Lineages of Scholars in pre-industrial Europe: Nepotism vs Intergenerational Human Capital Transmission

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Abstract

We propose a new methodology to disentangle two determinants of intergenerational persistence: inherited human capital vs. nepotism. This requires jointly addressing measurement error in human-capital proxies and the selection bias inherent to nepotism. We do so by exploiting standard multi-generation correlations together with distributional differences across generations in the same occupation. These two moments identify the structural parameters of a first-order Markov process of human-capital endowments' transmission, extended to account for nepotism. We apply our method to a newly built database of more than one thousand scholar lineages in higher education institutions over the period 1000-1800. Our results show that 15 percent of scholar's sons were nepotic scholars. Nepotism declined during the Scientific Revolution and the Enlightenment, was more prominent in Catholic than in Protestant institutions, and was higher in law than in sciences. Human-capital endowments were inherited with an intergenerational elasticity of 0.6, higher than suggested by parent-child elasticities in observed outcomes (publications), yet lower than recent estimates in the literature (0.75) which do not account for nepotism.

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JEL Codes: *C31, E24, J1*

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1 Introduction

To what extent are inequalities passed down from one generation to the next? While parent-child correlations in, e.g., earnings, wealth, or education are moderate,[1] recent studies show that, across multiple generations, these socio-economic outcomes are highly persistent.[2] This additional persistence has often been interpreted as evidence that children inherit a set of highly-persistent underlying endowments, which are later transformed into observed socio-outcomes with noise (Clark and Cummins 2015; Braun and Stuhler 2018).[3] Yet, the nature of these inherited endowments is a matter of strong debate. On the one hand, inherited endowments may be human capital, abilities, or genetic advantages. For example, Clark (2015) argues that the rate at which children inherit their parents' underlying endowments is constant across social systems and time. Hence, these endowments should reflect nature rather than nurture. On the other hand, several measures of intergenerational inequality are associated to the economic environment (Chetty et al. 2014; Güell et al. 2018). Specifically, in settings where nepotism is prevalent, i.e., where children may use their parents' connections to obtain jobs, we observe family dynasties in top professions.[4] This suggests that, together with human capital and abilities, parents also transmit their social networks and connections to their offspring, which can lead to nepotism.

Disentangling inherited human capital from nepotism is important both from a policy perspective and in terms of measuring the true rate of persistence of intergenerational inequality. The reason is that, from a statistical point of view, inherited human capital and nepotism are associated to different biases: While the former can lead to measurement error—human capital, abilities, or genetic advantages are only imperfectly reflected in socio-economic outcomes—nepotism leads to a selection problem. For example, nepotism can bias persistence estimates by generating barriers to certain occupations. Traditional persistence estimates that bundle human capital and nepotism do not address both biases jointly, and

[1]See Solon (1999), Corak (2006), and Black and Devereux (2011) for literature reviews

[2]Güell, Rodríguez Mora, and Telmer (2015), Clark (2015), Clark and Cummins (2015), Lindahl et al. (2015), Braun and Stuhler (2018).

[3]Alternatively, it has been suggested that grandparents can have independent effects on the outcomes of current generations (Zeng and Xie 2014; Lindahl et al. 2015; Adermon, Lindahl, and Waldenström 2018; Long and Ferrie 2018; Colagrossi, d'Hombres, and Schnepf 2019).

[4] Examples include doctors (Lentz and Laband 1989), lawyers (Laband and Lentz 1992; Raitano and Vona 2018), politicians (Dal Bó, Dal Bó, and Snyder 2009), inventors (Bell et al. 2018), CEOs (Pérez-González 2006; Bennedsen et al. 2007), pharmacists (Mocetti 2016), self-employed (Dunn and Holtz-Eakin 2000), liberal professions (Aina and Nicoletti 2018; Mocetti et al. 2018), and university professors (Durante, Labartino, and Perotti 2011).

hence, provide unreliable estimates of intergenerational persistence.

In this paper, we open the black box of the underlying endowments transmitted across generations. We propose a novel method to disentangle inherited human capital and abilities from nepotism. Our method exploits multi-generation correlations in observed outcomes and distributional differences between adjacent generations in the same occupation. These two sets of moments can be used to address measurement error and selection issues, and hence, to disentangle inherited human capital endowments from nepotism. Formally, these moments can identify the structural parameters of a first-order Markov process of human-capital endowments' transmission, where endowments are transformed into observed outcomes with measurement error, and the observed population is selected under nepotism. We then apply our method to a newly built dataset of scholar lineages in universities and scientific academies in pre-industrial Europe. Our results show that nepotism was prevalent: around 15 percent of sons of scholars were "nepotic" scholars. We also find that underlying human-capital endowments were transmitted with an intergenerational elasticity of 0.6. This estimate is higher than suggested by father-son correlations in observed outcomes (e.g., publications), and lower than estimates based on multi-generation correlations alone. Hence, failing to account for nepotism can overstate the true rate of persistence of underlying human-capital endowments.

Our first contribution is to propose a novel framework to disentangle human capital transmission from nepotism. We argue that standard two-generation correlations in socio-economic outcomes provide biased estimates of the transmission of underlying endowments both due to measurement error and selection, especially in settings where nepotism is prevalent. One branch of the literature ignores selection and addresses measurement error by using correlations across three or more generations (Braun and Stuhler 2018), group-averages for siblings (Braun and Stuhler 2018) or people sharing rare surnames (Clark and Cummins 2015), the informational content of surnames (Güell, Rodríguez Mora, and Telmer 2015), or horizontal kinship correlations (Collado, Ortuno-Ortin, and Stuhler 2018). Another branch of literature documents nepotism in top professions but does not aim to characterize the persistence of inherited endowments in the long run.[5] Hence, this literature ignores measurement error and addresses selection by exploiting natural experiments which altered the importance of connections to access jobs.

