

## Human Capital in Britain, 1760 to 2009

Jan Kunnas, Nick Hanley (University of Stirling), Eoin McLaughlin, David Greasley (University of Edinburgh), Les Oxley (University of Waikato) & Paul Warde (University of East Anglia)<sup>1</sup>

Work in progress

### Abstract

Human capital can be defined as the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being. It is arguably one of the most important determinants of economic growth. In general, human capital has been calculated with two different approaches: 1) retrospective method through the expenditures on education, 2) prospective through the discounted sum of the wages it would receive over the expected number of remaining working years.

In this paper we use the prospective method to calculate human capital in the UK from the mid 18<sup>th</sup> century to the present. To overcome the problems related to the scarcity of historical data, we have developed a method which is able to make the most efficient use of the scarce data available for the 18<sup>th</sup> and 19<sup>th</sup> centuries. Our calculations show a 122-fold increase of human capital, and a 14-fold increase of human capital per worker and per capita from 1760 to 2009. Using cumulative schooling expenditures from 1833-2000, we test whether increased spending on schooling explains this phenomenal growth in human capital.

### 1. Introduction

The OECD (2001) defines human capital as “*the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being.*” In this paper we will use a narrower definition provided by the World Bank (2006): *the skills and know-how embodied in the labor force.* Its wealth estimates suggest that human capital along with other forms of intangible capital—the quality of formal and informal institutions—is the preeminent form of wealth worldwide. Furthermore, it is arguably one of the most important determinants of

---

<sup>1</sup> We thank the Leverhulme Trust for funding this work. Address of correspondence Jan Kunnas [j.g.kunnas@stir.ac.uk](mailto:j.g.kunnas@stir.ac.uk)

economic growth. Galor and Weil (2000), for example, argue that an increase in the level of human capital can trigger a takeoff from a Malthusian stagnation to a modern growth regime.

Despite arguments about its importance, measuring human capital empirically is problematic. In general, human capital has been calculated using two different approaches (see Le, Gibson and Gibson (2003) for a comprehensive review) : 1) retrospective (or resource-cost) methods utilising expenditures on education, 2) prospective methods utilising the discounted sum of the wages that the labour force (or those employed) would receive over the expected number of their remaining working life. Occasionally, a combination of these two approaches has also been used. Alternative approaches include methods that evaluate some components of human capital using indicators for example, literacy or numeracy (Romer 1990). An example of the latter is the age heaping method, which is often used to examine inequalities in human capital between regions and countries (Hippe and Baten 2011, Crayen & Baten 2010).

In this paper we have calculated human capital by wages in the UK from the mid 18<sup>th</sup> century to the present. To achieve this, we have estimated a human capital series using historical data on wages, employment, life expectancy, age distribution of the population, male and female labour force participation, and the male and female share of wages. Our calculations show a large 122-fold increase in our measure of human capital, and a 14-fold increase of human capital per worker and per capita from 1760 to 2009. Using a similar approach we also estimate the cumulative public schooling expenditures which we use to consider whether increased spending on schooling explains the growth in human capital.

## **2. The retrospective method**

The retrospective or resource-cost method is usually associated with the work of Kendrick (1976), and Abramovitz and David (1996). Kendrick separates tangible and intangible human capital and equates the investment in tangible human capital to the rearing cost of children up to the age of 14, including the full value of their consumption. As investments in intangible human capital, he includes investments in education and training, investments in health, mobility and R&D. The investment in intangible human capital by education and training includes the costs of schools and the foregone earnings of students 14 years and over.<sup>2</sup>

---

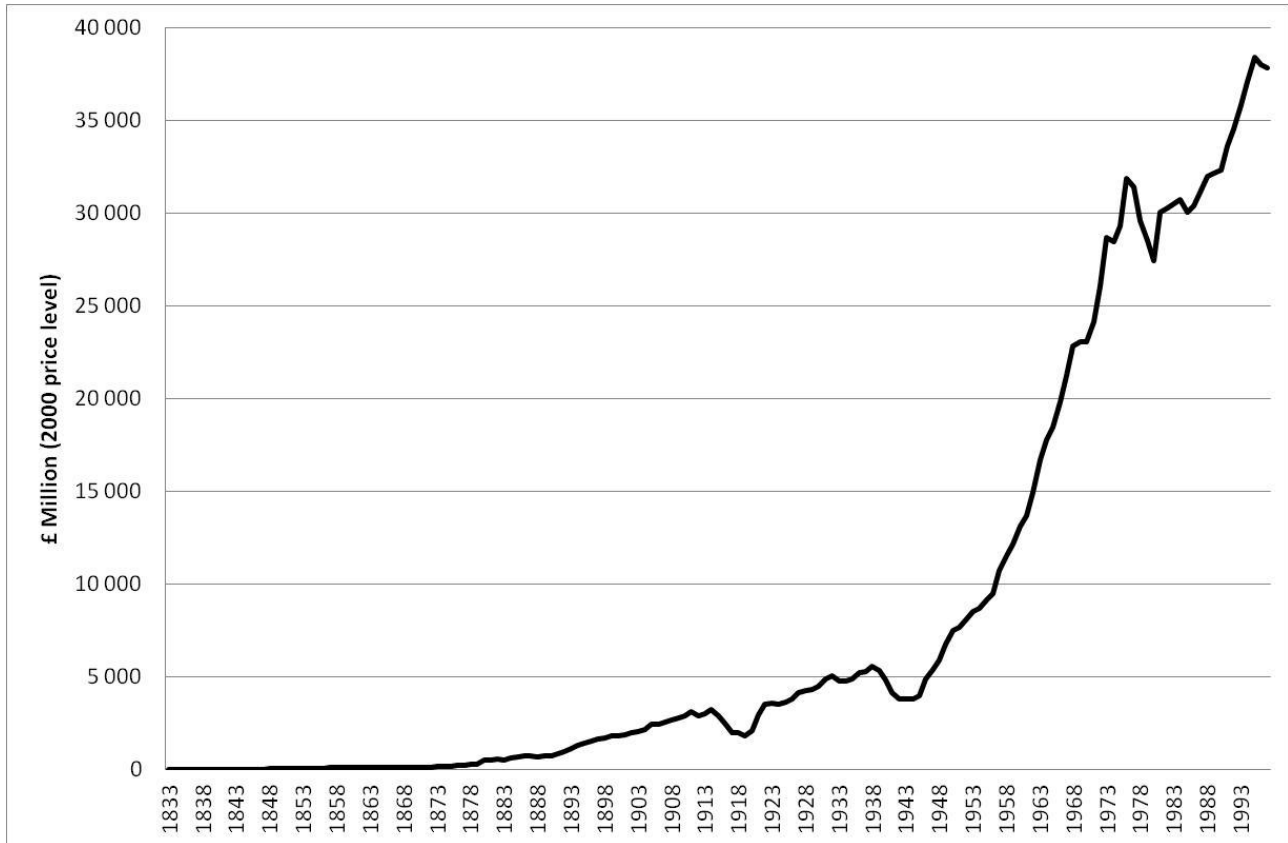
<sup>2</sup> For a further discussion of Kendrick's approach, see Kokkinen (2012) pp. 80-86.

In a calculation using the retrospective method on the development of Finland's human capital from 1877 to 2000, Kokkinen (2012) concentrates on paid monetary flows as investments in formal education for two particular reasons: First, his aim was to explore whether schooling has had a role in the standard GDP growth; Second, if foregone earnings are added to both investments and to GDP, it results in an approximately 20-30% increase in the level of GDP (Kendrick, 1976). "When the connection of human capital in accordance with such investments would be explored with GDP, a long run equilibrium type of cointegration relation would be empirically much easier to achieve. Therefore, in empirics, at least to start with, it would be good to make sure that the connection human capital by education can strictly be found with the standard GDP." Furthermore, children below the age of 14 would have been fed and nourished with the same goods and services regardless of whether they have enrolled in schooling or not, and also even if they have not been able to participate later in the labor force.

Kokkinen (2012, 104-134) does not argue that his calculation would be a comprehensive measure for human capital, and underlines this by naming his measure "intangible human capital by schooling". In his study, students will produce and embody human capital by using education services as intermediate inputs. The new skills the students have embodied are treated as produced human capital by schooling, which is valued through the expense of providing their education. When a student has finally graduated from their highest level of education and enters the labour force, the accumulated stock of human capital by schooling is calculated as the amount of all accumulated education expenditures the student has used up to that date. The depreciation rate of the productive stock of intangible human capital by schooling is calculated using the assumption of a geometric age-efficiency profile, calculated separately as basic, upper secondary, professional and university education in accordance with the average service lives, assuming that the average retirement age is 65. Furthermore, the stock is adjusted by those killed in wars and by net migration.

One major flaw with the retrospective method is that it assumes that a dollar of educational expenditure translates into a dollar increase in human capital; something that studies in both rich and poor countries has been shown to be a poor assumption (Ferreira & Vincent 2005, Jorgenson and Fraumeni 1992, and Schultz 1988). Furthermore, it assumes that educational expenditures are the only source of human capital. This is likely to be accentuated the further back in time we consider, as the role of schooling diminishes for example, Humphries (2010) estimates that by the early 19th century, England had more than a million child workers accounting for 15 per cent of the total labor force. Of these, 350,000 were seven- to ten -year-olds. During most of the 18th century only perhaps 35 % of ten-year-old working-class boys were in the labor force while the figure for

1791-1820 was closer to 55 %, rising to 60 per cent for the period of 1821-1850. Approximately one third of the eight-year-old working-class was part of the work force between 1791 and 1850 compared to fewer than 20 per cent before 1791. This would leave little room for formal schooling.<sup>3</sup> Furthermore data collected by Carpentier (2001) on public educational expenditure shows that public expenditure on education was more or less non-existent until the late 19<sup>th</sup> century (Figure 1).



**Figure 1:** Public educational expenditure in United Kingdom, 1833-1997

Source: Carpentier, V. 2001, *Système éducatif et performances économiques au Royaume-Uni: 19<sup>ème</sup> et 20<sup>ème</sup> siècle*, L'Harmattan, Paris.

