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Food supply, health and economic development in England and Wales during the eighteenth and nineteenth centuries

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Abstract

This paper examines food availability in England and Wales during the eighteenth and nineteenth centuries and its implications for the history of height, health and economic development.

During the last thirty years, anthropometric historians have devoted increasing attention to the study of human height and, to a lesser extent, weight. As Phyllis Eveleth and James Tanner (1976: 1; 1990: 1) explained, 'the average values of children's height and weights reflect accurately the state of a nation's public health and the average nutritional status of its citizens, when appropriate allowance is made for differences, if any, in genetic potential'. Anthropometric historians have used this insight to develop new ways of measuring changes in the health and physical wellbeing of populations in many different parts of the world in both the short and long terms (Floud, Harris and Hong 2014: xiii-xiv).

In 2011, Floud, Fogel, Harris and Hong (2011) published a major synthesis of the research which had been undertaken into changes in the average height and weight of populations in Europe and North America since *circa* 1700. They also linked this work to the theory of 'technophysio evolution' which Fogel and Costa had advanced some years earlier (Fogel and Costa 1997). This theory rested 'on the proposition that, during the last three hundred years, humans have gained an unprecedented degree of control over their environment – a degree of control so great that it sets them apart not only from all other species, but also from all previous generations of *homo sapiens*' (Fogel and Costa 1997: 49). Floud and his coauthors incorporated this theory into a five-stage model of human development, linking the investments in health made by each generation to the health and productivity of its successors.

Floud *et al.* also examined the relationship between different measures of health and improvements in diet, sanitation, environmental conditions and medical care. They devoted particular attention to the estimation of the number of calories which might have been consumed by people living in England and Wales during the eighteenth and nineteenth centuries and explored the extent to which variations in the food supply may have underpinned improvements in health and mortality. They argued that increases in food availability may have contributed to economic growth by increasing the proportion of the population which was able to engage in remunerative labour and the number of hours for which they could work. They also explored the extent to which these changes were associated with a more equitable distribution of food within the household and suggested that this may have had particular implications for the health of children and adult women.

The changing body was only one of a series of publications which included more- or less-detailed estimates of the amount of food available for human consumption in England and Wales at different points in time since the late-thirteenth century. Overton and Campbell published their initial estimates in 1996 (Overton and Campbell 1996; 2006) and Robert Allen published his series in 2005. Other figures have been published by Muldrew (2011), Kelly and Ó Gráda (2013a; 2013b), Meredith and Oxley (2014), and Broadberry *et al.* (2011; 2015). Many of these publications reached quite different conclusions about trends and levels of food availability during this period. Both in their original publications, and in the work they subsequently co-authored with Broadberry, Klein and van Leeuwen, Overton and Campbell argued that average per capita consumption remained at a low and relatively constant level from the end of the thirteenth century to the middle of the nineteenth century (Overton and Campbell 1996; 2006; Broadberry *et al.* 2011; 2015). Allen (2005) argued that consumption levels began at a lower level than Overton and Campbell but doubled between 1270 and 1500, before rising again between 1700 and 1750 and then falling back. Muldrew (2011) argued that food availability increased sharply from the end of the sixteenth century, reaching a peak of over 5000 calories per head in 1770. Kelly and Ó Gráda (2013) compared Allen's estimates for 1750 and 1800 with Broadberry *et al.*'s estimates for 1770 and 1800 and concluded that the truth lay somewhere between them. Meredith and Oxley (2013) applied some of Floud *et al.*'s conversion factors to Muldrew's data, but still concluded that consumption levels fell substantially from the late-eighteenth century.

Since the publication of their original estimates, Floud and his coauthors have corrected an error in their calculations and made a series of additional revisions in response to these other publications. These changes are described in the first three sections of this paper. Section 4 discusses the impact of the changes on Floud *et al.*'s assessment of changes in the composition of the average diet between *circa* 1700 and 1913. Sections 5 and 6 examine changes in the composition of British diets and attempt to estimate the proportions of the population consuming different amounts of food under conditions of 'low, 'moderate' and 'high' egalitarianism. The concluding sections compare Floud *et al.*'s revised and corrected estimates with those published by other authors and assess the impact of the changes on our understanding of the relationship between food availability, health and economic development in Britain before the First World War.

Corrections to Floud et al.'s original estimates

When Floud *et al.* published their initial figures, they provided two different sets of estimates. These were based on the use of different sources to estimate the average yields of different cereal crops in the years 1750, 1800 and 1850. Based on these estimates, they concluded that the average number of calories consumed per person per day in 1750 was either 2100 calories (Estimate A) or 2237 calories (Estimate B) (Floud *et al.* 2011: 154-7, 205-9). When these figures were combined with their other figures, they implied that average consumption either fell between 1700 and 1750, or rose almost imperceptibly. However, both of the calculations for 1750 included a spreadsheet error which was subsequently identified by Deborah Oxley. Once this error had been corrected, the revised estimates for 1750 increased to 2327 calories (Estimate A) or 2515 calories (Estimate B) (see Table 1). Nevertheless, Floud *et al.*'s estimates still fell well below those published by Allen (2005) and Muldrew (2011), and they remained very similar to those published by Broadberry *et al.* (2011).

