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ORIGINAL PAPER

Human capital formation in the long run: evidence from average years of schooling in England, 1300–1900

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Abstract In this paper, I quantify average years of education present in the English population between 1307 and 1900. The estimates are based on extensive source material on literacy rates, number of primary and secondary schools and enrolment figures. An additional distinction is made on the basis of gender and of level of schooling. The trends in the data are indicative of significant increases in the level of educational attainment during the sixteenth and seventeenth centuries. This remarkable growth in schooling was followed by a strong decline in average years of education after ca. 1720. Whilst one in seven boys entered secondary schooling at the end of seventeenth century, this had decreased to one in thirty by the 1880s. Overall, the trends in the data suggest that education was beneficial to pre-industrial economic growth, but this was not sustained following the initial stage of the industrialisation process.

Keywords Human capital · Industrial revolution · Economic growth · England

JEL Classification N13 · N34 · J24 · O10

1 Introduction

Economic models of the Industrial Revolution increasingly emphasise the key role of human capital in promoting economic growth (e.g. Becker et al. 2011; Galor 2011), and empirical studies have shown that education is a strong predictor of per capita GDP (Barro 1991; Mankiw et al. 1992; Aghion and Howitt 1992; Krueger

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and Lindahl 2001; Cohen and Soto 2007; Goldin and Katz 1998; Hanushek and Woessmann 2008).[1] The logic behind this is that human capital facilitated technological adoption and innovation (cf. Nelson and Phelps 1966; Schultz 1975; Benhabib and Spiegel 1994). Contrary to what the theory predicts, economic historians have described the role of human capital in the English Industrial Revolution as minor (Mokyr 1990; Nicholas and Nicholas 1992; Mitch 1993; Crafts 1996; Clark 2005). Literacy rates were at best mediocre. Around 1800, literacy rates were about 60% for males and 40% for females (Cressy 1980). Reis (2005) has shown that this was slightly higher than France, but significantly lower than the Netherlands, Sweden and Germany. For instance, Sweden was fully literate by the early nineteenth century.[2] There was not much improvement in literacy during the Industrial Revolution itself: male literacy rates fluctuated around 60% between 1750 and 1850 (Mitch 1993). Similar conclusions can be drawn from school enrolment figures. Out of the male population in the age bracket between 5 and 14, 28% were enrolled in schools in 1830. In 1850, by the end of the first Industrial Revolution, it had increased to 50%, but this was equal to France (51%) and considerably less than Prussia (73%) (Lindert 2004).[3]

The conclusion that human capital did not play an important role in the British Industrial Revolution draws upon records of school enrolment and literacy.[4] Literacy rates are likely to underestimate the overall level of formal education, as they only proxy primary schooling (reading and writing abilities) and enrolment rates do not take into account the age structure of the population. What is more, by largely focussing on the period after 1750, these measures are expected to understate the growth of literacy and that of schooling in general, which occurred in the centuries leading up to the Industrial Revolution.[5] The recent studies of Baten and van Zanden (2008), Buringh and van Zanden (2009) and Boucekkine et al. (2007) introduce more comprehensive measures of schooling levels, such as per capita book consumption and the number of (secondary) schools, and trace their evolution back to the mediaeval period. What these studies show is that the level of schooling was much higher in England than previously assumed from the evidence on literacy and enrolment rates. For instance, in the first half of the eighteenth century, levels of book consumption per capita were highest in Holland and England, whilst the rest of the continent lagged behind (see Buringh and van Zanden 2009). Likewise, Boucekkine et al. (2007) document significant growth in the number of new school foundations in England between ca. 1500 and 1660. Baten

[1] There is an extensive debate amongst economists about the relationship between human capital and economic growth (see Gurgand 2005; Demeulemeester and Diebolt 2011; Diebolt and Hippe 2016 who provide overviews on this topic).

[2] Sandberg (1979) argues that Sweden became Europe's 'impoverished sophisticate'. Although literacy rates were ca. 100%, its industrialization was relatively late.

[3] Literacy rates were higher in protestant countries/regions than in non-protestant countries/regions (see Becker and Woessmann 2009; Diebolt et al. 2016).

[4] Notably the records of school enrolment of Flora et al. (1983) and the literacy rates of Schofield (1981) and Cressy (1980).

[5] An important exception stems from Kelly and Ó Gráda (2014) who acknowledge a steady increase in literacy rates between 1500 and 1750.

and van Zanden (2008) and de Pleijt and van Zanden (2016) moreover empirically demonstrate that human capital formation contributed to pre-industrial economic growth.[6]

Therefore, no clear consensus exists on the importance of human capital for the growth record of England in the very long run. Economic theory suggests that it may have been crucial, but the empirical record is rather mixed, sometimes confirming theoretical expectations, in other cases demonstrating the limited impact of human capital. Part of the apparent confusion is probably due to the use of different measures for human capital, and part is probably related to the fact that different periods are studied—the years before the start of industrialisation may be telling a different story than the Industrial Revolution itself. One way to extend this debate is to study the same concept—human capital measured as average years of education—in the very long run and see how this established metric relates to the process of growth in the different periods concerned.

In this paper, I therefore apply a Perpetual Inventory Method to estimate average years of education for England between 1300 and 1900. The estimates on the stock incorporate extensive statistical evidence on literacy rates, the number of primary and secondary schools and their average class sizes, and matriculations to the Universities of Cambridge, Oxford and London. Assumptions about demographic ratios, such as survival ratios of individuals, are applied to estimate average years of schooling. An additional distinction is made on the basis of gender (years of education of males and females) and of level (primary, secondary and tertiary education). It is shown that years of schooling can be quantified rather well, in particular for the period after 1540. The estimates presented in this paper are therefore able to give a far more coherent picture on the evolution of formal schooling in the long run than do literacy rates alone. In this way, it becomes possible to examine the extent of formal schooling in the period preceding, as well as during, the Industrial Revolution.

It should be mentioned here that the estimates of educational attainment refer to just one part of the 'human capital variable'—i.e. formal education. It does not capture the part of the stock of human capital, which did not involve formal schooling, but which could have been important for the productivity of workers. This includes, amongst others, apprenticeships and on-the-job learning (see Humphries 2003; Wallis 2008; Mokyr 2009). In most growth models, however, estimates of average years of education are used as the best proxy for human capital (see Gurgand 2005; Sunde and Vischer 2011 for overviews).

It is possible to draw some conclusions from the series on educational attainment. To start with, the years of schooling measure began to increase rapidly after the 1530s. The basis for this growth was laid in the Middle Ages, when many new secondary schools were founded. Following Orme (2006), the number of secondary schools had increased from ca. 100 in 1400 to 230 in 1530, whereas the population had only slightly increased from 2.1 to 2.6 million. Between 1530 and 1700,

[6] Allen's (2003) regressions, however, suggest that 'literacy was generally unimportant for growth' between 1300 and 1800 (p. 433). This result might be explained by his estimates of literacy: for 1500, his estimates are based on the urbanization ratio, which assumes that 23% of the urban and 5% of the rural population was literate (p. 415).

secondary education accounted for over half of the share of the overall education stock of males. One in seven boys went up to the secondary level by the turn of the seventeenth century. A pronounced shift occurred after 1720, as indicated by stagnation in average years of primary schooling and a vast decline in attainment levels of secondary and tertiary schooling. By the second half of the nineteenth century, only one in thirty boys went up to the secondary level. The educational attainment levels of females were well below those of males, although it is the only series that shows consistent growth until 1800. Over the course of the nineteenth century, females rapidly caught up with males in terms of average years of primary schooling. Overall, from the evidence on the evolution of average years of education, it can be concluded that the first Industrial Revolution coincided with a pronounced decline in secondary schooling levels of males.

There was substantial growth in per capita GDP after 1750 whilst the average level of schooling stagnated, and, in the case of higher education, sharply declined (Broadberry et al. 2015). This finding provides further evidence for the predominant view that the benefits of formal education were not sustained following the initial stages of the industrialisation process (e.g. Nicholas and Nicholas 1992; Mitch 1993; A'Hearn et al. 2009). Relative to this strand of the literature, several contributions are made. Previous conclusions are derived from the observation of a pause in the growth of male literacy between 1750 and 1850. The trends in the stock of primary education of males indeed suggest that this must have been so. However, the movement away from formal secondary and tertiary schooling during the first Industrial Revolution is a factor that should not be overlooked. The decrease in average years of schooling was much greater than the evidence on the spread of literacy alone would suggest. The findings in this paper therefore show that previous research has underestimated the decline in formal education between 1750 and 1850.