### 3. The prospective method

The assumption that educational expenditures are the only source of human capital can be avoided by using the prospective method or "discounted lifetime earnings" approach. This method adopts the assumption that wages equal the marginal product of labour and that the discounted sum of wages over their lifetime equals human capital. An advantage of using the prospective approach is that it automatically takes into account factors affecting health, such as pollution, by capturing the impact on people's capacity to work, their time as part of the work force and their margin product (wage). Fouquet (2011) estimated that since 1800 approximately 4.5 million people died

<sup>3</sup> See also Horrell and Humpries (1995).

prematurely as a result of coal production and use, most due to air pollution. The skills and know-how embodied in the labour force that is thus lost, will be automatically accounted for via this method by its impact on the size of the workforce and the payments they receive (or otherwise) for their work.

The prospective method is most often associated with the work of Jorgenson and Fraumeni (1989, 1992a & b), and Graham and Webb (1979). The starting point for the analysis of Jorgenson and Fraumeni (1989) is an analogy between investments in physical capital and investments in human beings. Present expenditures yield returns over the future, thus the investments in human capital (tangible and intangible) can be valued as the present value of lifetime labour incomes for all individuals in the population. They also include (controversially given how it effects the overall measure derived) in the labour compensation the value of nonmarket activities, for example, household production and leisure time. Furthermore, they include investments in education.

Jorgenson and Fraumeni (1989) assume that the time available for all market and nonmarket activities by an individual is equal to fourteen hours per day based upon studies of time allocation, for all individuals between work, schooling, household production and leisure, and maintenance. They forecast the expected incomes in future periods by assuming firstly that the expected incomes are equal to the incomes of an older aged individual with the same sex and education as is being considered. Secondly, they assume future real incomes increase at a rate that represents the Harrod-neutral technical change, or 2% per year. Jorgenson and Fraumeni weight the income for each future year by the probability of survival by sex. Finally they calculate the present value of future income by discounting at a real rate of return, using an estimate of 4% per year.<sup>4</sup>

Le, Gibson and Oxley (2006) exclude non-market activities from their calculations for the human capital in New Zealand. They argue that a full imputation of non-employment overestimates a country's stock of human capital:

The rates of participation and employment are important indicators of an economy's performance; assuming equal value between a full-time worker and a non-participant is not justifiable, from an economic point of view. For that reason, we exclude the human capital of those individuals who are out of employment as well as the contribution that employed individuals make outside paid work. ...The working capital of employed individuals directly participates in economic production, hence it is arguably a better measure of the country's productive capacity. p. 595

---

<sup>4</sup> For a further discussion of Jorgenson and Fraumeni's approach, see Kokkinen (2012) pp. 86-93.

This approach can be considered an under estimate, as they argue that “knowledge and skills that are not used in economic activities are useless.”<sup>5</sup> Clearly, many unpaid activities, like child rearing, voluntary action, etc. benefit society and thus also economic growth in the long run by keeping society stable. Furthermore, their method “rests crucially on the assumption that differences in wages perfectly mirror the differences in marginal productivity of labour, and that productivity is a proxy for human capital.”<sup>6</sup> It might thus be more appropriate to rename human capital calculations using wages in a similar fashion to that of Arto Kokkinen (2012) who calls his calculations based on the effects of schooling “human capital by schooling.” Similarly, human capital calculated from wages can be called “human capital by wages”, thus not giving the impression of being a comprehensive estimate of human capital.

Le, Gibson and Oxley (2006) estimate the present value of lifetime labour income using cross-sectional data. They assume that a person aged  $a$  years with a certain level of education bases their expected earnings  $nt$  years in the future on the current earnings of people of the same education and gender who are  $a + t$  years old.

For example, if people retire at age 65, the present value of the lifetime labour income of 64-year-olds is simply their current labour income. The lifetime labour income of a 63-year-old individual is equal to their current labour income plus the present value of lifetime labour income of the 64-year-old, and so forth. This model can be extended to incorporate a growth rate in real income that is constant across ages and education levels.

Formally,

$$h_a^{ei} = W_a^{ei} Y_a^{ei} + S_{a,a+1}^{ei} h_{a+1}^{ei} d$$

$h_a^{ei}$  is the average human capital for individuals aged  $a$  with educational attainment  $ei$ ;

$W$  is the probability of engaging in paid work, defined as the number of employed people over the population

$Y$  is the average current annual labour income of employed individuals;

$S_{a,a+1}$  is the probability of surviving one more year from age  $a$ ;

$d = (1 + g)/(1 + i)$ ;  $g$  is the income growth rate;  $i$  is the discount rate. (pp. 595-596)

---

<sup>5</sup> ...in terms of their aim of creating a monetary measure of human capital using the prospective income approach.

<sup>6</sup> In some extreme cases though, the wage level has straight implications for labour efficiency. For example Rowntree (1908, 303) argued in his examination of poverty in York in 1899 that the labouring class received in upon the average about 25 per cent less food than has been proved by scientific experts to be necessary for the maintenance of physical efficiency. Thus increased wages if used for food would have increased labour productivity. Indeed, Walker (1891, 54) argued that what the employer will get out of his workman will depend very much on what he first gets into him: “If his diet be liberal, his work might be mighty. If he be underfed, he must underwork.”

Another practical question is how to take into account the increasing role of wage labor over self-employment. For example, the rise of agrarian capitalism and the decline of family farming (Shaw-Taylor 2012). Our calculation based on wage incomes does not include incomes from selfemployment. On the other hand, GDP has a bias against subsistence farming and production within households (Crayen and Baten 2010). However, as we want to use human capital to explain GDP growth, this bias is less important as is the case for Le et.al. (2006) who had the same aim.

#### 4. Human capital by wages in the UK 1760-2009

One of the major drawbacks of applying the Le et al. (2006) approach historically is the substantial amount of information that would need to be collected. In addition to wage rates in different age and occupation groups and life expectancies in different groups, it requires estimates or measures of the participation rate in the workforce and number of days worked per year.<sup>7</sup> Voth (2001) identifies a profound increase in the working year in England between 1750 and 1800, as well as a subsequent decrease in 1830. Hours worked in the United Kingdom per year declined from 2,755 hours in 1870, to 2,656 in 1913, and further to 2,200 in 1938 (Feinstein 1972).

To overcome the problems related to the scarcity of historical data, we have developed a method that is able to make the most efficient use of the scarce data available for the 19<sup>th</sup> and 18<sup>th</sup> centuries. This method allows us to use the prospective method to calculate human capital in UK from the mid 18<sup>th</sup> century to present. Our method is based on the following simplified formula:

$$H_t = W_t + W_{t+1}r^2 + W_{t+2}r^3 + \dots + W_{t+n}r^n$$

$H_t$  = Human capital in point t

$W$  = the total annual income from employment and self-employment

$r = 1 -$  discount rate

$n$  = the average years left in the work life of the population in working age weighted by the wage share of males and females

---

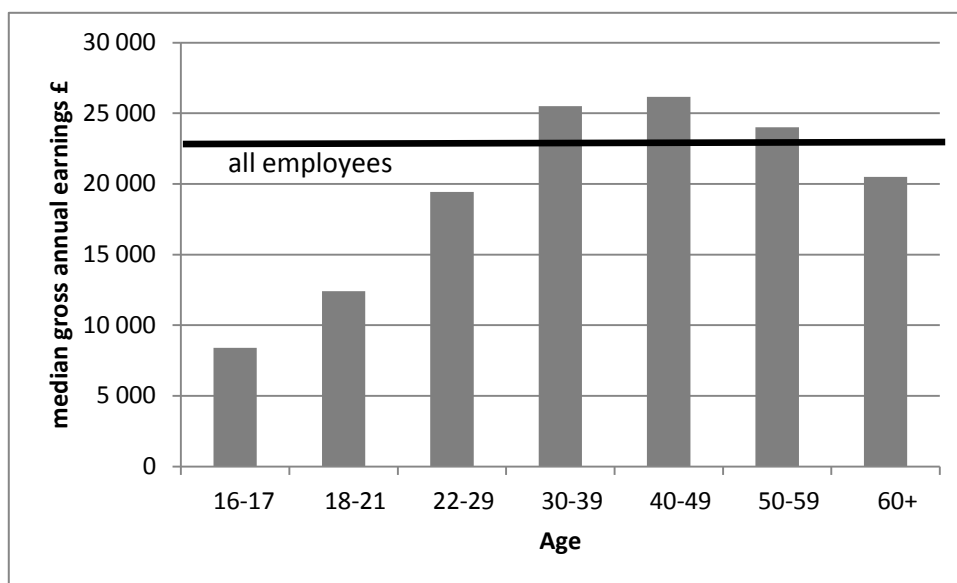
<sup>7</sup> In their case this is less of a problem given they were using recent Census data.

## 4.1 Time in labour force

The starting point for our calculation of human capital by wages is the average time that the current population of working age will remain in the labour force. For the period 1841 to 2008 this is calculated by combining separate tables of life expectancy for males and females with separate estimates of the male and female population divided into age groups. From 1760 to 1840 we are using a simplified approach, which will be explained below.

Starting from separate estimates of the male and female population in England, Wales and Scotland we divide people into age groups with five years intervals (15-19, 20-24...) from 1841 onwards. For the years 1841, 1851, 1861, 1871, 1881, 1891, 1901, 1911, 1921, 1931 and 1951, the source is Mitchell and Deane (1962), and for 1961 Mitchell (2003). From 1971 onwards we have annual records from the Office for National Statistics, National Records of Scotland, Northern Ireland Statistics and Research Agency (ONS 2011). Missing years have been linearly interpolated.

Of the age group 15-19 only half have been included from 1760 to 1950, to account for their lower wages and that some are in education. For some years within this period the age group we have information on is 15-24 year, and for them we have included  $\frac{3}{4}$ , for the same reasons. For example in 2006, the median gross annual earnings of full-time employees in the age group 16-17 years old was 36 percent of the median annual earnings, and in the age group 18-21 years it was 53 percent of median as we can see from Figure 2 (ONS 2012). Burnette (2010) reports a similar wage structure for the wages of factory workers in 1833, with a steep increase in the wage level up to 20 years of age, a peak in wages after 30 years of age.