Extraction rates

When estimating the number of calories obtained from cereal production, it is also necessary to make allowances for seeding, the consumption of grain by animals, processing, distribution and wastage. Floud

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: 160, 205-9

Table 2. Differences between estimates, using Broadberry et al.'s extraction rates

	Crop	Floud *et al.* A (Calories per person per day)				Floud *et al.* B (Calories per person per day)			
		1700	1750	1800	1850	1700	1750	1800	1850
(1) Original extraction rates	Wheat	502.43	657.28	732.04	706.28	502.43	804.29	717.77	729.03
(2) Original extraction rates	Rye	250.76	131.15	76.31	14.09	250.76	131.15	68.75	14.01
(3) Original extraction rates	Barley	598.22	421.05	314.98	227.49	598.22	417.67	306.75	226.80
(4) Original extraction rates	Oats	122.19	204.98	172.02	101.14	122.19	269.00	183.94	119.88
(5) Original extraction rates	Total	1473.60	1414.46	1295.35	1049.00	1473.60	1622.11	1277.21	1089.72
(6) Broadberry *et al.*'s extraction rates	Wheat	548.19	735.53	839.66	820.81	548.19	900.04	823.29	847.25
(7) Broadberry *et al.*'s extraction rate)	Rye	359.69	197.28	120.11	22.18	359.69	197.28	108.22	22.05
(8) Broadberry *et al.*'s extraction rates	Barley	467.31	320.68	233.73	126.43	467.31	318.10	227.63	126.05
(9) Broadberry *et al.*'s extraction rates	Oats	154.69	233.13	173.52	52.35	154.69	305.95	185.54	62.05
(10) Broadberry *et al.*'s extraction rates	Total	1529.88	1486.62	1367.02	1021.77	1529.88	1721.37	1344.68	1057.40
(11) Difference between (5) and (10)		56.28	72.16	71.67	(27.23)	56.28	99.26	67.47	(32.32)

Sources: Harris, Floud and Hong 2015: Table 12.

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.

Kelly and Ó Gráda (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.

As we have already seen, Floud *et al.* assumed that the overall proportions of each crop which were 'lost' in the form of seeding, animal consumption, processing and waste remained constant over the whole of their period. However, it is probably more reasonable to assume that seed ratios fell as yields rose; and that the losses associated with crops such as oats and barley would have increased as a result of changes in the proportion of food fed to animals and in the conversion of barley to beer. Harris *et al.* (2015) have therefore recalculated their data using the extraction rates proposed by Overton and Campbell (1996; 2006). These rates also underpin the data published by Broadberry *et al.* (2011). The results are not radically different from Floud *et al.*'s original calculations but they do make a difference to the overall figures. These differences are shown in more detail in Table 2.

The problem of internal trade

One of the main differences between the different contributions to these debates has been the amount of attention devoted to the number of calories associated with imports and exports. Both Allen (2005) and Muldrew (2011) focused exclusively on domestic production and assumed that all of the calories produced in England (or England and Wales) were consumed within the same territory. Broadberry *et al.* (2011) and Floud *et al.* (2011) did make allowances for imports and exports but reached different conclusions regarding their magnitude. However, as both Kelly and Ó Gráda (2013a) and Meredith and Oxley (2014) have noted, neither Broadberry *et al.* nor Floud *et al.* took any account of the flow of items between the constituent parts of the United Kingdom. Meredith and Oxley (2014: 172) claimed that 'Scotland, Wales and especially Ireland were key suppliers [of English food]: as early as the 1750s and 1760s, beef imports from Ireland trebled, and there were big increases in butter and pork'. Kelly and Ó Gráda (2013a: 1154) argued that 'allowing for imports of Irish meat and butter and … Scottish cattle would increase Broadberry *et al.*'s total by a further 60/75 kcals in 1800 and by perhaps 20/25 kcals in 1750'. They also suggested that the inclusion of Irish grain imports would have 'accounted for about 100 kilocalories daily per head in 1850 and perhaps double that before the Great Famine' (*ibid.*: 1155).

Harris *et al.* (2015) have now attempted to fill the gap in their original analysis by including new estimates of the number of calories derived from a range of Irish imports, including processed meat and dairy products, livestock, cereals and potatoes. They concluded that these sources added an extra 89 calories to the average daily diet at the end of the eighteenth century and 155 calories fifty years later. However, they also acknowledged that the data were subject to limitations and that these were compounded by the choice of base years (see Table 3).

