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ORIGINAL PAPER

Escaping from hunger before WW1: the nutritional transition and living standards in Western Europe and USA in the late nineteenth century

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Abstract
Using the US Commissioner of Labor household survey, we estimate calories available to workers' households in USA, Belgium, Britain, France and Germany in 1888/90. We make raw comparisons of the data and utilise propensity score matching techniques to attempt to overcome differences between the nature of the country samples included in the original survey. We find that US households had on average 500 daily calories per capita more than French and Germans households, with the Belgians and British households closer to the USA. We ask if US workers had more energy for work, once likely differences in stature between national sub-samples are taken into account, and conclude it was a minor advantage. Finally, we ask if economic migration leads to taller children. We find that US-based British households were able to provide more calories than those in Britain in response to an additional child, so that, other things being equal, their children would grow taller.

Keywords Living standards · Nutrition · International comparisons · Migration

JEL Classification J11 · J61 · N30

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1 Introduction

In *The Changing Body* (2011), Floud et al. develop the analysis of the relationship between nutrition, physical work, stature and labour productivity during the early phases of the demographic transition, first outlined by Fogel (2004) in *The Escape from Hunger and Premature Death,* 1700–2100. During the eighteenth and nineteenth centuries in Europe and America, the move to industrial production entailed increases in physically demanding work (of at least 10 h hard labour a day). Floud et al. (2011) maintain that the diet required to fuel this intensity of work had to produce at least 3500 kcal per day, even allowing for the relatively slight average stature of nineteenth-century workers and, by modern standards, their stunted average heights. They argue that during the nineteenth century average ‘physiological capital’ rose, as diets provided more energy, which allowed both height and stature and labour productivity to increase. In turn, this increase in dietary energy reduced pauperism, as a greater proportion of the labour force was able to sustain demanding work.[1] A precursor to this analysis is provided by Freudenberger and Cumins (1976) who argued along similar lines that lower work intensity prior to industrialisation may have been due to poor nutrition and energy scarcity, resulting from debilitating disease and a constrained food supply. The increase in work intensity as real incomes rose during the nineteenth century is seen by them as being the outcome of better health and nutrition.[2]

According to Fogel (2004:18–19), this transition in Europe and North America was well advanced, though not complete by the late nineteenth century:

> The prevalence of meagre diets in much of Europe, and the cycling of stature and mortality even in a country as bountiful in food as the United States, shows how persistent misery was down almost to the end of the nineteenth century and how diverse were the factors that prolonged misery.

While Fogel and Floud et al. provide good comparative data on heights in the USA, Great Britain and Europe, the evidence on energy availability is not as geographically wide ranging, and is based on production, rather than consumption data. On that basis they estimate that in the USA in 1890, energy availability was 3134 kcal per capita[3] and 2977 kcal for England and Wales in 1909–1913.[4]

The aim of this paper is to investigate international differences in energy availability derived directly from household consumption data and to compare these with estimates of the energy required to sustain up to 10 h of hard manual labour a day, taking account of variations in sex, age and body stature across four European countries and the USA. In so doing, we aim to chart international variations in the extent to which industrial workers had been able to escape hunger in their country of birth in the late nineteenth

[1] Floud et al (2011) pp. 164–168 and pp. 311–317 and Fogel (2004) pp. 8–19.

[2] Freudenberger and Cummins (1976). Health, work and leisure before the industrial revolution. *Explorations in Economic History*, 13, pp. 1–12.

[3] Floud et al. p. 314 Table 6.6.

[4] Floud et al. p. 161 Table 4.10.

century and thus contribute to both the literature on the progress of the nutritional transition and the debate on 'best poor man's country' in the period before the First World War. We find that the available energy gap between the average European and average American household was substantial at around 500 kcal per equivalent adult per day, though for UK households the gap was much less, with the USA and UK further advanced in the transition from widespread dietary energy scarcity to a position of satisfying energy needs of the majority of households. The 500 kcal difference between the average dietary energy availability for European and American households was roughly equivalent to the additional energy required for an adult male to work in a physically demanding occupation rather than one with only moderate energy needs. For all countries in our sample, estimates of physiological capital are below the figures cited by Floud et al. derived from production data. But not everyone lived and died in the same country. International migration rates were historically high in the late nineteenth century, as workers and their families in Europe tried to escape hunger at home by emigrating to the New World. Using the same household expenditure data, we also investigate the nutritional welfare gain associated with migration from Europe to America at this time and conclude that ethnic Europeans who had migrated to America were significantly better off in terms of the energy available in their diets.

In Sect. 1.1, we evaluate the US Commissioner of Labor's 1889/90 household survey that forms the basis of this investigation, noting that it was a biased sample of the industries covered, and that the biases varied across the countries included in the survey. We discuss how these concerns can be mitigated using propensity-matching techniques. In Sect. 1.2, we discuss the evolution of modern standards of nutritional adequacy and the difficulties associated with the use of household expenditure survey material for nutritional analysis (Appendix A1 provides details of the foods included in this analysis, along with details of the calories they provide). Section 1.3 reports our estimates of household energy availability from the survey data by country, making simple and propensity-matched international comparisons. Overall, we show that in terms of energy available per equivalent adult per day, there was on average a deficit of about 500 cal between Europeans and Americans. These estimates of energy availability are evaluated relative to modern recommendations on energy requirements in Sect. 1.4, taking account of differences in physical stature, physical activity levels based upon declared occupation, age and sex. Adjusting for differences in stature is important for international comparisons of energy availability relative to modern standards. This is especially true in the context of a UK–USA comparison, where adjusting for stature, eliminates an apparent UK deficit. Finally, in Sect. 1.5, we evaluate the nutritional welfare gain associated with migration from Europe to the USA and the data suggest that Europeans could eliminate any energy shortfall in their diets by migrating from the old to the new world, confirming the USA as the best 'poor man's country'.

2 The survey

This article is based on the analysis of data collected by the US Commissioner of Labor, 1888–1890 (hereafter USCL). This was the first large-scale international survey of living standards and was based upon the collection and analysis of 8544 household budgets. The 1890 and 1891 *Sixth and Seventh Reports* of the US Commissioner of Labor have been widely used in the years since the data was first extracted by Haines (1979). While the American and UK budgets have been extensively analysed, the continental European budgets have been utilised far less. Because of its value as a large-scale trans-national survey, a number of attempts have been made to explore the likely biases of the dataset but, despite this scholarship, the method of implementation of the USCL survey is known only in the most general terms. The survey was implemented during Carroll D. Wright's tenure at the Massachusetts Bureau of Statistics of Labor. According to Williamson, Wright had developed and perfected advanced census techniques in a number of enquiries before the *Sixth Annual Report* in 1890.[5] The *Sixth* and *Seventh Reports* were motivated by the McKinley Tariff question. This led the Commissioners to focus exclusively on export industries in the countries studied. To this end, Wright was interested in data relating to the cost of production and the cost of living in nine industries in Europe and America (Pig Iron, Bar Iron, Steel, Coal, Coke, Iron Ore, Cotton, Wool, Glass),[6] which were all already protected industries in America. Data were collected for twenty-four states in America and five European countries (Belgium France, Germany, Great Britain and Switzerland).[7]

Williamson points out that the *Reports* represent the combination of results of two separate surveys—iron, steel and coal in 1888–1890 and textiles and glass 1888–1891.[8] Nearly one third of the international sample related to cotton textiles (31.8%), while less than one in ten related to steel coke and iron ore (9.9%).[9] Moreover, the vast majority of these households were from the USA [6809], with those from the UK [1024] comprising the second largest group. There are relatively few households from Continental European countries contained within the sample [France 335, Belgium 124, Germany 200, Switzerland 52].

The Reports are of fixed-format structure and provide comprehensive details of household structure and characteristics, income and expenditures, converted from local currency and reported in annual US dollars. According to Haines, the vast majority (97.8%) of the families across the entire survey were male headed.[10] The published reports themselves provide only the briefest of description of the way in which families were selected and family structure and expenditure information recorded. An oft-quoted passage of the Report states (in relation to Pig Iron):

> The Department has aimed to secure accounts from a representative number of the employees of the establishments...and also from those families whose

5 Williamson, J.G. Consumer Behavior in the Ninetieth Century: Carroll D. Wright's Massachusetts Workers in 1875' (1967) pp. 102–3.

6 Ibid. p. 105.

7 Haines, Michael, 'Industrial Work and the Family Life Cycle, 1889–1890', *Research in Economic History*, Vol 4 pp. 289–356. (1979) p. 293.

8 Cited in Logan (2006) p. 316.

9 Haines (1979) p. 293.

10 Haines p. 293–4. Haines' investigation of the life-cycle and labour force activity, based on the analysis of the household budgets for all the industries in all countries (8544 families). 'Industrial Work and the Family Life Cycle, 1889–1890', *Research in Economic History*, Vol 4. pp. 289–356. 1979.

> surroundings and conditions made them representative of the whole body of employees in any particular establishment. The representative character, however, has been impaired in some measure by two features: first some families have not been willing to give the information desired; while second, other families, perfectly willing, have not been able to give reasonably exact accounts of their living expenses.[11]

The Report continues to highlight the fact that the families were asked to keep 'accounts for a year's living' and that the word family is actually used to describe households, as the family is meant as a 'totality—husband wife, children, boarders, everybody that goes to make up the household'.[12] According to Lees, the head of the travelling commissioners claimed that employers supplied wage data and that 'home visits were made in the company of trusted local people to ask for information when regular accounts were not kept'.[13] It was Henry Higgs, a contemporary writing in 1893, who, according to Lees, guessed that the yearly totals were estimated from records kept over a much shorter period.[14]

A comparison of household size, women and children's labour market participation, and nominal income and expenditure levels by country is set out in Table 1. It can be seen from this table that the American households in the sample were significantly better-off in nominal terms than households in any other country.