Instead, we jointly address measurement error and selection by using two sets of moments to characterize intergenerational persistence: one standard in the liter-

[5]See references in footnote 4.

ature, another new. The first are correlations in observed outcomes across multiple generations. As explained above, these correlations have been used to address measurement error. The idea is that, under the assumption that measurement error is constant across generations, multi-generation correlations reflect the transmission of (unobserved) underlying human capital endowments. The second set of moments are distributional differences in observed outcomes between fathers and sons in the same occupation. Specifically, we consider an occupation which is subject to selection and where the entry criterion may be different for sons of insiders than it was for their fathers.[6] We argue that, under the assumption that the distribution of human capital is stationarity over the entire population of potential candidates, nepotism lowers the selected sons' human capital relative to that of the selected fathers. This generates distributional differences in observed outcomes across generations, especially at the bottom of the distribution, i.e., closer to the selection thresholds. Such distributional differences, hence, can be used to identify nepotism.[7]

Our second contribution is to apply our proposed method to evaluate the determinants of intergenerational inequality in a top occupation: university scholars. University scholars provide an ideal test bed: they constitute a very well defined universe to which sons of scholars can access more easily due to nepotism. In addition, we can measure each scholar's scientific output by tracking their publication record. Publications provide us an outcome variable that is noisily correlated with inherited endowments, e.g., human capital, abilities, and innate skills.

We build a new dataset of ca. 1,103 lineages of scholars in 86 universities and 30 scientific academies in pre-industrial Europe. We do so by using university catalogues and secondary sources, such as books on the history of the university and compendia of university professors. We then match the names found with old biographical dictionaries, such as Michaud (1811), and with online encyclopedia such as the *Allgemeine Deutsche Biographie*, the *Treccani*, or the Dictionary of National Biography. Our database contains information on 969 fathers and 1,103 sons who were members of the same university or scientific academy between 1000 and 1800. We also observe 105 families with three or more generations or scholars. To measure each individual's scientific output, we collect information on the number of publications that are available in libraries today from WorldCat.

[6] That is, for the first generation in the family that became a scholar.

[7] In addition, we exploit the fact that an increase in nepotism (measurement error): increases (does not increase) the variance of the sons' outcomes relative to their fathers'; and increases (reduces) the information that father-son correlations convey about the human-capital transmission. See Section 5 for details.

We document two facts for lineages of scholars in pre-industrial Europe. First, a high elasticity of publications across generations: We estimate a 0.34 elasticity on the extensive margin, comparable, e.g., to the elasticity of wealth in pre-modern agricultural societies (Mulder et al. 2009). But lineages with at least three generations of scholars display larger elasticities than predicted by the iteration of the two-generation elasticity. This suggests that the underlying endowments determining publications, e.g., human capital, were strongly transmitted from parents to children—probably, at a higher rate than what father-son correlations reflect. Second, the publications' distribution of fathers first-order stochastically dominates that of sons. These distributional differences are larger below the median. This suggests that, compared to selected sons, selected fathers had higher endowments of human capital, abilities, skills etc. which then translated into a better publication record. This difference in endowments could be the result of nepotism. We use these two facts to estimate the structural parameters of our model, that is, the parameters of our underlying first-order Markov process (Clark and Cummins 2015; Braun and Stuhler 2018), extended to account for nepotism.

Our first result is that nepotism was quantitatively important in pre-industrial universities and scientific academies. Specifically, we estimate that the son of a scholar could become a scholar even if his underlying human capital endowment was 2.4 standard deviations lower than the average potential scholar, and 1.6 standard deviations lower than marginal outsider scholars. Overall, around 15 percent of scholars' sons were nepotic scholars according to our estimates. That is, they would not have become scholars under the same criterium that applied to outsiders. These estimates are quantitatively important: A counterfactual exercise suggests that removing nepotism would increase scientific output by almost 18 percent. We also document that nepotism was most prevalent among lineages in which the son was appointed during his father's lifetime.

Second, we find an intergenerational elasticity of underlying human-capital endowments of about 0.6. This value is higher than what father-son correlations in observed outcomes (publications) suggest. Yet, our estimate is in the lower range of persistence parameters estimated elsewhere via multi-generational correlations, group-averages, or the informational content of surnames. Moreover, we show that, in settings where nepotism and selection are prevalent, multi-generation estimates tend to overstate the rate of persistence. Specifically, when we omit selection and, especially, nepotism, our method delivers large intergenerational human-capital elasticities, close to the 0.7–0.8 range estimated by Clark (2015). Finally, our findings do not support the hypothesis that the rate of persistence is constant through different historical periods and across fields of study. In fact, the transmission of human capital endowments and nepotism follows an inverse relationship over time, suggesting that institutional factors can affect the degree of persistence. More specifically, lineages of scholars became more meritocratic around 1800.

Relative to the existing literature, we make the following contributions. First, we show that accounting for nepotism is crucial to obtain reliable estimates of intergenerational persistence. Previous literature has argued that father-son correlations in observed outcomes can under-predict the rate of persistence due to measurement error, and has proposed various methods to correct for this attenuation bias based on multi-generation correlations (see references above). We argue that, by ignoring selection, these methods may overstate the rate of persistence of underlying endowments like human capital, abilities, or genetic advantages.

