (Broadberry *et al.* 2011: 36). As we can see from Table 13, these figures imply that the total amount of land devoted to the cultivation of cereals and pulses fell from 6.36 million acres in 1700 to 6.31 million acres in 1750. The amount of land associated with the cultivation of wheat fell, according to their calculations, from 1.99

million acres to 1.95, whereas Muldrew's calculations imply that it increased from 1.6 million acres to 2.57 million acres over the same period (see Table 12).

Table 12. Land under cultivation: Muldrew versus Floud et al. (millions of acres)

	Floud *et al.* 2011				Muldrew 2011			
	1700	1750	1770	1800	1700	1750	1770	1800
Wheat	1.361	1.800	2.080	2.500	1.600	2.569	2.957	3.104
Rye	0.890	0.500	0.420	0.300	0.520	0.602	0.635	0.097
Barley	1.901	1.400	1.360	1.300	2.040	1.935	1.892	1.843
Oats	1.223	2.000	2.000	2.000	1.060	1.228	2.522	2.522
Beans and Peas	1.300	1.000	1.080	1.000	0.980	1.135	1.198	1.067
Total	6.675	6.700	6.940	7.300	6.200	7.470	7.978	8.633

Notes. For the methods used to calculate values for Floud *et al.* in 1770 and Muldrew in 1750, see Table 10.

Sources: Floud *et al.* 2011: 205-7; Muldrew 2011: 142-3.

The second major cause of variation lies in the different assumptions which Floud *et al.* and Muldrew made when they converted the original crop into edible food. This can involve up to four separate calculations, taking account of the amount of grain used for seed, the proportion used as animal feed, processing, and distribution and wastage.

As we have already seen, Floud *et al.* (2011: 154) did not distinguish between the amount of grain used for seed and the amount fed to animals when they calculated the proportion of cereals and pulses entering gross product. However, they assumed implicitly that this figure was a constant proportion of the gross yield. By contrast, most other authors have assumed that the amount used as seed was a constant or even declining figure (see e.g. Overton and Campbell 1996: 292-5; 2006: 37-44; Allen 2005: 34), and that the proportion of each grain which was used as seed also declined as productivity increased. This explains why Muldrew's figures show that the proportion of each crop which remained after seeding increased over the course of the period (Table 14).

Table 14 also enables us to see the amount of grain which Muldrew allocated to animals. He assumed that the only crops fed to animals were oats, beans and peas. However, in contrast to Overton and Campbell (1996: 292-5; 2006: 37-44), he also assumed that the proportion of the oat crop which was fed to animals declined over the course of the century, with the result that a much higher proportion of the original crop remained available for human consumption. On the other hand, he also assumed that animals consumed a higher proportion of beans and peas.

One of the most important areas of disagreement concerns the amount of crop lost as a result of processing and wastage. Muldrew (2011: 146-7) assumed that none of the wheat, rye or beans and peas was lost as a result of processing and that, after making allowances for seeding, only 7.5 per cent of the remaining crop was lost as a result of wastage (primarily, as a result of mice and mould). He argued that a similar proportion of the barley and oat crop was also wasted, but that these losses were augmented by the effects of processing. He assumed that forty per cent of the raw oat crop was lost in the process of converting it to oatmeal, which brought his final figure much closer to Floud *et al.*'s, but that only twenty per cent of barley was lost in this way. In contrast to Overton and Campbell (1996: 292-5; 2006: 37-44), he also assumed that the proportion of barley brewed as beer remained constant over the course of the century, whereas they assumed that it increased.

Table 13. Land under cultivation, 1270-1871.

		Cereals and pulses						Other crops						Fallow/ unsown	Total
		Wheat	Rye	Barley	Oats	Beans/ Peas/ Pulses	**Total cereal and pulses**	Turnips	Potatoes	Clover etc.	Other crops	**Total other crops**	**Total sown area**		
1270	Broadberry et al. 2011: 36*	2.21	0.72	1.23	2.94	0.29	**7.39**	-	0.00	-	0.00	**0.00**	**7.39**	5.13	**12.52**
1300	Allen 2005: 28	2.70	0.60	1.50	2.70	0.60	**8.10**	0.00	0.00	0.00	-	**0.00**	**8.10**	4.00	**12.10**
1300	Broadberry et al. 2011: 36*	2.68	0.60	1.27	3.16	0.45	**8.16**	-	0.00	-	0.00	**0.00**	**8.16**	4.56	**12.72**
1300	Overton and Campbell 1996: Table 5*	2.28	0.47	1.24	2.24	0.53	**6.76**	0.00	0.00	0.00	0.00	**0.00**	**6.76**	3.77	**10.53**
1380	Broadberry et al. 2011: 36*	1.83	0.36	1.22	1.87	0.47	**5.75**	-	0.00	-	0.00	**0.00**	**5.75**	3.89	**9.64**
1380	Overton and Campbell 1996: Table 5*	1.49	0.16	1.26	1.10	0.69	**4.70**	0.00	0.00	0.00	0.00	**0.00**	**4.70**	3.22	**7.92**
1420	Broadberry et al. 2011: 36*	1.61	0.32	1.17	1.66	0.45	**5.21**	-	0.00	-	0.00	**0.00**	**5.21**	3.53	**8.74**
1450	Broadberry et al. 2011: 36*	1.53	0.31	1.15	1.59	0.44	**5.02**	-	0.00	-	0.00	**0.00**	**5.02**	3.41	**8.43**
1500	Allen 2005: 28	1.80	0.20	1.50	1.30	1.20	**6.00**	0.00	0.00	0.00	-	**0.00**	**6.00**	3.00	**9.00**
1500	Broadberry et al. 2011: 36*	1.58	0.37	1.19	1.56	0.47	**5.17**	-	0.00	-	0.10	**0.10**	**5.27**	3.24	**8.51**
1600	Broadberry et al. 2011: 36*	1.85	0.77	1.44	1.32	0.61	**5.99**	-	0.00	-	0.72	**0.72**	**6.71**	2.16	**8.87**
1600	Muldrew 2011: 143*	1.53	0.47	1.78	0.89	0.83	**5.50**	-	-	-	0.50	**0.50**	**6.00**	2.00	**8.00**
1600	Overton and Campbell 1996: Table 5*	1.56	0.47	1.78	0.89	0.83	**5.53**	0.00	0.00	0.00	0.70	**0.70**	**6.23**	2.00	**8.23**
1650	Broadberry et al. 2011: 36*	2.00	0.39	1.86	1.13	1.02	**6.40**	-	0.00	-	1.36	**1.36**	**7.76**	1.88	**9.64**
1650	Muldrew 2011: 143*	1.60	0.52	2.04	1.06	0.98	**6.20**	-	-	-	1.00	**1.00**	**7.20**	1.80	**9.00**
1695	Chartres 1985: 444	1.36	0.89	1.90	1.22	-	**5.38**	-	-	-	-	-	-	-	-
1700	Allen 2005: 28	1.40	0.90	1.90	1.20	1.30	**6.70**	0.40	0.10	0.50	-	**1.00**	**7.70**	3.30	**11.00**
1700	Broadberry et al. 2011: 36*	1.99	0.42	1.82	1.15	0.98	**6.36**	-	0.00	-	1.30	**1.30**	**7.66**	1.91	**9.57**
1700	Muldrew 2011: 143*	1.60	0.52	2.04	1.06	0.98	**6.20**	-	-	-	1.00	**1.00**	**7.20**	1.80	**9.00**
1700	Overton 1996: 76	-	-	-	-	-	-	-	-	-	-	-	**7.20**	1.80	**9.00**
1700	Overton and Campbell 1996: Table 5*	1.60	0.52	2.04	1.06	0.98	**6.20**	0.00	0.00	0.00	1.00	**1.00**	**7.20**	1.80	**9.00**
1750	Allen 2005: 28	2.10	0.50	1.70	1.40	1.30	**7.00**	0.75	0.20	0.75	-	**1.70**	**8.70**	2.50	**11.20**
1750	Broadberry et al. 2011: 36*	1.95	0.06	1.50	1.82	0.98	**6.31**	-	0.08	-	2.53	**2.61**	**8.92**	1.59	**10.51**
1750	Chartres 1985: 444	2.10	0.53	1.66	1.44	-	**5.73**	-	-	-	-	-	-	-	-
1750	Holderness 1985: 145	1.80	0.50	1.40	2.00	1.00	**6.70**	1.00	0.20	1.00	-	**2.20**	**8.90**	-	-
1770	Muldrew 2011: 143*	2.96	0.64	1.89	1.30	1.20	**7.98**	-	-	-	1.22	**1.22**	**9.20**	1.80	**11.00**
1770	Young 1771: 256-61 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-	**10.30**	-	**10.30**
1770	Young 1771: 256-61 (John 1989: 1045)	2.80	-	2.60	1.50	0.9	**7.80**	1.70	-	3.20	-	**4.90**	**12.70**	0.80	**13.50**
1800	Allen 2005: 28	2.50	0.30	1.30	2.00	1.20	**7.30**	1.30	0.30	1.20	-	**2.80**	**10.10**	1.50	**11.60**
1800	Broadberry et al. 2011: 36*	2.97	0.06	1.62	1.97	0.83	**7.45**	-	0.17	-	2.90	**3.07**	**10.52**	1.28	**11.80**
1800	Holderness 1985: 145	2.50	0.30	1.30	2.00	1.20	**7.30**	1.30	0.30	1.20	-	**2.80**	**10.10**	-	**10.10**
1800	Muldrew 2011: 143*	3.10	0.10	1.84	2.52	1.07	**8.63**	-	-	-	1.07	**1.07**	**9.70**	1.80	**11.50**
1800	Overton 1996: 76	-	-	-	-	-	-	-	-	-	-	-	**9.70**	1.80	**11.50**
1800	Overton and Campbell 1996: Table 5*	2.44	0.06	1.38	1.93	0.78	**6.59**	0.68	0.16	1.20	0.86	**2.90**	**9.49**	1.20	**10.69**