**Figure 2** Median Gross annual earnings (£) in UK 2006

Source: ONS Annual Survey of Hours and Earnings <http://www.ons.gov.uk/ons/publications/reference-tables.html?edition=tcM%3A77-250731> Released: 24 February 2012



In England in 1985 the employment rate of 16 to 18 year olds was 60.7 % of the employment rate of all aged 16 to 64; by 2009 this share had dropped to 24.7 %. We do not have information for the age group 15-19 years as we would need, but we assume that the assumedly lower participation rate and wages of 15 years old counters the assumedly higher participation rate of 19 years old and higher wages of 20-21 year old. Furthermore, we assume that the average annual wage in the age group 15-19 years would remain at a stable level of 44.5 % of the average wage  $(36+53)/2$ , and take thus into account 27 percent  $(60.7\% * 44.5\%)$  of the persons in the age group 15-19, and 11 %  $(24.7\% * 44.5\%)$  in 2009. Years in between has been calculated similarly with the employment rates for each year and the 2006 earnings. From 1951 to 1985 we assume a linear decline of this ratio from the above mentioned 50 % to 27 percent. For the whole period 1760 to 2009 the part of the age groups 15-19 or 15-24 years old not included has been added to the next age group 20-24 or 25-29 to as they are entering the workforce or getting full wages.

In 2006 the wage level peaks in the age group 40-49 years, while in 1833 wages peaked after 30 years of age. In both cases the latter decline is not as profound as the increase from 16-30 years of age and we have not taken into account the decline in older age groups. (ONS 2012 & Burnette (2010)). Effectively, we assume the same wage for all age groups over 20 years. The motivation for this assumption is that we are calculating the discounted cumulative wages over the average time in workforce, thus this difference in wages typically cancels out over the years that the wages are discounted.

The estimates of the male and female population divided into age groups have been combined with life expectancy tables from the office of national statistics, which give the expectation of life by single year of age separately for males and females for the periods 1841, 1838-44, 1838-54 and from 1871-80 to 1901-10 for each decade. From 1920-22 to 2000-2 they provide the life expectancies in the first three years of each decade. (ONS 2009b). From such sources we have calculated the average life expectancy for each of the 5-year age groups the population estimates are divided into.

Prior to 1949, we assume that everyone works until they turn 70 or die. From 1950 onwards we have assumed everyone to work until retirement. As the retirement age we have assumed 70 years in 1950 with a linear decrease for males to 67.71 years, and 65.70 for females by 1965. From 1965 and onwards we have used OECD (2012) calculations on the average effective age of retirement.

Multiplying the size of each age group with their estimated time remaining in the working population (alive and below 70 years or age of retirement), we obtain the total work years that the female and male population of working age will remain in the working population for each year

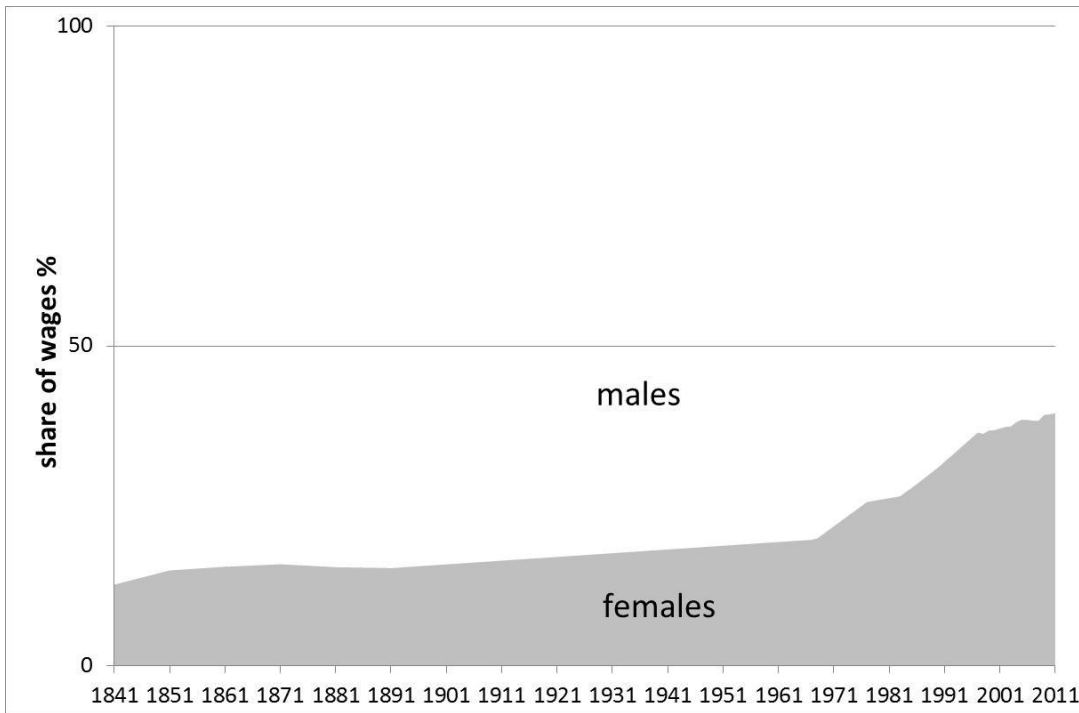
under scrutiny. Dividing these estimates by the total size of the age groups included, we get the average time that the population will remain in work (the size of the 15-19/24 year old age group has been corrected to take into account that only 11-50 percent of it has been included).

These separate estimates for the male and female population have been weighted by the share of the wages of males and females in total wages (Figure 3). The female share has been calculated by multiplying the share of women in the total workforce by the average female wage of the average wage for both sexes. The male share is  $1 - \text{female wage share}$ . For 1841, 1851, 1861, 1871, 1881 and 1891 the participation rate for male and females are taken from Armstrong (1972, 280) The female wage is assumed to have varied from one-third to two-thirds depending on the type of work and location, giving an average of 41.7 % of the male wage (Burnette 1997, 257). These calculations return a female wage share of 12.7 % in 1841, rising to 15.3 by 1891.<sup>8</sup> A similar calculation based on Bowley (1942) indicates that this share increased to 17 % by 1924, and remained at this level to 1935. By 1968 the female wage share was 19.9 percent of total wages; by 1977 this rose to 26.6 percent, and 31.1 percent by 1990 (Davies and Joshi 1998). From 1993 to 2009 we used figures from the ONS (2012a), and the mean gross weekly earnings of males and female from the Annual Survey of Hours and Earnings ONS (2012b). Our calculations indicate that the female share of total wages has increased to 36.5 percent by 1997, and to 39.2 percent by 2009.<sup>9</sup>

---

<sup>8</sup> This calculation can be compared to Rowntree (1908, 83), who estimated that the average earnings of the males in a working class family in York in 1899 was 28 shillings and 8 pence, and that of the females was 3 shillings and ¼ pence. This would return an even lower female wage share of around ten percent.

<sup>9</sup> The lower share of wages received by females does not imply a lower human capital for females. Our calculation of human capital using wages only catches the human capital contained in the labour force, and should not be interpreted as a comprehensive estimate of human capital. Following Mincer (1984, 199) we stress that much of the accumulation of a person's human capital, that is later taken up by the wages he receive, takes place in the home, and is to a great extent carried out by females. Thus although, especially in earlier periods, human capital is mainly measured by the wages received by males, the role of females to create this capital is essential.



**Figure 3.** Male and female share of wages, 1841—2011

Source: see text

The average time left in the working age is calculated as follows: the female share of total wages times their average time left in the work force plus the male share of total wages times their average time left in work force. Given that the female share of the wage sum is small, the average years left in the work life is mainly driven by the male series, as we can see from Figure 4.

For the period 1760 to 1840 we have used a simpler method to calculate the average years left in the work life where we have taken life expectancy at birth from Wrigley & Schofield (1981, 529) and have assumed that the relationship between the expectation of life at birth and the average time left in the working population was the same as in 1841. In 1841 our calculated average time in the working population was 29.33 years, while the expectation of life was 40.28. Thus we get, for example, the average time of working life for 1761 by multiplying the average life expectancy of 34.23 years in 1761 by the weighted average time in the workforce in 1841 (29.33 years) divided by the average life expectancy in 1841 (40.28 years). This gives an average time of working life of 25.37 years for 1761. The data provided by Wrigley & Schofield are with 5 year intervals, and the years between have been linearly interpolated. We support the use of this simpler measure by the fact that the relative size of different age groups remained fairly stable over this period. From 1761 to 1841 the size of the age groups 0-4 years and 5-14 years increased by 1 ½ percent points, that of the age group 15-24 by 2 ½ percent points, while the age group 25-59 shrunk by 3 ½ percent points, and that over 60 years old shrunk by 2 percent.