Floud et al.: Revised estimates

Harris *et al.* (2015) have now incorporated the results of these additional calculations into their previous findings. The effects are shown in the following two graphs. Figure 1 compares the corrected version of Floud *et al.*'s original findings with new figures which reflect the introduction of Overton and Campbell's extraction rates and the new data on calories derived

Table 3. Calories derived from Irish dairy, meat and grain imports

	1700	1750	1800	1850
Grain imports*	0.00	0.00	31.70	64.49
Meat imports**	0.00	0.00	10.52	5.83
Butter imports†	0.00	0.00	21.77	50.71
Livestock	0.00	0.00	5.30	33.84
Potatoes‡	0.00	0.00	19.77	0.00
Total	0.00	0.00	89.06	154.87

Notes
* The average number of calories derived from grain imports during the period 1841-5 was 140.86 calories.
** In estimating the calorific value of meat imports, we have assumed that 50% of the imported beef and pork was consumed elsewhere.
† We have also assumed that the number of calories derived from butter in 1850 was the same as the average figure for the years 1823-5.
‡ If we had used the recorded data for 1800, the calorific value of imported potatoes would have been worth 0.01 calories per person per day. If we had used Bourke's figures to calculate the number of calories derived from potatoes in a 'normal' year and applied this figure to 1850 (i.e. ignored the effects of the Famine), the calorific value of potato imports in this year might have been equivalent to approximately 30 calories per person per day.
Sources: See Harris *et al.* 2015: Tables 2, 13, 16, 22-24 and text.

from Irish imports. Both of the revised sets of estimates suggest that food availability rose during the first half of the eighteenth century. The revised version of Estimate A suggests that the rate of increase accelerated during the second half of the eighteenth century before levelling off. The revised version of Estimate B suggests that there was a small decline in food availability during the second half of the eighteenth century, followed by a slightly larger increase. Both estimates suggest that food availability was significantly higher even than the corrected version of Floud *et al.*'s original estimates. However, the revised estimates are still much closer to Broadberry *et al.*'s estimates than to the much higher figures proposed by Allen (2005) and Muldrew (2011) (see Figure 2). They are also well below the 'compromise' figures proposed by Kelly and Ó Gráda (2013a; 2013b) and by Meredith and Oxley (2014) for the years before 1800.

The distribution of calories

The preceding sections have concentrated on various attempts to estimate the average number of calories available per head but it is also important to consider how food was distributed within the population and its relationship to nutritional needs.

Floud *et al.* sought to address this question in two ways. In the first instance, they transformed the number of calories per head into the number of calories per consuming unit, or adult male equivalent. This takes account of the fact that men and women, and adults and children, have different energy needs. They then attempted to estimate the distribution of calories between different deciles of the population by making different assumptions about levels of inequality. They estimated that between eighty and ninety per cent of the French population consumed fewer than 3000 calories per consuming unit on the eve of the French Revolution (Floud *et al.* 2011: 53). The bottom forty per cent of the Anglo-Welsh population in 1800 also fell below this figure (Floud *et al.* 2011: 56).

Table 4 presents new figures based on the revised estimates of average calorie consumption presented in this paper. Although the new estimates suggest that the average number of calories was greater than previously supposed, a significant proportion of the popu-