1801	Capper 1801 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-	**11.35**	-	-
1801	Turner 1981: 291-302 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-	**7.86**	-	-
1801	Turner 1981: 295-7 (Prince 1989: 41)	2.60	-	1.50	2.10	0.80	**7.00**	0.70	-	-	-	**0.70**	**7.70**	-	-
1808	Comber 1808 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-	**11.58**	-	-
1810	Holderness 1985: 145	2.90	0.10	1.30	2.10	1.20	**7.60**	1.60	0.40	1.70	-	**3.70**	**11.30**	-	-
1827	Parliamentary Papers 1827: Tables 359-61 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-	**11.14**	-	-
1830	Broadberry et al. 2011: 36*	2.08	0.06	1.82	1.39	0.63	**5.98**	-	0.26	-	4.46	**4.72**	**10.70**	1.30	**12.00**
1830	Overton and Campbell 1996: Table 5*	3.40	0.06	2.00	1.60	0.60	**7.66**	1.44	0.29	2.89	0.58	**5.20**	**12.86**	1.33	**14.19**
1836	Kain 1986: 460 (Prince 1989: 41)*	3.40	-	2.00	1.60	0.60	**7.60**	1.30	-	-	-	-	-	-	-
1836	Kain and Prince 1985: 104 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-	**15.09**	-	**15.09**
1850	Allen 2005: 28	3.60	0.10	1.50	2.00	1.00	**8.20**	2.00	0.40	2.20	-	**4.60**	**12.80**	1.80	**14.60**
1850	Holderness 1985: 145	3.60	0.10	1.50	2.00	1.00	**8.20**	2.00	0.40	2.20	-	**4.60**	**12.80**	-	-
1850	Overton 1996: 76	-	-	-	-	-	-	-	-	-	-	-	**14.30**	1.00	**15.30**
1851	Caird 1852: 522 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-	**13.67**	-	-
1854	Parliamentary Papers 1854, 495 (Prince 1989: 31)	-	-	-	-	-	-	-	-	-	-	-		-	**15.26**
1854	Parliamentary Papers 1854, 495 (Prince 1989: 41)	3.80	-	2.70	1.30	0.70	**8.50**	2.30	-	-	-	-	-	-	-
1854	Parliamentary Papers 1854, 495 (John1989: 1042)	3.81	0.02	2.67	1.30	0.70	**8.50**	2.27	0.19	2.82	0.54	**3.00**	**11.55**	0.90	**15.26**
1871	Broadberry et al. 2011: 36*	3.31	0.06	1.96	1.45	0.90	**7.68**	-	0.39	-	5.28	**5.67**	**13.35**	0.48	**13.83**
1871	Overton 1996: 76	-	-	-	-	-	-	-	-	-	-	-	**14.40**	0.50	**14.90**
1871	Overton and Campbell 1996: Table 5*	3.32	0.06	1.96	1.45	0.90	**7.69**	2.14	0.39	3.06	0.08	**5.67**	**13.36**	0.48	**13.84**

Notes: Floud *et al.*'s figures were derived from Chartres (for 1695/1700) and Holderness (1750-1850). For 1380, Overton and Campbell's figures sum to 7.92 acres (shown here) but their published figure was 7.98. They estimated the amount of land under cultivation by each crop in 1600 and 1700 by extrapolating their results for Cornwall, Hampshire, Kent, Lincolnshire, Norfolk, Suffolk and Worcestershire. Young's (1770) figure for the amount of fallow land (0.8 million acres) included 'other crops'. Kain's (1986) figures for 1836 and the Parliamentary figures for 1854 aggregate the amount of land under cultivation by wheat and and rye. Asterisked publications refer to England only; all other publications refer to England and Wales as a whole.