**Figure 4.** Time left in working age weighted by wages, 1760 to 2009

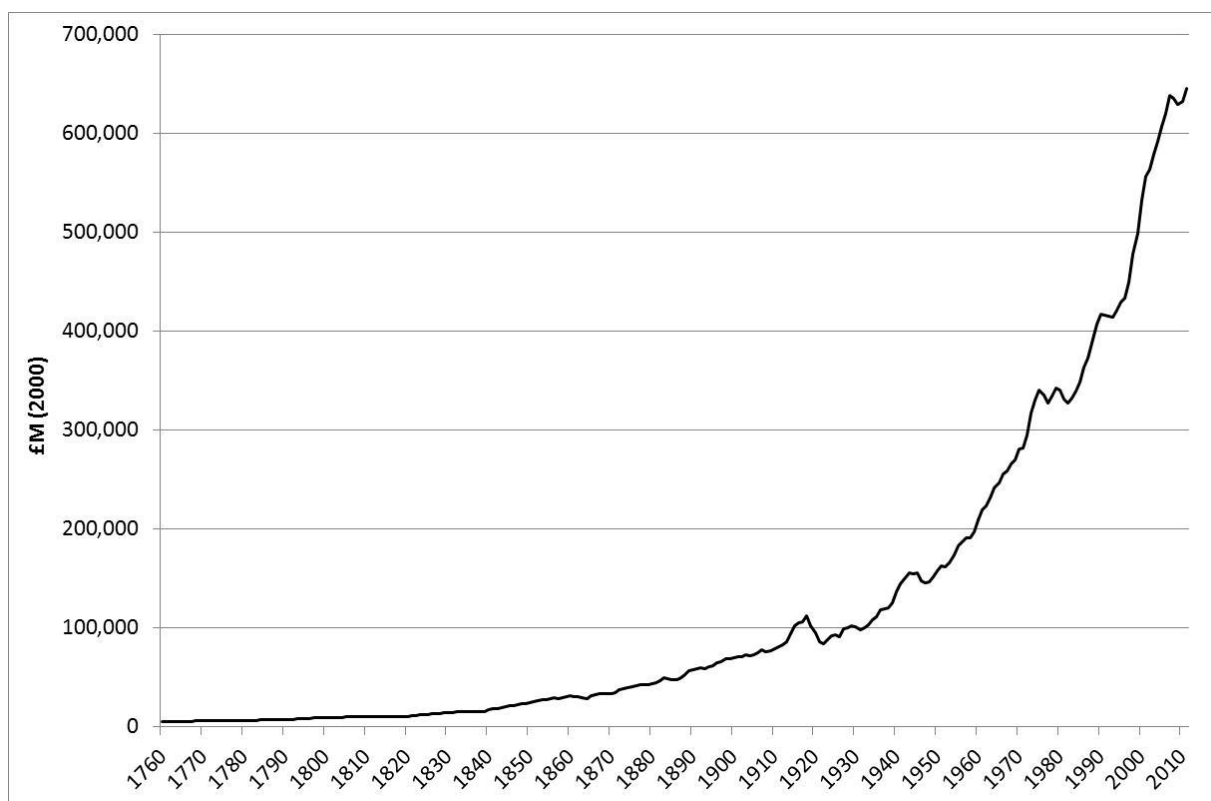
Source: calculations made by the authors

The period 1841 to 1871 witnessed a slight rise in the average age of the workforce, with the share of those between 15 and 34 decreasing by three percent units. Combined with a slight decline in the life expectancies of the male population, this caused a one and a half year decline in the average life left in the working age. The share of those between 15 and 34 years declined another three percent from 1871 to 1920, this was, however, counteracted by an increase in life expectancy between five and seven years in the same age groups. As life expectancy also rose in most other age groups, the average time left in the workforce increased by almost three years. Since 1920, the average life left in the working age has, however been in a more or less constant decline, dropping from 31 years to 27 years by early 1970s. Initially this decline was driven by an ageing population; the share of those between 15 and 34 years declined, from 49 percent in 1920 to 40 percent in 1961. A brief reversal of this development saw the share of those between 15 and 34 to reach 43 percent in 1973 and 48 percent by the 1980s, and the average time left in working life to reach 28 years in 1975. Since that the average time left in working life continued to decline and dropped close to 23 years by 1999, as the population grew older again and retired earlier. In 1965-70 the average effective age of retirement for females was 65.7 years and for males 67.7 years, by mid 1980s the female retirement age dropped below 61 years and male below 63 years. This development was slightly reversed at the turn of the century, and in 2004-09 the average retirement age for female was 62.1 years and for

males 64.3 years. Thus the average time left in the workforce rebounded to 25 years in 2009. (Wrigley & Schofield 1981, 529; OECD 2012; ONS 2011).

## 4.2 Wages

In this section we present estimates of the total annual income from employment for the period under consideration (Figure 5). For the period 1855 to 1947 the source is Feinstein (1972) and from 1948 to the present, the Office of National Statistics (ONS). For the period before 1855, we calculated the income from employment using the labour force participation rate adjusted for unemployment from Voth (2000, 220) and the average annual nominal earnings taken from *Measuring Worth* (Clark 2011). We have used real wages in our calculations which have been obtained using nominal wages deflated by a GDP deflator for 1750-1870 from Broadberry et al (2011) 1870-1965 from Feinstein(1972) , 1966-2000 from ONS (2006) and 2001-2011 from *Measuring Worth*. In contrast to Le, Gibson and Oxley (2006) we do not consider different educational attainment and its effect on the wage level.



**Figure 5.** Total annual income from employment and self-employment 1760 to 2009 (2000 price level). Source: see text

Feinstein's total wage from 1855 to 1920 is for Great Britain, and prior to that, so are our own wage estimates. Thus our human capital measure relates to GB alone from 1760 to 1920, and for the UK from 1921 to 2002 (although at this scale of aggregation the difference is negligible). Indeed the post WW1 depression equates to the deflated total wage series falling from £116 million (2000 price level) in 1920 to £105 million in 1921, when the data shifts to UK instead of GB. In 2009 the number of jobs were 18,210 thousand in Great Britain and 18,884 thousand in United Kingdom; the mean wage in Great Britain was £26,614 and £26,450 in UK as a whole. Thus the total wage sum in GB was 97.2 percent of that of UK in 2009.

As our estimates of human capital are based upon future wages we need wages for the time a person remains in the workforce. For most of our study we use historical data but from 1988 to 2009, we need an estimate of total wages for 2012 to 2034 (assuming 25 years in the labour force). From 2011 onwards we have assumed a constant 2 percent per annum growth of the total wage sum. Thus we get results comparable to the calculation for UK human capital in the years 2001 to 2010 by Jones and Fender (2011), who assume that labour productivity grows by two percent per annum.

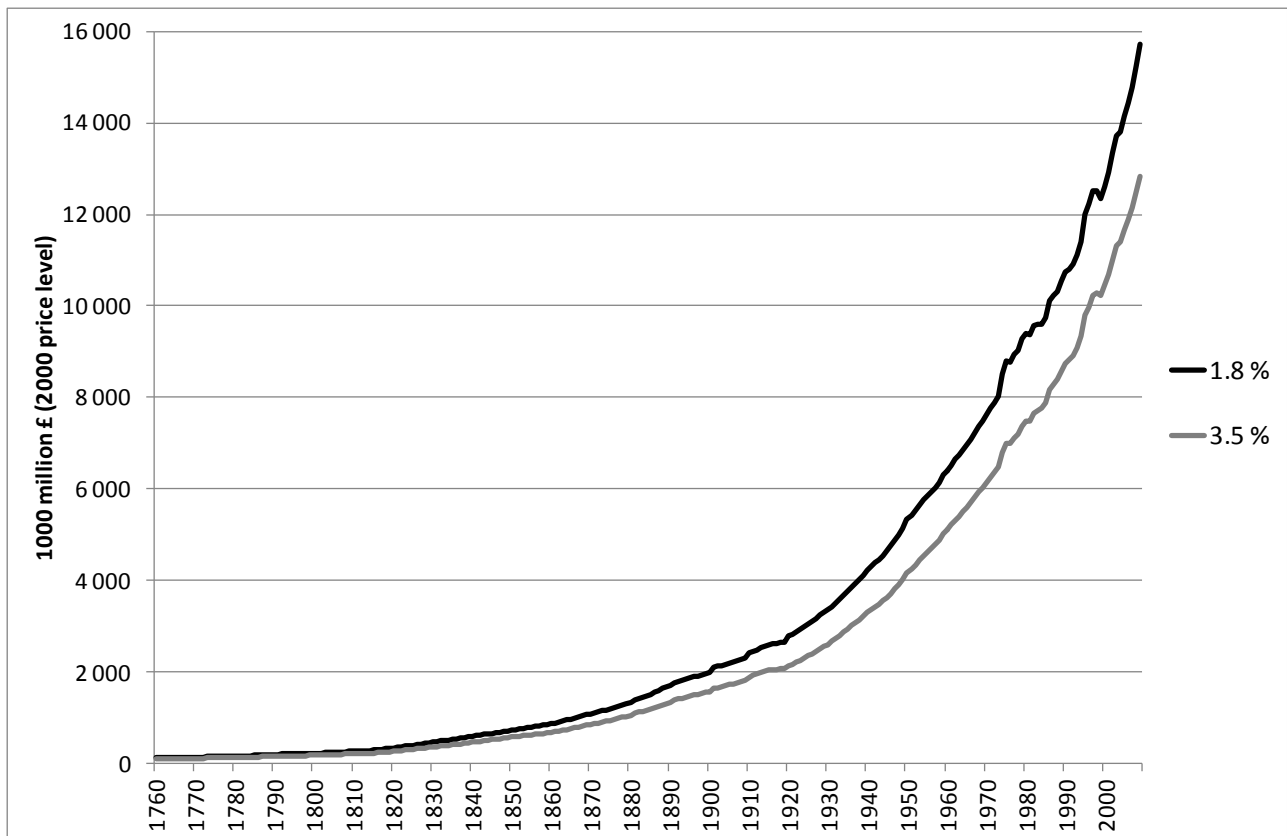
### **Discount rate**

To discount lifetime earnings we use the average GDP growth rate for the UK over the period under consideration, 1.8 %; and 3.5 %, as suggested by HM Treasury (2003), and used by Jones and Fender (2011) in their calculation of UK human capital from 2001 to 2010. Furthermore, we use a 3.5 % discount rate to allow comparisons with their calculations. As we can see from Figure 6, the discount rate has a major influence on the absolute level of human capital, but shape is relatively insensitive to the chosen discount rate given that we are discounting future incomes over a period of 22 to 32 years.

