Book Production and the Onset of Modern Economic Growth

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Abstract

We provide a new data set on per capita book production as a proxy for advanced literacy skills, and assess this relative to other measures. While literacy proxies very basic skills, book production per capita is an indicator for more advanced capabilities. Growth theory suggests that human capital formation plays a significant role in creating the 'wealth of nations.' This study tests whether human capital formation has an impact on early-modern growth disparities. In contrast to some previous studies which denied the role of human capital as a crucial determinant of long-term growth, we confirm its importance.

JEL: O14, O40, N10

Keywords: Book Production, Economic Growth, Human Capital

1. Introduction

There is considerable debate about the causes of economic growth and the role of human capital formation in the process of industrialization (Galor and Weil 2000, Acemoglu, Johnson, Robinson 2001, Glaeser et al. 2004). Unified growth theory has underlined the role of human capital in the transition to sustained economic growth (Galor and Weil 2000, Galor 2005). In particular, in contrast to earlier findings by economic historians (Mokyr 2002; Allen 2003), recent advancements (Galor and Moav (2002) and Boucekkine, de la Croix, and Peeters (2007a, 2007b)) have suggested that human capital formation played an important role in the Industrial Revolution.

Earlier empirical attempts to identify the role of human capital in the process of industrialization face the problem that human capital formation is difficult to quantify, in particular for the pre-modern period. We provide in this study a new indicator for early modern advanced literacy skills: book production, or to be more exact: new book editions per capita.[1] The concept of edition and re-edition is important for our study, since it partially solves the problem of weighting books by importance. Books that were considered particularly important for the development of social life (such as religious texts), for the functioning or improvement of institutions, or the transfer of essential scientific knowledge were re-edited, sometimes again and again. Hence, we measure not only the quantity of books, but also their implicit importance as indicated by their re-editions. But for stylistic simplicity, we will call this variable "book production". We propose that book production is better suited to measure a number of aspects of human capital formation than traditional measures such as literacy, i.e. the ability to sign a contract or register. This study is the first to present a time variant proxy for human capital as far back as the late Middle Ages for eight European countries. Moreover, little was previously known about the human capital of countries such as India, China, Indonesia, and Japan. Our primary hypothesis is that human

capital, as measured by our indicator of book production, can explain differences in economic growth over the period under study.

The evolution of movable printing sharply reduced the access costs to scientific knowledge, thereby raising the productivity and profitability of scientific activity dramatically. This, in turn, strongly stimulated the scientific branch of the economy. Qualitative interpretations of the long-term effects of the invention of printing have put forward that both the Reformation of the 16th century and, perhaps more importantly, the Scientific Revolution of the 17th century would not have occurred without the printing press which made it possible to distribute the heterodox ideas of reformers and scholars in spite of manifold attempts to suppress them (Eisenstein 1979). The increasing production of useful knowledge which resulted from these developments laid the basis for the 'Industrial Enlightenment,' which according to Mokyr (2002) was one of the main causes behind the Industrial Revolution of the 18th century. Moreover, it motivated processes of literacy creation, intensified reading activity (which might not be perfectly correlated with basic literacy skills), and induced a relatively high willingness to pay for books – at least in some countries.

The advantage of book production as a measure of human capital is that it is a truly economic variable which is closely linked to the demand for books in any given society and period. Hence, it reflects the degree to which a society has become literate and in which mass demand for books has emerged, which makes this index easier to interpret than the usual measures of literacy, which often define literacy as the mere ability to sign one's name under a contract (such as a marriage contract).[2]

Boucekkine, de la Croix, and Peeters (2007a) have studied the microfoundations of early human capital creation in England and France (BCL from here).[3] Following Cressy (1980), who found an almost constant literacy increase in England since 1540, BCL studied two booms of school formation – in the late 16th and early 18th century – and compared the

improvements in France between the late 17th and 18th centuries with the English development (on France, see Fleury and Valmary, 1957; more recently Houdaille, 1977).[4] Perhaps the most important contribution of BCL was to suggest a model with clear microfoundations explaining how population density translated into early schooling achievements, based on the consideration that school children could not travel over longer distances at this time. The parents who expected higher income (or religious capabilities, one could add) of their children acted rationally in their decisions about school attendance and the best location of schools. The authors argued that this model provided microfoundations to the mechanism which unified growth theory suggested for the switch from Malthusian stagnation to the First Industrial Revolution. They quantified the contribution of population density as being one third, life expectancy one sixth, and TFP growth one half, to literacy growth (Boucekkine, de la Croix, and Peeters 2007b). Below, we will compare the predictions of their model of human capital formation with the new evidence presented here.

Our paper is structured as follows. The newly created data set and its sources are presented in section 2. There we also present our measure of economic growth, the growth of real wages – a measure that extends from the 15th century to the 19th century for a number of countries (Allen 2001, 2003). In the third section we conduct a regression analysis where we estimate the impact of human capital on growth while controlling for a number of other variables. In particular, we allow for two competing explanations of early economic growth: intercontinental trade and growth enhancing institutions. In the fourth section, we conduct an out-of-sample test to see if the model from section 3 helps explain the early portion of the Great Divergence over the 19th century. The paper ends with summary of our findings.

2. Data: Book production and other indicators

The estimates of the output of printed books is based on the number of titles or editions that appeared in Western Europe between 1454 and 1800. The most important sources for

counting new titles are meta-catalogues (or short title catalogues) that are based on the books in library catalogues and are inventories of editions published in different countries and/or languages. Such meta-catalogues are available for Incunabula (all books printed in Western Europe before 1501), for books printed in the Netherlands and Belgium, for books in English (covering not only Great Britain but also Ireland, the United States, Canada etc.), and – but this catalogue is unfortunately incomplete – for books published in Western Europe between 1454 and 1830 (the so-called *Hand-Press Book File*). Other countries (France, Sweden, also Denmark, which is not included here) have national libraries, in which a copy of all books published are being stored, making it possible to estimate total book production in the past. Finally, the catalogues of the Leipziger and Frankfurter Buchmesse have also been published (a series which begins in 1565); this allows us to estimate the international book trade.[5] For the details about the data set, there is a longer working paper version (Baten and van Zanden 2006), where we also discuss the questions on book imports and exports, production and consumption. Our individual observation units, "titles " include both first editions and re-editions, the latter being publications distinguished from previous editions by changes made in the contents (revised edition) or layout (new edition). To illustrate this, the first printing of Gutenberg's bible is considered an individual title, as is any new edition of that bible, whereas a reprint of exactly the same manuscript would not count as a title as such. The concept of edition and re-edition is important for our study, since it partially solves the problem of weighting books by importance. Books that were considered particularly important for the development of social life (such as religious texts), for the functioning or improvement of institutions, or the transfer of essential scientific knowledge were re-edited, sometimes again and again. Hence, we measure not only the quantity of books, but also their implicit importance as indicated by their re-editions.

Book production and consumption could be estimated for eight countries (Great Britain, the Netherlands, Belgium, France, Germany, Sweden, Spain and Italy) for the whole

1450-1800 period; the regressions were based on averages for periods of fifty years (1450/1499, 1500/1549 etc.), always per capita.