Sources: See Table.

Table 14. Calories from global crop production: Muldrew's figures, using Floud et al.*'s format*

		Millions of acres	Yields per acre (gross)	Gross output	Yields per acre (net of seed)	Proportion fed to livestock	% entering gross product	Millions of bushels as food	Lbs per bushel	Lbs of food	kCal per lb	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	Muldrew (published totals)
		(1)	(2)	(3)	(4A)	(4B)	(4C)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
								(3)*(4C)		(5)*(6)			(7)*(8)*(9)		(10)/(11)	
1700	Wheat	1.60000	17.0	27.2	14.5	0.0	0.853	23.2	56	1,299	1,431	0.9250	1,719,719	4,896,666	962.20	965
	Rye	0.52000	15.0	7.8	12.5	0.0	0.833	6.5	56	364	1,508	0.9250	507,744	4,896,666	284.09	285
	Barley	2.04000	20.0	40.8	16.0	0.0	0.800	32.6	48	1,567	1,650	0.7300	1,887,114	4,896,666	1,055.86	1,060
	Oats	1.06000	22.0	23.3	16.0	0.5	0.364	8.5	38	322	1,805	0.5550	322,812	4,896,666	180.62	181
	Beans & peas	0.98000	17.0	16.7	13.0	0.6	0.306	5.1	56	285	1,290	0.9250	340,525	4,896,666	190.53	191
	Total														2,673.28	2,682
1770	Wheat	2.95720	20.0	59.1	17.5	0.0	0.875	51.8	56	2,898	1,431	0.9250	3,836,084	6,405,166	1,640.83	1,646
	Rye	0.63544	22.0	14.0	19.5	0.0	0.886	12.4	56	694	1,508	0.9250	967,922	6,405,166	414.02	415
	Barley	1.89248	30.0	56.8	26.0	0.0	0.867	49.2	48	2,362	1,650	0.7300	2,844,806	6,405,166	1,216.83	1,222
	Oats	1.29532	38.0	49.2	32.0	0.3	0.603	29.7	38	1,127	1,805	0.5550	1,129,196	6,405,166	483.00	483
	Beans & peas	1.19756	20.0	24.0	16.0	0.6	0.320	7.7	56	429	1,290	0.9250	512,149	6,405,166	219.07	220
	Total														3,973.74	3,986
1800	Wheat	3.10400	20.5	63.6	18.0	0.0	0.878	55.9	56	3,129	1,431	0.9250	4,141,557	8,606,033	1,318.46	1,322
	Rye	0.09700	25.5	2.5	23.0	0.0	0.902	2.2	56	125	1,508	0.9250	174,273	8,606,033	55.48	56
	Barley	1.84300	28.0	51.6	24.0	0.0	0.857	44.2	48	2,123	1,650	0.7300	2,557,317	8,606,033	814.12	817
	Oats	2.52200	38.0	95.8	32.0	0.2	0.703	67.3	38	2,559	1,805	0.5550	2,563,226	8,606,033	816.00	816
	Beans & peas	1.06700	23.5	25.1	19.5	0.6	0.332	8.3	56	466	1,290	0.9250	556,133	8,606,033	177.04	177
	Total														3,181.11	3,188

Notes. Figures showing the gross yield per acre, proportions fed to livestock and allowances for processing and wastage have been derived from the text. All other figures are derived from Table 3.14 of Muldrew's study. The figures in column 12 differ from the published figures in column 13 as a result of rounding.

Source: Muldrew 2011: 140-9.

Muldrew also reached different conclusions about the number of calories derived from meat and, especially, dairy products. Although he estimated that the calorific value of the meat derived from cattle, sheep and pigs was generally lower than Floud *et al.*, he also assumed that the number of animals was much larger. However, in comparison with the estimated value of the food consumed from other sources, the differences were not very large. If we bear in mind that our figures for Muldrew in 1750 and for Floud *et al.* in 1770 have been interpolated from other data, then the information in Table 15 implies that Muldrew's consumers derived substantially more calories from meat in 1700 and 1770, but similar amounts in 1750 and 1800.

These differences are less marked, and less systematic, than the differences in the numbers of calories derived from dairy products. Floud *et al.* derived their estimates of the number of calories obtained from milk, butter and cheese in 1750, 1800 and 1850 from Holderness (1989: 170) and estimated the number of dairy calories in 1700 from the ratio of meat products to dairy products in 1750. Muldrew estimated the total number of milk cows in 1700 using information from Gregory King (1696) and then assumed that the number did not change for the rest of the century. However, he did assume that the average yield per cow increased by 25 per cent between 1700 and 1770. He did not attempt to distinguish between calories consumed as milk and calories consumed as cheese or butter, but he did assume that 20 per cent of all calories were 'lost' in the form of animal feed.

Table 15. Meat consumption: Muldrew versus Floud et al.

1695 (1700)										
	Muldrew 2011					Floud et al. 2011				
	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)
Beef and veal (includes cattle and calves)	280,000,000	4,896,666	0.1567	1,000	156.7	208,000,000	5,444,426	0.1047	1,318	137.98
Sheep	200,000,000	4,896,666	0.1119	1,000	111.9	102,400,000	5,444,426	0.0515	1,472	75.86
Swine (includes pork, ham and lard)	200,000,000	4,896,666	0.1119	1,114	124.7	70,638,750	5,444,426	0.0355	2,348	83.46
Others (includes chickens, turkeys, geese, ducks and deer)	50,400,000	4,896,666	0.0282	1,026	28.9	27,890,000	5,444,426	0.0140	687	9.65
Total	1,010,400,000	4,896,666	0.4087	-	422.1	47,020,000	5,444,426	0.0237	-	306.94
1750										
	Muldrew 2011: 142-3 (interpolated)					Floud et al. 2011: 210-11				
	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)
Beef and veal (includes cattle and calves)	367,857,143	5,974,166	0.1679	1,071	179	285,600,000	6,192,091	0.1264	1,318	166.58
Sheep	381,600,000	5,974,166	0.1708	1,071	185	217,280,000	6,192,091	0.0961	1,472	141.53
Swine (includes pork, ham and lard)	242,857,143	5,974,166	0.1114	1,185	132	191,835,000	6,192,091	0.0849	2,348	199.27
Others (includes chickens, turkeys, geese, ducks and deer)	84,114,286	5,974,166	0.0379	293	38	-	6,192,091	-	687	0.00
Total	1,444,285,714	5,974,166	0.4879	0	534	47,020,000	6,192,091	-	-	507.38
1770										
	Muldrew 2011					Floud et al. 2011 (interpolated)				