Before the 'dramatic' decline in years of schooling during the years of the Industrial Revolution, there was, however, an almost equally 'dramatic' rise in human capital in the late medieval period and, in particular, in the years between 1530 and 1720. This important result may suggest that the growth of the English economy in the ages before the industrialisation of the eighteenth century was associated with the rise of the level of schooling during those years.[7] Recent research by Broadberry et al. (2015) has shown convincingly how dynamic the English economy was in this period. This paper adds to this picture by showing the equally dynamic development of literacy and secondary schooling.

The remainder of the paper is organised as follows: Section 2 presents the data on average years of education and elaborates on the assumptions underlying the estimates. Section 3 discusses the implications of the findings for the debate on the nature of human capital formation in England and that for the relationship between human capital and economic growth more generally. Section 4 summarises the main results.

[7] This is not, however, to suggest that the development of education was only coupled with economic reasons. de Pleijt and van Zanden (2016), for instance, documented that Protestantism contributed to the formation of human capital (see van Zanden (2009) for an in-depth discussion).

2 Estimating average years of education

The stock of human capital, H_t, is computed as years of formal education present in the total population between 1307 and 1900. Since the lifetime of individual humans (and therefore the lifetime of their human capital) is finite, it is possible to apply the Perpetual Inventory Method (henceforth PIM) to compute average years of schooling. The PIM requires two basic series: the annual flow of investments in formal schooling, IH_t, and the annual flow of years of schooling retiring, δH_t. The PIM furthermore requires an estimate of the initial stock of years of education. The different types of schooling are cumulated taking their average lifetime into account to estimate the 1307 stock of average years of education (this is the first year for which there is sufficient evidence on schooling).[8] Using this resultant estimate for the initial 1307 stock makes it possible to cumulate by means of the basic relationship given in Eq. (1).

$$H_t = H_{t-1} + IH_t - \delta H_t \tag{1}$$

To estimate the annual flow of average years of primary schooling, the paper makes use of statistical source material on literacy rates. The evidence on literacy rates between 1300 and 1900 is converted to the absolute number of children that enrolled in primary schooling. To estimate the flow of average years of secondary schooling, evidence on the number of secondary schools and their average population level are used. This makes it possible to estimate annual enrolment in secondary education. Finally, to estimate the annual flow of average years of tertiary schooling, the paper makes use of matriculations to the Universities of Cambridge, Oxford and London.

The flows enter the stock in the year at which children finished schooling and entered the labour market. For the purpose of estimating average years of education, it is furthermore required to apply a set of weights to the flows of the different types of schooling that enter the stock. Since literacy proxies a relatively sustained and prolonged effort of learning in primary schooling, it is given a weight of 2 years of schooling. After finishing elementary schooling, boys could enter the secondary level.[9] They did so when they were in the age bracket between 8 and 11 and stayed for 6 additional years. Boys enrolling into secondary schooling had completed the 'official' primary schooling programme of 3 years. For that reason, it is assumed that the number of boys that went up to secondary level had followed 3 years instead of 2 years of primary education. Immediately after finishing secondary schooling, boys could enter one of the universities where they studied for 2, 4 or 7 additional years depending on their status on completion. The retirements of human capital depend upon its average lifetime, for which is made use of estimates on average life expectancy. The current section describes the procedure, and Appendix 1 summarises the various sources used and assumptions made to derive average years of schooling.

[8] The stock is independent of the initial 1307 estimate after ca. 1350.

[9] Girls were not admitted to secondary education before the nineteenth century (Stone 1964; Jewell 1998).

2.1 Primary education

To estimate the annual flow of years of primary education entering the stock between 1550 and 1900, existing statistical evidence on literacy rates is combined. Literacy rates are measured as the capacity of individuals to sign their names on documents. The estimates of literacy are derived from church and secular records for the period prior to 1754 and marriage contracts for the years thereafter. The statistics on literacy of Cressy (1980, 1981) are used for the years 1550–1754; those of Schofield (1981) for the years 1754–1840; those of Stephens (1987) for the years 1840–1885; and finally, those of Cressy (1980) for the years after 1885.

Preference for literacy rates is for a variety of reasons. To begin with, the capacity to sign documents is said to give a fair indication of the share of the population that could read at an advanced level, as well as a certain ability to handle writing materials.[10] Unlike nowadays, reading and writing were taught in separate and successive periods of about two to three years at a time. Signature evidence is therefore argued to proxy a relatively sustained and prolonged effort of learning in primary schooling (Schofield 1968; Reis 2005). Secondly, it has the merit of being fairly homogeneous across time and space (Albers 1997). More specifically, with respect to the history of schooling in England, there were different ways for children to learn basic reading and writing skills. Children could have learned to read and write at churches, at work, or informally at home (Williams 1961; Schofield 1981). If children were sent to school, then there were different types of elementary schools, where they could choose from: ABC-, song-, reading-, writing- and petty-schools. Even more types of schools were founded after 1700. Examples of these include Sunday-, charity-, monitorial-, industrial- and workhouse-schools. It should be noted that the uncertainty of how basic reading and writing skills were learned, and also differences in the learning objectives of the schools, could potentially create a bias in the estimated stock. For instance, ABC-, song- and reading-schools were concerned with reading, whilst charity- and Sunday-schools taught moral and religious courses (see discussion in Jewell 1998 and Stone 1969). In short, the use of literacy rates has the merit of capturing only the share of the population that obtained reading and writing abilities.

Statistics provided by Hoeppner Moran (1985) allow for an estimation of the flow of years of primary education during the medieval period. Hoeppner Moran (1985) traces the evolution of schooling in the Diocese of York between 1300 and 1548 by using the number of primary schools (song- and reading-schools) and the number of secondary schools (notably Latin grammar schools) from Orme (1973). The estimates are presented in Fig. 1. Based on the increase in the number of primary schools, Hoeppner Moran estimates the average literacy rate to have been around 15% in the 1530s. Her estimate is higher than Cressy's (1980) figure of 8.2% for this period.[11] In order to quantify years of primary schooling, it is important to make the

[10] Literacy rates do, however, overestimate the share of the population with advanced writing skills (see discussion below).

[11] According to Moran, 22.5% of the males and 7.5% of the females were literate. Following Cressy (1980), this was ca. 13.6 and 2.8%, respectively.

Fig. 1 Growth in elementary and secondary (grammar) education in York diocese, pre-1300 to 1548. *Source*: Hoeppner Moran (1985, p. 118)

datasets comparable. Therefore, I now briefly turn to the two reasons that account for the disparities in the numbers, i.e. (a) the applied definition of literacy and (b) Cressy's underestimation of the spread of literacy by the 1530s (see also discussion in Hoeppner Moran 1985).

About two-thirds of the difference can be attributed to the applied definition of literacy.[12] Whereas the literacy estimates of Cressy are based on evidence of signatures, those of Hoeppner Moran are derived from the growth in the number of song- and reading-schools. Since song- and reading schools were mainly concerned with teaching pupils how to read, Hoeppner Moran concludes that her estimates are likely to capture 'reading-literacy' rather than 'signature-literacy' as those of Cressy (see Hoeppner Moran 1985, p. 225).