Notice, too, in the summary data reported in Table 1, that average household size varies across the sample, with German households being the largest and the British households the smallest. Szreter (1997) describes how textile workers, about one-third of the UK USCL sample, tended to have much smaller families than others. For example, cotton workers' families had, on average 2.1 children in the USCL sample, while steel workers' families had on average 2.7 children. The absence of textile workers in the Belgium sample might help explain why the average household size is larger. Though it is also worth noting that the German sample does contain textile workers and yet German households were the largest of all countries included in the survey. The UK sample has the smallest household size, followed by the French and then the Americans.

The international differences in nominal household income were largely due to variations in the average pay of the husband. As Table 1 shows, a relatively small proportion of women were working (other than in France), but variations in children's work between countries made a significant difference to the household economy. The proportion of households where children were working varies between 0.29 (USA) and 0.51 (Belgium). The relatively low labour market engagement of children in German households, coupled with lower-than-average husband's pay, are the proximate reasons why the Germans were comparatively poor in nominal

[11] Sixth Annual Report of the United States Commissioner of Labour pp. 610–11. This same passage is quoted by Haines, Hatton and Bailey.

[12] ibid p. 611.

[13] Lees, Lynn Hollen ''Getting and Spending: The Family Budgets of English Industrial Workers in 1890' in *Consciousness and Class Experiences in nineteenth century Eur*ope (London, 1980), p. 170.

[14] ibid p. 170.

Table 1 USCL household income and composition 1889/90 (annual US $)

	Mean HH size	Mean total HH income	Mean hus-band's income	Mean wife's income	No. HH eomen working (share)	Mean chil-dren's income	No. HH children working (share)	Mean total HH Exp	Mean total HH Exp. per capita
USA	5.19	686	529	13	470 (0.07)	122	1979 (0.29)	619	135
UK	5.01	534	398	11	60 (0.06)	125	424 (0.41)	488	107
Germany	5.66	305	218	8	19 (0.09)	59	65 (0.34)	300	58
Belgium	5.57	421	271	2	1 (<0.01)	147	63 (0.51)	388	77
France	5.04	411	274	30	82 (0.25)	129	144 (0.43)	370	81

Authors' calculations from USCL survey data (share of households Column 6 and 8 in parenthesis, household abbreviated to HH).See text for a discussion. In the fifth and seventh columns, the share in brackets refers to the proportions of households in which women or children were recorded as working terms.[15] Note too that average recorded total household expenditure is less than average recorded total household income, and this is true for the budgets for each country. This is unusual in historic household budget studies, where the reverse is typically the case as components of household income are seemingly under-recorded.[16]

Part of the discrepancy in nominal incomes across the sample is mitigated by the behaviour of prices. The relative cost of average baskets of sixteen foods purchased by households at prevailing retail prices in each of the different countries is given in Table 2.[17] These are not standardised household budgets, so some part of the variation between countries is due to differences in average household size. Notwithstanding this, it can be seen that it was cheaper to buy a UK basket of these 16 foods at UK prices than at US prices, but also a US basket was cheaper in UK prices than in US prices. Generally, US prices were higher for all continental European baskets and German and Belgian prices were lower for all baskets relative to cost of their own basket at domestic prices. Thus, the discrepancy in nominal incomes between relatively rich American households and relatively poor German households was not quite as great in real terms as it appears in Table 1.

The survey was idiosyncratic in a number of ways. It was focused solely on export trades, and it is a highly selective sample of industrial workers in each of the countries studied. A number of writers have attempted to investigate the extent to which the USCL survey was representative of workers in those export industries in the 1890s. According to Logan (2006), most of this scholarship has concluded that the US households selected 'appear to be broadly representative of the industrial households employed in the industries surveyed'.[18] This judgement seems to have been reached largely on the basis of Haines' comparison of the age structure of the survey households in relation to data from the 1890 US Census.

With respect to the households in the UK sample, Hatton et al. (1994) found that the skill of the head of household varied across industries such that 'unskilled workers form the dominant group in pig-iron and coke; semi-skilled workers the dominant group in cotton, wool and coal; and skilled workers the dominant group in steel, bar-iron and glass'.[19] Looking at average income by industry, therefore, gives a misleading impression of the hierarchy of high and low wage industries. Overall, therefore, the UK households are a somewhat aberrant sample of the eight industries

[15] There is a difference in the proportion of childless households. On average, European households are less childless than Americans and this is significant. Within Europeans, the Germans are half as likely to be childless than Americans. The proportions are 13.1% for USA and 6.5% for Germany. However, the proportion of children working does not significantly differ across the two countries, even on the conditional sample with children. So, childlessness is not the explanation.

[16] See Gazeley (1985). The analysis of household budget studies for the UK carried out before WW1 revealed that in most cases average recorded expenditure exceeded recorded income.

[17] This a subset of 16 of the 21 food types recorded in the survey. We have excluded some foods from this comparison where the description is ambiguous or are relatively unimportant in total consumption. For eight of these 16 foods, we have used in survey implicit unit prices (derived from recorded expenditure and quantity data). For the other eight foods, we have utilised the contemporary retail price data described in Sect. 1.2 to generate quantity estimates from the recorded expenditure data in the survey.

[18] Logan (2006) p. 316.

[19] Hatton Boyer and Bailey (1994) p. 440.

surveyed and not a representative sample of the industrial working population generally.

Little attention has been paid hitherto to the continental European budgets of the USCL survey. They are significantly fewer in number and it is less likely that such small samples will be representative of the industries covered. Moreover, the European samples are based on surveys of a smaller number of industries (Germany 7, Belgium 5 and France 3). Only in the USA are all nine industries included in the survey. In the UK, iron ore was not included, in Germany, pig iron and glass were not present and in Belgium, coke, iron ore, cotton and wool were not covered and in France, only bar iron, cotton and wool were included.

In summary, therefore, the extent to which the overall sample is representative of the export trades in each country is unknown; but variations in sample size for each country, industrial coverage between countries and skill mix within industries give cause for concern if the objective is to make comparisons across countries. It is clear that because of variations in the construction of the national sub-samples in the USCL survey, any comparison across countries is not based on a true like-for-like comparison. Any differences in estimates of available energy derived from the analysis of the foods purchased by the households could be due to differences in sampling, or variations in the underlying population, rather than international differences in the economic circumstances facing similar households.

To overcome this problem, we employ propensity score matching developed by Rosenbaum and Rubin (1983) (see Rosenbaum 2010; Imbens and Rubin 2015; Morgan and Winship 2015 for surveys). The application of these matching techniques is straightforward and intuitive. We treat the USCL households as comprised of a sample of observations N which comprise two sub-populations: those that are 'treated' N_1 versus those that are 'controls' N_0. It follows that $N = N_0 + N_1$. In the present analysis, we make the following pairwise comparisons: belonging to a given European countries sample (viz. Belgium, France, Great Britain or Germany) are the 'treated' versus the American 'control' sample, and the combined European 'treated' versus the much larger American 'control' sample.

To see the method, let D be an indicator function for the treatment status. Following from Rubin (1974), each member, *i,* of a population can be said to have the following *potential* outcomes Y_{i1} and Y_{i0}. We observe only actual Y_i outcomes for the respective sub-samples alongside a matrix of covariates X. The ideal situation would be to estimate the average treatment effect on the treated:

$$\tau_{\text{ATT}} = E\left(Y_{i1} - Y_{i0}|D_i = 1\right)$$

This, however, is subject to the fundamental problem of causal inference as we cannot observe the counterfactual outcome $E\left(Y_{i0}|D_i = 1\right)$. In other words, we cannot observe a treated household being simultaneously treated and untreated, so the question is how to construct a suitable counterfactual to use as a valid untreated comparison group for treated households? This is where the X matrix of covariates comes into play. In our application X comprises the following household characteristics: family size, the presence of boarders, the age of the head of household and his wife, the demographic composition of children within the household (as determined

Table 2 The relative cost of food

	US Basket	Belgian Basket	French Basket	German Basket	UK Basket
US prices	100	161	167	160	123
Belgian prices	63	100	88	95	86
French prices	74	125	100	129	103
German prices	68	112	87	100	93
UK prices	75	140	140	126	100

Authors' calculations from USCL survey data

by a series of dummy variables for age and gender), and finally the skill group and industry of the head of household.

Rosenbaum and Rubin (1983) show that under the identifying assumption of unconfoundedness, or conditional independence in the sense of Dawid (1979), conditioning on X, any differences will be as good as random. In other words, this assumption implies that selection into the treated group occurs solely the basis of observable characteristics.[20]

In practice, the application of this technique employs a two-step approach. In the first, the probability of belonging to the 'treatment' group, conditional on covariates, is used to estimate the propensity score. In other words, we estimate the probability of being treated and a function of the covariates, $\Pr(D = 1) = \Phi\left(X'\beta\right)$ from which we obtain $p(X)$ the estimated probability of belonging to the treated group. This is the propensity score. From Rosenbaum and Rubin (1983), the propensity score theorem gives that under the assumption of conditional independence, conditioning on the propensity score will yield independence between the treatment and control outcomes.