	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)
Beef and veal (includes cattle and calves)	403,000,000	6,405,166	0.1724	1,100.0	187.7	316,960,000	7,404,583	0.1191	1,318	156.96
Sheep	454,240,000	6,405,166	0.1943	1,100.0	213.7	255,808,000	7,404,583	0.0949	1,472	139.77
Swine (includes pork, ham and lard)	260,000,000	6,405,166	0.1112	1,214.0	135.0	214,590,500	7,404,583	0.0805	2,348	188.95
Others (includes chickens, turkeys, geese, ducks and deer)	97,600,000	6,405,166	0.0417	-	41.9	0	7,404,583	-	687	0.00
Total	1,617,840,000	6,405,166	0.5196	-	578.3	28,212,000	3,715,255	-	0	485.68
					1800					
			Muldrew 2011					Floud et al. 2011		
	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)	Total weight of consumption (lbs)	Population	Pounds per person per day (calculated)	Calories per pound	Calories per day (calculated)
Beef and veal (includes cattle and calves)	-	-	-	-	-	364,000,000	9,223,320	0.1081	1,318	142.53
Sheep	-	-	-	-	-	313,600,000	9,223,320	0.0932	1,472	137.14
Swine (includes pork, ham and lard)	-	-	-	-	-	248,723,750	9,223,320	0.0739	2,348	173.46
Others (includes chickens, turkeys, geese, ducks and deer)	-	-	-	-	-	-	9,223,320	-	687	0.00
Total	-	-	-	-	428.0	-	-	-	-	453.13

Notes. Figures may differ slightly from published figures as a result of rounding.

Sources: Muldrew 2011: 142-3, 154-6; Floud *et al.* 2011 : 201-11.

It is difficult to compare the two sets of figures directly because Floud *et al.* only offered detailed breakdowns of their figures for 1750, 1800 and 1850, and Muldrew only provided detailed figures for 1700 and 1770, although we can infer the nature of his calculations for 1800 from this. However, Table 16 suggests that the two sets of figures differ mainly because of assumptions about the number of animals producing dairy products. Although King (1696: 54) estimated the overall number of 'beeves, sterks and calves' as 4.5 million, he did not attempt to break the figures down further, and Muldrew's suggestion of 1.1 million milk cows must therefore be regarded as conjecture. Both King's figures and Muldrew's can also be contrasted with the figures suggested by Arthur Young in 1771 and by the Poor Law Inspectors in 1854. Young (1771: 256-61) estimated that there were 741,532 milk cows in the whole of England and Wales in 1770, and A.H. John's (1989: 1044) calculations suggest that this figure had only risen to 1.38 million more than eighty years later.

Table 16. Calories from dairy products: Muldrew versus Floud et al.

		Floud et al.			Muldrew		
	Units	1750	1800	1850	1700	1770	1800
Cows producing milk (millions)		0.015	-	0.150	-	-	-
Cow producing butter and flet cheese (millions)		0.500	-	0.700	-	-	-
Cows producing cheese (millions)		0.250	-	0.350	-	-	-
Total dairy cows (millions)		0.765	-	1.200	1.100	1.100	1.100
Yield per cow (milk)	gallons	600	-	600	300	400	400
Yield per cow (butter)	lbs	140	-	200	-	-	-
Yield per cow (cheese)	lbs	336	-	448	-	-	-
Yield per cow (by-products, all cows)	gallons (millions)	67	-	76	-	-	-
Total yield (fresh milk)	gallons (millions)	9	-	90	-	-	-
Total yield (milk by-products)	gallons (millions)	51.37	-	90.62	-	-	-
Total yield (milk and milk by-products)	gallons (millions)	60.37	54	180.62	-	-	-
Total yield (butter)	lbs (millions)	70	74	140	-	-	-
Total yield (cheese)	lbs (millions)	84	-	157	-	-	-
Total yield (flet cheese)	lbs (millions)	16	-	34	-	-	-
Total yield (cheese and flet cheese)	lbs (millions)	99.68	135	190.40	-	-	-
Population (millions)		6.192	9.223	17.926	4.897	6.405	8.606
Yield per head per day (fresh milk)	fluid ounces	0.64	-	2.20	-	-	-
Yield per head per day (milk by-products)	ounces	3.64	-	2.22	-	-	-
Yield per head per day (milk and milk by-products)		-	2.57	-	-	-	-
Yield per head per day (butter)	ounces	0.50	0.50	0.34	-	-	-
Yield per head per day (cheese)	ounces	0.59	-	0.38	-	-	-
Yield per head per day (flet cheese)	ounces	0.11	-	0.08	-	-	-
Yield per head day (cheese and flet cheese)	ounces	-	0.64	-	-	-	-
Calories per gallon of milk		3,256	3,256	3,256	3,200	3,200	3,200
Calories per pound of butter		3,612	3,612	3,612	-	-	-
Calories per pound of cheese (including flet cheese)		1,758	1,758	1,758	-	-	-
Calories from milk and milk by-products (million)		196,574	176,165	588,114	-	-	-
Calories from butter (million)		252,874	38,005	505,747	-	-	-
Calories from cheese (million)		175,198	237,736	334,647	-	-	-
Total calories (millions)		624,645	451,905	1,428,508	1,056,000	1,408,000	1,408,000
Calories per cow		816,530	-	1,190,423	960,000	1,280,000	1,280,000
% dairy products fed to animals		-	-	-	0.2	0.2	0.2
Calories per person per day (milk and milk by-products)		86.98	52.33	89.87	-	-	-
Calories per person per day (butter)		111.89	112.89	77.29	-	-	-
Calories per person per day (cheese and flet cheese)		77.52	70.62	51.14	-	-	-
Calories per person per day		276.38	235.84	218.30	472.67	481.80	358.59

Notes. Figures may differ slightly from published figures as a result of rounding.

Sources: Muldrew 2011: 142-3, 154-6, 253; Holderness 1989: 170 ; Floud *et al.* 2011: 201-11.

4. The search for compromise

The number and variety of the estimates offered by different authors has encouraged others to enter the field. Kelly and Ó Gráda have contrasted Broadberry *et al.*'s estimates with Muldrew's and suggested alternatives to both. However, some of their revisions are quite approximate and they still leave a large gap between the two series (Kelly and Ó Gráda 2012: 20 [Table 4]; 2013b: 3 [Appendix Table 3]; see also Appendix 1 below). Meredith and Oxley's (2014) project was more ambitious. They contrasted Muldrew's estimates with those of Floud *et al.* and also examined the effect of applying the different authors' assumptions to each other's data. This enabled them to recalculate Muldrew's figures by using Floud *et al.*'s assumptions about seeding, animal consumption, processing and wastage, and adding the resulting estimates to Muldrew's own figures for the number of calories obtained from meat and dairy products. They then combined these figures with Floud *et al.*'s data for imports and exports in 1700 and 1800 to produce a new series of total calories available per person per day net of trade, and used Floud *et al.*'s data for 1850 and 1909/13 to extend this series to the start of the First World War.