[Figure 1 around here]

We first discuss the general tendencies observable from the raw data. In the centuries after Gutenberg, production and consumption of books increased dramatically in Western Europe. [6]

For the 15th century, Belgium and Italy have the highest levels of book production per capita, overtaken at around 1600 by the Netherlands and Great Britain (Figure 1). This is an important result in itself, because literacy values in England during the Industrial Revolution were previously estimated as relatively modest and stagnant (Mitch 1993). However, such a pessimistic view of human capital formation during the 1750-1850 period tends to overlook the strong increase which occurred in the centuries before 1750, when Great Britain became one of the most literate countries of Europe.[7] The strong growth of human capital formation in the Low Countries and England is consistent with what we know from other studies (Hoeppner Moran 1985; Stephens 1990; Reis 2005). Thus, the higher number of books per capita could have created substantially greater growth capabilities. Germany, the country where Gutenberg invented the moveable type, belonged to the middle group as it had clearly less books per capita than Great Britain or the Netherlands. Belgium displayed an interesting development, starting out from a high level but falling off heavily in relative terms in the 18th century. This is consistent with Vandenbroeke's argument (1985) that the level of literacy may have declined in Belgium in the late 18th and the first half of the 19th century. Spain started at similarly low values as Great Britain in the 16th century, and arrived at the lowest overall value in 1750-99. The biggest growth success was Sweden, rising from the lowest value in 1450-1599 to a position on par with Great Britain in the late 18th century. The

Swedish and Dutch gained enormously during that period, relative to the Germans, for example, who destroyed their economy in religious wars.

Previous research charting the long term development of human capital formation before 1800 has almost exclusively focused on the rise of literacy in this period. For a few countries (England since the late 15th, France since the 17th century) more or less consistent estimates are available of the share of the population able to sign an act or register (see the overview by Reis, 2005; on England: Stephens, 1990; Cressy, 1980; Van Zanden 2004). [8] Average literacy in Western Europe might have increased from slightly less than 10 percent in 1500 to about one third in 1800; in the Low Countries, Great Britain, Scandinavia and northern Germany this increase was much larger than in the southern and eastern parts of Europe, which lagged behind. It is not always clear, however, what the ability to sign ones name means – it may or may not imply being able to read and write. In Sweden, for example, already at the end of the 18th century almost all people signed their marriage register, but a large part of them was unable to read. Reis (2005) estimates the level of overall ability to read *and write* in Sweden at only 20-25%, whereas reading ability is estimated as being close to 100% (Graff 1987, p. 226). The Swedish case may be exceptional, but it illustrates the limitations of the concept of literacy. Instead, we propose to use estimates of the production and/or consumption of books as a measure of human capital. The advantages of book consumption are that it measures the size of the market for books and therefore represents actual use of reading skills, and is closely related to more advanced levels of human capital formation beyond literacy. Moreover, it can be estimated in a consistent way for a relatively large number of countries spanning a period of four and a half centuries. How does our book indicator correlate with literacy rates? Available evidence for England, France and Spain suggests a general correspondence (Figure 2). For England and France, we found a relatively close correlation, but for Spain between 1500-49 and 1600-49, only literacy increases rapidly, whereas our book indicator does not grow very much. Nalle (1989) reports that literacy of

ordinary peasants and craftsmen accused by the inquisition was as high as in England. Even more convincing, she reports other samples – tax registers from Santiago and wills from Madrid – which support this surprisingly high Spanish literacy. We would agree that in Spain basic literacy was probably growing, but not the more advanced components of human capital that we measure with our indicator. To sum up, the main trends known from the study of literacy are present in our estimates of book production, but there are also crucial differences, such as the Spanish case.

The model of Boucekkine, de la Croix, and Peeters (2007a) mentioned above is consistent with the fact that Central, Eastern and Northern Europe were too sparsely developed for early school development. In contrast, the Netherlands developed the remarkable book per capita values due to their high population density. Moreover, the BCL model can help to explain why Spain had quite good literacy values and a relatively large number of schools in the late 16th and early 17th century. Spain had a peculiarly high urbanization rate, which stems from the fact that many farmers lived within city boundaries (Alvarez and Prados 2007). Hence the school commuting time could have been low for the Spanish school children, and literacy increased over the 16th century. We hypothesize that while basic literacy was available, more advanced forms of human capital, which were required for welfare growth, were lacking. Clearly Spain had one of the most disappointing real wage development records, jointly with Italy, during this period. The Spanish case again points to the limitations of using simple signature counts as an index of human capital.

[Figure 2 and 3 around here]

Real wages are taken from the internet data archive set up and documented by Allen (2001). As exhibited in Figure 3, in most countries real wages declined during this period of rapid population growth, consistent with the predictions of the Malthusian model. As shown by

Allen (2001), a few countries (England, Belgium and the Netherlands) already seem to escape the Malthusian trap during the early modern period; there, wages in the long run were more or less stabilized at the high level attained during the 15th century, when real wages reached a peak due to the decline of the population after the arrival of the Black Death in 1347 (Pamuk 2007). The hypothesis tested here is that this 'little divergence' (between those three countries and the rest of the continent) is caused by the accumulation of human capital in the countries concerned.[9] The net effect of the long term stabilization of real wages in the North Sea area and the decline elsewhere was a process of unconditional divergence, with the coefficient of variation almost doubling between the 15th and the 18th centuries.

One question that clearly should be discussed is the choice of the dependent variable – should it be population growth, as in a Malthusian world technological and educational progress might have lead to an increased population, or rather per capita income (approximated with real wages here).[10] Breaking free of Malthusian constraints as phase 1 of the transition to self-sustaining growth is essential to the unified growth framework as pioneered by Galor and Weil (2000). When exactly this point was reached is a matter of dispute. A growing number of papers has concluded that Malthusian checks and balances were weak and operated slowly in the early modern period, at least in many parts of Europe (Anderson and Lee 2007; Clark 2007; Mokyr and Voth 2007), and that parts of Western Europe (the Low Countries and England) maintained levels of welfare well above 'subsistence', probably due to the rise of a new demographic regime (Allen 2001; De Moor and Van Zanden 2005; Pamuk 2007). If so, we need explanations for what accounted for the contrasting fortunes of leading and lagging European states. For these reasons we do not opt for an analysis of the economic success of countries in terms of their population growth, but in terms of the increase of their real income.

Table 1 shows the descriptive statistics of the explanatory variables used in the following section. All of them are in logs, except for the dummy variables and

intercontinental trade, which follows the original specification chosen in Allen (2003), partly because most values are zeros and cannot be put in logarithmic form.