Second, our proposed method circumvents some of the data requirements that have limited the study of intergenerational persistence. Previous methods require census-like data with links across multiple-generations (Lindahl et al. 2015; Braun and Stuhler 2018; Colagrossi, d'Hombres, and Schnepf 2019), horizontal kinship relations (Collado, Ortuno-Ortin, and Stuhler 2018) or the entire distribution of surnames (Güell, Rodríguez Mora, and Telmer 2015). Such comprehensive census may be difficult to obtain, particularly in historical settings. In contrast, since our approach addresses selection issues, we only require observing a well-defined universe, for example, a top occupation. Others circumvent the need for census data by using the share of rare-surnames in top occupations (Clark and Cummins 2015) or universities (Clark and Cummins 2014) in repeated cross-sections. Finally, relative to the literature examining the concentration of certain families in top occupations, our approach allows us to estimate nepotism across time and space, beyond the specific instances in which a natural experiment is available.

Third, our empirical application sheds new light to a growing literature that highlights the importance of upper-tail human capital for economic growth. Specifically, this literature argues that upper-tail human capital—such as the knowledge produced at universities—was an important factor in explaining the Commercial Revolution (Cantoni and Yuchtman 2014) and the Industrial Revolution (Mokyr et al. 2002; Mokyr 2016; Squicciarini and Voigtländer 2015). We contribute to this literature by identifying two important aspects affecting the production of scientific knowledge: the transmission of human capital across generations and nepotism. Our results suggest that periods of advancement in sciences, like the Scientific Revolution or the Enlightenment, were associated with lower degrees of nepotism in universities and scientific academies. This finding supports the hypothesis by

Greif (2006) and de la Croix, Doepke, and Mokyr (2018), that the dissemination of new productive knowledge in pre-industrial European corporations relied little on the transmission of knowledge within families. We also find that nepotism was negligible in protestant universities and scientific academies. In contrast, catholic institutions seem to have relied more on the transmission of knowledge within families of scholars. These factors, hence, can partly explain the divergent path of catholic and protestant universities after the Reformation (Merton 1938).

The article proceeds as follows: Section 2 discusses different methods used to measure intergenerational persistence and points to two potential biases: measurement error and selection. Section 3 presents the data and two stylized facts about scholar's lineages. The model, identification, and main results are in Sections 4 and 5. Section 6 shows extensions to our analysis and Section 7 concludes.

2 Literature and methods review

To study the extent to which inequalities are transmitted across generations, economists typically estimate coefficient b in:

$$y_{i,t+1} = b\, y_{i,t} + e_{i,t+1} \ , \tag{1}$$

where i indexes families, t parents, and $t+1$ children. The outcome y is a measure of social status (e.g., income, wealth, education, occupation) and is in logarithms. The coefficient b, hence, is the intergenerational elasticity of outcome y. It determines the speed at which the outcome reverts to the mean. To see this, note that the half-life of y, i.e., the number of generations until the gap with the mean halves, is:

$$t_{\frac{1}{2}} = -\frac{\ln(2)}{\ln(|b|)} \ ,$$

which depends negatively on b.

Table 1, Panel A summarizes estimates of b in the literature.[8] These suggest that social status is not very persistent in general, but more persistent in the United States than in Europe. In detail, an intergenerational elasticity, e.g., $b = 0.5$ (US earnings, Corak (2006)) implies a half-life of $t_{\frac{1}{2}} = 1$. Hence, half the gap with the mean is expected to be filled after a generation and 3/4 of the gap after two generations. In other words, the reported estimates imply that social status will revert to the mean after two to three generations.

[8] For a more thorough review, see Solon (1999), (Corak 2006), and Black and Devereux (2011).

Table 1: Persistence of social status in the literature.

Panel A: Estimates of b		
$\hat{b}$	y_t	Country & Source
0.31–0.41	Wealth	Agricultural societies (Mulder et al. 2009)
0.48–0.59	Wealth	UK (Harbury and Hitchins 1979)
0.6	Earnings	USA (Mazumder 2005)
0.34	Earnings	USA (Chetty et al. 2014)†
0.47	Earnings	USA (Corak 2006)
0.19–0.26	Earnings	Sweden (Jantti et al. 2006)
0.11–0.16	Earnings	Norway (Jantti et al. 2006)
0.46	Education	USA (Hertz et al. 2007)
0.71	Education	UK (Hertz et al. 2007)
0.35	Education	Sweden (Lindahl et al. 2015)
0.35	Body Mass Index	USA (Classen 2010)

Panel B: Estimates of β		
$\hat{\beta}$	y_t	Data & Source
0.70–0.75	Wealth	UK probate records (1858–2012) (Clark and Cummins 2015)
0.70–0.90	Oxbridge attend.	UK (1170–2012) (Clark and Cummins 2014)
0.61–0.65	Occupation status	Germany, 3 generations (Braun and Stuhler 2018)
0.49–0.70	Educ. attainment	Germany, 4 generations (Braun and Stuhler 2018)
0.6	Educ. attainment	2001 census, Catalonia (Spain) (Güell, Rodríguez Mora, and Telmer 2015)
0.61	Schooling	Sweden, 4 generations (Lindahl et al. 2015)
0.49	Earnings	Sweden, 4 generations (Lindahl et al. 2015)
0.74	Educ. attainment	EU-28, 3 generations (Colagrossi, d'Hombres, and Schnepf 2019)
0.8	Educ. attainment	2001 census, Cantabria (Spain) (Collado, Ortuno-Ortin, and Stuhler 2018)

† Chetty et al. (2014) estimate rank-rank correlations instead of elasticities based on equation (1).

However, recent studies looking at correlations across multiple generations and across kinship groups suggests that, in the long-run, social status is more persistent that what parent-child correlations suggest. Next, we review this literature and discuss two possible explanations for this divergence: one is based on measurement error, another is based on selection.