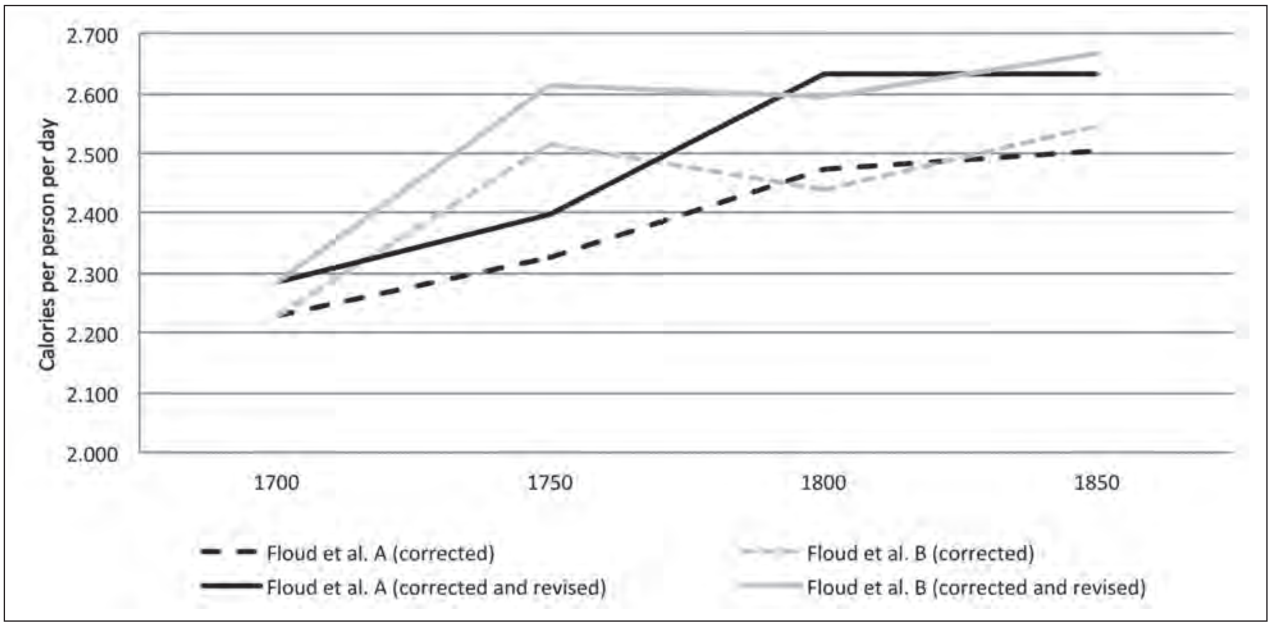

Figure 1. Calorie availability in England and Wales, circa 1700-1909/13: Corrected and revised estimates.

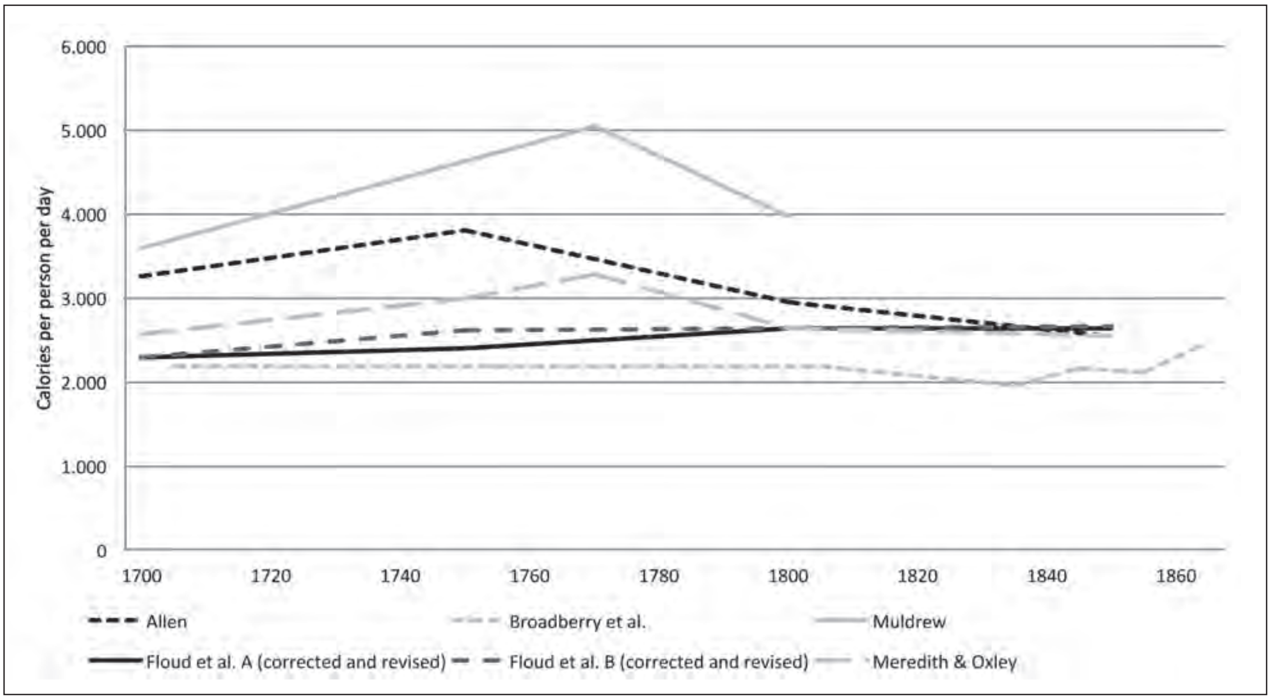

Figure 2. Calorie availabilty in England and Wales, circa 1700-1871.