[Table 1 around here]

3. Regression analyses

We first run two fixed effects regressions, including dummies for all centuries under study (with the 17th century serving as the reference category), of the econometric form:

$$[(\mathrm{Ln}(rw_{it}) - \mathrm{Ln}(rw_{it-1})] =$$

$$\beta_1 \mathrm{Ln}\, bo_{it-1} + \beta_2 \mathrm{Ln}\, rw_{it-1} + \beta_3 tr_{it-1} + \beta_4 cap_{it-1}$$

$$+ \sum_{k=1}^{p} \beta_k X_{kit-1} + \sum_{n=1}^{q} \beta_n D_{nit-1} + \mu_i + u_{it}$$

where $[(\mathrm{Ln}(rw_{it}) - \mathrm{Ln}(rw_{it-1})]$ is the increase of real wages in country i between the initial half of the century t-1 and the current half of the century t; $\mathrm{Ln}\, bo_{it-1}$ equals Log book production (the human capital proxy) in the initial half of the century, with $\mathrm{Ln}\, rw_{it-1}$ indicating the level of real wages in the initial half of the century in log form, and tr and cap serving as our 'alternative/complementary hypothesis' variables for intercontinental trade and capital-protecting institutional constraints on the executive (explained below). X is a vector of p control variables such as changes in land per capita, the Thirty Years' War, and similar variables. D is a set of q century dummies which control for technological change in book production, the time variant impact of the growth impact per book between centuries, relative price changes, and similar factors. Finally, μ_i are country fixed effects to control for unobservable country characteristics, and u_{it} is a stochastic error term.

Since the dependent variable is the real wage growth between the first and the second half of the century, it is unlikely that unit root problems arise (panel unit root tests with such small samples have very limited power). As all explanatory variables refer to the initial half of the century, we avoid contemporaneous correlation problems. Please note that we regress growth rates on a set of "growth capabilities" measured in levels. Doing this, we want to document basic patterns in early modern data that are compatible with causal interpretations of human capital influence. Glaeser et al. (2004) developed a broad-based human capital approach which clarifies why the better-endowed countries had relatively better growth experiences (see also Arnold, Bassanini, and Scarpetta 2007 for a recent approach).

Having discussed the international trade of books in the working paper version, we decided to test both the per capita production and consumption of books as indicators of human capital (Table 2). This dual approach allows us to assess the robustness to changes in concept.

We find that the influence on real wage growth was statistically significant and substantial, even after controlling for a number of other factors. For example, the effect of an additional conditioned standard deviation of book production per capita is 0.89*0.33=0.29. This is quite a substantial value, given that the standard deviation of real wage growth is only 0.76. Hence, human capital as measured in books per capita had indeed a strong, positive, and economically significant impact on welfare growth. What does the above term "conditioned" mean in this context? In order to perform this calculation, we had to condition book production on time, by regressing the book production values on a set of time dummies and save the predicted values. Otherwise we would have compared book production in 1500 and 1750, without taking into account that much of the variance in book production is over time.[11]

We would argue that existing human capital estimates are relatively weak in measurement quality and that the capabilities are slightly too basic (such as writing one's name). In order to show that the traditional ones have less explanatory power than our new

proxy, we perform a horse-race between the existing estimates of literacy and the book variable. It turns out that literacy is indeed insignificant and cannot explain differences in real wage growth. [12] We also included both variables, and estimated literacy became insignificant. The direct confrontation of both potential human capital proxy in Table 2, column 1, 3, and 4 shows clearly that book production per capita proxies the more relevant components of human capital relatively well.

An alternative interpretation is that international trade – and in particular the rise of the Atlantic economy – is driving the changes in real wages (Allen 2003). We test for this by including the proxy variable for intercontinental trade encompassing Atlantic imports and exports per head of the population, which is however insignificant once we control for human capital, conditional convergence effects, and other variables. Moreover, this result is quite robust across various models (see also the regressions below). It is important to note that in spite of the skewed distribution (Table 1), this regression coefficient is not determined by one or two influential values.[13]

Acemoglu, Johnson, Robinson (2002) have suggested a measure of property rights especially for urban merchants, which departs from the idea that monarchs and the nobility might feel tempted to expropriate successful merchants, unless the merchants and their capital would be protected by good institutions. As a source, they used an encyclopedia of political and constitutional developments, which they used to code an index variable between 1 (=unconstrained monarchs and nobility, insecure property rights for merchants) and 7 (=government effectively in the hands of merchants and the middle classes). This measure of capitalist property rights turns out as an important determinant of growth. However, the positive influence of this variable does not change the other results significantly (in spite of some collinearity with our book production indicator, as indicated by the correlation coefficient of 0.56). Hence, human capital as proxied by book production might have been an additional factor in the facilitation of welfare growth, independent of the institutional factors

(which were also important). We can therefore confirm our main hypothesis, and provide evidence for the hypothesis that institutions protecting capital mattered, whereas we find no confirmation for intercontinental trade to increase welfare levels.

The level of initial real wages is significantly negative, pointing to the existence of conditional convergence in early modern Europe. We would not put too much emphasis on this finding, given that fixed effects are somewhat biased towards indicating convergence effects (Durlauf et al. 2005). But to a certain extent, this might imply that technology transfer to initially less sophisticated countries (such as Sweden) took place.

The change of land per agricultural worker turned out to be insignificant. The sign is negative, which might be caused by the fact the most successful economies (such as England) might have had a rapid decline of land per agricultural worker, but we would not put too much interpretation into an insignificant coefficient. Nevertheless, we hold it important to control for Malthusian forces here, even if Malthus did not take into account the positive counter-forces of human capital accumulation.

Somewhat related to population size, we also tested the effects of the occurence of the bubonic plague after 1450, which was more or less endemic in those countries until the late 17th century. The outbreaks of the bubonic plague were quite exogeneous, as opposed to the occurence of other epidemic diseases – those were to a larger extent influenced by nutritional conditions, and hence by welfare levels. The bubonic plague is of special interest, because it might have disappeared earlier in countries with higher human capital such as England, whereas in France there were outbreaks until the early 18th century.[14] The expected impact of plague on real wage growth might have a positive sign, as the reduction of labor force mechanically increases wages, and land and physical capital were less affected. On the other hand, one could imagine a negative correlation with human capital formation (and via this channel on wages), as lower life expectancies and greater uncertainty about survival might reduce the willingness to invest in learning. These effects with opposite signs might cancel

each other out, as we find empirically only insignificant and small coefficients for the plague dummy (which is one if there was plague in a country and half century). Another explanation of the insignificance might be that the quantitative effect of the plague and other epidemic diseases was already reflected in our variable 'change in land per agricultural worker', which is closely related to population losses or increase.

[Table 2 around here]

Among the control variables, we add a dummy variable for Germany during the Thirty Years' War for obvious reasons, and another for the post-war period (omitting them does not change the other results). Hence, we are able to quantify the effect of the Thirty Year's War on Germany while controlling for the other relevant factors. Real wage growth was substantially lower in the early 17th century, although this result is only economically, but not statistically significant. The recovery effect after the war was also not significant.

These results are very robust to various specifications (not shown). We also tested the random effects model, but rejected it on the basis of the Hausman test. Nevertheless, even in the random effects specification, books per capita have a significant impact on real wage growth.