2.1 Measurement error

The true rate of persistence may be higher than what parent-child correlations suggest because there is a highly-persistent inherited endowment that wealth, income, occupation, education, or even body mass index only reflect with a noise. Specifically, children do not inherit their social status directly from their parents. Instead, children inherit an unobserved endowment h (e.g., skills, genes, preferences...) which then translates into the observed outcome y imperfectly. Formally:

$$h_{i,t+1} = \beta h_{i,t} + u_{i,t+1} , \quad (2)$$

$$y_{i,t+1} = h_{i,t+1} + \varepsilon_{i,t+1} , \quad (3)$$

where $h_{i,t} \sim N(\mu_h, \sigma_h^2)$ and $u_{i,t+1}$ and $\varepsilon_{i,t+1}$ are independent noise terms. The coefficient β in Equation (2) captures the extent to which the parents' endowment h is inherited by their children. In this sense, β is the parameter governing the true rate of persistence of social status across generations. In contrast, Equation (3) determines how well this endowment is reflected in the observed outcome y. A larger variance in the noise term, σ_ε^2, is associated with a lower observability of the endowment h.

According to this model, the intergenerational elasticity of outcome y estimated from equation (1) will be:

$$E(\hat{b}) = \beta \, \frac{\sigma_h^2}{\sigma_h^2 + \sigma_\varepsilon^2} := \beta \; \theta,$$

where $\theta < 1$ is an attenuation bias for β.

Several methods have been used to identify the true rate of persistence, β. One possibility is to exploit correlations in y across multiple generations.[9] The model above implies that the elasticity of outcome y is $\beta\theta$ between parents, t, and children, $t + 1$, and $\beta^2\theta$ between parents, t, and grandchildren, $t + 2$ (as long as the signal-to-noise ratio is stable across generations). Hence, the ratio of these

[9]Lindahl et al. (2015), Braun and Stuhler (2018), Colagrossi, d'Hombres, and Schnepf (2019).

elasticities identifies β. Intuitively, β is identified because, between parents and grandchildren, the underlying endowment h is inherited three times but only twice transformed into the observed outcome y with a noise. Another identification strategy for β is to estimate intergenerational regressions of equation 1's form with group-average data for siblings (Braun and Stuhler 2018) or for people with the same rare surname (Clark and Cummins 2015). The idea is that, by grouping individuals with a similar underlying endowment, the noise term ε is averaged away. Güell, Rodríguez Mora, and Telmer (2015) propose an alternative method to identify β through the informational content of rare surnames (ICS)—a moment capturing how much individual surnames explain the total variance of individual outcomes.[10] Importantly, this method only requires cross-sectional data; i.e., it does not require to link data across generations. Similarly, Collado, Ortuno-Ortin, and Stuhler (2018) estimate β using horizontal kinship correlations in the cross-section.

Table 1, Panel B reports estimates of β from these different approaches. The estimates range between 0.49 and 0.90, and hence, are substantially larger than the parent-child correlations b. In other words, the endowment determining social status that children inherit from their parents is much more persistent than what parent-child correlations in social status suggest. Furthermore, Clark (2015)'s comprehensive evidence suggests that β is close to a "universal constant" across societies and historical periods. This finding is disputed by studies using the ICS (Güell et al. 2018) or multi-generation links (Lindahl et al. 2015; Braun and Stuhler 2018; Colagrossi, d'Hombres, and Schnepf 2019) instead of surname-average evidence.

In light of this evidence, the unobserved endowment that children inherit from their parents has often been interpreted as skills, preferences, or even genes. First, because these endowments reflect well the measurement error problem described here: wealth, income, education, etc. only reflect skills and innate abilities with a noise. Second, because if β is a universal constant, it should reflect nature rather than nurture. In other words, if β does not vary substantially across time and space, an obvious conclusion is that institutions, social policies, or processes of structural economic transformation cannot affect social mobility in the long run.

We argue that, together with endowments like skills, preferences, or genes, parents also transmit their offspring their social connections. This can lead to

[10]The ICS is the difference in the R^2 of two regressions: one in which y is regressed on a vector of dummies indicating surnames, another in which this vector indicates "fake" surnames. Güell, Rodríguez Mora, and Telmer (2015) use this moment, together with other moments of the surname distribution, to structurally estimate the true rate of persistence in social status.

nepotism, that is, the practice among those with power and influence of favoring relatives. For example, estimates of occupational persistence may be affected by the fact that certain jobs have higher entry barriers for outsiders than for sons of selected individuals. Econometrically, this introduces a very different source of bias that has been ignored in the literature: selection.

2.2 Selection

Beyond measurement error, parent-child correlations in outcomes may be subject to another source of bias: selection. Specifically, whether observations are sampled or not may depend on the unobserved endowment h, which, as explained above, is inherited by children and then translates into the observed outcome y imperfectly. This additional source of bias is usually disregarded when estimating the persistence of social status across generations, even though selection is inherent to many of the data sources used.

In detail, selection issues are prevalent in empirical applications that focus on a specific subgroup of the whole population. For example, estimates on the intergenerational elasticity of wealth typically rely on wills and probate records data (Clark and Cummins 2015). Only individuals leaving wealth above a minimum legal requirement were probated, a selection criterium that is likely to depend on an individual's underlying endowment inherited from his parents (e.g., social competence, skills, genes, etc.). Similarly, several studies evaluate social mobility by focusing on top professions.[11] In these samples, selection often takes the form of nepotism: the practice among those in a top profession of favoring relatives, especially by giving them jobs. Selection may also arise in empirical applications covering intergenerational links across the whole population (Lindahl et al. 2015; Braun and Stuhler 2018). For example, in census data families are not observed if a generation migrates or dies before outcomes are realized (e.g., occupational choice, wage). This attrition is likely correlated with the underlying endowment h. The selection bias is more acute for historical data and for studies covering long time-spans. Historically, lineages in the same profession (e.g., university professors or artists) are easier to track than lineages in which each generation makes a dif-