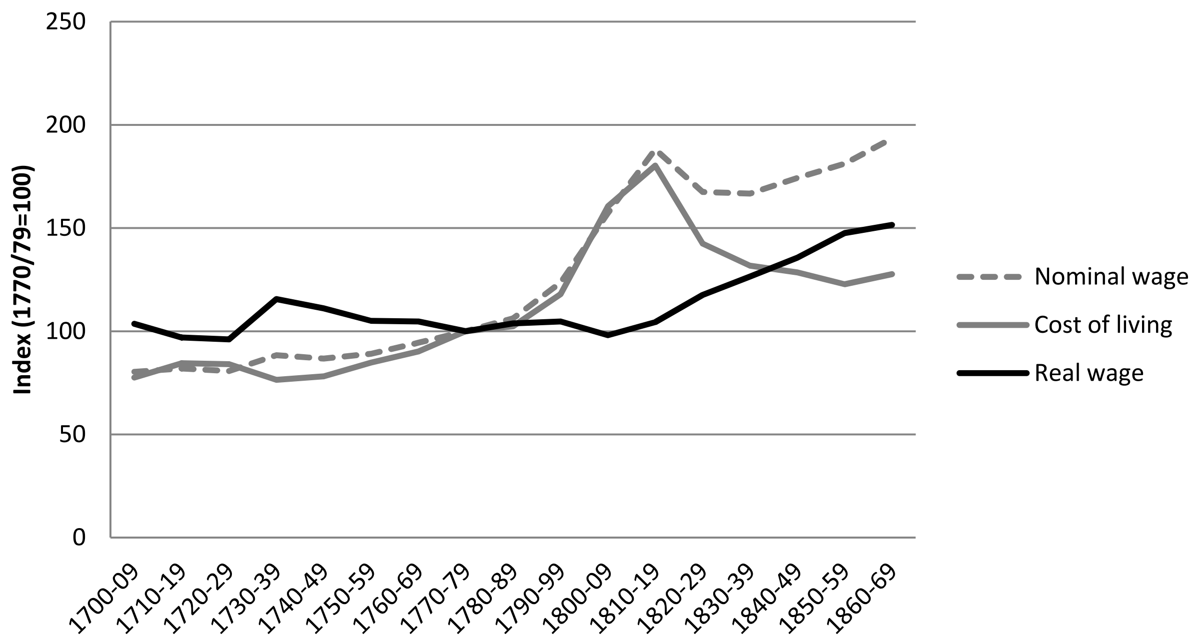
Although this strategy helps to modify some of Muldrew's original claims, it also raises new questions of its own. As we have already seen, there are some minor differences between the figures which Muldrew and Floud *et al.* used to convert bushels into pounds and to estimate the calorific value of different cereals, and a more serious difference between the figures they used to calculate the calorific value of beans and peas. They also used different values to calculate the number of calories obtained from meat and dairy products. Although these differences are not particularly dramatic, they do create inconsistencies when seeking to create a single series which uses Muldrew's values to estimate the number of calories derived from domestic food products between 1700 and 1800, and Floud *et al.*'s values to calculate the calorific value of domestically-produced food between 1850 and 1909/13, and the calorific value of imported foods over the period as a whole.

Meredith and Oxley's paper also raises some important questions about the overall trajectory of domestic agriculture during the eighteenth and nineteenth centuries. As we have already seen, Muldrew did not attempt to extend his series beyond 1800, and this meant that he was able to avoid a direct contrast between his estimates and those of nineteenth-century observers. However, by combining his figures on the amount of land under cultivation and the number of cattle in the eighteenth century with Floud *et al.*'s figures for the nineteenth century, Meredith and Oxley are forced into the position of not only accepting his eighteenth-century figures, but also accepting that the pace of change during the first half of the nineteenth century was much lower than other accounts might suggest. It then becomes necessary to explain, not only why increases in domestic agricultural production were so marked before 1800, but also why the pace of change was so much slower in the fifty years which followed.

Meredith and Oxley have also sought to reinforce their revised food estimates by comparing them with information on prices and stature. They argue that 'when nutrition was improving over the eighteenth century, prices were low. When per capita output dropped, food prices escalated, exacerbated by war expenditure. When war ended, prices stabilised, but at a higher level than earlier, squeezing family incomes at a time when families had more mouths than ever before' (Meredith and Oxley 2014: 184). However, while this may be true, it is also important to take account of changing wage levels. When wages and prices are combined, the case for nutritional pessimism becomes less convincing.

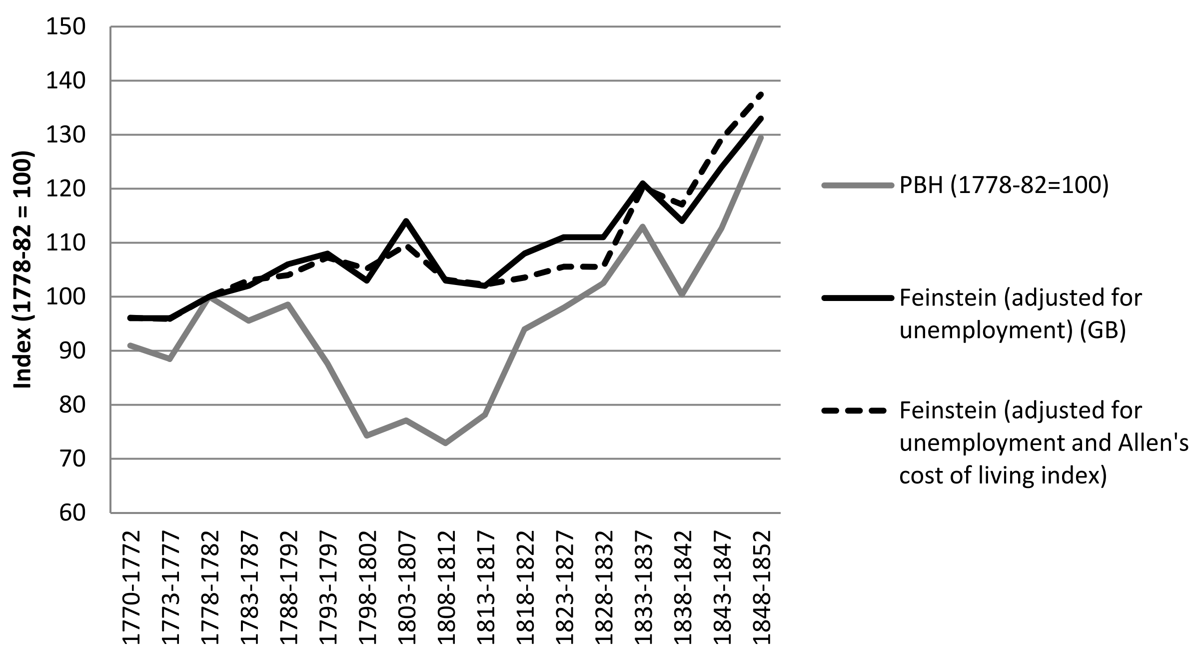
We can explore this question in more detail by comparing three sets of price and wage estimates. Figure 2 is derived from Gregory Clark's (2007: Table 4) calculations, showing changes in farm workers' wages and the cost of living between 1700 and 1849. It shows that prices did indeed rise sharply from the 1780s onwards, but so did wages, and the increase in wages appears to have outstripped prices from the early-1800s. Figure 3 compares Phelps Brown and Hopkins' classic account of real wages in the country as a whole with the more recent series published by Charles Feinstein (1998) and Robert Allen (2007). In contrast to the earlier work, both Feinstein and Allen find evidence of a slow improvement in purchasing power between 1770 and 1800, followed by a period of more rapid improvement beginning in either the 1820s or 1830s.