Table 4. Calories per consuming unit, by decile of the population, under conditions of 'low', 'medium' and 'high' egalitarianism

	% calories consumed	1700	1750A	1750B	1800A	1800B	1850A	1850B	1909/13
				High egalitarianism (s/x=0.2)					
Highest	13.90	4,203	4,407	4,802	4,873	4,804	4,833	4,898	5,409
9th	12.06	3,648	3,825	4,168	4,230	4,169	4,195	4,251	4,694
8th	11.22	3,392	3,556	3,875	3,933	3,877	3,901	3,953	4,365
7th	10.59	3,202	3,357	3,659	3,713	3,660	3,683	3,732	4,121
6th	10.06	3,041	3,189	3,475	3,526	3,476	3,497	3,544	3,913
5th	9.57	2,893	3,033	3,305	3,354	3,307	3,327	3,372	3,723
4th	9.09	2,747	2,881	3,139	3,186	3,140	3,160	3,202	3,536
3rd	8.58	2,594	2,720	2,964	3,007	2,965	2,983	3,023	3,338
2nd	7.98	2,412	2,529	2,756	2,796	2,757	2,774	2,811	3,104
Lowest	6.96	2,104	2,207	2,405	2,440	2,405	2,420	2,453	2,708
				Medium egalitarianism (s/x=0.3)					
Highest	16.11	4,867	5,104	5,562	5,644	5,563	5,598	5,673	6,264
9th	13.03	3,938	4,129	4,499	4,566	4,501	4,529	4,589	5,067
8th	11.70	3,535	3,706	4,039	4,098	4,040	4,065	4,120	4,549
7th	10.74	3,245	3,403	3,708	3,763	3,709	3,732	3,782	4,176
6th	9.95	3,006	3,152	3,435	3,486	3,436	3,458	3,504	3,869
5th	9.24	2,792	2,928	3,190	3,237	3,191	3,211	3,254	3,593
4th	8.56	2,586	2,712	2,955	2,999	2,956	2,975	3,014	3,329
3rd	7.86	2,375	2,490	2,714	2,754	2,714	2,731	2,768	3,056
2nd	7.06	2,132	2,236	2,437	2,473	2,437	2,452	2,485	2,744
Lowest	5.77	1,745	1,830	1,994	2,024	1,995	2,007	2,034	2,246
				Low egalitarianism (s/x=0.4)					
Highest	18.42	5,565	5,835	6,358	6,452	6,360	6,400	6,486	7,161
9th	13.91	4,202	4,406	4,801	4,872	4,803	4,833	4,897	5,408
8th	12.07	3,646	3,823	4,166	4,228	4,168	4,194	4,250	4,692
7th	10.79	3,260	3,418	3,724	3,779	3,726	3,749	3,799	4,195
6th	9.76	2,948	3,091	3,369	3,418	3,370	3,391	3,436	3,794
5th	8.86	2,675	2,805	3,057	3,102	3,058	3,077	3,118	3,443
4th	8.01	2,420	2,538	2,765	2,806	2,766	2,783	2,821	3,114
3rd	7.16	2,164	2,269	2,472	2,509	2,473	2,489	2,522	2,785
2nd	6.22	1,879	1,970	2,147	2,178	2,147	2,161	2,190	2,418
Lowest	4.79	1,448	1,518	1,654	1,679	1,655	1,665	1,687	1,863

Notes. For further discussion of the definitions of 'low', 'medium' and 'high' egalitarianism and the methods used to estimate consumption levels in different population deciles, see Floud *et al.* 2011: 49-57. In the current table, values below 3000 calories per consuming unit have been shaded. The light shading indicates estimates based on the revised versions of Floud *et al.*'s Estimate A and the dark shading indicates estimates based on the revised versions of Estimate B.

Table 5. Calories per adult male equivalent and requirements for heavy work.

	1700	1750	1800	1850	1909/13
Estimate A (Revised)	2,284.91	2,399.32	2,632.85	2,631.72	2,976.72
Estimate B (Revised)	2,284.91	2,614.58	2,595.42	2,666.92	2,976.72
Conversion ratios	0.7553	0.7564	0.7506	0.7564	0.7646
Estimate A (Revised)	3,025.17	3,172.03	3,507.66	3,479.26	3,893.17
Estimate B (Revised)	3,025.17	3,456.61	3,457.79	3,525.80	3,893.17
Requirement for heavy work			3,376.89	3,470.28	3,433.05

Sources: Calories per head: see Figure 2 and text; Conversion ratios: Floud *et al.*, 2011, p. 167; Requirements for heavy work: Floud *et al.*, 2011, p. 169.

lation consumed fewer than 3000 calories per consuming unit under conditions of what Floud *et al.* (2011:53) called 'medium egalitarianism'. The table also illustrates the extent to which these calculations are sensitive to changes in the degree of egalitarianism which can be assumed. Changes in the distribution of calories may therefore have been just as important as changes in the overall supply of calories in determining the relationship between consumption and health during this period (see also Allen 2009).

Floud *et al.* (2011: 167-9) also sought to compare the distribution of calories with the number of calories required to perform different kinds of labour. They suggested that the number of calories needed to enable an adult male of average height and weight to perform eight hours of 'heavy work' was between 3377 and 3470 calories per day. The new estimates suggest that the average number of calories per consuming unit may have reached this figure either by 1750 (Estimate B) or 1800 (Estimate A), but the proportion of the population whose consumption fell below this level remained substantial (see Table 5). This shortfall was likely to have continued to exert an effect on the health of working-class men and their families throughout the nineteenth century (Gazeley and Newell 2015).