Kremer (1993) has argued that initial population size (or initial land area) might impact on technological development in the long run, in particular that technology increases more than proportionally with population size. He argued that the much larger land mass of Eurasia led to its superiority over the Americas, and those over Australia, Tasmania and Flinders island, respectively. As a proxy for technological development he used the availability of single technologies, such as "did those economies already have stone tools", "were they engaged in metallurgy" and so on, and population growth.[15] We cannot satisfactorily test his argument here, as the European countries were much more integrated

than Eurasia, the Americas, and Tasmania, which were divided by oceans (and his argument refers to the development over millennia). However, we performed the experiment to include (a) initial population size and (b) the agricultural land area in our regressions, in order not to neglect his influential reasoning. However, those variables turned out insignificant, and their inclusion did not change the significance of our human capital proxy (results available from authors).

A partial regression plot allows to assess the potentially influential cases that might drive the relationship between our proxy for advanced human capital and real wage growth, after taking into account all the other variables, and also removing their influence from the explanatory variable we are most interested in. In order to generate this plot, we ran two partial regressions which removed the influence of the other variables from real wage growth and book production per capita (including country and century dummies). The residuals of those two regressions are plotted in Figure 4, with the residual real wage growth on the vertical and the residual book production on the horizontal axis. While there is a substantial part of unexplained variation, it is also clear that the slope of an imagined regression line is upward. High values of residual book production and substantial real wage growth can be observed in Italy 1500, Sweden 1700, and the UK 1700. On the other side, a growth failure record can be found in Belgium 1800, Sweden 1600, and Italy 1750, for example. It is remarkable that the extreme cases often stem from the same countries: Italy and Sweden are among the success cases as well as among the failure cases. Among the outliers with slower real wage growth than expected from our human capital proxy are, for example, the Netherlands 1800.

[Figure 4 and Table 3 around here]

We also need to address the issue of endogeneity. After all, books are a normal good, i.e. consumed more heavily with rising income. One strategy here which was already applied above is to take human capital as levels, and subsequent welfare growth in differences, in order to avoid contemporaneous correlation (and to measure growth capabilities). Moreover, we perform instrumental variable estimation (Table 3), with mainly two instruments (plus some robustness checks below with a third one). Which instrumental variables come to mind for advanced literacy? In the recent growth literature, a number of variables related to war and religion have been used, as those factors tend to contain a large exogenous component (even if some elements of endogeneity can also be speculated about, if one intends to). For our period, the share of protestant population could be a variable that influences human capital formation positively, if we follow Weberian line of reasoning. However, Max Weber (1958) also hypothesized other channels through which the share of Protestantism might have influenced economic growth, such as the work effort which protestants were willing to invest. Hence the protestant share is not a good instrument for our purposes. However, a related variable has much better properties: religious diversity could stimulate book production, without having a clear direct impact on economic growth (McLeary and Barro 2006). The database also strongly suggests that religious competition leads to increased book production; for example, during the English Civil War book production suddenly exploded, and the same happened during the Dutch Revolt of the late 16th century. We construct this variable as taking the value of zero for the protestant country of Sweden, as it had no official religious diversity after reformation – it was almost 100 % protestant. This "religious diversity" variable is also zero for countries such as Italy and Spain, as those did not partly become protestant countries. We only coded Spain in 1450-99 with one, as before the expulsion and/or forced conversion of the Muslim and Jewish minorities during the 16th century it was still rather heterogeneous. Before reformation we kept zeros for all other countries. After the reformation the Netherlands, Germany, and the UK are coded as 1, because of continuing

religious competition there. Belgium had religious competition before 1585 (when Spain finished its reconquest of the Southern Netherlands), and France until 1685 (when the Edict of Nantes was cancelled), but both became homogenous countries afterwards. Hence there is quite a bit of variation in this variable, both across countries and over time. Its correlation with our potentially endogenous variable book production is 0.34 (p-value=0.00).

A second variable that is inspired by religious enthusiasm, but without causing economic growth by itself (except via human capital formation) is the introduction of compulsory schooling laws or similar measures aimed at increasing the literacy of the population (De la Croix and Doepke 2004). Sweden was a pioneer in this field; it introduced a Church Law aimed at raising literacy already in 1686; it is clearly one of the poorest nations under study, hence this was not inspired by an income shock which influenced the creation of the compulsory schooling laws and might have caused endogeneity problems. Moreover, Sweden remained among the poorer nations for another two centuries. Therefore, this law of the late 17th century is not likely to have stimulated economic growth in Sweden via a separate channel. There were only two other cases of major schooling laws introduced in our eight countries – Scotland took similar measures during the late 17th century, followed by Prussia in 1717 (and Saxony in 1772). Those cases both covered only parts of the countries which we use here as observation units, but large enough parts to have an influence on human capital formation on a national scale (plus, there might have been spill-over effects into neighbouring regions). We coded a "schooling laws" dummy variable as 1 for those three countries, the correlation with book production was 0.36 (p-value=0.00).

Using those two instrumental variables, we still obtain a significant coefficient for book production (Table 3). In order to check whether our instruments are correlated with the error term, we performed the panel version of the Sargan test for over-identifying restrictions, and found that with a Chi-sq(1) of 1.61 and a p-value of 0.21, the Sargan test indicates that there are no major concerns about instrument validity from this side. We also performed -- as

an exercise about the robustness of those two "main" instrumental variable -- two other regressions in which we combined each of them with the lag in book production (corresponding to t-2 in the econometric model above, i.e. book production almost one century before the wage development to be explained). We are fully aware of the criticism of taking lagged explanatory variables as instruments, but the fact that the results are similar might provide some modest additional information about the robustness of our other two "main" instruments. In sum, we conclude that endogeneity is not a major problem for our study.

4. Out-of-sample test: can 18th century book production explain GDP growth between 1820 and 1913, as well as the Great Divergence?

In order to test whether book production can account for economic growth in the 19th century, we perform a partial out-of-sample test of the relation between books per capita and GDP growth, using an enlarged data set which includes a number of non-European countries. Apart from this out-of-sample test, it is also interesting to assess whether the production of knowledge as proxied by book production can explain the 'Great Divergence,' i.e. the fact that Western Europe and North America grew rapidly in the 19th century whereas (previously) highly developed regions such as China and India lagged behind (Pomeranz 2000). In other words, can we predict 19th century growth using 18th century book production estimates? In order to test this idea, the dataset is extended to include a number of countries for which data are available on the second half of the 18th century – some of them European (Ireland, Switzerland, Poland, Russia), others non-European (United States, China, Indonesia, Japan and India).[16] For the period of 1820-1913, relatively reliable GDP estimates are available. Figure 5 shows the relationship between book production in the second half of the 18th century, and the growth of GDP per capita over the 19th century (the period of 1820-1913), according to Maddison's (2001) estimates.