Figure 2. Farm workers' wages, 1700/09-1860/69



Source: Clark 2007: 130-4.

Figure 3. Real wages 1770/2-1848/52



Sources: Wrigley and Schofield 1981: 642-4; Feinstein 1998: 648; Allen 2007: 36.

Meredith and Oxley have also compared changes in food availability with average male stature. As they rightly suggest, 'the dimensions of the human body – its height, weight, body mass, waist-hip ratio – are clues to the nutritional experience of individuals' (Meredith and Oxley 2014: 184), although it is important to emphasise that height itself measures the net impact of diet on human growth after taking account of the demands imposed by physical activity and the disease environment. Their argument that changes in average stature reflect increases in nutritional hardship is based on four anthropometric series. Three of these are drawn from the measurements of convicts and prisoners, and the fourth from military data.

Meredith and Oxley obtained data on the heights of men who were imprisoned in Bedford and Wandsworth (London), and compared these with the heights of convicts who were transported from Britain to New South Wales and Van Diemen's Land. The oldest men in the Wandsworth dataset were only born during the second decade of the nineteenth century and therefore provide limited information about trends in height before that period, and neither the Bedford prisoners nor the Australian convicts provide unequivocal evidence of declines in stature before the 1820s (see Meredith and Oxley 2014: 188-91). However, Meredith and Oxley also revisited Floud, Wachter and Gregory's (1990) military data. Their reworking of these statistics provided much sharper evidence of a decline in stature from the birth cohorts of the 1770s onwards.

The estimation of the height of eighteenth-century military recruits has long been the subject of controversy. A number of authors, including John Komlos (Komlos 1993a; 1993b; Komlos and Küchenhoff 2012) and Francesco Cinnirella (2008), have argued that the data provide evidence of declines in stature of up to five inches (12.7 cm) between the birth cohorts of the 1740s and the 1850s. By contrast, Floud, Wachter and Gregory (1990: 134-49) argued that there was a slow and irregular improvement in the average height of successive cohorts of British males born between the 1740s and the 1820s.

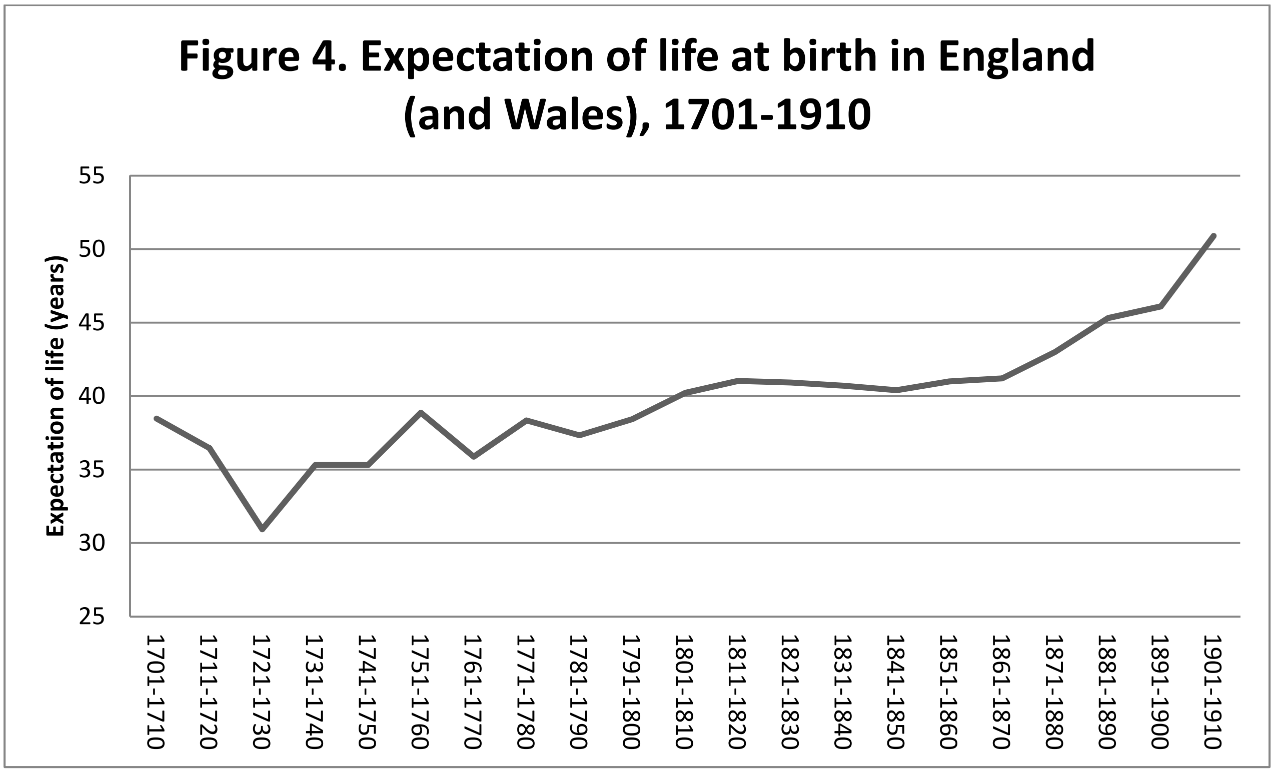
One of the main areas of contention has been the question of whether, and at what point, it might be appropriate to pool the results obtained from the analysis of the Army and the Marines. Komlos (1993a: 132) and Cinnirella (2008: 328) argued that the two services recruited men from different sections of the population and should therefore be treated separately. Floud, Wachter and Gregory (1990: 139-50; 1993: 147-8) disputed this, arguing that recruits to both the Army and the Marines were drawn from the same section of the population (the male working class) and that the allocation of recruits to different services was simply a matter of military convenience.

Meredith and Oxley agreed with Floud, Wachter and Gregory on this point. However, they also noted that the Army and the Marines had different height profiles, and they argued that Floud and his coauthors misrepresented the overall trend by overweighting the proportion of Marines in the overall sample. They then recalculated Floud, Wachter and Gregory's results after reweighting the data to take account of the actual proportions of Army and Marine recruits and excluding recruits from outside England and Wales, and this formed the basis of their revised estimates (Meredith and Oxley 2014: 188; see also Floud, Wachter and Gregory 1993: 147-8).