The composition of average diets

When Floud *et al.* published their original estimates, they also estimated the number of calories derived from different food sources. The results suggested that the proportion of calories derived from cereals fell substantially between 1700 and 1750 but then rose between 1750 and 1800 (Floud *et al.* 2011: 161). The revised estimates suggest that the proportion of calories derived from cereals fell during the first half of the eighteenth century but to a much smaller extent, and that there was relatively little changes in this figure over the next century. However, the percentage of calories derived from cereals fell dramatically between 1850 and 1909/13, and there were corresponding increases in the proportions derived from meat and dairy products and other food sources, including sugar (Table 6.

Lean and plenty

It is difficult to analyse Allen's data in great detail because of a lack of information in the original paper, but Harris *et al.* (2015) have compared their data with Muldrew's. They argued that Muldrew's figures exaggerated the amount of land under cultivation; underestimated the proportions of different crops which were used for human consumption; and overestimated the number of animals providing meat and, espe-

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

	Estimate A: Crop yields from Chartres, Holderness and Allen									
	Calories					Percentage				
Source of calories	1700	1750	1800	1850	1909-13	1700	1750	1800	1850	1909-13
Cereals	1,517	1,318	1,485	1,433	999	66.37	54.94	56.41	54.44	33.55
Fish	24	24	24	24	32	1.04	0.99	0.90	0.90	1.08
Fruit and vegetables (inc. potatoes)	167	189	266	338	349	7.31	7.86	10.12	12.84	11.72
Meat and dairy products	538	786	745	689	1,067	23.52	32.75	28.31	26.19	35.85
Other	40	83	112	148	530	1.75	3.46	4.25	5.62	17.80
Grand total	2,285	2,399	2,632	2,632	2,977	100.00	100.00	100.00	100.00	100.00
	Estimate B: Crop yields from Turner, Beckett and Afton									
	Calories					Percentage				
Source of calories	1700	1750	1800	1850	1909-13	1700	1750	1800	1850	1909-13
Cereals	1,517	1,553	1,463	1,469	999	66.37	59.40	56.37	55.06	33.55
Fish	24	24	24	24	32	1.04	0.91	0.92	0.89	1.08
Fruit and vegetables (inc. potatoes)	167	169	251	338	349	7.31	6.46	9.68	12.65	11.72
Meat and dairy products	538	786	745	689	1,067	23.52	30.06	28.72	25.84	35.85
Other	40	83	112	148	530	1.75	3.17	4.32	5.55	17.80
Grand total	2,285	2,614	2,595	2,667	2,977	100.00	100.00	100.00	100.00	100.00

Sources: See text.

cially, dairy products. They also rejected Meredith and Oxley's (2014) attempts to construct a new series by combining Muldrew's figures for land use and crop yields with Floud *et al.*'s data on imports and exports and extraction rates during the eighteenth century, and then merging these data with Floud *et al.*'s original data for 1850 and 1909/13. They argued that this approach introduced inconsistencies in the use of different figures to estimate calorie values and made implausible assumptions about changes in land use between 1800 and 1850. They also rejected Meredith and Oxley's attempts to reconcile their new series with other data on the cost of living and adult male heights.

Food, wages, population and health

Meredith and Oxley (2014) argued that prices in agricultural areas rose significantly during the second half of the eighteenth century and that this was consistent with growing food shortages. However, Figure 3 suggests that increases in price levels were matched by improvements in farm workers' wages from the 1750s onwards. Moreover, recent attempts to examine changes in both wages and prices suggest that the average value of real wages across the country as a whole was also increasing, albeit very slowly, over much of this period (Figure 4).

Floud *et al.* (2011: 262-3) also argued that their original figures were 'broadly consistent' with the