We then apply the nearest neighbour matching algorithm to obtain those observations in the control group (or in our application the American sub-sample) which have the nearest propensity score to each given 'treatment' unit or, for us, European household. In practice the quality of the match may be problematic, and it is possible to trade-off between one-to-one matching and many-to-one matching by oversampling control units picked for each treatment unit. We adopt matching on the five nearest neighbours with replacement. We can now estimate the average treatment effect for the treated by:

[20] One further identifying assumption is required is common support, or overlap. For the conditioning on X to be valid it must be that for each value of X there must be a positive probability of being treated or control, $0 < Pr(D = 1|X) < 1$. This assumption is necessary to avoid bias. It simply states that there must be some overlap in the conditioning variables across 'treatment' and 'control'. Otherwise controlling for the X matrix will not balance the observable characteristics across these groups as there will be some columns for which there are 'treated' observations but no comparable 'control' observations. In the language of Rosenbaum and Rubin (1983) conditioning on common support is strongly ignorable, or unconfounded. Heckman et al. (1997, 1998) provide evidence that failure to meet this assumption will lead to substantial bias in the estimates obtained. In our analysis we restrict our comparison to those households on the common support between distributions.

$$\hat{\tau}_{\mathrm{ATT}} = \frac{1}{5} \sum_{i:D_i=1} \left(Y_i - \widehat{Y_{i0}} \right)$$

where $\widehat{Y_{i0}}$ is the average outcomes in Y for the five nearest neighbours.[21] In the Supplementary Tables, we present a sensitivity analysis of our results to the choice the number of neighbours.

Following the above exposition, it stands to reason that whilst we assume unconfoundedness, it is possible to verify whether the matching procedure has worked by exploring the balance of observable characteristics on the matched sample. If the difference in the covariates between treatment and control matched samples is not statistically significant, then the matching exercise can be said to have been successful and covariate balance has been achieved.

The final stage of this approach is to estimate the mean difference between the matched European and American units. Conditional on the identifying assumption holding and suitable balance in the observable characteristics, we can say that we have controlled for differences in the samples and have an estimate of the differences inherent between the two sets of industrial workers.

3 Energy availability and adequacy

Before considering the results of our analysis, it is important to foreground a consideration of some of the difficulties associated with these calculations. These fall into two broad categories relating to (1) the use of recommended energy intakes as measures of adequacy and associated with this, assumptions relating to the choice of physical activity levels, and the impact of stature, gender and age on the assessment of adequate intakes (2) estimates of energy availability from household budget data.

The Institute of Medicine (2005:107) provide a summary of the biological role of energy in humans:

> Energy is required to sustain the body's various functions, including respiration, circulation, physical work, and maintenance of core body temperature. The energy in foods is released in the body by oxidation, yielding the chemical energy needed to sustain metabolism, nerve transmission, respiration, circulation, and physical work. The heat produced during these processes is used to maintain body temperature. Energy balance in an individual depends on his or her dietary energy intake and energy expenditure.

Governmental and NGO recommended individual intakes for energy (and macro and micro-nutrients) have evolved over the twentieth century in response to

[21] A final point in terms of inference. Abadie and Imbens (2008) show that statistical inference drawn from bootstrapping the nearest neighbour procedure is not valid and will lead to biased variance estimation. Abadie and Imbens (2006) provide a formula for analytical standard errors for the ATT which relies on utilising the variation from further neighbours to estimate the asymptotically correct variance. We utilise this method for the inference drawn in our analysis.

advances in scientific understanding.[22] The US Institute of Medicine (2005) defines the Estimated Energy Requirement (EER) as 'the average dietary energy intake that is predicted to maintain energy balance in a healthy adult of a defined age, gender, weight, height, and level of physical activity consistent with good health'. The EER is the basal energy expenditure (BEE) multiplied by the physical activity level (PAL). The BEE is the basal metabolic rate (BMR) extrapolated to a 24-h period. The BMR is the 'energy needed to sustain the metabolic activities of cells and tissues, plus energy needed to maintain blood circulation, respiration, gastrointestinal and renal processing'.[23]

We have chosen to utilise the older Committee on Medical Aspects of Food and Nutrition Policy (hereafter COMA) 1991, rather than the current Scientific Advisory Committee on Nutrition (hereafter SACN) 2011 recommendations. This is because SACN 2011 'chose a prescriptive approach to estimating energy reference values', influenced by the recent dramatic increase in obesity and overweight individuals. The current UK 2011 energy intake recommendations are referenced on body weight ranges consistent with 'long-term good health', implying a reduction in obesity and the incidence of overweight individuals if the recommendations are followed.[24] From the perspective of the investigation of historic data, where under-nourishment, rather than over-nourishment, was the predominant issue, it seems appropriate to work with a recommended standard based on population estimated average requirements. Moreover, the use of COMA (1991), allows comparison with our previous work energy availability in UK historic diets.[25]

[22] The FAO/WHO 1985 recommendations incorporated estimates of BMR derived from Schofield et al.'s (1985) analysis of age, sex and body mass of 7,173 BMR data points. Schofield et al.'s BMR estimates have been shown to be too high, especially for Asian populations (see Henry 2005 Table 5). This finding also implies that both the FAO/WHO 1985 and UK Report of the *Committee on Medical Aspects of Food and Nutrition Polic*y (COMA, Department of Health 1991 recommendations) estimated energy requirements are too high, as these both utilised BMR estimates based on age, sex, and body mass data using Schofield et al (1985) estimating equations. Nevertheless, the subsequent FAO/WHO 2004 Report on *Human Energy Requirements*, having reviewed the evidence and the predictive accuracy of new BMR estimating equations derived from a broader 'geographical and ethnic database', concluded in favour of the continued use of Schofield et al's 1985 equations to derive adult recommended energy intakes by age, sex and body mass (FAO/WHO 2004:37). The first break with this methodology was the US National Academy of Sciences Institute of Medicine (2005) report on *Dietary Reference Intakes* that provides estimates of Total Energy Estimates using revised BEE predictive equations (IOM 2005:205–206).

[23] IoM (2005) p. 112.

[24] A BMI of 22.5 kg/m^2, designed to reduce the incidence of obesity at the current average height of the UK population. SACN p.1. This represents a significant departure from previous UK recommendations, which followed the established convention of setting energy intake recommendations equal to the estimated average requirement (EAR), which would maintain energy balance. The 2011 EER/1991 EER relationship varies by age group and gender. For adult males, the 2011 EER is marginally higher (3%), significantly higher for adolescent boys (15–18%), but lower for pre-adolescent children of both sexes (6–9%). SACN 2011 summary S52.

[25] Nevertheless, in view of the recent research on overestimation of energy requirements based on Schofield et al (1985) and the inaccuracies involved with the use of factorial approaches to estimating PALs, we have also undertaken sensitivity tests using BEEs from Institute of Medicine (2005), but their use does not substantially alter our conclusions.

We apply the COMA (1991) standard as a tool to examine international differences in energy availability relative to a fixed standard of nutritional adequacy. It is not the case, however, that modern standards can be straightforwardly applied to data relating to individuals surveyed a century earlier. For example, the COMA (1991) energy values for 75 kg adult men aged 30–59 years of 2550 kcal per day are based on an overall physical activity level (PAL) for a 24-h period of around 1.4 or 1.5.[26] PAL values reported by in UK 1991 range from 1.4 ('light' occupational and non-occupational activity) to 1.9 (moderate/heavy' occupational activity) and 2.12 (very active' non-occupational activity). Practice in the UK prior to 1991 was to specify different energy requirements for various levels of physical activity that were explicitly related to an individual's occupation (from 'very active' to 'sedentary'). The number of 'very active' occupations has declined over the twentieth century, and leisure activity now generally has a much greater influence on an individual's energy requirements than it did earlier, making a classification based upon occupation less useful today that it was a century ago.[27]

The appropriate EER would have been higher for working-class individuals in 1890 than today because of the preponderance of more energy demanding occupations and longer working hours. On the other hand, individuals in 1890 were generally lighter and of smaller stature, which would have tended to lower BEE, but not enough to offset the higher energy demands of prolonged physically demanding work. In 1890, the stature of adult men varied by country. For those men reaching maturity in the last quarter of the nineteenth century, Floud et al. (2011) gives a figure of 168 cm for Great Britain, and 165.4 cm for France. They indicate that German men were likely a little shorter than their French counterparts and American men were probably about 3 cm taller on average than those in GB.[28] Belgian men were about 2 cm shorter on average than those from Britain, but taller than Frenchmen.[29] These estimates of average height differ slightly from European heights reported in Hatton and Bray (2011).[30]

[26] *Dietary Reference values*, 1991, Table 2.7 p. 27. 2550 kcal/d is about 10.6 MJ/d, which for an adult male aged 30–59 years of 75 kg is between PAR 1.4 and 1.5 (mean 1.47 PAL). It is important to note that, the more recent recommended energy requirements produced by the UK Scientific Advisory Committee on Nutrition (SCAN) 2011 and US Institute of Medicine (2005), are based on total energy expenditure estimates derived from the doubly labelled water method, which allows for the estimation of total C02 production, and coupled with knowledge of the respiratory quotient of the food consumed during the observation period, energy expenditure can be calculated. These are considerably more accurate that those derived from food intake data coupled with a factorial approach to physical activity levels based on questionnaire data, as used to inform the 1985 WHO/FAO and COMA 1991 recommendations.