Meredith and Oxley's estimates represent an important contribution to anthropometric history, but their decision to reweight the data according to the proportions of Army and Marine recruits is surely open to question. They argued that pooling the data without reweighting would be analogous to 'mix[ing] up disproportionate shares of males and females and consider[ing] the outcome representative' (Meredith and Oxley 2014: 187-8). However, the reason why it would be inappropriate to mix up disproportionate (and varying) shares of males and females is because the distributions of heights in the underlying populations are different. If one accepts the view that both the Army recruits and the Marine recruits were drawn from the *same* population, then it is appropriate to combine them, providing one makes appropriate allowances for variations in the height standards used to select them (see Floud, Wachter and Gregory 1990: 111-4; 1993: 147-8).

Meredith and Oxley sought to allow for the effects of truncation by controlling for the size of the Army and Marine establishments in the year of recruitment. Even though this did not allow them to infer the actual heights of the underlying population, they argued that it was sufficient to enable them to estimate overall trends (Meredith and Oxley 2014: 188). However, other contributors to these debates have been much less reticent. Indeed, many of the main disagreements between Komlos and Cinnirella, and Floud and his coauthors, have concerned the identification and development of the most appropriate procedures for making inferences about the heights of underlying populations from truncated samples, and this remains a hotly-contested issue (see e.g. Komlos 2004; Floud *et al.* 2011: 65-7, 137).

In the absence of any unequivocal resolution of these debates, it may be more appropriate, at this juncture, to compare the latest height series with changes in mortality. Although there has been some debate over the course of mortality change during the first half of the eighteenth century (Razzell 1994: 185-95; 1998: 485-500), most observers seem content to accept Wrigley and Schofield's broad depiction of changes in life expectancy during the second half of the eighteenth century and the first half of the nineteenth century (see e.g. Hinde 2003: 184, 194). However, as we can see from Figure 4, these data provide relatively little evidence of any clear decline in life expectancy before the second quarter of the nineteenth century. If nutritional standards were falling as sharply as Meredith and Oxley suggest, there is little evidence that this had any effect on mortality.



Source: Floud *et al.* 2011: 146.

5. Conclusions

As this paper has demonstrated, there is a sizable gap between the conclusions which different authors have reached regarding the amount of food which was available for human consumption in England, or England and Wales, between *circa* 1700 and 1850. Both Broadberry *et al.* (2011; forthcoming) and Floud *et al.* (2011) argued that nutritional levels were generally quite low throughout the eighteenth and earlynineteenth centuries, although Floud *et al.*'s figures were more generous, and they saw more evidence of improvement over the period as a whole. Both Allen (2005) and Muldrew (2011) reached much more optimistic conclusions about the amount of food available before the mid- to late-eighteenth century, although Allen believed that food supplies declined sharply after that point. Meredith and Oxley's (2014) conclusions imply that the amount of food was somewhat lower than either Allen or Muldrew suggested, but they still see evidence of a substantial decline between the late-eighteenth and mid-nineteenth centuries.

These disparities reflect differences in both assumptions and methods. As Meredith and Oxley (2014: 173) have pointed out, Muldrew and Floud *et al.* used similar methods but reached very divergent conclusions. Broadberry *et al.* approached the subject in a rather different way to Floud and his coauthors and there are disagreements, but their results are broadly similar (at least in terms of levels, if not trajectory). The main reasons for the disparity between Muldrew's series and those of other authors lie in the assumptions he makes about the amount of land under cultivation, especially towards the end of the eighteenth century; the number of animals producing food for human consumption; and the amount of food lost during the production process. Many of these assumptions seem highly optimistic when compared with the conclusions reached by other authors, and this suggests that the truth is likely to lie somewhat closer to Floud *et al.* and Broadberry *et al.*, even if further revision of their estimates may still be necessary.

Although there is a broad similarity between Floud *et al.*'s results and those of Broadberry *et al.*, there are also differences. As we have seen, Floud *et al.* have already presented two different sets of estimates, reflecting different assumptions about arable productivity. The corrected version of Estimate A suggests that there was a slow but relatively consistent improvement in food availability between 1700 and 1850, whereas the corrected version of Estimate B suggests that availability declined between 1750 and 1800. Broadberry *et al.*'s figures are more consistent with the latter view but this conclusion can also be questioned. If we were to apply Floud *et al.*'s assessment of the number of calories supplied by imported foods to Broadberry *et al.*'s domestic figures, the overall pattern would be much closer to the corrected version of Estimate A (see Appendix 1).

In the meantime, it is also important to consider what these figures might say about the overall level of nutritional adequacy. As Floud *et al.* (2011: 41, 77-8, 129-30, 162) pointed out, the nutritional adequacy of a diet depends not only on its size but also its composition (and the environment in which it is consumed). Eric Schneider (2013) has taken this argument further by applying modern theories about the 'digestibility' of different foods to Floud *et al.*'s corrected data. Although his findings do little to alter the overall trajectory of nutritional change, they provide further grounds for thinking that the nutritional lot of eighteenth and nineteenth century consumers left much to be desired.

Appendix 1.