[Figure 5 around here]

The relationship is quite strong. Per capita book production in Asia was close to zero in the cases of India and Indonesia, and at about 3 per million inhabitants in China. In Japan, book production per capita, at almost 7 per million inhabitants, was more higher than in Russia, but still much lower than in Western Europe. Variation within Europe was also large, with the highest levels being attained by the Netherlands (538), Sweden (219), and Great Britain (198); not far behind came the U.S. with 141 books per million inhabitants per year. However, this large variation within Europe does not affect the overall results much. Only China is somewhat of an outlier in Figure 5, but has no greater influence on the relationship between the two variables. Both figures show that a close relationship exists between our measure of human capital formation for the 18th century, and economic performance in the period of the Industrial Revolution and its aftermath. Countries with a low level of human capital formation were unable to participate in the industrialization process which transformed the world economy, whereas countries with a better starting position managed to catch up with Great Britain – or even to overtake it. It is interesting to note that Japan invested heavily in schooling as early as the 18th century, which is evident from the existence of a mass market for books. The high level of schooling in pre-Meiji Japan is also confirmed by other evidence (Hayami and Kitô 1999; see also Van Leeuwen (2007) for the large difference between Japan on the one hand, and Indonesia and India on the other hand). Apparently, Japan's high level of education formed the basis to make it a successful modernizer, whereas other Asian countries failed to industrialize in the 19th century.

Now, one could object that this could just be the beginning of the great divergence: countries with higher GDP during the 18th century which produced more books grew faster in the 19th century. In order to sort this out, we controlled for initial GDP per capita level, which

was available for 15 contries, and tested the book variable against this initial level effect (Table 4). In the first model, we regressed the level in 1870 on the level in 1700 and the book production "capabilities" during the 18th century. Book production was still positively significant. The same applies to the second, which takes a shorter time horizon (GDP per capita in 1820 is the dependent variable here). Finally, the third model uses the annual growth rate of GDP per capita between 1820 and 1870, and while controlling for GDP per capita in 1700 – which is insignificant – still the book production variable determines the growth successes and failures during this 19th century period.

5. Conclusion

In this study, we provided a new indicator for advanced literacy by employing the number of books per capita in pre-industrial Europe. It was exactly in the countries in which book production increased fastest that real wages developed systematically better over the centuries before the Industrial Revolution than in countries with lagging human capital formation. We performed a number of tests to counter-check the validity of those results, such as robustness tests, instrumental variable estimations, and controlling for additional variables, but the results remained robust. Therefore, we may conclude that human capital formation as measured in this way had a strong and positive effect on economic performance in the centuries before 1800. This confirms the view of Unified Growth Theory, which has underlined the role of human capital for the switch to sustained economic growth (Galor and Weil 2000, Galor and Moav 2002, Galor 2005).

We also assessed two alternative hypotheses regarding the role of institutions and international (and in particular trans-Atlantic) trade in the growth process. Institutional patterns had a positive and independent effect, whereas an effect of intercontinental trade could not be established, when we controlled for book production.

Finally, we assessed the movement of human capital formation and economic growth beyond 1800, until 1913, considering a larger sample of countries. Again, the number of book editions per capita allowed a forecast of countries' subsequent growth capabilities in the century of the Great Divergence. Countries with high levels of human capital formation in the 18th century initiated or participated in the industrialization process of the 19th century, whereas countries with low levels of human capital formation were unable to do so, among them many of today's Less Developed Countries such as India, Indonesia, and China.

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Tables

Table 1: Descriptive statistics of the variables used in the regressions

Variable	Obs	Mean	Std.Dev.	Min	Max
Real Wage Change	54	-0.209	0.759	-1.662	1.734
Book Consumption	54	3.886	1.253	0.399	6.248
Book Production	54	3.870	1.300	0.399	6.296
Conditioned Book Production*	54	3.814	0.887	2.446	4.759
Initial Real Wage	54	5.142	1.545	2.530	7.979
Change in Land per Agric. Pop.	54	-0.014	0.014	-0.052	0.007
Intercont. Trade	54	128.209	446.534	0	2726.4
Bubonic Plague	54	0.556	0.502	0	1
Post-war	54	0.019	0.136	0	1
30-Years-War	54	0.019	0.136	0	1
Capital Protection	54	2.296	1.574	1	7
Literacy (est.)	54	0.225	0.154	0.06	0.68
Religious Diversity	54	0.463	0.503	0	1
Compulsory schooling laws	54	0.185	0.392	0	1

* Predicted values from the book production variable regressed on a set of century dummies.

Sources and definitions: book production/consumption: see text; capital protection: Acemoglu et al. (2002); other variables: Allen (2003), except were data were missing (agricultural land taken from van Zanden 1991). Real wages for Sweden were friendly provided by Christiaan van Bochove. 30-Years-War and Post-War relate to Germany. Postwar is 1 for Germany during the half century after the Thirty Years' War. Book production and consumption, as well as intercontinental trade, are per capita. Bubonic plague is 1 if an outbreak is recorded for a country and half-century. We thank Leondro Prados de la Escosura, Paola Malanima, Carlos Álvarez-Nogal, and Sören Edvinsson for important information on the plague occurences. Our data set is complete for the countries uk, it, nl, be, es, fr, de, se for each half century from 1500 to 1800 , except Germany and Sweden in 1500, and except for land per agricultural population and protection of capital, for which hard data were only available with a century resolution.Which of the variables are period averages and which are available point-in-time? Real wage: We averaged annual real wage bz half centuries (1500-49 etc.). For land per agricultural population, we had observations for points in time (1500, 1600 etc.), which had to interpolated to obtain the values for 1500 etc, and took the point in time for the start of the period. International trade is available for points in time, each half century for the relevant time period, except Spain 1650, for which had to take Spain in 1600. Protection of capital was available for centuries only, so we took the value 1600 for both 1600 and 1650 etc. The dummy variables for Thirty-Year's War, Postwar, and plague refer to the occurence of those events during the hald century. The estimation of literacy, religious diversity, and compulsory schooling laws are described in the text.

Table 2: Two fixed effects regressions of real wage changes, 1450-1849

	Model (1)	Model (2)	Model (3)	Model (4)
HC concept	Book prod.	Book cons.	Literacy	Book prod. and literacy
Books	0.22*	0.24*		0.21*
	(0.063)	(0.061)		(0.078)
Literacy			-1.17	-0.92
			(0.38)	(0.48)
Initial Real Wage	-0.68***	-0.69***	-0.60***	-0.63***
	(0.000074)	(0.000062)	(0.0012)	(0.00064)
Intercont. Trade	0.00	0.00	0.00	0.00
	(1.00)	(0.93)	(0.88)	(0.89)
Capital Protection	0.21*	0.21*	0.29**	0.22**
	(0.060)	(0.051)	(0.011)	(0.049)
Change of Land per agric. Worker	-5.34	-5.08	-3.28	-5.43
	(0.44)	(0.46)	(0.64)	(0.43)
Post-war	1.06	1.02	1.06	1.05
	(0.13)	(0.15)	(0.15)	(0.14)
30-Years-War	-0.91	-0.95	-0.99	-0.96
	(0.18)	(0.16)	(0.16)	(0.16)
Bubonic Plague	-0.38	-0.38	-0.28	-0.34
	(0.41)	(0.41)	(0.56)	(0.47)
D 16^{th}	0.07	0.08	-0.38	-0.10
	(0.81)	(0.79)	(0.31)	(0.79)
D 18^{th}	-0.65	-0.67	-0.35	-0.55
	(0.20)	(0.19)	(0.50)	(0.29)
D 19^{th}	-1.25**	-1.30**	-0.81	-1.07
	(0.035)	(0.031)	(0.21)	(0.10)
Constant	2.42**	2.40**	2.91***	2.33**

	(0.011)	(0.012)	(0.0025)	(0.016)
N	54	54	54	54
Number countries	8	8	8	8
R-Square	0.62	0.62	0.59	0.63

P-values in parentheses. ***, **, * refer to the 1, 5, and 10% level of significance. Notes: The dependent variable is always the first difference between the log real wage of one half century and the next. All explanatory variables refer to the initial half century, except the "change of land per agric. worker" variable. Sources: see Table 1. The construction of the literacy variable is as follows: literacy is taken from Allen (2003), p. 415, assuming for 1450-1499 the value of 1500, and interpolating linearly to 1800, for which direct estimates are available. We avoid using urbanisation proxies for the centuries between 1500 and 1800, as this could be seen as a separate growth determinant, whereas we want to measure the human capital effect as purely as possible. For Sweden, a value equal to that of Germany is assumed.