In order to make them comparable, the next step is to convert reading-literacy into signature-literacy. To do this, it is necessary to combine the length of the primary schooling programme with the estimates on literacy. As explained at the beginning of this section, signature-literacy gives a fair suggestion of the share of the population that could read. Certainly more people were able to read than could sign their name on a (marriage) contract, so the capacity to sign a document is likely to underestimate the share of the population that could read at a basic level. The

[12] Converting the reading-signature estimates of Hoeppner Moran into signature-literacy gives the following results: 7.6% of the population was literate in 1500 (11.4% of the males and 3.75% of the females). In 1530, this had increased to 11.3% (16.9% of the males and 5.6% of the females). The estimates of Cressy (1980) suggest a literacy rate of 5.5% in 1500 (10% of the males and 1% of the females), which had increased to 8.2% (13.6% of the males and 2.8% of the females) by 1530. Comparing the estimates implies that ca. 58–65% of the difference can be explained by the applied definition of literacy.

official length of the primary schooling programme at that time was 3 years, during which children first learned how to read and thereafter how to write at an advanced level (writing was taught at a later stage than reading). The ability of an individual to sign a (marriage) contract does not infer anything about the writing capabilities of that person. Although signature evidence is said to underestimate reading capabilities, it is very likely to overestimate advanced writing skills. Hence, the share of the population able to sign documents must have been higher than the share able to write at a reasonable level. Since it is known that children learned to read in about 1.5 years, reading-literacy is set equal to 1.5 years of primary schooling. Signature-literacy is likely to capture more advanced reading skills, whereas at the same time it is unclear whether the individuals were able to effectively write (see discussions in Schofield 1968; Cressy 1980; Stephens 1987). For the purposes of estimating the stock of average years of education, this paper considers it unreasonable to set signature-literacy equal to the length of the primary schooling programme (3 years), but rather it is fair to give it 2 years of education.

Combining the years of schooling with the estimates on signature- and reading-literacy indeed removes the greater part of the difference. However, there is still one-third of the disparity that cannot be explained by the applied definition of literacy. This implies that either Hoeppner Moran's figures overestimate the share of the population able to read and write, or that those of Cressy underestimate the spread of literacy. The study of Hoeppner Moran shows that the fifteenth century expansion of song- and reading-schools was followed by an increase in the number of secondary schools: from 25 in 1500 to 68 in 1548 (see Fig. 1). As will be discussed in greater detail in Sect. 2.2, scholars tend to agree on the extraordinary expansion of higher education over the sixteenth and seventeenth centuries, which was labelled the 'educational revolution in higher education' by Stone (1964; see also Leach 1915; Jordan 1959; Simon 1960). The onset and magnitude of the revolution square rather well with the trends that Hoeppner Moran sets out for the York Diocese: the growth of song- and reading-schools over the fifteenth and early sixteenth centuries, in which 50 schools were founded between 1400 and 1500, and 54 more between 1500 and 1548, must have paved the way for an expansion in grammar schooling. In other words, the enthusiasm for higher education in the sixteenth and early seventeenth centuries would have been unlikely without enough effective primary schools to support it, and the revolution in secondary and tertiary schooling of the sixteenth century can therefore be better understood given the preceding developments . Taking the trends in secondary and tertiary schooling into account, it is suggested here that Cressy slightly underestimates the spread of literacy by the early sixteenth century and preference is given for the estimates of Hoeppner Moran.[13]

[13] Converting the literacy rate of Cressy for 1500 into enrolment in primary schooling and comparing it to the enrolment figures in secondary education of Orme (2006) suggests that as many children were sent up to the secondary level as were able to read and write—a result that seems very unlikely. This finding also suggests that Cressy slightly underestimates the spread of literacy by the early sixteenth century. For the period after 1550, Cressy's estimates correspond well with the figures of Stone (1969, p. 101) and Schofield (1981).

Table 1 Literacy rates, 1300–1900. *Notes and sources* See main text. Percentages are rounded up to the nearest digit

Year	Men	Women
1300	2.0	0.7
1400	3.3	1.1
1500	11.4	3.8
1600	25	9.3
1700	42	24
1750	56	36
1800	64	42
1850	69	54
1900	95	94

The reading-literacy rates of Hoeppner Moran (1985) are projected backwards in time by taking the growth in primary schools into account (i.e. the trends as set out in Fig. 1).[14] In order to make it comparable with the evidence for the period after 1550, 'reading-literacy' is converted into 'signature-literacy' using the aforementioned assumption about attainment levels, i.e. reading-literacy is equal to 1.5 years of education and signature-literacy is equal to 2 years of education. The calculations are found in Appendix 1. Table 1 reports the results.[15]

Equation (2) is used to convert the literacy rates into primary school enrolment. Primary schooling opportunities opened up around the age of 5 and closed again as children entered the labour market around the age of 15 (e.g. Cressy 1980; Jewell 1998). The literacy rates, however, capture the reading and writing abilities of the population at the time of marriage. Schofield (1968) has shown that 72% of the spouses were in the age bracket between 20 and 29 when signing their marriage contracts. A lag of 15 years is employed to control for the time difference between entering primary schooling and marriage. The flow of primary schooling is therefore a function of literacy in $t + 15$. The next step is to convert rates of literacy to the absolute number of the population that enrolled in primary schooling in year t. Wrigley et al. (1997) provide reliable estimates on the share of the British population that was in the age bracket between 5 and 14 for the period 1541–1871, $\gamma(5\text{–}14)$, t. There is no such detailed evidence for the period before 1541, and for the purposes of this paper, it is assumed that the share of the population in this age bracket was equal to that of the 1540s (21%). In order to allow for the year required for enrolment, this share of the population is divided by 10 and then multiplied by

[14] It would of course be better to use the trends at the national level to project the literacy rates backwards in time. Unfortunately, to follow Orme (2006), whilst secondary schools are well recorded in the records, evidence on the number of primary schools is relatively scant.

[15] It is possible to perform a robustness check for the level of literacy in the fourteenth century. Lawson and Silver (1973) state that there were around 30,000 ordinary clergy, about 15,000 monks, canons and friars, and 7000 nuns. If all these people were literate, then they comprised up to 1.5% of the population. Including part of the lay civil servants, lay judges and some common lawyers, a part of the magnates, knights and leading burgesses, merchants and craftsmen brings the figure up to ca. 3%. This squares rather well with the estimates in Table 1: Taking the average of male and female literacy implies that 1.4% of the population was literate in 1300. In 1400, this had increased to 2.2%.

the latest population estimates of Broadberry et al. (2015), *nt*, to calculate primary school enrolment.

$$\text{Primary school enrolment}_t = \text{literacy}_{t+15} * \left(\frac{\gamma_{(5-14),t}}{10}\right) * n_t \quad (2)$$

2.2 Secondary and tertiary education

Regarding secondary education, Orme (2006) provides a very detailed list of (endowed) schools between 1300 and 1530. All of the secondary schools he recorded including, where appropriate, endowed schools, are coupled to a specific date at which the institution was first encountered in the records. Any subsequent dissolution of (endowed) schools was also recorded by Orme. Following the statistics derived from the study of Orme, there were 156 grammar schools in 1480 and 234 of such schools by the early 1530s. About 50% of the secondary schools recorded by Orme became endowed in the last two decades of the fifteenth century, and nearly all schools were still in existence by the 1530s. His findings therefore illustrate the continuing and long-lived tradition of the secondary schools reliably stressed by, amongst others, Stone (1964), Vincent (1969) and Jordan (1959).[16]

Detailed statistics on the number of secondary schools between 1530 and the 1860s are available from the report of the Schools Inquiry Commission (henceforth SIC), published in 1868. The SIC examined the quality of all secondary schools between 1864 and 1868, and the report provides information about the founding date of these schools. For instance, Withney Grammar school in the county of Oxford was founded and endowed by Henry Box in 1660 (SIC 1868: Volume 12, p. 274). It is important to note that this not only includes the Latin grammar schools, but any endowed institution offering education beyond the elementary level. Vincent (1969) argues that the focus on Latin grammar schools alone would underestimate the growth of secondary schooling (see also Stone 1964, 1969). England had many private fee-paying institutions in the early modern period: as many as 857 grammar schools, 301 private schools and 63 private tutors sent boys up to the four Cambridge colleges between 1600 and 1660.

Figure 2 shows the number of secondary schools recorded by the SIC in 1868. The data illustrate that the growth in the number of new school foundations slowed down between 1660 and 1720. Strikingly, there is a strong decline in the growth rate that sets in after this date, and to follow the report of the SIC, the eighteenth and nineteenth centuries saw a further decay in schooling. 799 secondary schools were of direct concern to the Commission in 1868. 500 of these schools were more than two centuries old and were supposedly classical grammar schools, but a mere 27% actually taught Greek and/or Latin, and fewer than 40 (8%) sent boys up to Oxford and Cambridge. The trends in the growth of schooling, as depicted in Fig. 2, are very similar to those as set out by Vincent (1969). His careful analysis of the

[16] Of the grammar schools listed by Orme (2006), 35 out of 156 of them were endowed in 1480, which had increased to 116 out of 234 by the 1530s (own calculations). This might also highlight the increase in demand for secondary education by the turn of the sixteenth century.