Year/s	Author/s	Domestic calories: Cereals, pulses and vegetables	Meat and dairy products	Other foods	Total	Imported calories: Cereals, pulses and vegetables	Meat and dairy products	Other foods	Total	Total: Cereals, pulses and vegetables	Meat and dairy products	Other foods	Total
1270/79	Broadberry et al., forthcoming	1,786	117	300	2,203	0	0	0	0	1,786	117	300	2,203
1300	Allen 2005	1,502	289	0	1,791	0	0	0	0	1,502	289	0	1,791
1300	Overton and Campbell 1996	1,446-1,626	n/a	n/a	n/a	0	n/a	n/a	n/a	1,446-1,626	n/a	n/a	n/a
1300/09	Broadberry et al., forthcoming	1,625	131	300	2,056	0	0	0	0	1,625	131	300	2,056
1310/19	Broadberry et al., forthcoming	1,576	122	300	1,998	0	0	0	0	1,576	122	300	1,998
1380	Overton and Campbell 1996	1,669-1,500	n/a	n/a	n/a	0	n/a	n/a	n/a	1,669-1,500	n/a	n/a	n/a
1380/89	Broadberry et al., forthcoming	2,076	191	200	2,467	0	0	0	0	2,076	191	200	2,467
1420/29	Broadberry et al., forthcoming	1,716	230	200	2,146	0	0	0	0	1,716	230	200	2,146
1450/59	Broadberry et al., forthcoming	1,712	264	200	2,176	0	0	0	0	1,712	264	200	2,176
1500	Allen 2005	2,733	664	0	3,397	0	0	0	0	2,733	664	0	3,397
1600	Muldrew 2011	1,968	1,094	0	3,062	0	0	0	0	1,968	1,094	0	3,062
1600	Overton and Campbell 1996	1,230	n/a	n/a	n/a	0	n/a	n/a	n/a	1,230	n/a	n/a	n/a
1600/09	Broadberry et al., forthcoming	1,698	206	200	2,104	0	0	0	0	1,698	206	200	2,104
1650/59	Broadberry et al., forthcoming	1,576	169	200	1,945	0	0	0	0	1,576	169	200	1,945
1700	Allen 2005	2,624	616	0	3,240	-23	38	0	15	2,601	654	0	3,255
1700	Floud et al. 2011 (Estimates A and B)	1,631	538	34	2,203	-13	0	40	27	1,618	538	74	2,230
1700	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2,095
1700	Meredith and Oxley 2014	1,633	897	0	2,530	-13	0	40	27	1,620	897	40	2,557
1700	Muldrew 2011	2,682	897	0	3,579	0	0	0	0	2,682	897	0	3,579
1700	Overton and Campbell 1996	3,014	n/a	n/a	n/a	-60	n/a	n/a	n/a	2,954	n/a	n/a	n/a
1700/09	Broadberry et al., forthcoming	1,777	210	200	2,187	0	0	0	0	1,777	210	200	2,187
1750	Allen 2005	3,157	752	0	3,909	-195	89	0	-106	2,962	841	0	3,803
1750	Floud et al. 2011 (Estimate A; with correction)	1,593	786	34	2,413	-168	0	83	-85	1,425	786	117	2,328
1750	Floud et al. 2011 (Estimate B; with correction)	1,781	786	34	2,601	-168	0	83	-85	1,613	786	117	2,516
1750	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2,168
1750	Kelly and Ó Gráda 2012	2,079-2,114	519-569	30	2,628-2,813	0	0	90	90	2,079-2,114	519-569	120	2,718-2,903
1750	Kelly and Ó Gráda 2013b	2,024-2,054	733	47	2,804-2,844	0	20-25	90	110-115	2,024-2,054	753-758	137	2,914-2,949
1750/59	Broadberry et al., forthcoming	1,734	319	200	2,253	20	0	0	20	1,754	319	200	2,273
1770	Kelly and Ó Gráda 2012	2,785	1,062	0	3,847	0	0	90	90	2,785	1,062	90	3,937
1770	Kelly and Ó Gráda 2013b	2,370	1,062	0	3,432	0	20-25	90	110-115	2,370	1,082-1,087	90	3,542-3,547
1770	Meredith and Oxley 2014	2,209	1,062	0	3,271	0	0	0	0	2,209	1,062	0	3,271
1770	Muldrew 2011	3,985	1,062	0	5,047	0	0	0	0	3,985	1,062	0	5,047
1800	Allen 2005	2,018	532	0	2,550	230	158	0	388	2,248	690	0	2,938
1800	Floud et al. (Estimate A)	1,532	692	34	2,258	86	16	112	214	1,618	708	146	2,472
1800	Floud et al. (Estimate B)	1,499	692	34	2,225	86	16	112	214	1,585	708	146	2,439

1800	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2,237
1800	Kelly and Ó Gráda 2012 (Estimate A)	2,269-2,569	788	0	3,057-3,357	0	0	110	110	2,269-2,569	788	110	3,167-3467
1800	Kelly and Ó Gráda 2012 (Estimate B)	1,556-1,596	585-635	200	2,341-2,431	168	0	110	278	1,724-1,764	695-745	250-260	2,619-2,709
1800	Kelly and Ó Gráda 2013b (Estimate A)	2,019	692	60	2,771	0	60-75	110	170-185	2,019	752-767	170	2,941-2,956
1800	Kelly and Ó Gráda 2013b (Estimate B)	1,576	735	100	2,365-2,395	168	60-75	110	338-353	1,744-1,774	749-764	210	2,749-2,794
1800	Meredith and Oxley 2014	1,618	788	0	2,406	86	16	112	214	1,704	804	112	2,620
1800	Muldrew 2011	3,189	788	0	3,977	0	0	0	0	3,189	788	0	3,977
1800	Overton and Campbell 1996	1,518	n/a	n/a	n/a	90	n/a	n/a	n/a	1,608	n/a	n/a	n/a
1800/09	Broadberry et al., forthcoming	1,436	385	200	2,021	168	0	0	168	1,604	385	200	2,189
1830	Overton and Campbell 1996	1,298	n/a	n/a	n/a	1,977	n/a	n/a	n/a	3,275	n/a	n/a	n/a
1830/39	Broadberry et al., forthcoming	1,300	311	200	1,811	160	0	0	160	1,460	311	200	1,971
1840/49	Broadberry et al., forthcoming	1,359	308	200	1,867	309	6	0	315	1,668	314	200	2,182
1850	Allen 2005	1,559	411	0	1,970	460	95	0	555	2,019	506	0	2,525
1850	Floud et al. 2011 (Estimate A)	1,349	567	34	1,950	366	32	157	555	1,715	599	191	2,505
1850	Floud et al. 2011 (Estimate B)/Meredith and Oxley 2013	1,389	567	34	1,990	366	32	157	555	1,755	599	191	2,545
1850	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2,362
1850/59	Broadberry et al., forthcoming	1,073	328	200	1,601	524	10	0	534	1,597	338	200	2,135
1861/70	Broadberry et al., forthcoming	1,035	320	200	1,555	930	22	0	952	1,965	342	200	2,507
1871	Overton and Campbell 1996	1,060	n/a	n/a	n/a	736	n/a	n/a	n/a	1,796	n/a	n/a	n/a
1909-13	Floud et al. 2011/Meredith and Oxley 2014	425	611	209	1,245	832	428	472	1,732	1,256	1,039	681	2,977
1909-13	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2,857
1954/55	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3,231
1961	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3,170
1965	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3,304
1989	Fogel 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3,149

Notes: The figures attributed to Kelly and Ó Gráda are derived from the adjustments they proposed to the estimates published by Muldrew (2011) and Broadberry *et al.* (2011). In relation to their estimates for 1800, Estimate A is reflects their amendments to Muldrew's figures and Estimate B reflects their amendments to Broadberry *et al.*'s figures. When Kelly and Ó Gráda first compared their figures with those published by Broadberry *et al.* (Kelly and Ó Gráda 2012: 20 [Table 4]), they included the additional calories derived from peas, beans and Irish imports under a single heading.

Sources: Allen 2005: 39 (Table 12); Broadberry *et al.*, forthcoming: Table 8.7; Floud *et al.* 2011: 156-60 (with corrections); Fogel 2004: 9; Kelly and Ó Gráda 2012: 20 (Table 4); Kelly and Ó Gráda 2013b: 3 (Appendix Table 3) ; Meredith and Oxley 2014: 169-70; Muldrew 2011: 140-56; Overton and Campbell 1996: 296 (Table 13); Overton and Campbell 2006: 45 (Table XIII).

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