Table 3: Controlling for endogeneity: IV fixed effects regressions of real wage changes, 1450-1849

Model	(1)	(2)	(3)
Instruments:	Relig. Divers., School Law	Relig. Divers., Lag(Books)	School Law, Lag(Books)
Book Production	0.37**	0.43**	0.42**
	(0.036)	(0.020)	(0.012)
Initial Real Wage	-0.68***	-0.94***	-0.94***
	(0.000012)	(0.0000047)	(0.0000042)
Intercont. Trade	0.00	0.00	0.00
	(0.42)	(0.14)	(0.14)
Change of Land per Agric. Worker	-6.11	-0.31	-0.25
	(0.40)	(0.97)	(0.98)
Post-war	1.08	0.61	0.62
	(0.13)	(0.39)	(0.39)
30-Years-War	-0.87	-1.09	-1.08
	(0.21)	(0.10)	(0.10)
D 16th	0.26	0.17	0.16
	(0.45)	(0.64)	(0.64)
D 18th	-0.38	-0.39	-0.38
	(0.14)	(0.13)	(0.13)
D 19th	-0.81**	-0.88**	-0.88**
	(0.025)	(0.021)	(0.019)
Constant	1.91*	3.01***	3.02***
	(0.054)	(0.0055)	(0.0048)
Observations	54	48	48
Countries	8	8	8
R-Square	0.19	0.15	0.15

P-values in parentheses. ***, **, * refer to the 1, 5, and 10% level of significance. Notes: see Table 1. The instrumental variables for book production and consumption are reported in the first row, “school law” means compulsory schooling laws.

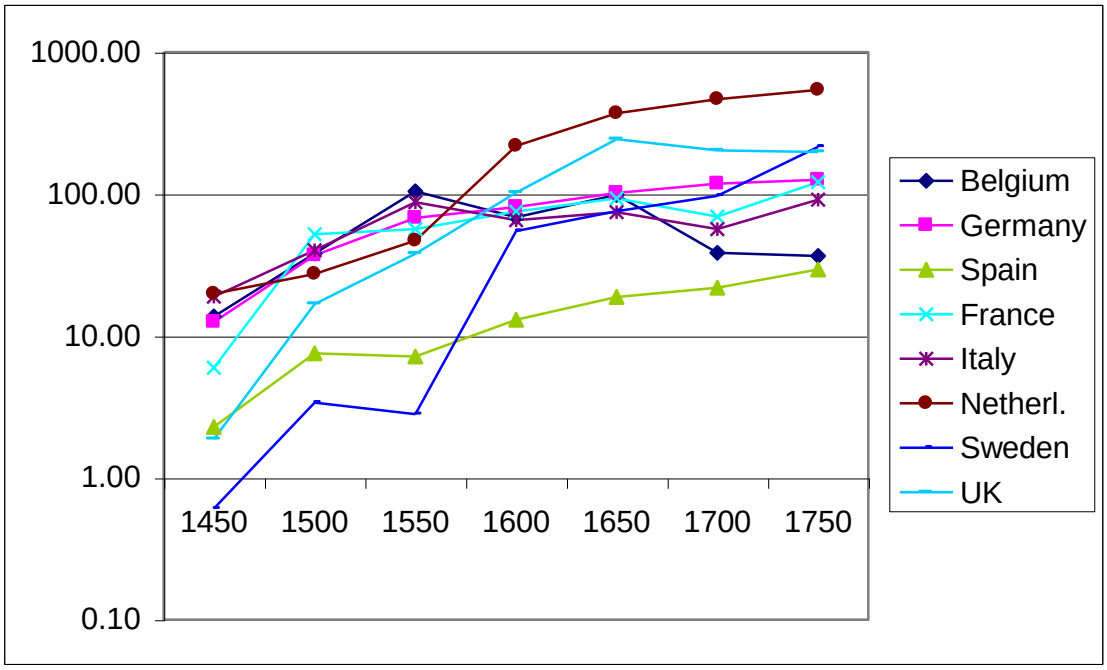
Table 4. The influence of book production and inital GDP level on subsequent growth

	Model (1)	Model (2)	Model (3)
Dependent variable	GDP/c 1870	GDP/c 1820	Annual GDP/c growth 1820-70
GDP/c level in 1700	0.29	0.40**	-0.23
	(0.326)	(0.011)	(0.574)
Book prod. p.c. 1750-1800	0.18***	0.09***	0.19***
	(0.001)	(0.001)	(0.009)
Constant	4.70**	3.90***	1.67
	(0.024)	(0.001)	(0.525)
N	15	15	15
Adj. R-square	0.30	0.86	0.46

P-values in parentheses. ***, **, * refer to the 1, 5, and 10% level of significance. Notes: Annual GDP/c growth 1820-70 is calculated as geometric mean of the average growth rate