[27] *Dietary reference values*, 1991, p. 22.

[28] Floud et al. (2011). GB and France, Table 2.3, p. 69. German male heights read from Fig. 5.2 p. 230, where adult heights of men in Wurttemberg born in 1868 are around 164 cm and American men read from Fig. 6.1 top panel, where men born in 1870 are around 171 cm tall on average.

[29] Alter et al. (2002) *Stature in Transition*, indicate that adult males aged born in the 1870s were around 166 cm tall (Table 5, p. 240).

[30] We estimated nutrition using average heights from Floud et al (2011) and cohort specific heights using the height data reported in Hatton and Bray (2011) for Europeans and Floud et al. for USA heights (2011: Ch 6).

These height data are doubtless imperfect estimates of the actual average adult male heights in the populations in 1890, as they are originally derived from military height records, adjusted for truncation. Moreover, they relate to young adults and the population is composed of individuals of all ages. Since heights for young men were generally increasing during the second half of the nineteenth century in Europe, the average heights of young men were likely to have been higher than the average of the population as a whole. This implies that the population average energy requirement for men would have been somewhat lower than the energy requirements for young adult men presented here. In the USA, heights in 1890 were recovering from a decline that began around 1830, lasting until the 1890, and thus men born around 1870 were likely to be slightly shorter than the average height of adult males in the population.[31]

We find only minor differences in the distribution of age of head of household across the countries included in the survey, so the comparison between European countries and America is likely somewhat understated in the height data used here because of the different trends in average height in the populations.[32] The energy requirements for adult women and children have been scaled on male requirements, using the COMA (1991) nutritional equivalence scale, as only piecemeal evidence exists on the heights of women and children at this time.

As Table 3 shows, these differences in adult male height (and implied BMI) make a significant difference to estimates of energy per day needed to satisfy basal metabolism compared with a modern 75 kg, 175 cm, adult male. For moderately active individuals in 1890 with PAL 1.47 kcal per day vary from a little over 2300 kcal per day for American adult males to just over 2000 kcal for Germans. But of course, most of these men worked in physically demanding jobs for long hours and following Fogel, they would need energy to satisfy a PAL of around 2.12 to sustain 10 h of heavy work a day. Here the variation is from 3509 kcal/day for American adult men to 3078 for German men, reflecting the differences in average BMI by country.

We have also been able to classify the 1890/91 survey based on the physical activity of the male head of household, as the original returns for the survey record head of household's occupation. All professional and clerical occupations have been classified as 'light', and all industrial occupations as 'heavy', with PALs of 1.47 and 2.12, respectively.[33] All adult females, who were not in paid work, have been treated as undertaking 'moderate' physical activity, with a PAL of 1.8 reflecting the

[31] Floud et al (2011) p. 331, Table 6.10.

[32] There were also minor variations in the average age of head of household by country, though not sufficient to seriously distort the results presented here. Mean age of head of household recorded in the USCL sample was: 42.9 Belgium, 40.3 France, 39.2 UK, 40.5 Germany and 39.3 USA. At various points, we used cohort specific heights based on the reported age of the head of household reported in Hatton and Bray (2011), but this does not make a significant difference to our estimates.

[33] It could be argued that professional and clerical occupations should be classified as 'moderate work', with accordingly higher PALs, because the energy required for work represents only one part of an individual's energy needs, and these non-paid work energy needs in 1890 was likely quite demanding. This judgment reflects energy required keeping warm in winter in houses that were inadequately heated, plus the energy needed to engage self-provisioning, walking to work, household chores, leisure activities etc. There are so few occupations in these categories, that revisions to the PAL applied are unlikely to substantially alter the results.

Table 3 Heights of adult males reaching maturity in 1890, and estimates of energy requirements assuming a PAL of 2.12

	Average adult male height (cm)	Average adult male weight (kg)	Average adult male BMI	Estimated kcal/d required for BMR	Estimated kcal/d required for PAL 1.47	Estimated kcal/d required for PAL 1.80	Estimated kcal/d required for PAL 2.12
USA	171	63.88	21.96	1656	2434	2981	3509
UK*	168	58.69	20.79	1577	2318	2839	3343
Belgium**	166	55.86	20.05	1528	2246	2750	3239
France	165	53.86	19.16	1503	2209	2705	3186
Germany	164	50.49	18.88	1452	2134	2614	3078

Source: Columns I–IV, Floud et al. (2011), p. 73, Table 2.6, Columns V, VI and VII, calculated as Column IV × 1.47, 1.8 and 2.12, respectively.

*Calculated from average of 167 and 169 cm, Floud et al. (2011), p. 73, Table 2.6.

**Alter et al. (2002), p. 240, Table 5. Average height of male recruits age 20 born in the 1870s (average of Limbourg, Tilleur and Verviers), rounded to nearest cm. Weight and BMI estimated from average for 165 cm and 167 cm given in Floud et al. Table 2.6

(assumed) energy required for domestic work, and we have adjusted adolescents and younger children's energy requirements for likely lower body weight, using the equivalence scale taken from the COMA 1991 recommendations. For all women, and youths and children in paid work, we have referenced their energy needs on the kcal per day for 'heavy work'.[34]

Turning now to the use of household budget data to derive estimates of nutritional intakes, there are a number of issues that must be addressed. Some of these are generic and others are specific to the USCL enquiry. The USCL survey reports food expenditures and quantities purchased over an unknown period of time. Although ostensibly reported as annual data, it is likely that the reporting period was significantly shorter—possibly just one week, as the reported totals are often multiples of 52. Records of weekly expenditures are likely to display higher variance than those collected over a longer period, and this would be particularly problematic if there was evidence that household budgets for one country were collected over a different time period. Moreover, as is typically the case with expenditure rather than dedicated nutritional surveys, no information is available on the existing household stock of food at the beginning of the reporting period, or how much of the purchased items remained unconsumed at the end. For the US households, it is known whether they kept livestock and whether they had a garden, but it is not known how much food was self-produced during the reporting period. In the case of the European households, there is no information on self-resourcing included in the published reports. None of the household budgets include details of food consumed away from the home or food given as gifts, though at this time, both probably represented a very small proportion of total food consumption.

Sometimes the description of the food purchased is vague in nutritional terms. This is particularly problematic in the case of meats, where the nutritional value varies by cut depending upon the proportion of waste and fat. We have utilised Paul and

[34] Equivalence scale for women and children by age from the Report by the Department of Health, *UK Dietary Reference Values* (COMA 1991), Table 1.1, where adult men require 2550 kcal/d. This corresponds to a PAL of around 1.47, assuming a mean weight of 75 kg and kcal/d for BMR of 1735 (where BMR = 11.5 W + 873, for men 30–59 years, from Table A1, p. 198 and Annex 2 p. 202). All adult men have been assumed to require PAL 2.12, except the relatively small number in professional and clerical occupations where PAL 1.47 has been used. Women's requirements have been scaled on adult men with a PAL 1.8, unless in paid work, where a PAL of 2.12 has been used. All boarders have been treated as requiring PAL 1.47. Where the child's sex is unknown and average equivalence has been used, by age. Children in paid work have been scaled on PAL 2.12, otherwise on PAL 1.47. The Physical Activity Levels assumed here are consistent with what is known about likely exergy requirements given the nature and intensity of work effort. The data here are taken from Department of Health, Dietary Reference Values (COMA 1991). PARs are multiples of BMR, ranging from 1.2 for sitting (no physical activity) to 3.7 for carpentry or bricklaying and 6.9 for energetic sports such as swimming. The PARs are estimates of average levels for a 24-h period. Daily energy expenditure can be thought of as = BMR [time in bed + sum of (time in each activity × PAR)]; ibid., p. 24. This report provides a useful table of PAR by type of work and leisure activity, which has been used as the basis for our calculations; ibid., annex 3, p. 203. A similar approach was utilized in Gazeley and Newell *Urban Working Class Food Consumption and Nutrition* (2015 pp. 117–8 Table 8 and 9. Note that the formula given in Department of Health (COMA 1991) gives estimates of kcal/d for BMR that are around 50 kcal/day lower than the figures given in Floud et al (2011) Table 2.6.

Southgate's McCance and Widdowson food composition tables, which incorporate quite high twentieth-century wastage assumptions. In the case of some cuts of meat, only 50–70% is available for consumption, depending upon the meat type and cut. In consequence, an average of several different cuts has been aggregated for each food type (such as beef or pork) including fatty cuts and some of those sold on the bone (see Appendix for full details). The aggregate food waste proportion has been used to deflate our estimates of available nutrition from each food type. It seems likely that less was wasted in late nineteenth-century households than in late twentieth-century households, so the use of McCance and Widdowson's waste assumptions probably imparts a downward bias to the estimates of energy and nutrient availability. The macro-nutrients (protein, fats, carbohydrates, calcium and iron) are not significantly affected by storage or cooking method. Micro-nutrients (all vitamins) can be. This is why estimates of the micro-nutrient content of diets are likely to be overestimates of the quantities available for bodily functions, irrespective of the wastage assumptions employed, whereas macro-nutrients (and hence energy estimates) are much less likely to be affected by methods of storage etc.