[11] Examples of occupational-persistence studies in top professions include: doctors (Lentz and Laband 1989), lawyers (Laband and Lentz 1992; Raitano and Vona 2018), politicians (Dal Bó, Dal Bó, and Snyder 2009; Gagliarducci and Manacorda 2016), inventors (Bell et al. 2018), CEOs (Pérez-González 2006; Bennedsen et al. 2007), pharmacists (Mocetti 2016), self-employed (Dunn and Holtz-Eakin 2000), managerial and professional jobs (Marcenaro-Gutierrez, Micklewright, and Vignoles 2014), liberal professions (Aina and Nicoletti 2018; Mocetti et al. 2018), and university professors (Durante, Labartino, and Perotti 2011).

ferent occupational choice. Finally, life-history data collected retrospectively may suffer from recall bias. This bias may depend on h, in the sense that families with large endowments (e.g., families at the top of the distribution) may have better knowledge of their ancestors.

Next, we discuss how this selection bias may affect intergenerational elasticity estimates. Let s be a selection indicator such that $s_i = 1$ if family i is used in the estimation, and $s_i = 0$ if it is not. The intergenerational elasticity of outcome y estimated from equation (1) is:

$$E(\hat{b}) = b + \frac{\text{Cov}\,(s_i y_{i,t},\ s_i e_{i,t+1})}{\text{Var}\,(s_i y_{i,t})}$$

If the condition $\text{Cov}\,(s_i y_{i,t},\ s_i e_{i,t+1}) = 0$ is satisfied, then $\hat{b}$ is an unbiased estimate of b and a biased estimate of β due to measurement error, i.e., $\hat{b} = \theta\beta$. However, if the selection indicator s_i depends on the underlying endowment transmitted across generations, $h_{i,t}$ and $h_{i,t+1}$, then the condition above is violated and $\hat{b}$ is a biased estimate of b.

These two biases can have very different implications. As described above, measurement error can be corrected using multi-generational correlations. The reason is that, across n generations, the underlying endowment is inherited n times at a rate β but only twice transformed into the observed outcome y with measurement error. This is not necessarily true for the selection bias: Across n generations the selection bias also depends on the h inherited by n generations. For example, consider parent-grandchild (and parent-child) correlations in outcomes: The correlations depend on β—which is inherited three (two) times, on the measurement error with which h is twice (twice) transformed into y, and on the selection bias—which also depends on each of the three (two) generation's endowment h. Hence, the ratio of parent-grandson to parent-son correlations in outcomes does not correct for selection.

Moreover, if selection criterium change over time—for example, due to changes in the prevalence of nepotism—the selection bias may be different across two and three generations. In other words, the ratio of parent-grandchild to parent-child correlations may provide upward or downward biased estimates of β, the rate at which the underlying factor is inherited across generations.[12] Finally, even if the multi-generations ratio estimate for β is unbiased, this method (and other comparable methods) bundle together the measurement error bias and the selection

[12] Formally, if $\frac{\text{Cov}(s_i y_{i,t},\ s_i e_{i,t+2})}{\text{Cov}(s_i y_{i,t},\ s_i e_{i,t+1})} > 1$, then the multi-generation ratio provides upward biased estimates of β.

bias in correlations in outcomes. These two biases have very different implications: while measurement error is associated to how well outcomes reflect underlying inherited factors, selection in the form of nepotism can shed light on an important institutional barrier to social mobility. Hence, from an economic perspective it is important to disentangle these two biases.

3 Data

We build a novel database of more than one thousand lineages of scholars in pre-industrial Europe. Our database contains information on fathers and sons who were members of the university or scientific academy. We cover 86 universities and 30 scientific academies before 1800. We also observe about one hundred families with three or more generations or scholars. To measure each individual's scientific output, we collect information on the number of publications that are available in libraries today. We also collect information on birth and death year, the date at which an individual was nominated to the university or the scientific academy, and his field of study (lawyers, physicians, theologians, and scientists). Finally, we have information at the institution level: for each university and scientific academy, we know from Frijhoff (1996) the foundation date and its religious affiliation after the Protestant reformation.

Next, we describe the original sources used to construct this dataset and its coverage. We then present qualitative evidence and three stylized facts on the importance of nepotism vs. the transmission of human capital, abilities, and innate skills across generations.

3.1 Original sources and coverage

We build our dataset by combining two sources of information. First, we use secondary sources on individual academies and universities. These include catalogues of members, books with members' biographies and bibliographies, and books on the history of each institution. Second, we use biographical dictionaries and encyclopedia on the subject of universities and in the regions where universities and scientific academies were located. From these different sources, we code fathers and sons who were members of the same institution.

Table 2 reports the ten institutions with the largest number of lineages. The first is the university of Bologna. Mazzetti (1847) provides a comprehensive list of professors at Bologna since the university's foundation and a brief biographical sketch. In some cases, we reconstruct family relations from the Italian encyclopedia Treccani. The second largest institution is the Royal Society. This academy has an online list of members, but provides no information on family links. We identify family links from various British biographical dictionaries, especially, from the Dictionary of National Biography. For other institution, there is neither a catalogue of members or a reference detailing the history of its different faculties. This is the case for the university of Avignon, which became important in the Middle Ages thanks to the presence of the papacy in the city.[13] In such cases, we can combine various sources to reconstitute a sample of professors: Laval (1889) for the medical faculty, Fournier (1892) and Teule (1887) for lawyers, and Duhamel (1895) for rectors. These individuals can be matched with their entries in the biographical dictionary of the Department of Vaucluse (now in France), Barjavel (1841). Next comes the university of Tübingen. In his thesis, Conrad (1960) provides a list of chair holders since the foundation of the university.[14] We established family links among Tubingen professors using the *Allgemeine Deutsche Biographie*. Specifically, we checked manually if professors with similar names were related. The fifth institution is the Leopoldina, Germany's National Academy of Sciences. A list of members is available from the academy's website. Family links were retrieved from the *Allgemeine Deutsche Biographie* and from other encyclopedia. Appendix A details the institutions covered and the primary sources used for the remaining universities and scientific academies.[15]