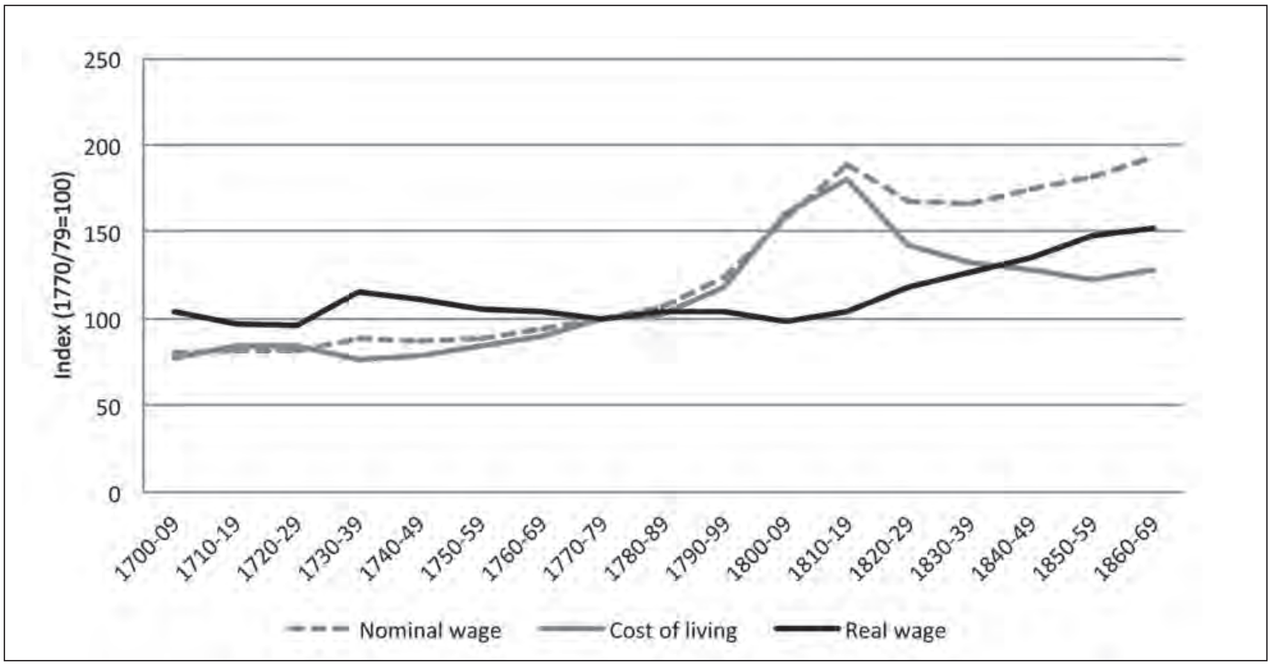

Figure 3. Farm worker's wages, 1700/09-1860/69.
Source: Clark, 2007, pp. 130-4.

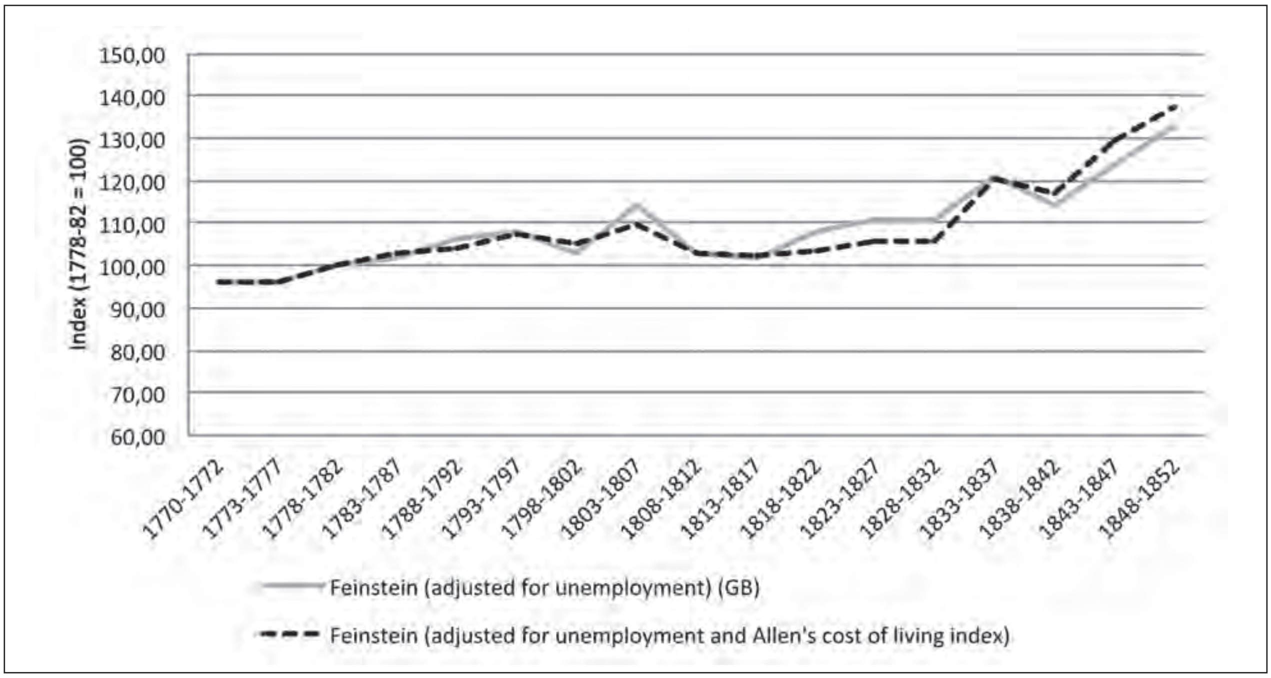

Figure 4. Real wages 1770/2-1848/52.
Sources: Feinstein, 1998, p. 648; Allen, 2007, p. 36.

height trends published by Floud, Wachter and Gregory (1990) 20 years earlier. Harris *et al.*'s (2015) revised and corrected figures suggest that this is still true of Estimate A, though not necessarily of the revised and corrected version of Estimate B. However, Meredith and Oxley (2014) have also recalculated Floud, Wachter and Gregory's height data. They argue that their recalculated data are much more closely aligned with their revised food data.