There are also other specific problems arising from the idiosyncrasies of the USCL survey. Recall that the *Reports* are fixed format with expenditure recorded for 21 foods. For 11 of these, quantity purchased is also normally recorded leaving 10 food items where the implicit quantities purchased must be estimated by deflating expenditure by consumer prices. The foods with missing quantities include several key items of consumption, (such as milk, flour, bread, cheese, fresh vegetables and fresh fruit). The prices for these 10 food items have been carefully matched from a variety of sources.[35] Generally, where direct comparison is possible, the in-survey prices were a little lower than reported consumer prices, implying a slight downward bias to the quantity estimates for foods where we have had to rely on external sources of retail price data.[36]

[35] USA: *Eighteenth Annual Report of the Commissioner of Labor: Cost of Living and Retail Prices of Food* (Washington D.C, 1904); Aldrich Report (1893). UK: House of Commons Parliamentary Papers (321). *Report on wholesale and retail prices in the United Kingdom in 1902, with comparative statistical tables for a series of years* (London: H.M.S.O., 1903); Aldrich Report (1893); A. R. Prest, *Consumer's Expenditure in the United Kingdom 1900–1919* (Cambridge: C.U.P., 1954). Germany: Franz Eulenburg, *Kosten der Lebenshaltung in deutschen Grossstadten*, (3 vols.). (Munchen und Leipzig: Verlag von Dunder and Humbolt, 1914–15). Belgium: Ministere de l'Agriculture, de l'industrie, et des Travaux publics, *Salaires et budgets ouvriers en Belgique au mois d'avril 1891* (Bruxelles, 1891); Fritz Michotte, 'L'évolution des prix de détail en Belgique de 1830 à 1913', *Bulletin de l'Institut des Sciences Économiques*, No. 3 (Mai 1937), pp. 345-357. **France:** Jeanne Singer-Kérel, *Le coût de la vie à Paris de 1840 à 1954,* (Paris: Librarie Armand Colin, 1961). In the case of the Aldrich Report (1893), retail prices for 1891 the UK and US are reported in US dollars. In the case of UK (HC321) and France, Belgium and Germany, prices were converted from local currency into standardized united of gold and then to US dollars.

[36] For the USA, two sets of prices are available for 1890, due to Aldrich 1893 and the USCL Report of 1903. We used both sets, but only report the results using Aldrich prices, which gave slightly more comprehensive coverage. Moreover, the differences in estimates of food quantity for US households, based on deflating expenditures by prices from these two sources, are not large. Only in the case of the USA budgets is there any regional information recorded, and then only at the aggregate level of the state of residence. The consumer prices used here reflect the average of a number of towns within each state, for each year of the survey.

We present measures of household energy adequacy aggregated from recommendations based on the needs of individuals. These needs vary by age, sex and levels of physical activity. As budget surveys rarely provide evidence on the distribution of food within the household, it is obviously possible for some individuals to have inadequate diets in households that seemingly have sufficient energy to meet the needs of all members.[37]

4 Estimates of household energy availability

Table 4 provides raw unadjusted estimates of per capita energy availability from the foods purchased in the survey across five countries, including energy derived from alcohol. These estimates take no account of differences in industrial coverage between countries, or the skill mix of occupations within industries. The energy derived from recorded expenditures on alcohol seems low, and it is likely that alcohol consumption is under-recorded in this survey.[38] These estimates for the UK are similar to the authors' previous estimates derived from this source, though the energy per capita estimates for the UK and USA are significantly greater than Logan's (2009) figures of around 1400 kcal/day for the UK and 1600 kcal/day for the USA. Gazeley et al. (2015) explain why they find Logan's estimates implausible.[39]

The country averages presented in Table 4 conceal significant differences by skill level, occupation and industry within country, as Tables 5 and 6 reveal, but without too much systematic variation across countries. White-collar workers are only present in the UK and USA, and in the UK, they are consuming fewer calories than their blue-collar peers. Generally, within country, households with a head working in coal mining consume more calories than most other industries, though German households are an exception to this statement. The overall raw average intake for German households of under 1600 kcal per capita looks implausibly low, even allowing for their larger than average size (where young children's energy requirements are significantly less than those of adults).[40]

[37] We also have no information about breastfeeding, which increases the energy requirements of the mother.

[38] Estimates of average energy per capita derived from alcohol, as recorded in the survey, are UK 32 kcal, USA 37 kcal, Germany 41 kcal, France 75 kcal and Belgium 85 kcal.

[39] We are unable to replicate Logan's results for the UK using the original dataset constructed by Haines (1979) or the independently created version by Gazeley (1985). Gazeley, Newell and Bezahib estimated a range of 1843–2245 kcal/day for the UK (using Haines' or Gazeley's extraction of the data and various combinations of Nutribase or McCance and Widdowson nutrient conversions and Aldrich UK prices or HC.321 UK retail prices).

[40] We have also estimated energy availability from the household budgets collected by the Board of Trade for their investigation of living conditions in Europe 1908–1912. The total number of European household budgets deemed useable by the Board of Trade was over 14,454 (including 1944 for the UK, 5046 for Germany). Expenditure and consumption data were converted by the Board of Trade from local currency and metric weights and volumes to sterling and imperial weights and volumes. We have used the consumption data to estimate energy availability per capita. We find that by 1908 German households still had fewer calories available than UK households (2247 kcal per capita available on average, compared with 2358 in the UK), Gazeley, I and Newell, A 'The First Globalisation: Progress in living standards in European countries 1890–1910' mimeo (2019).

The results reported in Tables 5 and 6 underline the potential importance of the influence of variations in the nature of the national samples on any international comparison. We attempt to adjust for differences in the occupational and industry mix across countries through 5-nearest-neighbour matching techniques described in Sect. 1.1, and these per capita estimates are reported in Table 7. Notice that on matched scores, the per capita energy availability deficit between all European households and those in the USA is slightly greater than the raw means suggest [−377 kcal per capita/day (Table 4) vs. −402 kcal per capita/day (Table 7)]. However, the deficits with matching for individual European countries move in different directions, reflecting the idiosyncratic nature of the national samples. Relative to the USA, the deficit for Belgium and GB worsens, but for France and, particularly for, Germany it improves. Overall, these national changes all but wash out in the calculation of the average for all European countries, but the best estimate we have for the inherent national differences in the energy available from national diets, controlling as far as we are able for differences in the samples for each country, is that the average industrial worker's household in Britain had available around 267 kcal per capita/day less than the average industrial worker's household in the USA (perhaps equivalent to the energy provided by a thick slice of bread with butter and jam). For Belgium, the figure is around 478 kcal per capita/day less than similar households in the USA, for France the deficit was 650 kcal per capita/day and Germany around 633 kcal per capita/day. These are really quite large and significant differences that have direct bearing on the countries time-path along the nutritional transition, as outlined by Fogel (2004). Taking the average of all Western European Households, the overall effect is to somewhat level up European household energy availability in per capita terms relative to American households.

We now move away from considering per capita estimates of energy availability, which treats the needs of adults and children the same, to an examination of per equivalent adult estimates, where the needs of adults and children differ. In Table 8, we report matched international comparisons that utilise the equivalence scale from the UK COMA (1991) energy recommendations (which are similar to the FAO/WHO 1985 recommendations). The move from raw per capita to raw equivalent adult increases the estimate of available energy in the diets for all countries, as young children are now being counted at a fraction of an adult rather than the same as an adult (compare Table 4 with Table 8). For the USA, the move from per capita to per equivalent adult raises the estimate of average energy availability from just over 2400 to just over 3000 kcal per day. Per equivalent adult, Belgium households have on average over 2600 and British households just fewer than 2800 kcal per day. The figures for France and Germany are much lower at around 2100 kcal per day, respectively. Table 8 also reports these figures in terms of country gaps compared with the USA, with the largest gap found among German and French households who have available just over 800 kcal per equivalent adult per day less than the average of those households in the survey from the USA. The overall conclusion of the analysis reported in Table 8 is that the average European late nineteenth-century industrial workers' household received a little less than 500 fewer calories per equivalent adult than their American counterparts. 500 cal per day would be a little less

Table 4 Raw mean energy per capita relative to the USA

	Mean difference	Mean country	Mean USA
Belgium–USA *N*	−285 (77) 6820	2134 (77) 122	2419 (10) 6698
France–USA *N*	−690 (43) 7029	1728 (42) 331	2419 (10) 6698
GB–USA *N*	−192 (23) 7712	2227 (21) 1014	2419 (10) 6698
Germany–USA *N*	−860 (33) 6896	1559 (32) 198	2419 (10) 6698
Europe–USA *N*	−377 (20) 8363	2042 (18) 1665	2419 (10) 6698

The first column gives the naive estimate of τ_{ATT} estimate given as the unadjusted mean difference between groups. Mean for USA can be considered the 'counterfactual mean', or the adjusted mean. Standard errors reported in parentheses.

than the energy available in two generous slices of bread and butter with jam.[41] It would translate into the energy difference between the energy needs of an adult male of 65 kg working in moderately physically demanding occupation for an average 9 h a day, 6 days a week (such as motor vehicle repair, carpentry or bricklaying) and the working in an extremely physically demanding occupation (such as labouring, road construction hoeing or tree-felling), assuming that all non-work activities remained the same.[42]

5 Energy availability relative to requirements

The question remains whether the available energy gap between American and European households persists given the differences in heights and stature across countries. As we established in Sect. 1.3, American adult males were on average likely to be about 3 cm taller than British adult males, who in turn were taller than other Europeans. Fewer calories were necessary to sustain shorter Europeans than

[41] McCance and Widdowson only quote nutritional information per 100 g, which is not ideal for this equivalence. Modern food composition tables on-line (www.Nutrionix.com) give 67 kcal bread, 102 for teaspoon of butter, and 37 kcal for teaspoon of jam (206 kcal). But this is for sliced bread. A thick slice of bread is 157 kcal (296 kcal for thick slice of bread, butter and jam).