The estimate of Jones and Fender (2011) for UK human capital in 2009 in 2000 prices was £13.1 Trillion, while our estimate with a 3.5 percent discount rate is £12.8 Trillion. Their estimate for 2001 was £11 Trillion in 2000 prices, and our estimate was 10.7 Trillion. Jones and Fender (2011) also used the discounted value of future income method, and as such their estimates and ours should be comparable. With slightly different method of calculation and assumptions, a difference less than three percent might be considered small.<sup>10</sup>

---

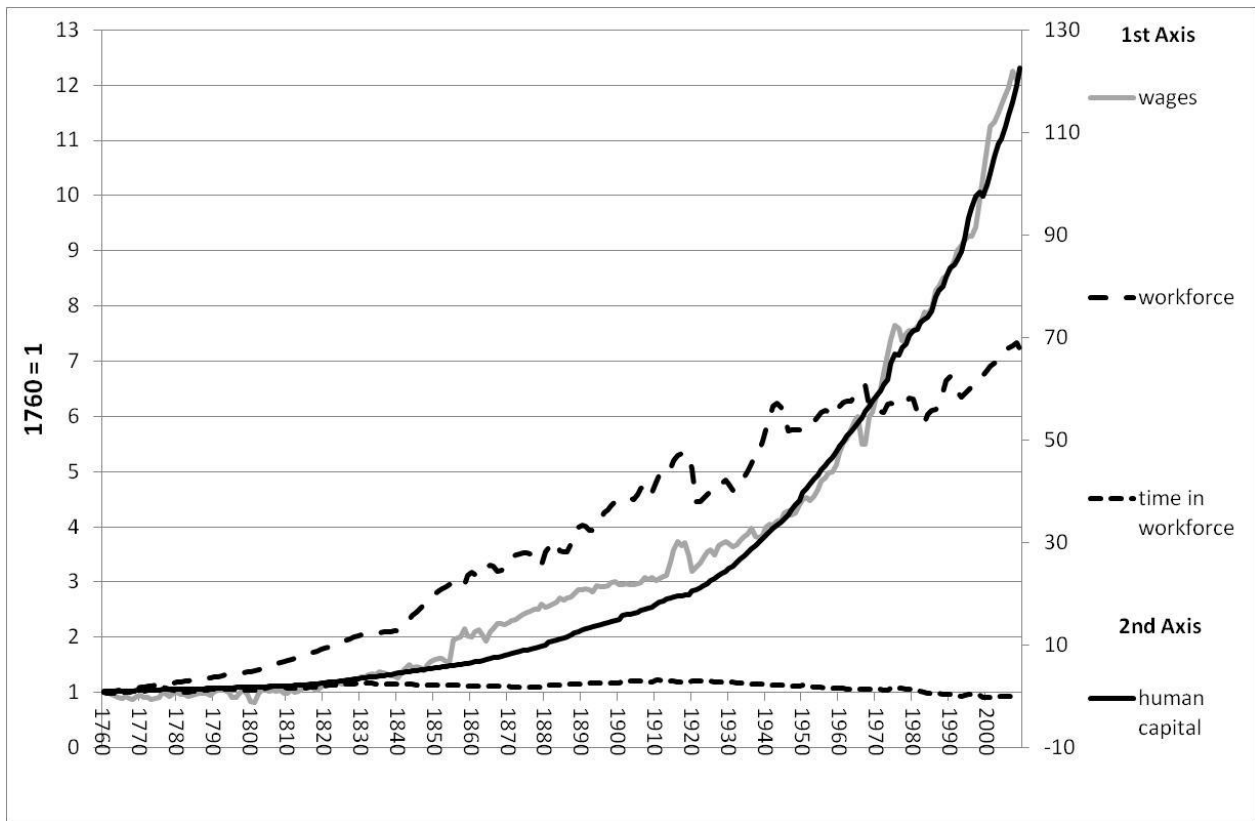
<sup>10</sup> We converted their estimates from 2010 prices (17.25 Trillion £ in 2009, and 14.5 Trillion £ in 2001) to 2000 prices to allow comparison with our figures.



**Figure 6.** Human capital 1760 to 2009 calculated with a 1.8 and 3.5 percent discount rate 1000 million £ (2000 price level).

#### 4.4 Robustness checks

Human capital calculated using a 3.5 percent discount rate led to a 122-fold increase in human capital from 1760 to 2009. To consider what might have caused this tremendous growth, we have in Figure 7 created an index of the changes in average annual wages, the size of the workforce, and the time people remain in the workforce, to consider what might have driven such an increase in human capital. Note that this breakdown does not show the relative effects of the factors causing the changes in human capital as we are summing the discounted wage incomes (wages\*workforce) over differing expected time left in the workforce. It does, however, provide an insight into the importance of each of the factors in the growth of human capital. For comparison, we have included an index for human capital as the second axis.



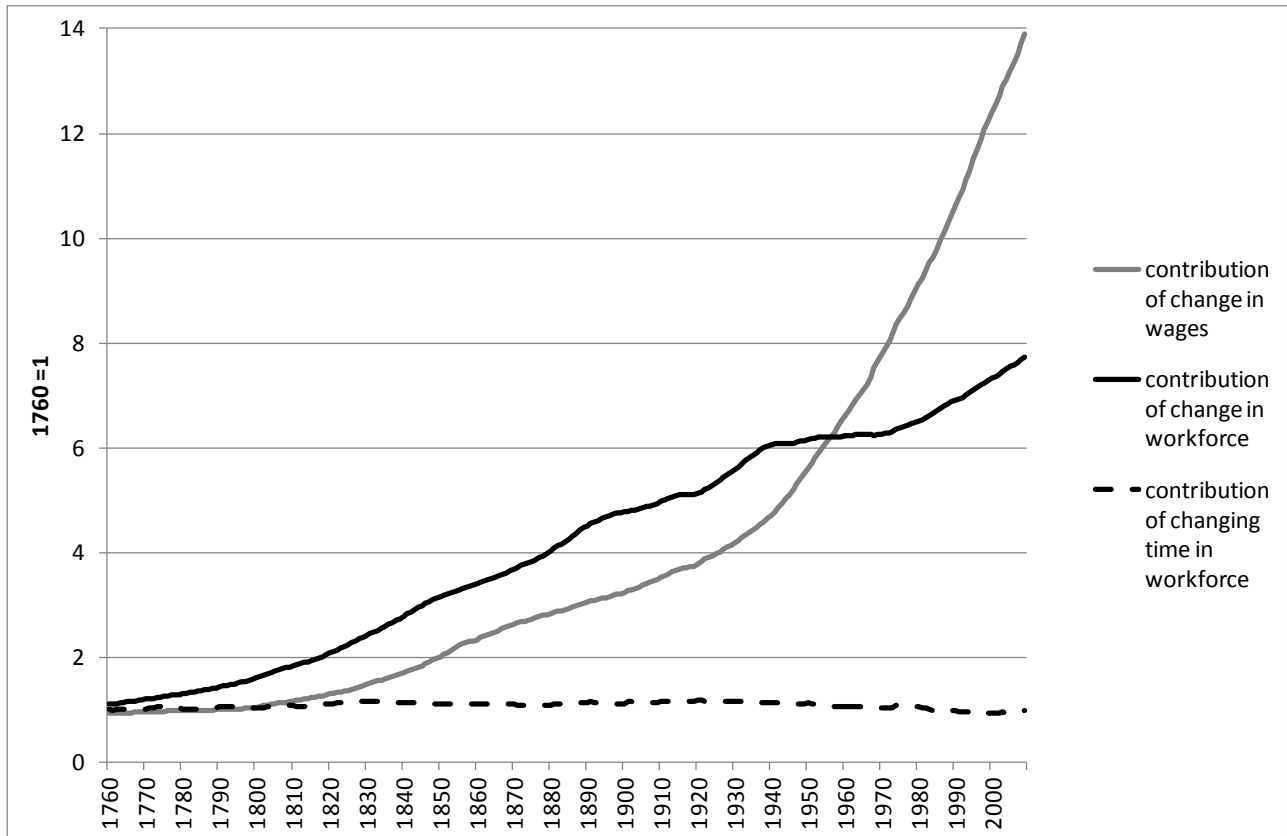
**Figure 7.** Change in wages, workforce and time in workforce 1760-2009, 1760=1

Holding one factor at a time constant, we get a clearer picture of the contribution of each. As we can see from Figure 8, the smallest impact on human capital comes from the change in the average time in the workforce, which fell from 1760 to 2009 by four percent from 25.8 years to 24.8 years. Using the 1760 figure for average time remaining in the workforce in the calculation of the human capital for 2009, would have resulted in only a six percent increase in human capital from £12.5 Trillion to £13.3 Trillion. In contrast, human capital in 2009 calculated using the workforce of 1760 is only £1.7 Trillion, thus the growth of the workforce from four to 29 million persons has resulted in an eight fold increase in human capital from 1760 to 2009. The main source of human capital growth has, however, been via the growth in real wages. Human capital in 2009, calculated using 1760 wages, is only £0.9 Trillion, thus the growth of wages and anticipated future growth of wages results in a fourteen-fold increase in human capital from 1760 to 2009.