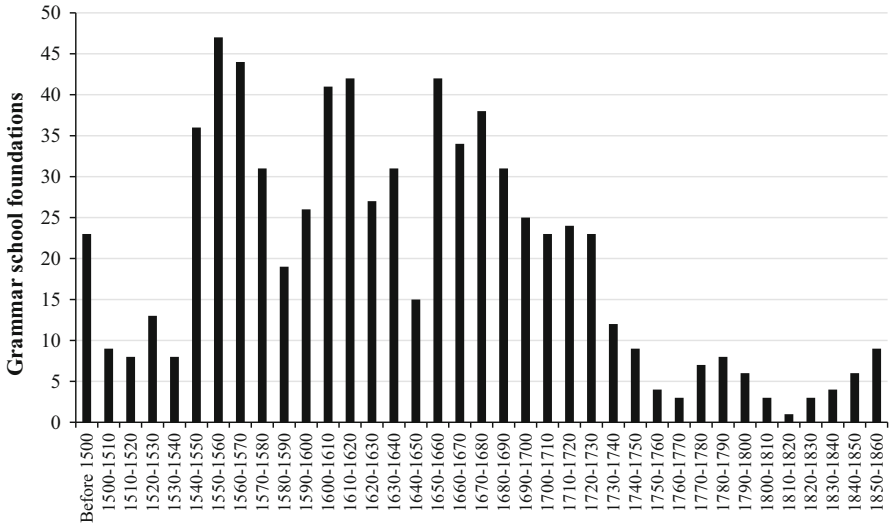

Fig. 2 Number of secondary schools found per decade, 1500–1860. *Notes and sources*: Decennial totals taken from Boucekkine et al. (2007, p. 214). The statistics summarise those of the Schools Inquiry Commission (1868: Volumes 10–20)

Cambridge student body shows that, between 1660 and 1720, the number of grammar schools and private schools sending boys up to the four Cambridge colleges had fallen from 857 to 738 and from 301 to 201, respectively. The real deterioration sets in after this date, decreasing further to 406 and 130, respectively, in 1780.

The number of secondary schools from the SIC report as summarised in Fig. 2 is added to the data derived from the study of Orme (2006) to derive the annual number of schools between 1307 and 1868. A possible disadvantage from making use of the SIC statistics is that they only record those secondary schools still in existence by the 1860s and therefore likely to lead to an overestimate of the growth of schools going forward in time to the 1860s. The dataset on the number of secondary schools is therefore adjusted upwards between 1300 and 1720 using the ratio of grammar schools to private schools of Vincent (1969) (see Appendix 1). No adjustments have been made for the period after 1720, because of the sharp deterioration in secondary schooling that sets in after this date (Vincent 1969; SIC 1868: Volumes 10–20).

The overall results suggest that there were 776 secondary schools by the 1660s and 825 by the 1720s. Following the results of the SIC, the number of schools for boys had fallen to 786 in 1860. The investigations of the SIC furthermore revealed the poor provision of secondary education, the uneven geographical distribution of schools, the misuse of endowments and the existence of only 13 secondary schools for girls in the country (SIC 1868: Volumes 10–20).[17] The SIC therefore

[17] Girls were not admitted to secondary and tertiary education before the nineteenth century (Stone 1969).

recommended the establishment of a national system of secondary education based on existing endowed schools. The result was the Endowed Schools Act of 1869, which created the Endowed Schools Commission with extensive powers over endowments of the schools. The policies were quite effective, as indicated by a staggering increase in the foundation of secondary schools after 1868: there were as many as 1353 schools in 1905 (Bolton 2007).

To derive the average number of pupils per school, the analysis used the secondary education endowment files, which can be derived from the SIC reports (1868: Volumes 10–20). For 78 of the schools founded between 1500 and 1720 (12%), the files give information about the number of pupils. For instance, the foundation deed of Holt Grammar School in Norfolk states that the 'number of free scholars to be 50, chosen from town of Holt and neighbourhood' (SIC 1868: Volume 13, p. 317). For this sub-sample of schools, it appears that the average population level of the schools in this period was 62. Evidence for the Middle Ages is harder to come by: for only four schools there is information about the number of scholars. The analysis therefore makes use of the qualitative evidence of Parry (1920) and Orme (2006), which suggests that there were fewer pupils per school in the Middle Ages. I have set this figure fixed at 50 for the period before the Black Death and assume it to have declined to 30 thereafter. It is then assumed that the number of pupils had climbed back to its pre-plague level between 1400 and 1480, which corresponds with the increase in school foundations (Orme 2006). To derive the average number of scholars for the period after 1720, this study again makes use of the SIC reports. For all secondary schools in the 1860s, the SIC reports provide information about the number of scholars. For instance, at Kington Grammar School in the county of Herefordshire there were 26 day scholars and 2 boarders on the books in 1864 (SIC 1868: Volume 15, p. 225). The average number of day scholars and boarders of the schools in the 1860s, however, was 47. The number of pupils per school is therefore assumed to have declined from 62 in 1720 to 47 in 1800 (Vincent 1969). Between 1800 and 1870, the level is assumed to have been stable at 47, which corresponds with the trends as set out by the SIC reports (1868: Volume 10–20), and the Charity Commissioners Reports of 1818–1837 (which are frequently cited in the SIC reports to compare the 1860s situation with that of the early nineteenth century). Finally, Bolton (2007), working with official government statistics, estimates the average population level to be 178 by the year 1909. Appendix 2 shows robustness checks using alternative estimates of the average number of pupils per school.

Equation (3) is used to calculate enrolment in secondary schooling. The number of boys entering secondary schooling in year t is a simple function of the number of schools and the average population level of the schools. Since the official length of the secondary schooling programme was 6 years at the time (Stone 1964), the population estimates are divided by 6 to calculate annual enrolment in secondary education.

$$\text{Secondary school enrolment}_t = \frac{\text{Schools}_t * \text{Average population}_t}{6} \quad (3)$$

To measure annual enrolment in tertiary education between 1500 and 1909, the estimates of Stone (1974) are used. His study includes statistics on the decennial averages of freshmen admissions to Oxford University and the University of Cambridge. In the 1820s, the University of London was founded for which Harte (1986) provides the number of graduates (men and women) between 1839 and 1900. The University of Oxford attracted two different groups of students. The first group opted for a career in church or in teaching and studied for about 4–7 years. The second group of students studied for a career in commercial professions (e.g. secretary, accountancy and public politics) and came to Oxford for about two years and used it primarily as a kind of finishing school. Stone distinguishes between the number of students who completed the bachelor programme and those who made it up to the masters' level, which makes it possible to correct for the number of students who never received a degree. On average, 724 freshmen a year came to the University of Oxford or Cambridge during the late sixteenth century, of which a mere 25% actually graduated. Although the share of graduates gradually increased to ca. 70% by the mid-nineteenth century, the average number of matriculations had only slightly risen to 811. Considering the significant growth of the English population at the time (from ca. 4.0 to 17.3 million between 1600 and 1850), this may suggest tertiary schooling had lost its popularity over the centuries (see also discussion in Stone 1964).

No such detailed dataset exists for the period before 1500. It was not until the mid-fifteenth century that provisions were made for what is known as matriculation. Freshmen were required to enter their names on a role of a master during the Middle Ages, but not a single example of such roll survived (Leader 1988). Population estimates for both universities are, however, available. Aston (1977) estimates the Oxford student body to be round about 1500 by the early fourteenth century, having previously fallen in the centuries following the Black Death to 1200 in 1400 and 1000 by the 1450s. Aston et al. (1980) provide estimates of the student body of Cambridge. This was about 500 in 1500, 400 in 1400 and between 755 and 810 in 1450. It is known that 20% of the student body was enrolled into tertiary education (Aston 1977), which makes it possible to calculate the student population. For both universities, this was 250, 200 and 223, respectively. Only 20% of the students entering one of the universities graduated, and of those who did 40% left after obtaining the bachelor's degree and 60% went up to the master's level (Aston 1977). These percentages are applied to convert population levels into annual matriculations. The annual number of matriculates was 115 in 1300. After the Black Death, this had decreased to 92, though climbed back somewhat closer to its pre-plague level by the mid-fifteenth century (i.e. to 103).