[42] Modern energy values for bread vary significantly by brand, depending upon size and thickness, so this is a very rough approximation. A medium slice of Warburton's bread (not toasted) provides just under 100 kcal and a thick slice just over 150 kcals. A teaspoon of butter is roughly equivalent to 100 kcals. The estimates of the differences in work activity are from Gazeley and Newell *Food Consumption and Nutrition* (2015, p. 117).

Table 5 Mean Calories per capita by country and occupation

	Belgium	France	GB	Germany	USA
Unskilled	2119.8	1673.1	2159.5	1577.4	2338.7
N	(167.5)	(98.3)	(43. 3)	(79.8)	(16.9)
	22	79	245	31	2009
Semi-Skilled	2058.0	1560.6	2231.6	1552.3	2449.9
N	(116.7)	(66.9)	(35.3)	(81.6)	(22.2)
	26	73	332	42	1320
Skilled	2175.2	1840.6	2252.965	1534.4	2473.7
N	(132.3)	(78.3)	(43.3)	(42.8)	(18.1
	52	83	264	95	2073
Craftsman	2187.2	1864.2	2322.1	1598.5	2446.0
N	(237.3)	(97.5)	(53.7)	(74.6)	(29.7)
	18	72	125	24	745
White collar	1	3	2122.0	1	2482.6
N			(170.9)		(66.4)
			11		112
Apprentices	3	0	2140.9	1	2359.3
N			(104.5)		(62.1)
			35		200
Other	0	1490.9	2	4	2373.9
N		(123.2)			(48.5)
		21			239

Means for cell sizes with fewer than 10 observations have been suppressed. Standard errors are in brackets

Americans at the same physical activity level. However, because we have the age of the Head of Household, we are also able to calculate the likely cohort specific heights from Hatton and Bray (2011) for European men and Floud et al.'s (2011) series of heights by birth cohort for Americans.[43] Moreover, we have seen that the USCL sample had vastly different coverage of occupations and industries by country. There were also systematic differences by country in the proportion of women and children working. All of these factors will influence the energy requirements of the household, via their assumed physical activity levels.

We have calculated the energy requirements of each household on the assumption that adult males working in manual work required a PAL of 2.12. Similarly, the energy requirements of adult women and children who were working were calculated using the same physical activity rates. Adult women who were not in paid work, would not have the same very high average energy requirements, but were still likely to require more energy than adult men in white-collar occupations. Women not in paid work were assumed to require a PAL of 1.8 and adult men, and non-working children were all assumed to require a PAL of 1.47. The vast proportion of adult men in this survey were working in energy demanding blue-collar work. This is true for all countries, but as Table 6 reveals, there were a number working in white-collar occupations in Britain and America, and we have taken account of their lower

[43] The cohort specific heights are derived from Hatton and Bray (2011). The US cohort specific heights derive from Floud et al (2011) Chapter 6.

Table 6 Mean calories per capita by country and industry

	Belgium	France	GB	Germany	USA
Pig Iron	2044.1	0	1850.2	0	2440.0
N	(252.3)		(57.9)		(34.7)
	11		65		708
Bar Iron	1889.5	2139.7	1901.7	1526.2	2469.9
N	(92.8)	(138.3)	(53.7)	(78.9)	(36.9)
	73	40	109	22	595
Steel	0	0	2231.5	1538.3	2310.0
N			(58.6)	(77.0)	(58.4)
			162	35	175
Coal	3036.9	0	2279.8	1485.4	2441.7
N	(197.5)		(45.9)	(105.6)	(37.0)
	10		166	18	505
Coke	4	0	2563.3	1659.7	2333.1
N			(157.9)	(153.4)	(50.4)
			14	10	249
Iron Ore	0	0	0	1452.7	2155.0
N				(75.0)	(56.0)
				19	165
Cotton	0	1674.0	2392.8	1589.6	2310.0
N		(56.8)	(37.1)	(56.2)	(14.7)
		114	341	71	2124
Wool	0	1670.6	2110.8	1626.3	2324.7
N		(59.6)	(44.5)	(102.6)	(24.0)
		177	131	23	907
Glass	2572.3	0	2397.2	0	2688.2
N	(156.7)		(150.4)		(23.6)
	24		26		1270

Means for cell sizes with fewer than 10 observations have been suppressed. Standard errors reported in parentheses

physical activity rates by adjusting the energy these individuals needed. Of course, these white-collar heads of households may have had wives in paid work or children working and this participation in the labour market is reflected in the assumptions we have made regarding their individual physical activity rates.[44] We have elsewhere attempted to justify similar assumptions with respect to British households at the turn of the twentieth century, breaking down activities across a 24-h period (Gazeley

[44] For example, we know if the household includes one or more children working, but the survey reports do not indicate which child is working. We have experimented with a number of approaches to this issue including assumptions relating to the age order of children and work, priority for male children over 12, assumption of work in head of household's industry etc. The difference is small and matters much less than say altering the BMR equations used. The reason for this is across the whole of the USCL dataset the sort order by gender rarely matters, partly because it is quite often that males are the reported eldest children. Assuming that second born rather than first born child was working, the mean difference between the two variables is 4 kcals with 95% of observations being ± 70 kcals. Here, we report in Table 10 through 12 the simplest set of assumptions we adopted, which are that working children are solely chosen by age, with no preference for gender or industry/occupation of parents.

Table 7 Matched estimates of energy per capita and per equivalent adult (5-nearest-neighbour matching)

	Mean difference	Mean country	Mean USA
Belgium–USA	–477***	2141	2618
N	(88)	(79)	(41)
	3409	112	423
France–USA	–650***	1711	2360
N	(51)	(42)	(23)
	3578	297	975
GB–USA	–267***	2221	2488
N	(31)	(21)	(17)
	740	991	2371
Germany–USA	–634***	1553	2187
N	(42)	(32)	(25)
	4495	187	705
Europe–USA	–402***	2040	2442
N	(26)	(18)	(14)
	8005	1593	3259

**, **, *denote statistical significance at the 1%, 5% and 10%, respectively. Average treatment effect is reported in the first column, this has been estimated with 5-nearest-neighbour matching as outlined in text. Dependent variable is Calories per capita. Mean for USA should be considered the 'counterfactual mean', or the adjusted mean. Abadie and Imbens (2006) robust standard errors computed on 14 nearest neighbours. Matching is done on the basis of industry, occupation, household size, family size, household head's age, wife's age and demographic composition of children

Table 8 Matched estimates of mean calories per equivalent adult

	Mean difference	Mean country	Mean USA
Belgium–USA *N*	–559***	2648	3207
	(98)	(92)	(46)
	3409	112	423
France–USA	–842***	2170	3012
N	(58)	(47)	(27)
	3578	297	975
GB–USA	–322***	2786	3108
N	(34)	(22)	(19)
	7240	991	2371
Germany–USA	–813***	2067	2880
N	(68)	(53)	(35)
	4495	187	705
Europe–USA	–488***	2577	3065
N	(29)	(20)	(16)
	8005	1593	3259

**, **, *denote statistical significance at the 1%, 5% and 10%, respectively. Average treatment effect is reported in the first column, this has been estimated with 5-nearest-neighbour matching as outlined in text. Dependent variable is Calories per equivalent adult Mean for USA should be considered the 'counterfactual mean', or the adjusted mean. Abadie and Imbens (2006) robust standard errors computed on 14 nearest neighbours Matching is done on the basis of industry, occupation, household size, family size, household head's age, wife's age and demographic composition of children and Newell 2015). The use of a factorial approach to estimating PAL is consistent with the methodology adopted in FAO/WHO 2004 and COMA (1991).

Table 9 reports the results of calculating the average energy availability relative to energy requirements based on the assumptions described above, relative to COMA (1991) energy requirements and an optimal distribution of food. A figure of 1.00 indicates that on average, available energy was sufficient to sustain the household given the likely BMI and physical activity rates of its members. The assumption of shorter European heights in Tables 9, and hence lower BMI and calorie requirements for the same PAL, transform the position of some European households in the USCL sample. Average UK households, which previously we had estimated as having diets that were not quite sufficient to meet the energy requirement of sustained physical work for 10 h a day, are now in a position where these requirements are met with a small surplus. As an example, consider the case of British households that we estimate on average to have a 15.7% surplus per capita per day relative to COMA (1991). This translates into roughly 350 kcal (based on an average recorded consumption of 2227 kcal per capita per day from Table 4), or roughly equivalent to two thin slices of bread and butter per day for every member of the household.[45] Similarly, the average position of Belgium households is modified from one of modest calorie deficit to modest calorie surplus. German and French households' energy availability relative to requirements also improves, once due account is taken for their smaller stature, though on average households in both countries still have a calorie deficit, and this remains a considerable one in the case of German households. These represent our best guess estimates of energy availability relative to energy requirements, after addressing the idiosyncrasies of the survey using matching techniques and adjusting energy requirements for likely differences arising from variations in average stature between countries.