As we can see from Figure 8, the role of the changing time in workforce has remained small during the whole period under consideration; as such we can equate most of the changes in human capital with the changes in real wages and in the size of workforce. As real wages remained almost constant in the late 18<sup>th</sup> and early 19<sup>th</sup> centuries, the change in the workforce was initially the main driver of changes in human capital. Increases in the workforce remained the major driver of growth in human capital, even after real wages began to grow after the first decade of the 19<sup>th</sup> century, as

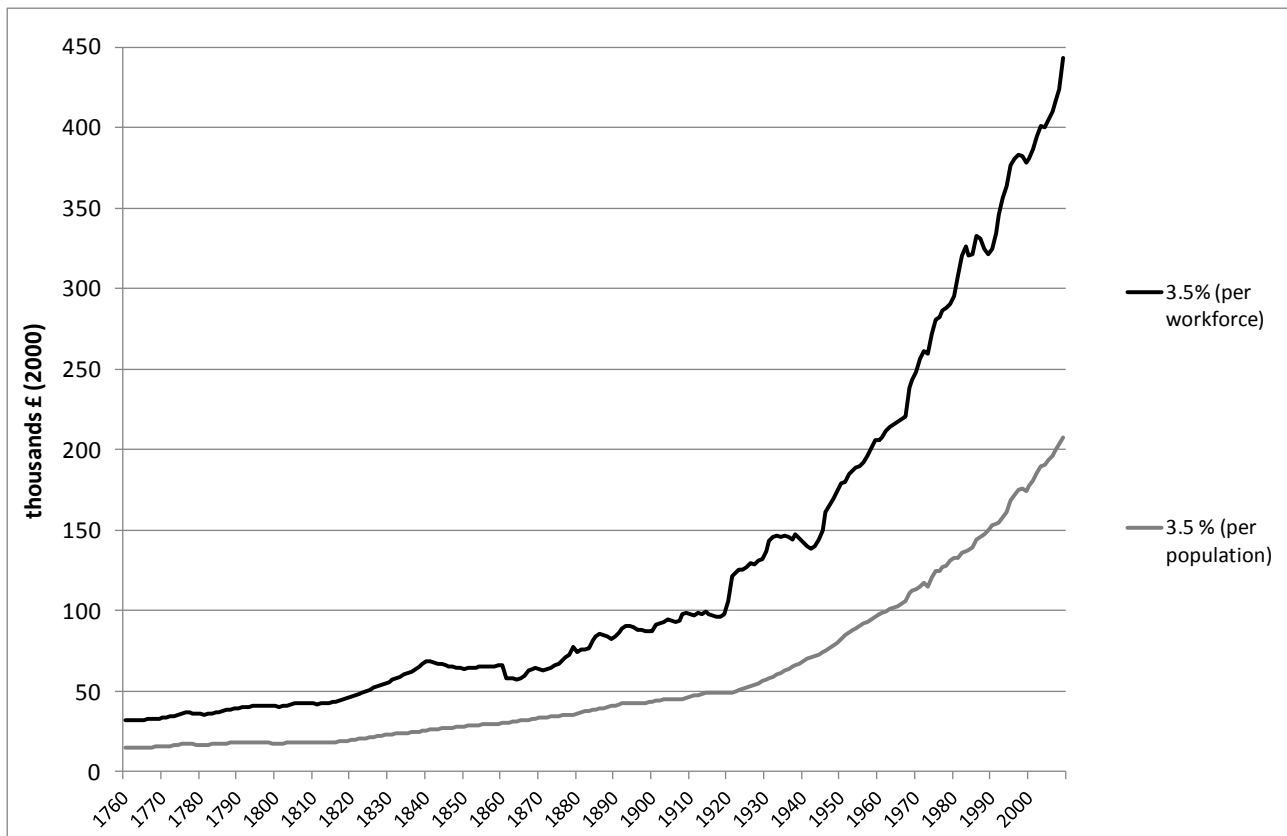


the workforce grew by twice the rate of wages up to the mid 19<sup>th</sup> century, and one third faster from the second half to the First World War. The period after the world wars witnessed fast growth in real wages, while the growth in the workforce stagnated until after 1983, when the size of the workforce reached its lowest point since the end the Second World War.



**Figure 8.** The contribution of change in wages, workforce and time in workforce to human capital, 1760-2009.

To further isolate the effects of increased wages on human capital, we next divide human capital by the workforce and by the total population (Figure 9). In 153 years, from 1760 to 1913, human capital per member of the workforce tripled from £32 000 to £98 000, while in 96 years from 1913 to 2009 it increased 4.5-fold to £443 000. Most happened since the end of the world wars, such that in 64 years since 1945 it increased 3-fold from £150 000. Accordingly, from 1760 to 1913 human capital per capita tripled from £15 000 to £48 000, and from 1913 to 2009 it increased 4.3-fold to £208 000.



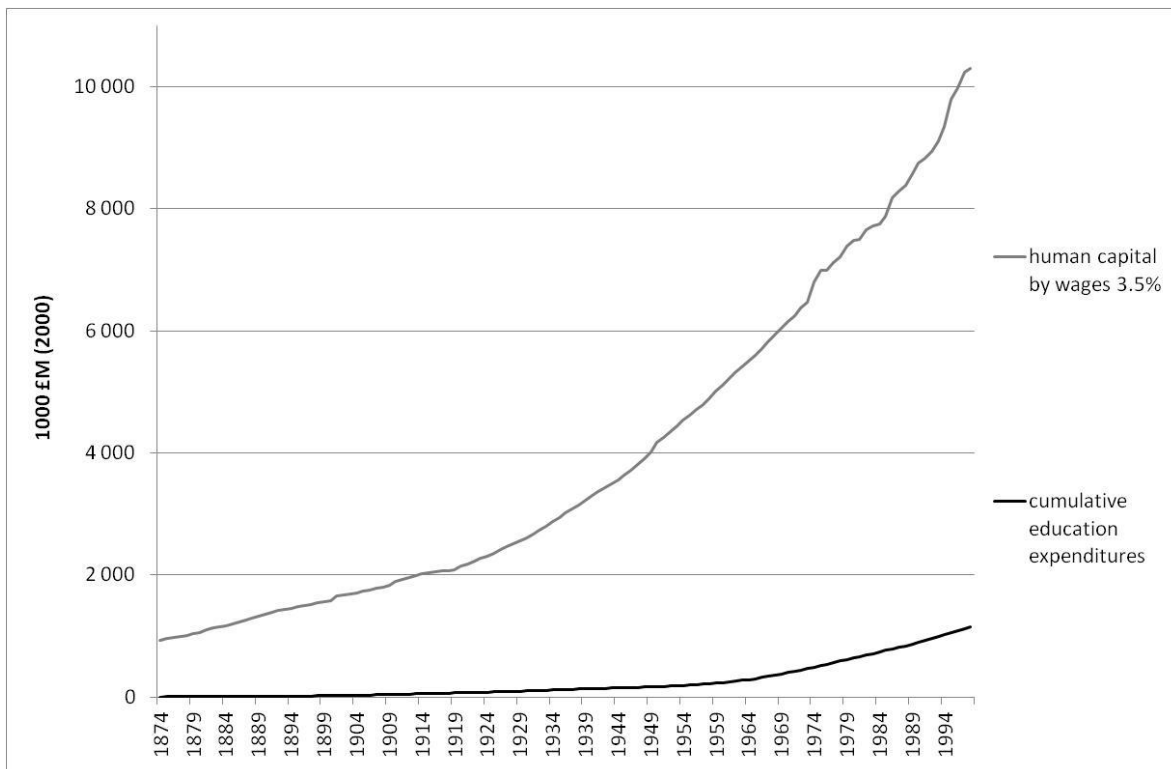
**Figure 9.** Human capital per work force and population 1760 to 2009

## 5 The growth of human capital explained as returns to knowledge

What has been the driver of this growth in human capital, especially since the end of the world wars? In accordance with the World Bank's (2005, 87) narrow definition of human capital, it could be argued that the reason stems from the growth of knowledge embodied in the labour force. One possible explanation for that again could be the increase in education especially education expenditure.

To test this hypothesis we calculated cumulative public expenditure on education for the period 1833-1997 using an approach similar to the one used to calculate human capital using wages. Our data are from Carpentier (2001) and includes public educational expenditure on preschool and compulsory education (nursery, primary, secondary and special education), post compulsory education (further education, higher education and teacher training) and related expenditures from administration to school welfare (e.g. transport, meals and milk, medicine and sport). We use this as a proxy for the total cumulative spending on education.

We also assume that each year's expenditure on education is effective as long as a 20 year old person, (which is our assumed age of fully entering the working population), still has expected years of life remaining. Thus, contrary to the 'human capital by wages' approach, we do not assume that retirement nullifies human capital, as educated persons can still pass-on their knowledge to other generations.<sup>11</sup> To give an example, in 1833 the estimated life expectancy of those aged 20 was 40 years such that when calculating human capital by expenditure in 1874, we would sum all the expenditure on education from 1833 to 1873. Due to this retrospective approach, 1874 is the first year we can calculate cumulative education expenditure.



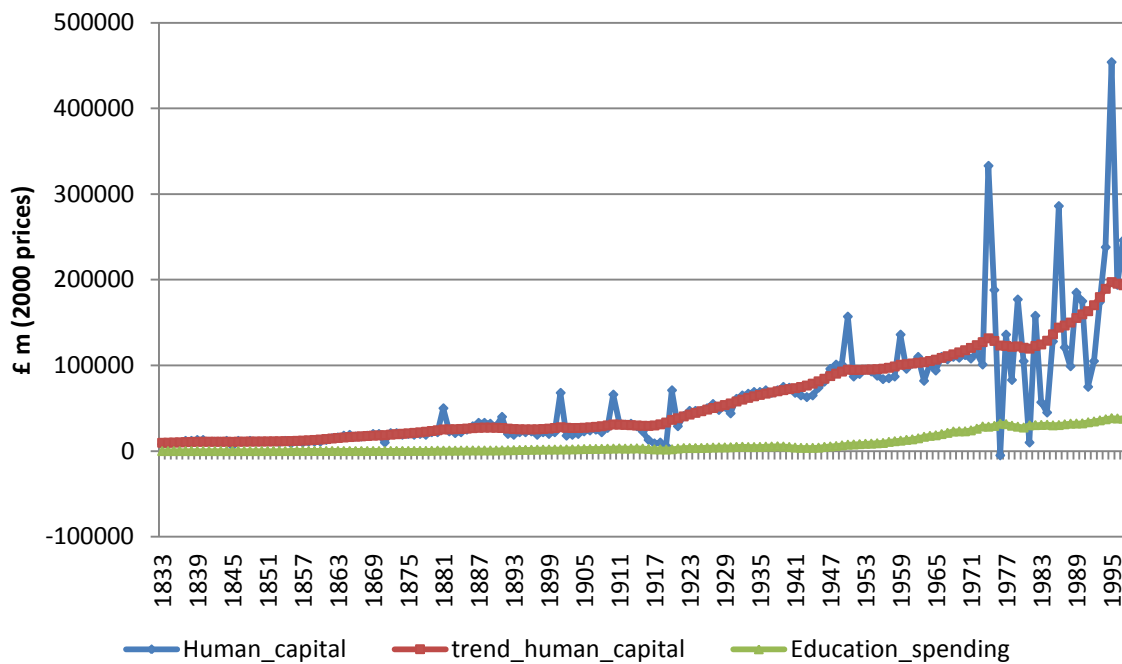
**Figure 10** Human capital by wages vs. cumulative education expenditures 1874-1997

In Figure 10, we compare the cumulative education expenditure with our 'human capital by wages'. Except for the assumed lifetime of education expenditures no further depreciation has been attached to education expenditures. Such depreciation would imply that the value of received education would diminish over the years. This is entirely plausible, after all, lots of education may become irrelevant – or forgotten – over time. We could though argue the opposite as well, that the value of schooling would increase over the time as people learn to put their schooling into practice. Nevertheless, the cumulative education expenditures are a small fraction of the human capital by wages measure. Even with a comparable amount of private spending, it would imply a considerable return to schooling expenditure, if we want to argue that this is the main reason behind the growth

<sup>11</sup> We could, however, easily model the effects of retirement.

in human capital post WW2. In other words, we're testing whether education itself is a kind of capital from which more human capital can be produced.