One of the main issues in this debate concerns the interpretation of trends in heights of men who were recruited by different branches of the armed forces. Floud, Wachter and Gregory (1990: 111-5) argued that it was appropriate to pool the results obtained from the analysis of the heights of the Army and the Marines because each branch drew its recruits from the same population. They also argued that it was appropriate to use unweighted samples of soldiers and marines for the same reason. Meredith and Oxley (2014: 186-7) agreed that the results ought to be pooled. However they argued that they should be weighted according to the shares of soldiers and marines in the armed forces because the two branches operated different height standards and that a failure to weight the results would be analogous to estimating the height of the underlying population from disproportionate numbers of males and females. Harris *et al.* (2015: 179) rejected this analogy, and argued that the results should be pooled without weighting, providing one used the correct procedures to move from the heights of the recruits to those of the population from which they were drawn.

In a series of papers, Bodenhorn, Guinnane and Mroz (2013; 2014; 2015) have criticised anthropometric historians for failing to take account of the impact of sample selection factors. In their earliest paper, they claimed to 'show strong evidence of selection using micro-data on the heights of British soldiers of the late-eighteen[th] and nineteenth centuries' and concluded that the results reported by previous authors may owe less to 'variations in living standards during a soldier's formative years' than to 'the process determining selection into the sample' around the time of recruitment (Bodenhorn *et al.* 2013: 2). However, it is arguable that they have failed to take account of all the work which has been undertaken on this topic. Contemporary commentators identified a series of factors which might have undermined the capacity of military recruiting statistics to shed light on changes in the health of the underlying population during the second half of the nineteenth century and many of these issues were discussed at length by Floud, Wachter and Gregory before they published *Height, health and history*. They concluded that 'the source is not seriously biased and that, after some statistical correction, the data suggest a gradual improvement in the … average height of the British working class' between 1870 and 1914 (Floud, Wachter and Gregory 1985).

Conclusions

Although Harris *et al.*'s corrected estimates are still well below the levels suggested by Allen (2005) and Muldrew (2011), as well as those suggested by Meredith and Oxley (2014), they are significantly greater than the figures published by Floud *et al.* in 2011, and the new data on extraction rates and Irish imports raise them further. What are the implications of these changes for our understanding of the relationship between changes in food supply and the path of economic and demographic development?

In their original study, Floud *et al.* (2011, pp. 162-3) argued that changes in food availability were 'broadly consistent' with changes in height and life expectancy during the late-eighteenth and early-nineteenth centuries and this supported the view that improvements in food availability were one cause of improvements in height and mortality during this period. Although this statement is still true of the revised version of Estimate A, it is less true of the revised version of Estimate B. The difference between the two estimates therefore helps to reinforce Joyce Burnette's (2014, p. 115) recent call for new research into the changing level of agricultural productivity before 1870.

The revised figures also suggest that the amount of food which was available for human consumption may have approached conventional levels of adequacy for a much larger section of the population at a somewhat earlier date that Floud *et al.* originally supposed. However, this conclusion should be treated cautiously. It is important to remember that eighteenth- and nineteenth-century consumers were exposed to much poorer environmental conditions, with a much higher incidence of diarrhoea and other enteric diseases. This problem would have been compounded by the high percentage of cereals in their diets. When Dasgupta and Ray (1990: 215-6) examined the nutritional status of individuals living under pre-industrial conditions in the modern world, they concluded that such individuals needed to increase their consumption by more than 35 per cent in order to derive the same nutritional benefit from the food they consumed as individuals living under more favourable circumstances (see also Floud *et al.* 2011: 130, 162; Schneider 2013).

It is also important to recognise the importance of inequalities in the distribution of calories. As this paper has shown, even under conditions of 'high' egalitarianism, it is likely that more than half the population consumed fewer than 3000 calories per adult male equivalent at the start of the eighteenth century and this may still have been true of consumers in the bottom decile of the population on the eve of the First World War. Many contemporary writers also pointed out that, when times were hard, it was women and children who often bore the greatest cost and the effects of this may have been felt, not only by themselves, but also by future generations (Harris 1998; 2008; Floud *et al.* 2011: 160-2; Osmani and Sen 2003).

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