We complement the list of fathers and sons who were scholars with additional information on their birth, nomination, and death year and their field of study. This is sometimes provided by the catalogues of professors and members of scientific academies. In many cases, however, we rely on other biographical sources. Overall, we find the birth year for 76.9% of the observations, the death year for 87.7%, the nomination date for 92.2%, and the field of study for all scholars. This additional information allows us to examine several questions: for example, did sons succeed to their fathers' chairs upon their death or were they nominated during their father's tenure? These two situations correspond to different forms of nepotism. In addition, the field of study allows us to test whether nepotism was more prevalent in certain fields. Specifically, we consider four fields: lawyers,

[13] Alice Fabre compiled Avignon's lawyers and rectors for (de la Croix et al. 2019).

[14] The list was digitalized by Robert Stelter for (de la Croix et al. 2019).

[15] In 30 institutions, we observe only one family of scholars. These families were typically mentioned in sources used to reconstruct families in other institutions. That said, these families represent only 2.7 percent of our sample and their exclusion does not affect the moments used in our estimations (the descriptives are available upon request).

Table 2: Institutions with the Largest Number of Lineages.

Institution (dates)	Nb. lineages	Main Sources	Main biograph. dictionary
Univ. of Bologna (1088–)	157	Mazzetti (1847)	Treccani
Royal Society (1660–)	71	`www.royalsociety.org/`	DNB
Univ. of Avignon (1303–1793)	58	Laval (1889), Fournier (1892) Teule (1887), Duhamel (1895)	Barjavel (1841)
Univ. of Tübingen (1476–)	42	Conrad (1960)	ADB
Leopoldina (1652–)	37	`www.leopoldina.org/`	ADB
Univ. of Basel (1460–)	34	Herzog (1780)	Michaud (1811)
Univ. of Padova (1222–)	32	Facciolati (1757)	Treccani
Univ. of Montpellier (1289–1793)	30	Dulieu (1975, 1979, 1983)	Clerc (2006)
Univ. of Jena (1558–)	27	Günther (1858)	ADB
Univ. of Pavia (1361–)	27	Raggi (1879)	Treccani

ADB: Allgemeine Deutsche Biographie.
DNB: Dictionary of National Biography.
Treccani: Enciclopedia italiana.

physicians, theologians, and scientists. These categories correspond to the three higher faculties into which early universities were organized, in addition to the art faculty in which the scientists gained importance progressively.

In addition, we collect information on the scientific output of scholars. To do so, we link each scholar to his entry in the WorldCat service—an online catalogue of the library holdings of more than 10,000 libraries worldwide. Our measure of a scholar's scientific output is the total number of library holdings of his publications. For each scholar, this measure includes all copies of books, volumes, issues, or documents written by himself that are available in WorldCat libraries today. It also includes publications about his work, even if they are written by a different author. Hence, our measure captures both the size and the relevance of a scholar's scientific production today. Appendix B shows that the moments used in the estimation are robust to an alternative measure of scientific output: the number of unique works by and about a scholar. Levels are different, but the properties of the distribution of unique works are very similar to those of library holdings.

We do not find WorldCat entries for 37.5% of sons and 30.3% of fathers in our dataset. This does not mean that these scholars did not publish any work, but that no copies are held in WorldCat libraries. To address this, throughout the paper we separate the intensive margin, i.e., the number of publications conditional on being listed in WorldCat, from the extensive margin, i.e., whether a scholar is listed in WorldCat.

Figure 1 illustrates our data collection through an example: Honoré Bicais and his son Michel, both professors at the university of Aix (Provence, France). The university of Aix does not have a historical catalogue of their professors. Instead, we identify scholar families in Aix from de la Croix and Fabre (2019), who used books on the history of the university to compile a list of their professors. Specifically, Honoré Bicais is listed as a professor in *Histoire de l'Ancienne Universite de Provence*, by Belin (1905). His entry states that his son, Michel, also became professor at Aix in the field of medicine. Since this entry does not provide information on birth and death years, de la Croix and Fabre (2019) use Honore Bicais' entry in a biographical dictionary of people in the department where Aix is located (*Les Bouches-du-Rhône, Encyclopédie Départementale* by Masson (1931)). Honoré's biography also mentions his son Michel, who succeeded him "in his chair and in his reputation." Finally, we link Honoré and Michel Bicais to their entries in the WorldCat service. Importantly, WorldCat considers different spellings of the family name: Bicais, Bicaise, and Bicays, as well as the latinized versions Bicaisius and Bicaissius. This facilitates the matching of scholars to their WorldCat entries. In terms of publications, Honoré Bicais was a prolific scholar: there are 267 library holdings on his work. These are all copies of books originally published by Honoré himself. In contrast, there are only 4 library holdings of his son Michel's work available in worldwide libraries today. In other words, while Michel succeeded his father in his chair, it is less clear that he did so too in his academic reputation.