However, formal schooling might well not have been the only or main source of human knowledge, instead human capital might be best considered the accumulated effects of by learning by doing. We will therefore consider next an estimated trend in the annual change in the human capital stock series using a Kalman filter, as shown in Figure 11. The change in human capital, the Kalman trend of the change in human capital and public expenditure on education are compared below.



**Figure 11**  $\Delta$  human capital stock, Kalman trend  $\Delta$  human capital stock and public education expenditure

Table 1 focuses on the time series properties of each series. The change in human capital does not appear to have a unit root whereas the Kalman trend of the change in human capital and education expenditure do. Testing whether the change in human capital is related to education spending is shown below. The change in human capital is correlated with public education spending and appears to be cointegrated.

	$\Delta$ Human capital	Trend $\Delta$ Human capital	$\Delta$ Human capital (first difference)
Augmented Dickey fuller unit root test (p-value for z-t)	0	1	1
Education spending	4.303*** (0.284)	4.057*** (0.114)	0.139 (0.348)
Constant	24,403*** (4,005)	25,801*** (1,603)	306.9 (4,921)
R2	0.5844	0.8865	0.001
Durbin Watson (residuals)	1.51	0.025	2.73
Observations	164	165	164

Standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table 1: Time series properties of  $\Delta$  Human capital, Trend  $\Delta$  Human capital and  $\Delta$  Human capital (first difference)**

## Conclusions

In this paper, we have calculated the human capital stock for Great Britain and subsequently the United Kingdom, from 1760-2009 using a Prospective method based upon discounted life time earnings. The advantage of this method over others for example, the Retrospective method that utilises expenditures on education, is that it avoids the assumption that educational expenditures are the only source of human capital growth. Furthermore the Prospective method automatically takes account of factors affecting for example, health, and pollution, etc., by capturing their impacts on people's capacity to work and their time in the work force.

Our calculations show a phenomenal 122-fold of human capital over this period, most of this was explained by growth in real wages and the growth of the working population, the average time in working force had only a minor effect. Using a similar approach we calculate the cumulative schooling expenditures from 1833 to 2000, and tested whether increased spending on schooling explains this phenomenal growth in human capital. Our calculations show that a meaningful relationship might be found from around the 1920s to present. Before that we suggest that formal schooling was not the main source of human knowledge, instead we suggest that human capital is mainly accumulated by learning by doing.

## Literature

- Abramovitz, M. and David, P. A. (1996), "Technological Change and the Rise of Intangible Investments: The U.S. Economy's Growth-path in the Twentieth Century", in *Employment and Growth in the Knowledge-based Economy*. OECD, Paris, pp. 35–50.
- Armstrong, W. A. (1972), "The use of information about occupation," pp. 191-310 in E. A. Wrigley (ed.) *Nineteenth-century society, Essays in the use of quantitative methods for the study of social data*. Cambridge at the University Press.
- Baten, J. & Van Zanden J., (2008) 'Book production and the onset of modern economic growth', *Journal of Economic Growth*, 13/3, pp. 217-235.
- Bolt, Katharine, Matete, Mampite, and Clemens, Michael (2002). *Manual for Calculating Adjusted Net Savings* Environment Department, World Bank, September.
- Bowley, A.L. (ed.) (1942) *Studies in the national income, 1924-1938*. Cambridge University Press, 1942
- Broadberry, Stephen, and Burhop, Carsten (2010), "Real Wages and Labor Productivity in Britain and Germany, 1871—1938," *The Journal of Economic History*, Vol. 70, No. 2, pp. 400-427.
- Broadberry, S., Campbell, B., Klein, A., Overton, M. & van Leeuwen, B. (2011), *British economic growth, 1270-1870*, viewed <http://www2.lse.ac.uk/economicHistory/whosWho/profiles/sbroadberry.aspx>
- Burnette, Joyce (2010) "Women Workers in the British Industrial Revolution," (Based on : "Report from Dr. James Mitchell to the Central Board of Commissioners, respecting the Returns made from the Factories, and the Results obtained from them." *British Parliamentary Papers*, 1834 (167) XIX) <http://eh.net/encyclopedia/article/burnette.women.workers.britain> (Posted 2010-02-05) 11:54
- Burnette, Joyce (1997), "An investigation of the femal-male wage gap during the industrial revolution in Britain", *Economic History Review*, vol 50, issue 2, 1997, 257-281.
- Carpentier, V. 2001, *Systeme éducatif et performances économiques au Royaume-Uni: 19eme et 20eme siecle*, L'Harmattan, Paris.
- Clark, Gregory (2011). "What Were the British Earnings and Prices Then? (New Series)" MeasuringWorth, 2011. <http://www.measuringworth.com/ukeyearnspi/>
- Clark, Gregory (2006). English prices and wages, 1209-1914 Accessed 20.09.2012 from: [gpih.ucdavis.edu/files/England\\_1209-1914\\_\(Clark\).xls](http://gpih.ucdavis.edu/files/England_1209-1914_(Clark).xls)
- Crafts, N. F. R. 1985, *British economic growth during the industrial revolution*, Clarendon Press - Oxford,
- Crayen, Dorothee and Baten, Joerg (2010), "New evidence and new methods to measure human capital inequality before and during the industrial revolution: France and the US in the seventeenth to nineteenth centuries", *Economic History Review*, 63, 2, pp. 452-478.
- Davies, Hugh and Joshi, Heather (1998), "Gender and income inequality on the UK 1968-1990: the feminization of earnings or of poverty?" *J.R. Statist. Soc A*. (1998) 161, Part 1, pp 33-61.
- DCSF (2008). *Education and Training Statistics for the United Kingdom: 2008*. Department for Children, Schools and Families. Accessed 19.9.2012 from <http://www.education.gov.uk/rsgateway/DB/VOL/v000823/index.shtml>

- De Munck, Bert (2011), ‘Gilding golden ages. Perspectives from early modern Antwerp on the guild-debate, c. 1450- c. 1650’, *European Review of Economic History*, August 2011 15 : pp 221-253. DOI: 10.1017/S1361491611000050
- Feinstein, C. H. a. & Pollard, S. 1988, *Studies in Capital Formation in the United Kingdom, 1750-1920*, Oxford University Press,
- Feinstein, Charles H. (1972). *National Income, Expenditure and Output of the United Kingdom 1855-1965*, Cambridge University Press, Cambridge.
- Feinstein, Charles H. (1995) ”Changes in nominal wages, the cost of living and real wages in the United Kingdom over two centuries, 1780-1990” Appendix, Table A.23, p. 258 in Peter Scholliers and V. Samagni (eds.) *Labour's Reward: Real Wages and Economic Change in 19th- and 20th-Century Europe*. Aldershot: Edward Elgar Publishing Limited.
- Ferreira, S., and J. Vincent. 2005. “Genuine Savings: Leading Indicator of Sustainable Development?” *Economic Development and Cultural Change* 53: 737–54.
- Fouquet, R. 2011. Long Run Trends in Energy-Related External Costs. *Ecological Economics* 70(12), 2380-9.
- Flinn, M. 1977, *Scottish population history from the 17th century to the 1930s*, Cambridge University Press,
- Galor, Oded and Weil, David N. (2000) “Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond” *The American Economic Review*, Vol. 90, No. 4, pp. 806-828 <http://www.jstor.org/stable/117309> .
- Hippe, Ralph and Baten, Joerg (2011), *Regional Inequality in Human Capital Formation in Europe, 1790—1880*, AFC Working Papers, Nr. 7.
- HM Treasury (2003) *The Green Book: Appraisal and Evaluation in Central Government*. London: TSO. Downloaded from [http://www.hm-treasury.gov.uk/d/green\\_book\\_complete.pdf](http://www.hm-treasury.gov.uk/d/green_book_complete.pdf) 19.11.2012
- Horrell, S. and Humphries, J. (1995) “”The exploitation of little children”: child labour and the family economy in the industrial revolution”, *Explorations in Economic History*, 32, pp. 485-516.
- Humphries, Jane (2010) *Childhood and Child Labour in the British Industrial Revolution*, Cambridge University Press.
- Jones, Richard and Fender, Valerie, *Human Capital Estimates – 2010*. Office for National Statistics 20 December 2011
- Jorgenson, Dale W., Fraumeni, Barbara M. (1989), ”The Accumulation of Human and Nonhuman Capital”, 1948-84. In R. E. Lipsey and H. S. Tice (eds.) *The Measurement of Saving, Investment and Wealth*.
- Jorgenson, Dale W., and Barbara M. Fraumeni. (1992), “The Output of the Education Sector.” In *Output Measurement in the Service Sectors*, ed. Zvi Griliches. Chicago: University of Chicago Press.
- ILO (2012). LABORSTA Labour Statistics Database: Table: 1A Total and economically active population, by age group. <http://laborsta.ilo.org/> Accessed 24.9.2012.
- Kander, Astrid and Warde, Paul (2011), “Energy availability from livestock and agricultural productivity in Europe, 1815—1913: a new comparison,” *The Economic History Review*, Vol. 64, No. 1, pp. 1-29.