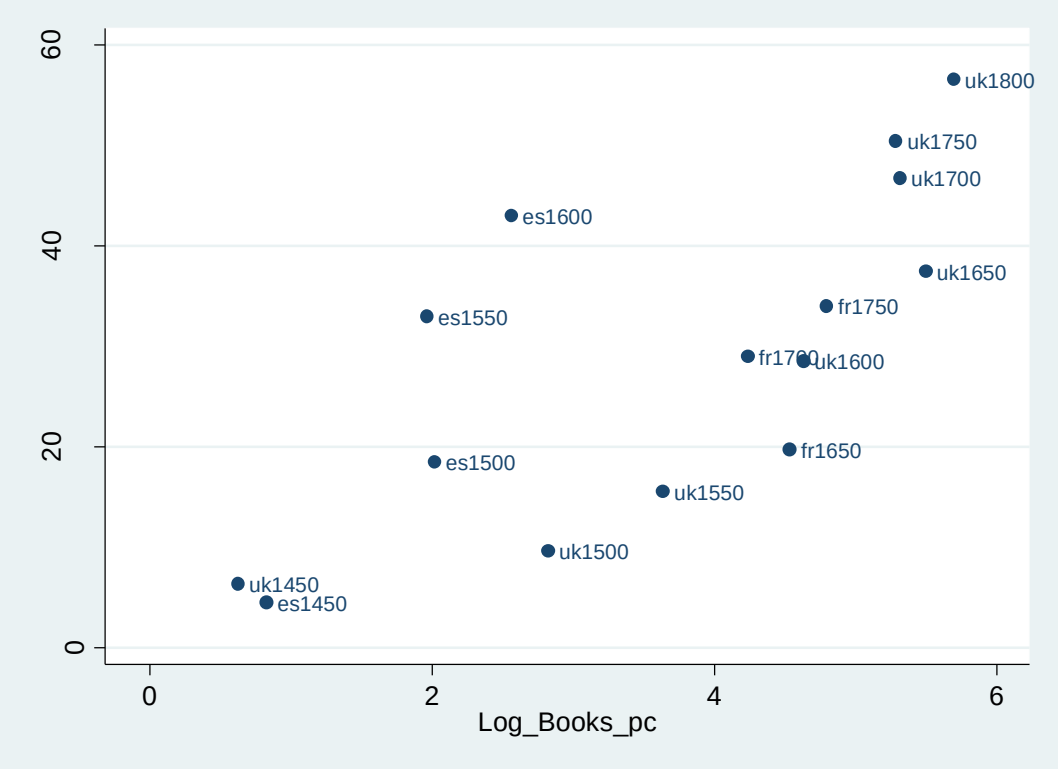
Figures

Figure 1: Book production in early modern Europe, 1450/99-1750/99 (number of new editions per million inhabitants, log scale of vertical axis)



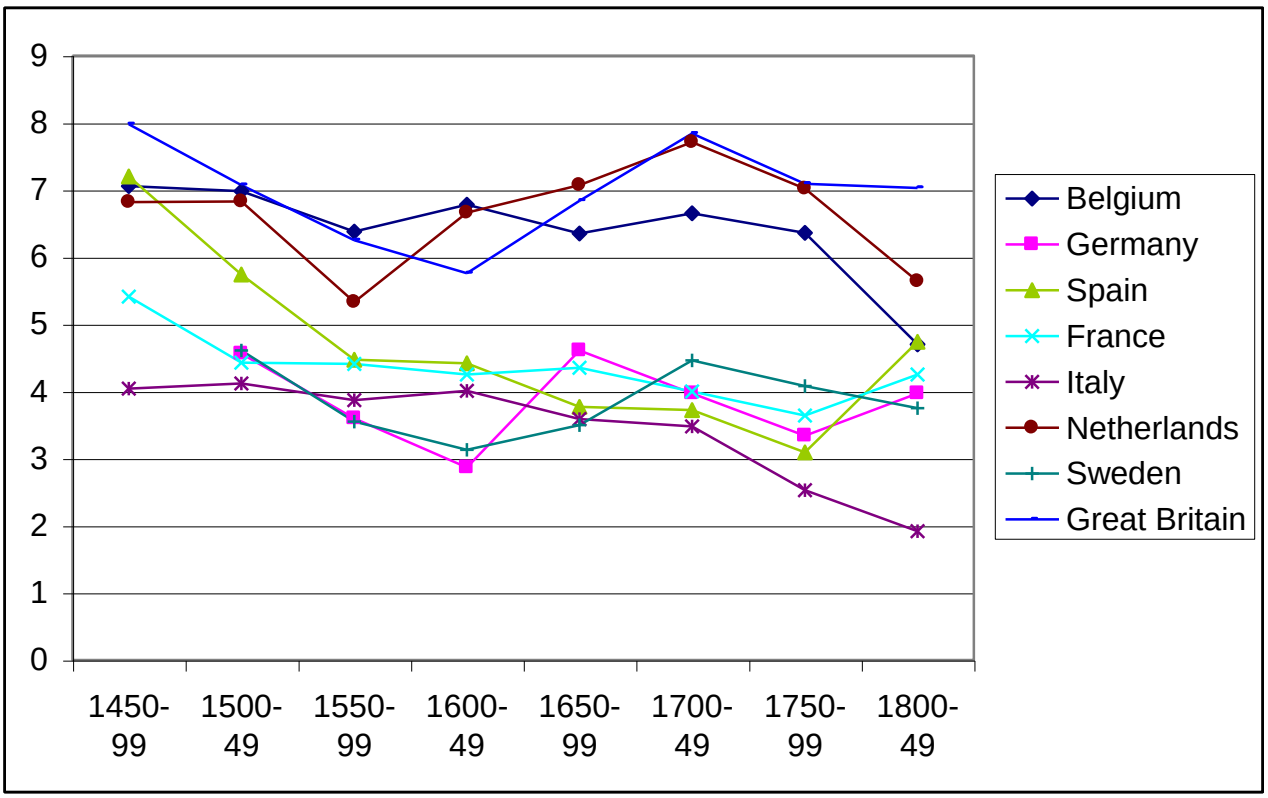
Source: see text.

Figure 2: Book production and literacy in England, France, and Spain



Note:UK excludes Scotland here (and Ireland). We included only those three countries with long-run literacy data which do not exclusively stem from very large cities.

Figure 3: Real wages in early modern Europe, 1450/99-1800/49



Source: see Table 1.

Figure 4: Residuals of book production (on horizontal al scale) and of real wage growth (on vertical scale)