There is little statistical evidence for the years between 1450 and 1500. Qualitative studies indicate that the universities benefited from the upsurge in grammar schooling between 1450 and 1530. This is especially apparent from the number of colleges founded, notably at Cambridge. Whereas Cambridge was only one-third of the size of Oxford by the early fifteenth century, it approximated Oxford in size by 1530: Cambridge had 14 colleges and Oxford 13 colleges (e.g. Cobban 1988). The years between 1450 and 1500 are interpolated, where growth in matriculations are added exponentially to match the trends as set out by the

qualitative studies as well as the trends in the growth of secondary schooling of Orme (2006). Although temptative, the results imply an increase in the number of freshmen admissions: from 103 in 1450 to 238 in 1500.[18]

2.3 Estimating average years of education

To estimate average years of education, it is necessary to apply a set of weights to the annual flows of primary, secondary and tertiary schooling entering the gross stock. As discussed in Sect. 2.1, the estimates of attainment levels assume 2 years of primary education. It is, however, necessary to make two exceptions to the number of years. First, the share of the boys that entered one of the secondary schools had completed the primary schooling programme (SIC 1868, see also discussion in Stone 1969). For instance, Newcastle Grammar School required that boys on admission were 'able to read and write and having some acquaintance with the four rules of arithmetic' (SIC 1868, Volume 19, p. 122). It is therefore reasonable to assume that the share of the boys that went up to the secondary level had followed the 'official' primary schooling programme, which was 3 years. Secondly, mass education became a nationwide concern in the nineteenth century. Several Factory Acts and Elementary Education Acts were implemented to reduce children's working hours and subsequently increase their school attendance. For instance, the 1860 Elementary School Code stipulated the leaving age at 12, and the 1870 Elementary Education Act introduced free and compulsory education for all children aged 5–13. The 1902 Balfour Act moreover abolished all schools boards and handed over their duties to local borough councils. The newly created Local Education Authorities were given powers to develop the existing system of elementary schools and to establish secondary and technical schools.[19] As a consequence, school attendance, as well as the average time spent in schooling, increased significantly over the course of the nineteenth century. The years of schooling had increased from ca. 2.3 in 1805 (Sanderson 1995) to ca. 3.8 in 1850; to ca. 4.8 in 1870; and finally, to ca. 5.5 in 1905 (Lawson and Silver 1973). The weight of primary schooling is therefore adjusted to take these increases in average years spent in primary schooling into account.

Boys entering secondary schooling did so immediately after finishing the primary level. They were in the age bracket between 8 and 11, and the average time spent at those schools was 6 years (Stone 1964; SIC 1868). The estimates of attainment levels therefore assume 6 years of education for secondary schooling. Regarding tertiary education, the proportion of the students that did not graduate from one of the universities attended for about 2 years; those students obtaining a bachelor degree studied for 4 years; and finally, those who made it up to the master's level, for 7 years (see Stone 1974). The estimates of attainment levels thus assume 2, 4 and 7 years of schooling, respectively.

[18] Emden (1957, 1963) estimates the total number of alumni at 22,000 for the period before 1500 (7000 at Cambridge and 15,000 at Oxford). The sum of all matriculates between 1300 and 1500 brings the number of students to 21,250, which is very close to the estimate of Emden.

[19] Galor and Moav (2006) moreover show the positive attitude of capitalists towards education reforms.

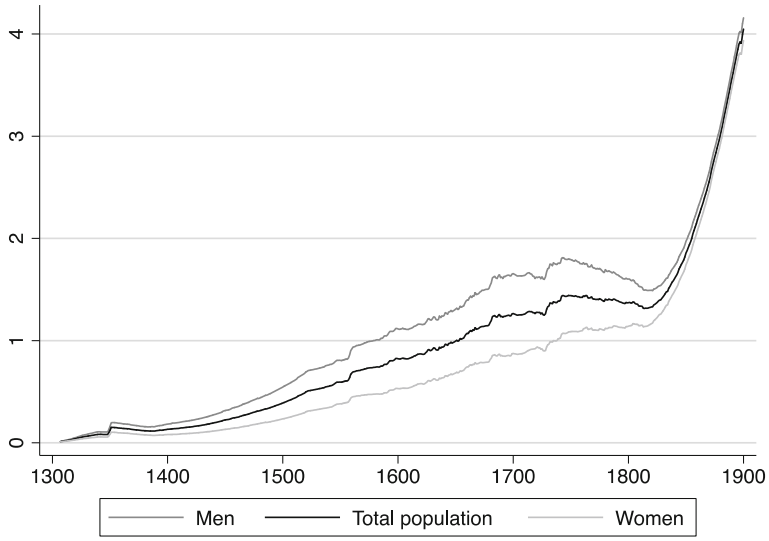

Fig. 3 Average years of education, 1300–1900. *Notes and sources*: See main text

To complete the series on average years of schooling, it is required to make assumptions about the date at which an individual's human capital enters the gross stock, as well as about its lifetime. Primary schooling opportunities opened up when children were 5 years old and closed again when they started working around the age of 15 (Jewell 1998). It is assumed that children enrolled into primary schooling at the age of 10 which is the median. The number of years of education of an individual enters the gross stock at the time the person finished primary schooling and entered the labour market. The individual's human capital leaves the stock at the time of death, which depends on average life expectancy. This paper uses data on life expectancy of Russel (1948), Hatcher (1986), Harvey (1995) and Jonker (2003) for the period before 1640; the data of Wrigley and Schofield (1981) for the years between 1640 and 1809; and finally, the estimates of The Human Mortality Database for the years after 1809. The estimates refer to remaining life expectancy at the age of 25, whereas the age at which an individual entered the labour market was ca. 12–13 years. The life expectancy estimates are therefore adjusted upwards by adding the difference in years.

A similar approach is used to derive estimates on average years of secondary and tertiary schooling. Pupils that went up to secondary level did so when they were in the age bracket between 8 and 11, staying there for 6 years (see discussion above). The average years of schooling of these individuals enter the stock in the year they are expected to have completed the programme, which was ca. 17 years. Students entered one of the Universities when they were in the age bracket between 16 and 18 years and studied for 2, 4 or 7 additional years (see discussion in Stone 1974). It was decided to take the median age, i.e. 17 years old, whilst computing the stock. This means that these individuals enter the gross stock in the year they left

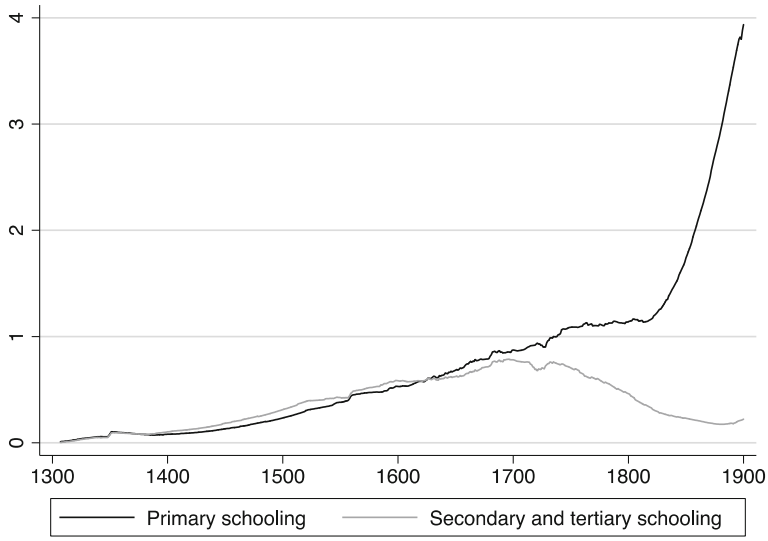

Fig. 4 Average years of education of males, 1300–1900: Primary, secondary and tertiary education. *Notes and sources*: See main text

University, which varies between 19 and 24 depending on their status on completion—i.e. Master, Bachelor or 'dropout'.