Overall, we collect information on 1,103 father-son and 135 grandfather-father-son lineages in 86 universities and 30 scientific academies. Figure 2 shows the geographical distribution of the covered institutions (green circles). We cover most of north-west and central Europe. For example, we cover 23 universities (and 5 academies) in the Holy Roman Empire (HRE), 20 (and 10) in France, 6 (and 4) in England and Scotland, and 6 universities in the Netherlands. For southern Europe, the data mostly comes from 12 universities and 8 scientific academies in Italy. We also cover a few universities in eastern (e.g., Moscow) and northern Europe (e.g., Copenhagen, Lund, Turku, and Uppsala). Universities had, on average, 10 families of scholars. Figure 2 also displays the birth places of scholars (orange for fathers, red for sons). As with universities, most scholars in our dataset originate from north-west and central Europe and from Italy. In Southern Europe, many scholars were ordained priest who, officially, could not have children.

Figure 1: Example of data collection.

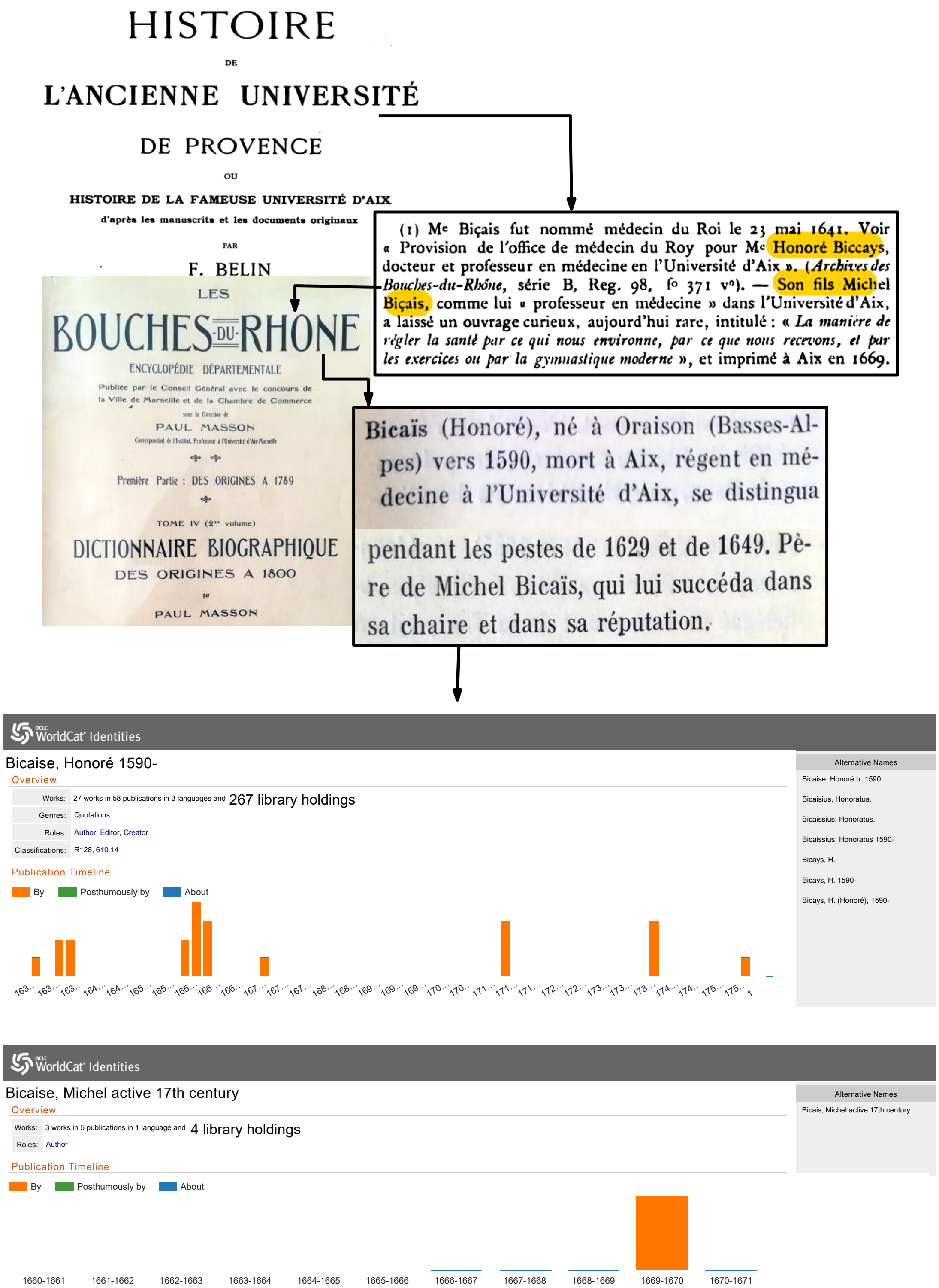


Figure 2: Geographical distribution of scholars' lineages

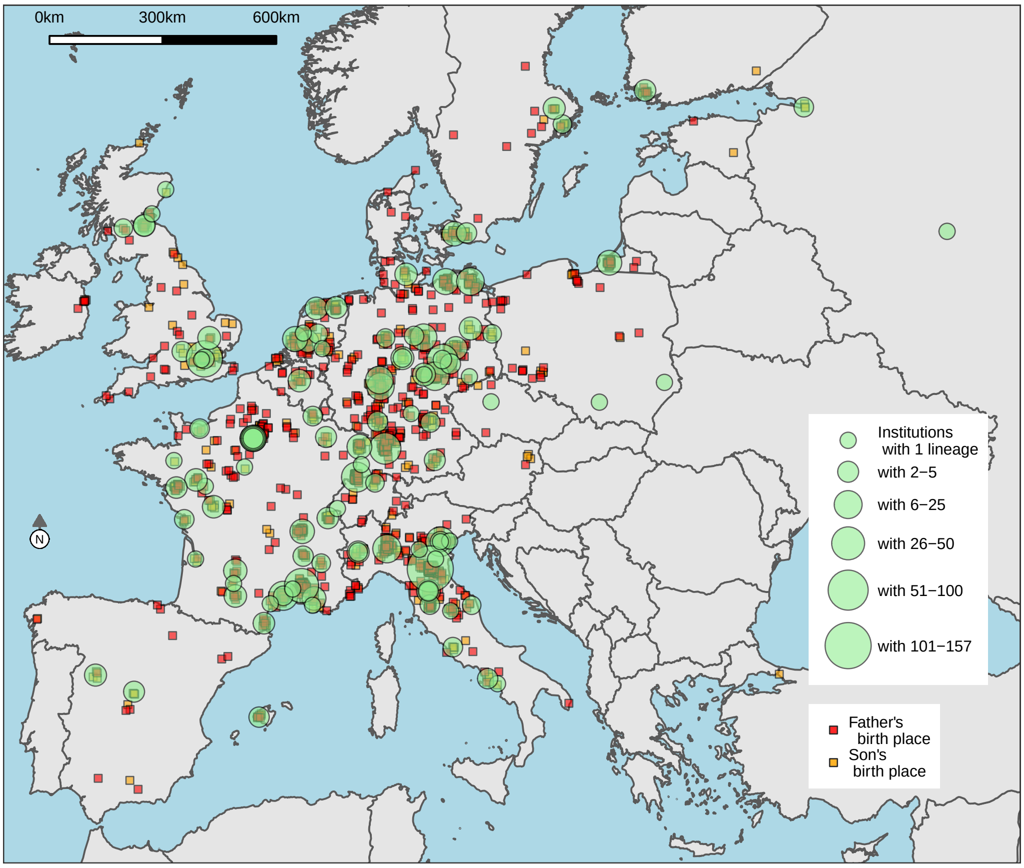
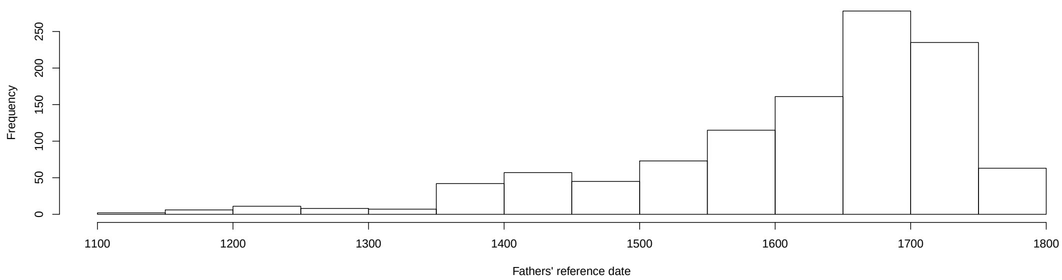
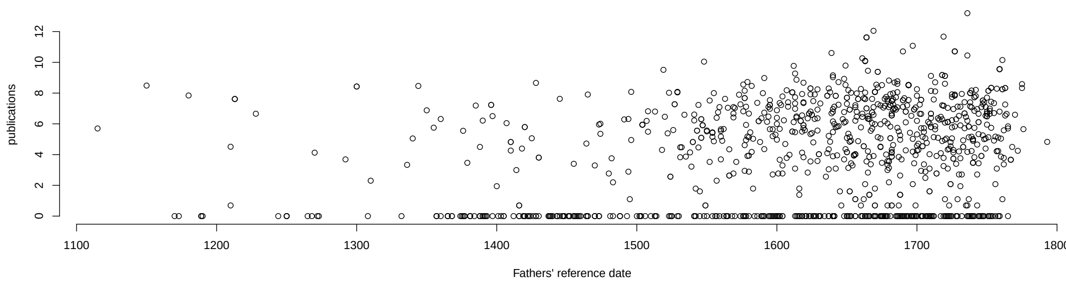


Figure 3: Number of families of scholars overtime and their publications





Notes: Fathers' reference date is based on information on his birth year, his nomination year, or his approximative activity year.

The dataset covers 800 years from 1088—the year of the foundation of the University of Bologna—to 1800. More than half of the universities in the dataset were established before 1500. For example, the University of Paris (officially established in 1200, but starting before), Oxford (1200), Cambridge (1209), and Salamanca (1218). In the HRE, the oldest university is Prague (1348). That said, most of the scholars under analysis are from after the 1400s. Figure 3 plots the number of scholar lineages overtime.