Do these results tell us anything about the performance of these economies, and, in particular, the consequences of differences in tariff regime between them? This analysis is based upon only one cross section of household budgets, but the results are consistent with a negative impact of agricultural tariff on workers living standards. The revolution in transportation and refrigeration that facilitated the entry of grain and cattle grown and raised in Canada, Australia, USA, Argentina and Russia into European markets in the 1870s lead to the imposition of tariffs on agricultural products in Germany and France.[46] Along with a run of bad harvests, agricultural tariffs in these two countries led to higher prices for workers and poorer nutrition.[47] In the USA, the 1890 McKinley tariffs only applied to industrial goods, and agricultural produce was exempt, whereas in the UK, which maintained free trade

[45] Nutrionix.com gives values of 67 kcal bread, 102 for teaspoon of butter or 169 kcal per buttered slice.

[46] Although most date the end of the liberal free trade era in France to 1892 and the imposition of the Meline Tariff, duties on wheat were raised in France in 1885 and again in 1887 (O'Rouke 2000, p. 459). In Germany, the 'coalition of rye and iron' led to the imposition of tariffs on grain and animal products from 1879.

[47] According to Torp (2010, p. 413), the run of bad harvests in Germany in the early 1890s led to a 'significant increase in food prices'.

following the repeal of the Corn Laws in 1846, cheaper imported meat and grain had a positive impact on household living standards and nutrition.

6 Welfare gains from migration

The US population census records a stock of 2.78 m native born Germans, and 1.25 m native born British in 1890.[48] These substantial expatriate groups were the result of substantial flows of emigrants from Europe to the USA during the nineteenth century. Hatton and Williamson (1998) quote decadal average gross emigration rates per 1000 of population as 2.18 for Germany and 5.71 for Great Britain.[49] This emigration from the old to new world was composed increasingly of young adult males.[50] According to Bade (2008), 60–70% of British migrants and 90% of Germans migrants headed to the USA in the last quarter of the nineteenth century, reaching a peak in 1880–1893 when 1.8 m Germans emigrated to the USA.[51] Between 1886 and 1890 the yearly average emigration of Europeans was 779,000, most of whom headed for the USA, though return migration was volatile and varied by country, and reached a peak of 60% in the 1890s for British migrants.[52]

Hatton and Williamson (2005) show that the welfare gains from migration were potentially large, as the average British wage was around 60% of the US wage in 1870. In the 1890 survey, average British household income per capita was 80% of US household per capita, with other European households on average around 50% of the US level (as Table 1 makes clear). These intercontinental relative wage differentials acted as key determinants of migration flows.[53] The USCL survey includes details of the ethnicity of the head of household for the American budgets (based on the country of birth), so it is also possible to make direct comparison between European households in Europe and ethnic Europeans living in the USA. The welfare gains to emigration can be seen from the comparison set out in Table 10, which records income of households in Europe compared with the same ethnicities in the USA. Clearly, it is possible that parts of these gains were the results of selection and sorting effects. The characteristics that led individuals to select migration could be unobserved characteristics that were favoured in the recipient labour market. Imperfections in recipient market sorting on these unobservable characteristics may also play a role. Clemens, Montenegro and Pritchett (2008) studied these effects for a host of countries and concluded that these effects would require deflating a wage ratio matched on observables by a factor of 1.5. It is impossible for us to estimate

[48] Plus 22,000 native born Belgians and 107,000 native born French.

[49] Hatton and Williamson (1998) *The Age of Mass Migration: Causes and Economic Impact*, Table 3.1 p. 33.

[50] Hatton (2001) The age of mass migration: what we can and can't explain, p. 2.

[51] Bade (2008) *Migration in European History*, pp.104–6.

[52] Bade (2008) p. 98 and p. 104.

[53] Hatton and Williamson (2005) *Global Migration and the World Economy: Two Centuries of Policy and Performance*. Cambridge. p. 55.

Table 9 Mean difference in calories relative to COMA 1991 requirements (5-nearest-neighbour matching). Floud et al. average heights

	Mean Difference	Mean Country	Mean USA
Belgium–USA	−0.132***	1.048	1.179
N	(0.037)	(0.036)	(0.016)
	3409	112	423
France–USA	−0.233***	0.873	1.106
N	(0.022)	(0.019)	(0.009)
	3578	297	975
GB–USA	0.019***	1.157	1.139
N	(0.013)	(0.009)	(0.007)
	7240	991	2371
Germany–USA	−0.267***	0.803	1.071
N	(0.025)	(0.020)	(0.012)
	4495	187	705
Europe–USA	−0.071***	1.055	1.125
N	(0.011)	(0.008)	(0.006)
	8005	1593	3259

**, **, *denote statistical significance at the 1%, 5% and 10%, respectively. Average treatment effect is reported in the first column, this has been estimated with 5-nearest-neighbour matching as outlined in text. Dependent variable is Relative Calories to COMA 1991 requirements assuming heights as in Floud et al. (2011). Working children are assumed by age, no preference for gender or industry of parents. Abadie and Imbens (2006) robust standard errors computed on 14-nearest-neigbour matching is done on the basis of industry, occupation, household size, family size, household head's age, wife's age and demographic composition of children

these biases on the USCL data due to its limited representativeness. Table 10 shows that the largest raw gains were for Germans, followed by the French and then the British. Even in the latter case the difference in income per capita between households in the UK and ethnic British household in the USA was substantial.

Geloso and Lindert (2020) document how the New World (North America and Australia) continued to be the best poor man's country in the nineteenth century, despite more egalitarian trends in the movement of the cost-of living between poor and rich households in the UK until the First World War. By this they mean that it was still relatively easier for households to satisfy basic subsistence needs in North America (though getting to consume other goods was harder). Here, the paper offers an alternative measure of the best poor man's country using working class household dietary energy availability.

In Table 11, we report in differences in nutritional status, defined as household energy availability relative to the COMA (1991) standard, by the survey's ethnic groups in the USA relative to the rest of the US sample and with respect to those who stayed in their home country. The qualifications with respect to interpretation discussed above hold here. The first column shows that Belgian, British and French households fared better than others, while the German households fared a little less well. It seems reasonable also to posit that poverty and hunger at home acted as a possible stimulus to migration and we have examined already the differences in the energy available from diets in Europe and America. Column one also tells us, indirectly, about who migrated, as it is likely that "movers" were taller than "stayers".[54] It is not, after all, a random sample of the European populations.

Comparing the second and fourth columns of Table 11 informs us about the welfare of migrants in the USA relative to the populations they left behind. It reveals that migration from Europe to the USA may have eliminated any energy deficiency evident in European diets. The average nutritional status (defined as household energy availability relative to the COMA 1991 standard) in the USA is higher than in the country of origin for all four national groups, strongly for Belgium, France and Germany, and marginally for Britain. Note these comparisons may understate the welfare gain because they assume that the ethnic Europeans (born in Europe) living in the USA were taller than their European counterparts. Given the likelihood that migration was of primarily of mature adults, ethnic Europeans in the USA were probably shorter than those US heads of households defining themselves as "American".

The kernel density plots in Figs. 1 and 2 demonstrate the subtle changes caused by differing height assumptions and their effects upon the performance of households relative to the COMA (1991) recommendations. Note that in Fig. 1, with the assumption of common heights in the USA, households are much more compactly distributed. Indeed, the USA and 'British' and German households are nearly indistinguishable. However, once the requirements are readjusted to take account of differing heights according to ethnicity within the USA, then the distributions subtly shift. American only households do not shift their position, but as expected there is differential creep for each distribution towards the right-hand side. That is, each ethnic group is doing much better in the USA than in Europe.

Changing the height requirement for each nationality not only creeps the distribution to the right, but also diminishes the density around meeting the requirement, but this density is now distributed more along the 1+ requirement. A good example of this phenomenon is the German distribution, where it can be seen from Fig. 2 that the peak of the distribution diminishes and the distribution also `flattens'. The 'British' households are much better fed than the average American household. Heights do not seem to affect the composition or density of points below requirement and in the extreme left tail. Indeed, the distributions remain largely the same.

Of course, these calculations also imply that our assumption that Americans were on average taller than their European counterparts is likely incorrect for those Americans in the sample who define themselves as ethnic European and were first-generation migrants. If we recalculate estimates of American energy availability relative to needs assuming ethnic Europeans in the USA have the same heights as they did in Europe, unsurprisingly this assumption improves the nutritional status of American households relative to their European peers, but it does not alter the broad conclusions we have drawn from this analysis, as the USA and British households remain roughly comparable in terms of energy availability relative to needs, despite a significant gap in income between USA and British households.

[54] See, for example, Haines et al.'s results for migration within the USA (2003, Table 6 and discussion pp. 403–4).

Table 10 Incomes at Home in the USA Authors' calculations

	Living in USA	Living in country of origin
British workers		
Income per capita (mean $ year)	134	107
Number in the household, mean	5.5	5.1
Husband's age, mean in years	42.5	39.2
Share of husband in household income	0.70	0.75
Share of wife in household income	0.02	0.02
German Workers		
Income per capita (mean $/year)	139	54
Number in the household, mean	5.0	5.7
Husband's age, mean in years	40.21	40.5
Share of husband in household income	0.86	0.72
Share of wife in household income	0.01	0.03
French workers		
Income per capita (mean $/year)	147	81
Number in the household, mean	5.0	5.0
Husband's age, mean in years	37.6	40.31
Share of husband in household income	0.77	0.67
Share of wife in household income	0.04	0.08

Finally, we ask if these data reveal anything about intergenerational nutrition and welfare? We know that more energy was consumed by the US-based respondents, but what about the treatment of children? Do those higher-income US households feed their children better? If so, then we have found evidence supportive of a more rapid growth trajectory for average body stature. In Table 12, we report the impact, or, more accurately the partial correlations of the presence of children in different age bands with adult-equivalent calorie availability. The equation estimated is:

$$\begin{aligned}\log\ \text{calories per head} &= \alpha_1 \log\ \text{income per head} + \text{controls for childrens age}\\ &+ \text{controls for industry of head} + \text{error term.}\end{aligned}$$

In the first column, we report results for workers in the USA reported as American. In the second column, the results are for workers in the USA reported as British, and finally in the third column the sample is for those reported to be British in Britain. We include industry controls in all regressions. Note first that the two USA-based samples generate lower estimates of income on calories. This is consistent with these higher-income samples generating flatter Engels curves.