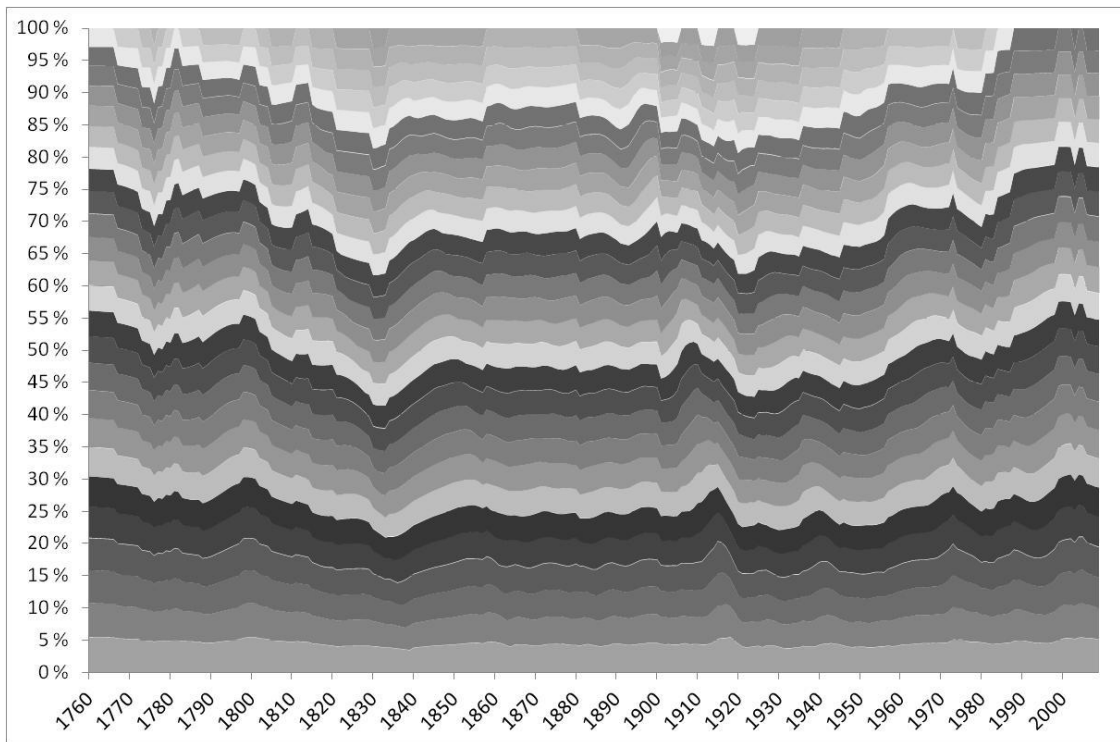
- Kendrick, John W. (1976). *The Formation and Stocks of Total Capital*, Columbia University Press for NBER, New York.
- Kokkinen, Arto (2012). *On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century*. Research Reports 258. Helsinki: Statistics Finland. Downloaded 24.09.2012 from <http://www.stat.fi/tup/julkaisut/tiedostot/978-952-244-334-2.pdf>
- Le, Trinh, Gibson, John and Oxley, Les (2003). [Cost- and Income-based Measures of Human Capital](#), *Journal of Economic Surveys*, 17(3), 271-307.
- Matthews, R.C.O., Feinstein C. H. and Odling-Smee, J. C. (1982). *British Economic Growth 1856-1973*. Clarendon Press, Oxford.
- Mincer, J. (1984), "Human Capital and Economic Growth," *Economics of Education Review*, Vol 3. No. 3, pp 195-205
- Mitchell, Brian R. and Deane, Phyllis (1962). *Abstract of British historical statistics*. Cambridge: Cambridge U.P.
- OECD (2012), *Average effective age of retirement in 1970-2005 in OECD countries*. Excel-file downloaded 19.9.2012 from <http://www.oecd.org/els/employmentpoliciesanddata/ageingandemploymentpolicies-statisticsonaverageeffectiveageofretirement.htm>
- OECD (2001) *The well-being of nations: the role of human and social capital*. OECD, Paris, 2001
- O'Mahony, M. & Timmer, M. P. 2009, 'Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database', *Economic Journal*, vol. 119, no. pp. 374-403.
- ONS (2012a) *Labour Market Statistics - Integrated FR - Labour market status by age group*. Office for national statistics. Downloaded 7.7.2012.
- ONS (2012b) Annual Survey of Hours and Earnings <http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-250731> Released: 24 February 2012.
- ONS (2011) Mid-1971 to Mid-2010 Population Estimates: Quinary age groups for Constituent Countries in the United Kingdom. Date supplied: 21 December 2011. [www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/population-estimates-timeseries-1971-to-current-year/rft---table-2-quinary-age-groups-constituent-countries.zip?format=hi-vis](http://www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/population-estimates-timeseries-1971-to-current-year/rft---table-2-quinary-age-groups-constituent-countries.zip?format=hi-vis) Accessed 15.1.2013
- ONS (2005 and 2009). *Annual Abstract of Statistics*. Basingstoke: Palgrave MacMillan
- ONS (1962, 1965, 1966, 1969, 1972, 1979, 1981, 1991, 1997 and 1999). *Annual Abstract of Statistics*. London: Her Majesty's Stationery Office.
- ONS (2006) *Economic Trends*.
- ONS (2009b) (Decennial Life Tables - Period expectations of life from English Life Tables: Nos. 1 to 16 (Excel sheet 56Kb) Release date 25 Jun 09 Downloaded from [ons.gov.uk](http://ons.gov.uk) 15.5.2012
- Romer, P. (1990), "Human Capital and Growth: Theory and Evidence," *Carnegie-Rochester Conference Series on Public Policy*, 32, 251-286.
- Rowntree, B. Seebohm (1908), *Poverty, A Study of Town Life*. New and cheaper Edition, Reprinted. London: MacMillan and Co.
- Schultz, T. Paul. 1988. "Education Investments and Returns." In *Handbook of Development Economics*, vol. 1, ed. Hollis Chenery and T. N. Srinivasan. Amsterdam: North-Holland.



- Shaw-Taylor, Leigh (2012), “The rise of agrarian capitalism and the decline of family farming in England,” *The Economic History Review*, Vol. 65, No. 1, pp. 26-60.
- Trinh Le, John Gibson and Les Oxley (2006) “A Forward Looking Measure of the Stock of Human Capital in New Zealand”, *The Manchester School* Vol 74 No. 5 September, pp. 593–609.
- van Zanden, Jan Luiten (2009) *The Long Road to the Industrial Revolution. The European Economy in a Global Perspective, 1000-1800*. Leiden.
- Voth, H.-J. “The longest years: new estimates of labour input in England, 1760—1830”, *Journal of Economic History*, 61, pp. 1065-82.
- Voth, H.-J. (2000) *Time and work in England 1750-1830.*, Oxford: Clarendon Press - Oxford.
- Walker, Francis A. (1891), *The Wages Question, A Treatise on Wages and the Wage Class*. London: MacMillan and Co.
- World Bank (2006). *Where Is the Wealth of Nations? Measuring Capital for the 21st Century*. Washington, D.C.: World Bank
- Wrigley, E.A. and Schofield, R.S. (1981). *The population history of England, 1541-1871: a reconstruction*. London: Edward Arnold for the Cambridge Group for the History of Population and Social Structure.
- Wrigley, E. A. & Schofield, R. S. 1989, *The Population History of England 1541–1871*, Cambridge University Press,

## Appendix 1

To see the impact of individual years in our calculation, we have calculated the relative contribution of the present and future wages to the human capital for each year with a 3.5 % discount rate. The contribution of the current year is at the bottom of the table, and the further up we go the more the wages will be discounted. This will also work as a check of our calculations. As the average growth of wages over the period under scrutiny is lower than the wages, the relative contribution should decline the further we go ahead in time. Our calculations pass this test, as the relative contribution of the current year ranges from 3.3% to 5.4 %, the relative contribution of the 23rd year is between 2.4 % and 3.7 %. At longest we are discounting over 31 full year years, which causes the relative contribution of the last full year to drop between 2.1 % and 2.7 %.



## Appendix 2: Returns to knowledge?

In the human capital by schooling approach, human capital is considered as a return to schooling. In our calculations it can be considered to a return to knowledge, whether is by schooling or by learning by doing at the work itself. If we want to have a similar approach, we can deduct the minimum wage, and then the remaining could be interpreted similarly as the return to knowledge. In practise we have deducted from the total wages, the result of the total workforce multiplied with an estimate of the minimum yearly wage. For the period 1855 to 1960 our estimate of the workforce comes from Feinstein (1972). His estimate of the workforce includes, however, also those self-employed. Our total wage sum serving as the base of our human capital calculations includes, however, only wage earners. To sort this out we multiplied our annual wages, with the result of the minimum wage times the total workforce divided by Feinstein's estimate of total wages from employment and self-employment. From 1760 we have used the wage of manual agricultural laborers as an estimate of the minimum wages, and from 1968 onwards the wage of the lowest decile.

For the period 1760 to 1779 we have used daily farm wages collected by Gregory Clark (2006). From 1780 to 1960 we have used the average weekly earnings for farm manual workers from Feinstein (1995). For the period 1760 to 1912 weekly wages have been transformed to annual wages assuming 49 work weeks per year, the average working weeks per years in 1856 according to

Matthews, Feinstein & Odling-Smee (1982, Table D1). From 1913 to 1960 they have reported the average working weeks in roughly ten years intervals, dropping from 48.81 weeks in 113 to 46.07 in 1960. From 1760 to 1779 we have in addition assumed 6 working days per week. The minimum wages from 1760 to 1960 have been scaled down assuming that 70 % of the wages goes to males and 30 % to females, and that female wages are 50 % of male wages. From 1968 to 2009 we have used the average weekly wage of the lowest decile of males and females from annual abstracts of statistics (ONS 1972, 1979, 1981, 1991, 1997, 1999, 2005 and 2009). They have been transformed to annual wages assuming 45 working weeks a year, the annual working weeks in 1973 taken from Matthews, Feinstein & Odling-Smee (1982, Table D1).