Figures 3 and 4 report the results. Figure 3 shows the evolution of average years of schooling of males, females and the overall population between 1307 and 1900. Figure 4 differentiates between the average years of primary schooling of males and average years of secondary and tertiary schooling of males. It should be stressed here that the years of education measure of females is based on the development of literacy and primary schooling before 1878, as women were not admitted to formal secondary and tertiary education.

3 Discussing the long-run trends in average years of schooling

Figure 3 illustrates that levels of formal education increased long before the Industrial Revolution began to take hold. In the 1340s, just before the arrival of the Black Death, educational attainment was a mere 0.03 years on average. After the Black Death, school foundations were laid all over the country. Growth was first of all in song- and reading schools, but, over the course of the fourteenth century, the demand for secondary schooling started to rise. Literacy therefore spread amongst the English population between 1300 and 1500. By the end of the Middle Ages, educational attainment had increased to 0.3 years on average and to 0.5 years for males. Graff (1987) has even shown that male literacy was as high as 40% in London during the 1460s, of which craftsmen formed a significant group of literate people.

These trends continued after 1500 and even accelerated during the sixteenth century. Between ca. 1560 and 1740, average years of education of males had increased from 1 to 1.8 years. As discussed in the previous section, the basis of this growth in schooling was the upsurge in secondary schooling in the fifteenth and sixteenth centuries, which set the pace for even faster growth after ca. 1530. As a result, between 1530 and 1700, secondary schooling accounted for over half of the share of the stock of formal education of males (see Fig. 4).

During the classic period of the Industrial Revolution, however, there was a decrease in educational attainment. Average years of schooling had fallen from ca. 1.4 years in 1740 to 1.25 years in 1820. A closer look at Fig. 4 reveals that this can be mainly attributed to a staggering decrease in secondary and tertiary schooling levels. Between 1700 and 1880, it had decreased from 0.8 to 0.2 years. The figure also shows that there were some increases in average years of primary schooling over the course of the eighteenth century, but this was not fast enough to counter balance the decline in attainment levels of secondary and tertiary education. Stone's (1964, p. 69) conclusion is that 'English higher education did not get back to the level of the 1630s until after the first World War; did not surpass it after the second' seems therefore rather acceptable. Strikingly, as Fig. 3 shows, average years of schooling of females in the period before 1740 were about half that of the level of males. In contrast to the stagnation in average years of education of males, attainment levels of females increased during the Industrial Revolution: between 1740 and 1830, it had increased from 1 to 1.3 year. Finally, the results in Fig. 3 highlight the growth in schooling over the course of the nineteenth century. The average years of education of males double, whereas those of females even quadruple.

A possible explanation for the observed rise in the level of schooling of the English population in the centuries preceding the Industrial Revolution is the European Marriage Pattern. It has been argued that the north-western part of Europe, notably England and the low countries, differed from the rest of the continent due to the favourable characteristics of the European Marriage Pattern. England enjoyed a relatively high degree of female agency, which was the outcome of two core institutions: consensus-based marriage and neo-locality of the household (see van Zanden 2011; de Moor and van Zanden 2010). This resulted in a relatively high age of marriage for women, a high percentage of singles and a low share of complex households, which was favourable to emerging commercial environment (England became a significant producer of finished cloth in the fifteenth century) and investments in human capital formation (probably via the lowering of fertility rates).[20] At the same time, the demand for skilled labour increased rapidly in sixteenth- and seventeenth-century England, as international trade, and the services sector, in general, expanded and the process of urbanisation accelerated.

[20] Neo-locality means that a newly married couple resides separately from both the husband's natal household and the wife's natal household. Complex households are single-parent families, extended families or families with more than two parents.

The explanation focusing on the role of the EMP has, however, not been accepted generally. The data collected by Humphries and Weisdorf (2015) show that wages for unmarried servants were developing less favourably than those of married women who worked for day wages in the century after the Black Death. From this, they have concluded that it was not rational for women to postpone marriage. Dennison and Ogilvie (2014) were even more outspoken in their criticism of the European Marriage Pattern as they did not find a link between marriage patterns and economic performance in Early Modern Europe. Subsequently, however, Dennison and Ogilvie's results have not remained unchallenged. Carmichael et al. (2016) have argued that they did not conceptualise the European Marriage Pattern correctly. The focus of Dennison and Ogilvie was on the share of singles, the age of marriage of females and the share of nuclear families, whereas attention should be on the broader context of how marriage responds to economic circumstances (see Carmichael et al. 2016; Dennison and Ogilvie 2016).[21]

The big puzzle of this paper is, however, why the observed rising trend in human capital suddenly broke off and why, during the greater part of the eighteenth century, levels of schooling showed decline. It is beyond the scope of this paper to explain this in great detail, but a few suggestions can be made. To begin with, whereas the relative wage of women had been relatively high during the late Middle Ages and the sixteenth century, the gender wage gap increased rapidly afterwards, implying that incentives for women to postpone marriage (and restrict fertility) were weakened (van Zanden 2011; Humphries and Weisdorf 2015). But at the same time the economic structure of the economy was also changing, possibly creating less demand for skilled labour—both in agriculture (where the rise of large farms resulted in the growth of the group of unskilled wage labourers) and in industry (where the transition from artisan workshop-to-factory production reduced the need for skilled workers) (see de Pleijt and Weisdorf 2017).

How does the evolution of formal schooling compare to England's economic development? The latest attempt to estimate English output and productivity levels reveals how dynamic per capita GDP growth was in the centuries before the Industrial Revolution (Broadberry et al. 2015). Both average years of schooling and per capita GDP share an upward trend in the century before industrialisation, which, given the earlier findings of a positive human capital growth relationship of Baten and van Zanden (2008) and de Pleijt and van Zanden (2016), may suggest that human capital contributed to pre-industrial growth in England. It is, however, difficult to prove this empirically due to unavailability of reliable control variables with which to perform meaningful regression analysis.

There was no positive relationship between average years of schooling and per capita GDP during the period of the Industrial Revolution. Per capita GDP growth takes off after 1750, whereas the average level of schooling stagnated, or, in the case of secondary education, even declined.[22] This finding corresponds with the

[21] Nuclear family is a family group consisting of a pair of adults and their children.

[22] Figure 3, however, shows a significant increase in average years of education of females. Diebolt and Perrin (2013) illustrate that a virtuous circle linking female empowerment, human capital accumulation and endogenous technological change could have triggered the demographic and economic transition.

conclusions of previous research focussing on literacy rates (Nicholas and Nicholas 1992; Mitch 1993; Clark 2005) and numeracy rates (A'Hearn et al. 2009). It is furthermore consistent with the evidence of Humphries (2010, p. 314) who derives average years of schooling of boys from autobiographical evidence. She has documented a similar dip in schooling during the first Industrial Revolution. However, as the results in this paper show, the decline in average years of schooling of males documented by Humphries (2010) can be attributed to the movement away from secondary (and to a lesser extent tertiary) schooling. Secondly, incorporating the evidence on secondary and tertiary schooling informs us that the movement away from formal schooling during the Industrial Revolution was much larger than the trends in (male) literacy alone would suggest. In other words, studies that have mainly focussed on literacy rates (e.g. Mitch 1993) have significantly underestimated the decline in general schooling levels of the English population. The findings presented in this paper therefore imply that the demand for formally educated workers had fallen remarkably over the course of England's early industrialisation.

The conclusion that human capital did not contribute to growth during the age of cotton and steam has implications for future research on the topic. It should be stressed here once more that focus is on the average level of schooling present in the population. It does not include the acquisition of those elements, which did not involve formal schooling, but which could have nevertheless been important for the productivity of workers, such as, amongst others, on-the-job learning and apprenticeships (see Humphries 2003; Wallis 2008; Mokyr 2009). In analysing the role of human capital after the initial stages of the Industrial Revolution, future research should therefore shift focus to measures capturing more informal skills. Economic historians have made some headway in this regard: Kelly et al. (2014) show English labourers were taller, heavier, savvier and more productive than elsewhere on the continent; Jacob (2014, p. 157) documents a significant increase in scientific training believed to be important in facilitating the Industrial Revolution; and Mitch (2004) argues that as many as one in four boys undertook some kind of apprenticeship in 1700.