In each cell, we report the coefficient associated with the number of children in the various age groups. To understand the scale of the results, take the estimated

Table 11 Mean difference in calories relative to COMA 1991 requirements for Ethnic Americans (5-nearest-neighbour matching; Floud et al 2011 average heights)

	Mean difference	Mean ethnic in USA	Mean rest of USA	Mean Country
Belgium–USA	0.191***	1.432	1.241	1.048
N	(0.096)	(0.082)	(0.051)	(0.036)
	674	12	48	112
France–USA	0.031***	1.178	1.147	0.873
N	(0.047)	(0.045)	(0.018)	(0.019)
	3370	79	369	297
GB–USA	0.065***	1.161	1.097	1.157
N	(0.015)	(0.009)	(0.006)	(0.009)
	4827	894	2109	1017
Germany–USA	−0.024***	1.122	1.145	0.803
N	(0.017)	(0.013)	(0.009)	(0.020)
	4559	626	1,703	187

**, **, *denote statistical significance at the 1%, 5% and 10%, respectively. Average treatment effect is reported in the first column, this has been estimated with 5-nearest-neighbour matching as outlined in text. Dependent variable is Relative Calories to COMA 1991 requirements assuming heights as in Floud et al. (2011) for Ethnic Americans. Heights, and thus implicit energy requirements are assumed to be the same for all. Abadie and Imbens (2006) robust standard errors computed on 14 nearest neighbours. Matching is done on the basis of industry, occupation, household size, family size, household head's age, wife's age and demographic composition of children

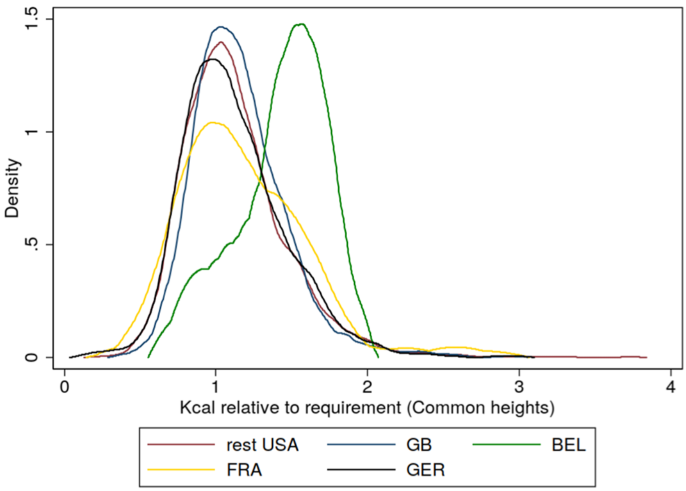

Fig. 1 Common heights kernel density plot

impact of children aged less than two years for the American households in the USA. Our regression estimate of −0.077 implies that, controlling for income and industry, replacing an average family member with a child under two years of age reduces calories per head by 7.5%. If the household with an initial 2400 kcal per capita at its disposal that would be 180 kcal (equivalent roughly to a medium slice

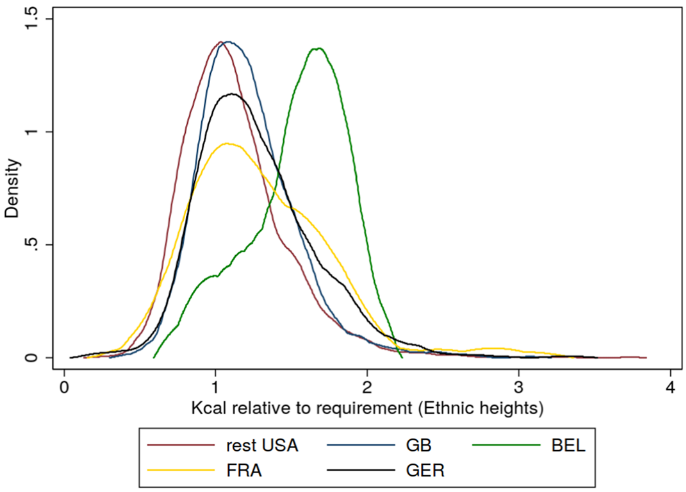

Fig. 2 Ethnic heights kernel density

of bread and butter). Given the lower energy requirements of infants, this result is as expected. Note also how these reductions become smaller as age is increased, again as expected. Looking across the columns, the results are mostly similar, except that the presence of a 10–15 year old is associated with lower calories in UK-based households but not in USA-based households. These coefficients tell us that on average US-based British households provided food for their children at least as well as their UK based counterparts, holding income constant. A reasonable prediction from this is that higher incomes in the USA lead to higher levels of calorie availability for children and thus would lead to more rapid increases in stature.

7 Conclusions

We find that American household diets had more energy available measured per capita or per equivalent adult than their European counterparts. On average, the European shortfall was around 500 cal per day per equivalent adult. But for all countries our estimates of physiological capital are significantly below the figures cited by Floud et al. derived from production data. We recognise that the survey data used to derive these estimates is not perfect and is in many ways an aberrant sample as the biases differ across countries. Analysing the data using propensity matching techniques makes like with like comparisons based upon the characteristics of the households. This technique increases the estimates of energy availability in French and German households and reduces them slightly for Belgian and British households, but the use of this technique does not suggest that a raw comparison of unmatched data would be wildly misleading. This article also reports the first attempt to estimate differences in energy availability relative to energy requirements that take account of differences in physical stature, physical activity levels, sex

Table 12 the impact of income and family structure on log calories *per capita* among various groups of households in the USCL data

	American workers in the USA	British workers in the USA	British workers in Britain
Explanatory variables			
Log income *per capita*	0.333***	0.346***	0.403***
Children under 2	−0.077***	−0.078***	−0.080***
Children 2–4 years	−0.059***	−0.032**	−0.052***
Children 5–9 years	−0.031**	−0.033***	−0.032***
Children 10–15 years	−0.006**	0.009	−0.021***
Sample size	3641	921	977

See text for explanation.

*** and **Denote conventional significance and the 1% and 5% levels, respectively

and age. Taking these factors into account, we find that superior American dietary energy over all European countries measured in per capita or per equivalent adult terms is partly over-turned. British households on average had at least the same energy availability relative to requirements as their American peers, though the gap between American households and other European households was still pronounced. In terms of Fogel's thesis, we find that on average, once due account is taken of likely differences in stature, both British and American households had diets supplying sufficient energy to sustain 10 h a day of hard physical labour. This was not the case for households in other European countries at this time, reflecting cross-country differences in the progress of the nutritional transition around 1890. This survey evidence of a large international difference in available nutrition is consistent with other data in the survey, such as the income differentials we saw in Table 1. But it is also largely consistent with the conclusions Fogel (2004) that we quoted from in the introduction, and with Allen (2001), who in an investigation of long-run trends in European wages claims that "it was only between 1870 and 1913 that the standard of living in the industrialised world rose noticeably above early-modern level. For many Europeans, the escape from mass poverty waited until the twentieth century".[55]

It might be expected, other things being equal, that these differences in energy availability relative to needs across countries would influence labour productivity. Indeed, Strauss and Thomas (1998) argue for a strong link between international differences in labour productivity and food availability. Only aggregate data exist for 1890, and not for all countries, but Broadberry (1997) indicates that labour productivity in the USA was roughly double that in the UK, which in turn was roughly equivalent to German levels.[56] We find a rough correspondence of energy

[55] Allen 'The Great Divergence in European Wages and Prices from the Middle Ages to the First World War' (2001 p. 413).

[56] Broadberry (1997), *The Productivity Race*, p. 2 Fig. 1.1.

availability relative to needs for the UK and USA, once differences in stature have been adjusted for, and the superior energy availability relative to needs of UK households compared to German households. This difference in rankings might be due to the fact that our results rest on the analysis of individual-level export industry worker micro-data and Broadberry's are aggregate economy-wide figures. Relations between productivity levels and real wages usually also refer to wages deflated by output prices, rather than by consumer prices, and this may go some way to explaining the differences in rankings.

Finally, we investigate the welfare gains in nutritional terms of emigration from continental European countries, where on average households are unable to satisfy the energy required for sustained physical work, to the USA. We find that all European ethnic groups in the USA have relatively energy-rich diets and that once the likely differences in physical stature are considered, the escape from hunger through intercontinental migration is all the more evident. We also show that British migrants to the USA are at least as generous in providing calories for the children as their counterparts in Britain, with the implication that the children of these migrants would, on average, be taller in adulthood, holding other variables constant.

Thus, industrial workers in the USA were ahead of their European counterparts in the race to escape hunger. But their brothers and sisters in Europe were getting close to ending hunger, and soon would. For Europe, these were some of labour's aristocrats, and it would be longer before the escape was complete for the whole of their populations. Clearly, escaping from hunger has more than one meaning for European migrants close to the breadline in the closing decades of the nineteenth century.

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