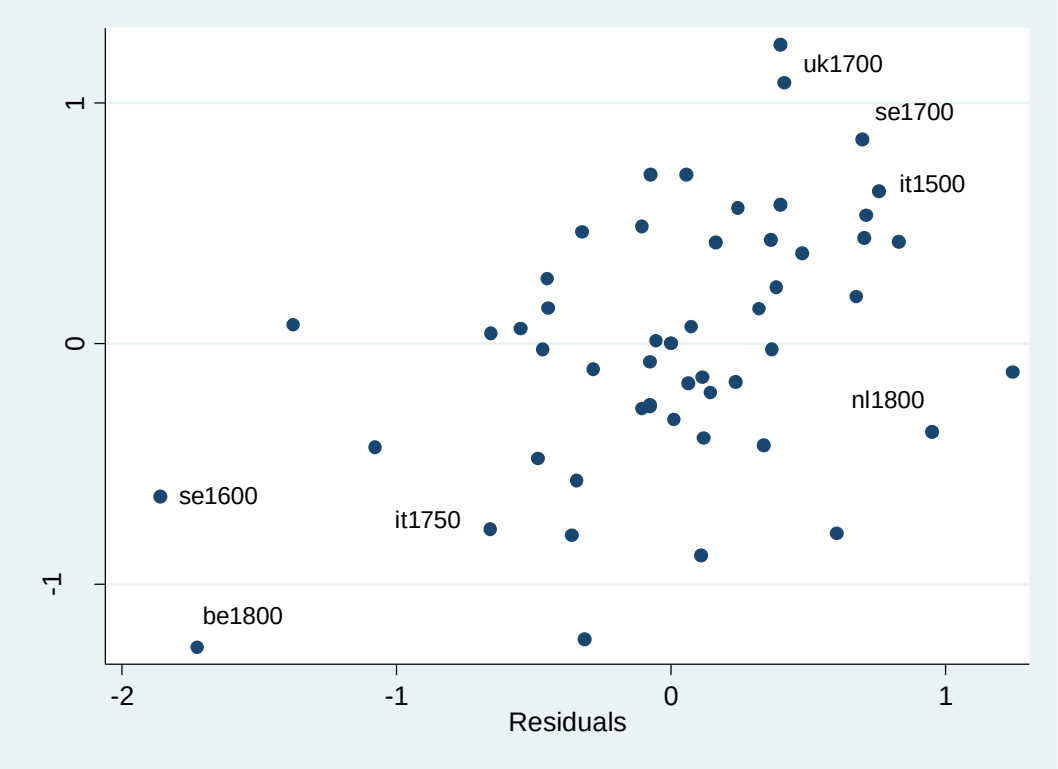
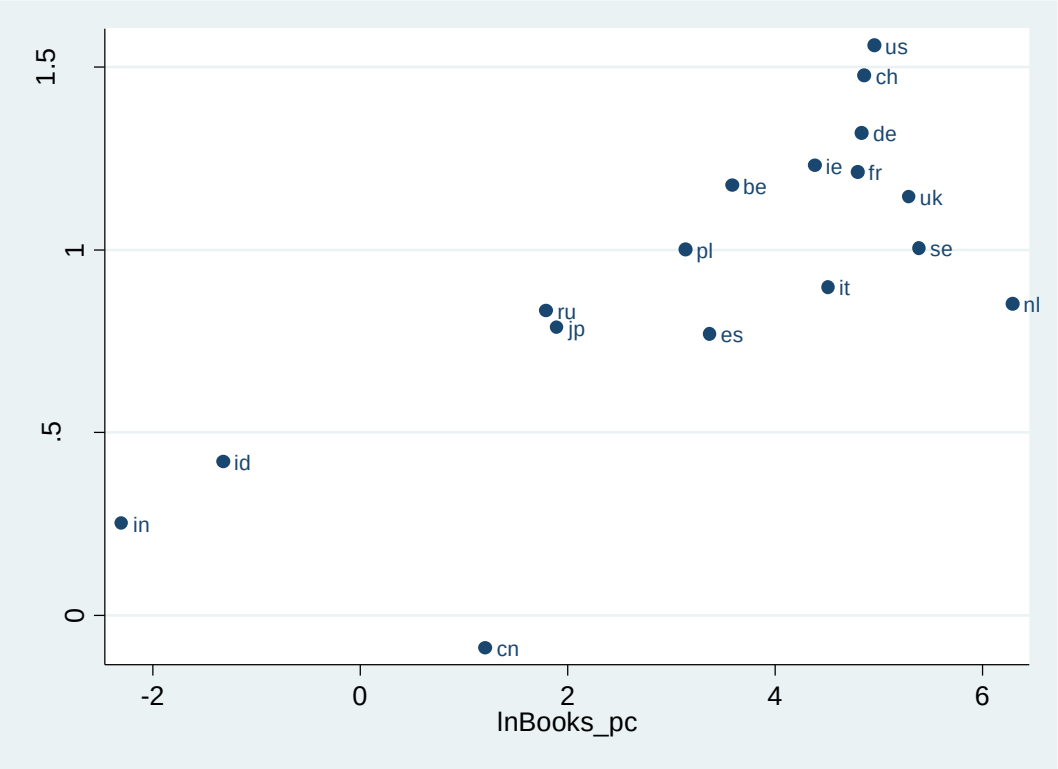


Figure 5: Book production per capita between 1750 and 1800, and GDP per capita growth in 1820-1913 (books on log scale)



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Endnotes

[1] Our individual observation units, "titles " include both first editions and re-editions, the latter being publications distinguished from previous editions by changes made in the contents (revised edition) or layout (new edition). To illustrate this, the first printing of Gutenberg's bible is considered an individual title, as is any new edition of that bible, whereas a reprint of exactly the same manuscript would not count as a title as such.

[2] Van Zanden (2004) has found a high correlation of book production with other proxies of human capital, such as skill premium, or literacy as defined in the traditional way.

[3] See also Boucekkine, de la Croix and Peeters (2007b), and Boucekkine, de la Croix and Licandro (2003) on the human capital effects on longevity.

[4] On student attendance at the medical school of Montpellier, see Chartier, Compère and Julia (1976)

[5] Most sources also contain information on the publisher and the place where the book is published, which in theory makes it possible to disaggregate the data to the city level or to the level of the individual producer/publisher.

[6] One factor behind the rapid growth was the strong decline in book prices occurring after the invention of movable type printing; in the Netherlands, for example, book prices declined by as much as 90% (compared with the consumer price index) between the 1470s and the late 18th century (Van Zanden 2004); Clark found a similar decline for England (Clark 2007).

[7] Although our results also indicate that after a strong growth during the 16th and 17th centuries, book consumption in England stagnated at a relatively high level during the 18th century; see also St. Clair (2004: 84-100) for an analysis of the slow growth of book production in this period.

[8] Moreover, for Holland the literacy of those born in or migrated to Amsterdam is available. In contrast, for most other countries the evidence is very weak and was often estimated taking the share of urban population as a proxy (the literacy of the urban and rural population of Venice was assumed to be similar in other parts of Europe, see Allen 2003).

[9] See also Allen 2003, who tried to test for this link, but did not find such a relationship between literacy and real wages, because – in our view – the estimates of literacy did not capture the growth of human capital in the different countries and periods, see footnote above.

[10] Other welfare indicators such as life expectancies and anthropometric indices confirm the real wage indicator, see Koepke and Baten 2005.

[11] We thank an anonymous referee for this hint. Without conditioning, the standard deviation would even be larger, hence the economic significance would look larger.

[12] The inclusion of the plague variable does not change the results.

[13] There are 12 values above zero of this variable included in the regression, and they stem from the four countries with major colonial Empires and other intercontinental trading activies, i.e. UK, NL, FR, ES. While it is true that the UK in 1800 had the maximum intercontinental trade among the included cases, this observation is not too distant from the Netherlands and other UK cases of the late 17th and 18th century. FR and ES had quite a bit lower values, but again those were not too remote from the Dutch cases. The strong asymmetry of this variable stems from the fact that so many cases were zero (42 of 54).

[14] We thank an anonymous referee for this comment on the plague as potential exogenous force. See also Herlihy (1997) for the literacy effects of the bubonic plague of the 14th century.

[15] Moreover, Kremer studies this question both theoretically and with time series data on the growth of world population, and finds that a larger population caused a stronger population growth.

[16] Sources: for the European countries and the US the same as for the other European countries: USA and Ireland the English Short Title Catalogue, Switzerland, Poland and Russia: the German book fairs in combination with the Hand-pressed book file (for Russia also Marker 1982); Indonesia: Isa 1972; Japan: Hayami and Kitô 1999: 241; China: Tsuen-Hsiun 1985: 190; India: Darnton 2002; see also the discussion of global patterns of book production in Van Zanden 2004. Because the 1820 estimates of GDP levels for the following test are relatively weak and subject to much debate – with the revisionists claiming that the gap between Europe and China was much smaller than estimated by Maddison (Pomeranz 2002) – we also compare absolute levels of GDP per capita in 1913, and the same book production data for the period of 1750-1800, and found our results confirmed.