Following the empirical findings of recent studies, an additional distinction should perhaps be made between the 'density in the upper tail of professional knowledge' (cf. Mokyr 2005; Mokyr and Voth 2009) and more widespread skills and education levels. de Pleijt and Weisdorf (2017) quantify the occupations of more than 30,000 English male workers according to the skill content of their work. Their results demonstrate an increase in the share of unskilled workers alongside a constant share of 'high-quality workmen' such as machine erectors and engineers deemed necessary by Meisenzahl and Mokyr (2012) in bringing about the Industrial Revolution. Similarly, Squicciarini and Voigtländer (2015) show that the French Industrial Revolution of the mid-nineteenth century was not spurred by a broad distribution of skills, but rather by a small highly knowledgeable elite. Hence, the case for the role of human capital as driver of the Industrial Revolution appears to focus on more work specific human capital rather than on the average level of formal education present in the workforce.

4 Conclusion

Economic historians have long debated whether formal schooling contributed to economic growth in England. One side of the debate holds that formal education was irrelevant to England's early industrialisation—a conclusion that has mainly been derived from the observation of stagnant male literacy rates between 1750 and 1850. The other side of the debate has focused on trends in human capital formation over the very long run and has found a positive association between human capital and development in the centuries before the Industrial Revolution. In this paper, it was argued that part of the difference in outcomes can be related to the fact that different periods have been analysed. In this paper, I therefore applied a Perpetual Inventory Method to estimate average years of education between 1300 and 1900 to revisit previous conclusions.

It was shown that the stock of average years of schooling can be quantified rather well, in particular for the early modern period. The trends in the data are indicative of significant increases in levels of formal education before the classic years of the Industrial Revolution. Secondary education comprised up to half of the stock of educational attainment of males, which means that previous studies that have used literacy rates as an indicator of human capital underestimated the spread of formal schooling on the eve of the Industrial Revolution (Allen 2003; Reis 2005). The same is true for the period of the Industrial Revolution itself. After ca. 1720, a profound decline in educational attainment levels began to take hold as indicated by stagnation in average years of primary education and a vast decline in years of secondary and tertiary schooling. From this, it can be concluded that the decrease in schooling levels was much more pronounced than the evidence of literacy alone would suggest.

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Appendix 1: Data construction

This Appendix summarises the various datasets used and the assumptions made to derive average years of education in England over the long run. The datasets underlying the estimates of educational attainment for the period after 1540 are relatively rich. The estimates for the Middle Ages are less reliable as statistical evidence was harder to come by. For instance, data on the spread of literacy in the Middle Ages are derived from evidence for the Diocese of York and may not be representative for England as a whole.

Table 2 Reading-literacy rates, 1300–1548 *Notes and sources*: See Sect. 2.1. Percentages are rounded up to the nearest digit. Bolt typeface indicates the year from which is projected backwards in time

Year	1300	1350	1400	1450	1500	**1530**	1548
Elementary schools	12	20	20	36	70	104	124
Male literacy	2.6	4.3	4.3	7.8	15.2	**22.5**	26.9
Female literacy	0.9	1.5	1.5	2.6	5.1	**7.5**	9.0

Primary schooling

Literacy rates: *1300–1550*: The reading-literacy estimate from Hoeppner Moran (1985) for the Diocese of York in 1530 is projected backwards and forwards in time by taking the growth in primary schools into account (see Appendix Table 2) . This generates observations for the years 1300, 1350, 1400, 1450, 1530 and 1548. Dates in the interval are interpolated. Multiplying the reading-literacy rates by 0.75 (level of schooling which is based on ratio of reading- to signature-literacy) gives the results summarised in Table 1 (see Sect. 2.1). *1550–1754*: The study of Cressy (1980) provides evidence on literacy for the years 1550, 1560, 1580, 1600, 1610, 1640, 1660, 1680, 1710 and 1750. The growth of literacy between 1500 and 1750 was an unstable and noncumulative process. Cressy (1981) distinguishes between eight different phases in the development of literacy in this period. Dates in the interval are interpolated and take the variations in the development of literacy into account. *1754–1840*: The estimates of Schofield (1981) are used for sub-period 1754–1840. Lord Hardwicke's Marriage Act (1754) prescribed that grooms and bridges should sign their names in the marriage register, which means that after ca. 1750 there exists abundant evidence about literacy rates (of both sexes). The estimates of Schofield are derived from a random sample of 274 English parish registers to estimate the annual percentage of males and females able to sign their marriage contracts. *1840–1915*: Stephens (1987) gives the percentage of illiterate brides and grooms between 1839 and 1885. The largest part of his statistics concern yearly observations. Cressy's (1980) estimates are again used to derive the literacy rates for sub-period 1885–1915.

Weight: *1300–1775*: A literate individual is assumed to have followed 2 years of primary schooling. For boys that entered secondary schooling this was 3 years. *1775–1900*: Weight increases from 2 to 2.3 between 1775 and 1805; to 3.8 in 1850; to 4.8 in 1870; to 5.5 in 1905. For boys going to secondary schooling, this is assumed to have increased from 3 to 3.8 between 1775 and 1850; to 4.8 in 1870; and to 5.5 in 1905 (Sanderson 1995; Lawson and Silver 1973). Dates in the interval are linearly interpolated.

Secondary schooling

Number of schools: *1300–1530*: Annual number of secondary schools from Orme (2006). *1530–1868*: Annual number of secondary schools from SIC (1868: Volumes 10–20). To control for the overestimate of schools going forward in time to the 1860s, the dataset on number of schools is adjusted upwards using the ratio of

grammar schools to private schools of Vincent (1969). For sub-period 1300–1660, this was 857/1158; for sub-period 1660–1720 this was 738/939. *1868–1900*: Bolton (2007) gives the number of secondary schools in 1905. The growth in the number of schools between the dates is added exponentially as it is reasonable to assume that it takes time for government policies to be effectively implemented.

Number of pupils per school: *1500–1720*: For a sub-sample of 78 schools founded in this period, I was able to derive information about the population level (SIC 1868: Volumes 10–20). From this, it appears that the average population in this period was 62. *1307–1500*: The average number of pupils per school is assumed to have been 50 for period before the Black Death; it is assumed to have declined to 30 thereafter; and finally, it is assumed to have climbed back to its pre-plague level between 1400 and 1480. The increase in the number of pupils per school between 1480 and 1500 is linearly interpolated. *1720–1900*: The SIC reports (1868) give the number of day scholars and boarders of all 799 schools in 1868. Form this, it appears that the average number of pupils was 47. The number of pupils per school is assumed to have declined from 62 in 1720 to 47 in 1800, which follows the trends as set out by Vincent (1969). The years in between have been linearly interpolated. Between 1800 and 1870, the level is assumed to have been stable at 47, which follows the reports of the SIC (1868). Bolton (2007) gives the average population level in 1909. The increase in the average number between 1868 and 1909 is added exponentially.

Weight: The estimates of average years of schooling assume 6 years of schooling for secondary education.

Tertiary schooling

Number of students: *1307–1500*: Aston (1977) and Aston et al. (1980) provide population estimates for Oxford and Cambridge. The years include 1300, 1400 and 1450. Dates in the interval are interpolated, and population levels are converted to estimates of annual matriculations (see Sect. 2.2). The gap between 1450 and 1500 is linearly interpolated. *1500–1900*: The decennial numbers of freshmen admissions to Oxford and Cambridge are taken from Stone (1974).[23] For Oxford, Stone distinguishes between the number of students who completed the bachelor programme; those who never received a degree ('dropouts'); and those who made it up to the masters' level. This made it possible to derive the number of students that graduated. The same set of weights is used to calculate the number of graduates from Cambridge. Harte (1986) gives the number of graduates from the University of London between 1839 and 1900 (men and women).

Weight: The estimates of educational attainment assume 2 years of education for 'dropouts'; those obtaining a bachelor degree get 4 years; and finally, those who made it to the master's level 7 years (Stone 1974).

[23] The decennial numbers of freshmen admissions are divided by 10 to generate annual estimates. This hardly has any consequences for the reliability of the series of educational attainment: the contribution of tertiary education to the stock was very small. In 1641, the year where the growth in tertiary schooling was fastest, it adds a mere 0.046 years to the total stock.

Other datasets used

Population: Population estimates are from Broadberry et al. (2015). These concern point estimates for period 1307–1540 and annual observations for sub-period 1540–1900. The population estimates refer to England between 1300 and 1700 and the Great Britain between 1700 and 1870. To estimate population levels for England between 1700 and 1870, the growth rate of population numbers for Great Britain is benchmarked at the population estimate for England in 1700. Similarly, for the period 1870–1900, I have made use of the growth rate of the UK from Maddison (2003) to estimate population numbers for England.

Share of population in age bracket 5–14: Estimates on the share of the population in the age bracket between 5 and 14 are from Wrigley et al. (1997). These concern 5-year intervals for sub-period 1541–1871. Gaps are linearly interpolated. No such detailed evidence was available for period before 1541 and for years after 1871. The shares are quite stable over time: it increases from 21% in 1540s to 22% in 1870s. It is therefore assumed that the share of the population in this age bracket was 21% in period before 1541 and 22% in the period after 1871.

Life expectancy: *1307–1477*: Point estimates are taken from Russel (1948), Hatcher (1986) and Jonker (2003). The gaps are linearly interpolated. *1477–1595*: Harvey (1995) provides observations for the years between 1440 and 1595. Her life expectancy rates are derived from evidence on English monasteries and are indicative of high mortality rates between 1470 and 1530. Regarding the representativeness of the data, Harvey (p. 142) concludes that high mortality was 'a case of roughly equal vulnerability to disease, shared between those inside the cloister and those outside'. However, the mortality of monks was enhanced by their exposure to infectious diseases: the vast majority of the people living outside the cloister enjoyed more favourable conditions (see discussion in Hatcher et al. 2006).[24] For the above-mentioned reasons, I decided to interpolate the years between 1447 and 1530. For sub-period 1530–1595, the life expectancy rates of Harvey are used. *1595–1809*: estimates for sub-period 1640–1809 are taken from Wrigley and Schofield (1981). These concern estimates for every 5 years. Gaps are linearly interpolated. The years between 1595 and 1640 have also been interpolated. *1809–1900*: Annual estimates from The Human Mortality Database. All estimates refer to remaining life expectancy at the age of 25.

Appendix 2: Robustness checks

The current Appendix provides alternative estimates of average years of schooling. More specifically, the average population level of the secondary schools is a crucial figure, but unfortunately, it was one for which evidence is relatively scant. I therefore have performed two robustness checks.

The first robustness check assumes that the population of the schools had increased from 50 to 75 between 1480 and 1550; that this stayed constant at 75 until

[24] I am grateful to Jim Oeppen for pointing this out.

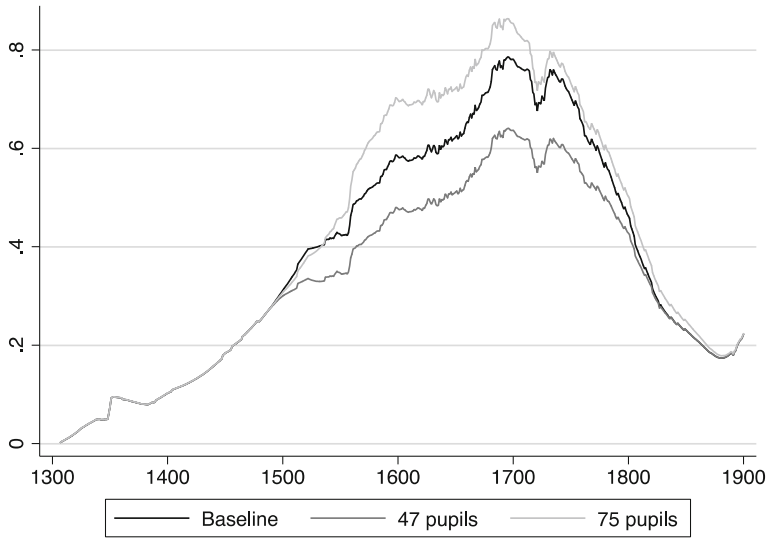

Fig. 5 Average years of higher education of males, 1300–1900: Robustness

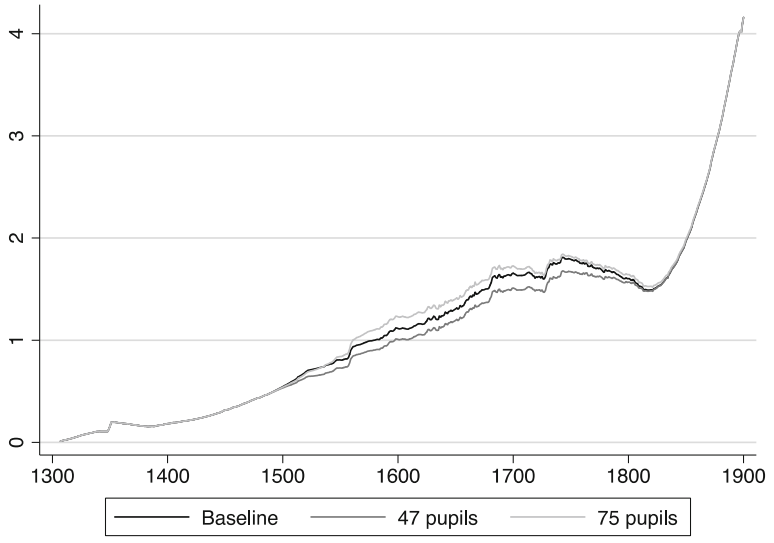

Fig. 6 Average years of education of males, 1300–1900: Robustness

1600; and finally, that the average number declined to 47 between 1600 and 1868. The figure of 75 is taken from Stowe (1908) who used a sample of 31 grammar schools in the reign of Queen Elizabeth to derive the average population level (denoted '75 pupils' in the figures below). The second robustness check assumes the population level to have remained constant at 47 pupils per school going back to

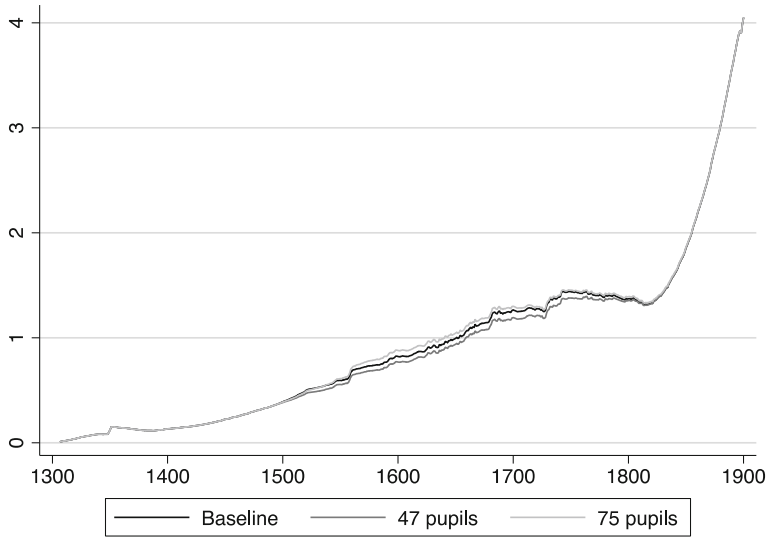

Fig. 7 Average years of education, 1300–1900: Robustness

1500. The literature indicates that the population of the secondary schools was never found to be lower than in the 1860s (e.g. Stone 1964, 1969). Therefore, this figure can be taken as a clear lower bound (denoted '47 pupils' in the figures below).

Figures 5, 6 and 7 show how the two alternative series compare to the baseline estimates presented in Sect. 2. The estimates of average years of higher education (Fig. 5) still illustrate a significant increase in secondary schooling over the sixteenth and seventeenth centuries and a decline in the level during the period of the Industrial Revolution. If the population level had increased to 75, growth would have been a slightly faster over the sixteenth century. If the average population level would have been 47 between 1500 and 1868, one in nine instead of one in seven boys would have entered secondary schooling at the end of the seventeenth century. Figures 6 and 7 illustrate that the average years of education of males and of the total population are less sensitive to the average number of pupils per school: the alternative estimates do not significantly deviate from the baseline estimates presented in Sect. 2.

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