[16] Before 1400, we only observe around 50 families of scholars. The number of families increases afterwards and peaks during the Scientific Revolution of the 16th and 17th centuries. The Figure also plots the number of recorded publications of scholars overtime. Specifically, we consider the logarithm of one plus the total number of publications by and about fathers (the figure is similar for sons). The number of observed publications increases after the invention of the printing press around 1450. That said, for periods in which we have similar numbers of families, there does not seem to be a clear upward trend in publications. To illustrate this, we have regressed the number of publications (conditional on being positive) on a constant and a time trend. The coefficient on the time trend is not statistically different from zero.

3.2 Evidence on nepotism and human capital transmission

Anecdotal evidence suggests that both nepotism and the human capital transmitted from fathers to sons played a role for pre-industrial scholars' careers. For example, Jean Bauhin (1541–1613), professor in Basel, holds a remarkable publication record: there are 1,016 library holdings about his work. Michaud's *Biographie Universelle* emphasizes how Jean Bauhin's knowledge was inherited from his father, also a professor in Basel:

> Jean Bauhin (1541–1613) learned very early the ancient languages and humanities. His father, Jean Bauhin, was his first master in the study of medicine and of all the underlying sciences.

This contrasts the case of the Benavente family at the University of Salamanca. Juan Alfonso Benavente has 81 publications available in WorldCat libraries today. According to the *Diccionario Biográfico Español*, he used his power and influence to pass down his chair to his son Diego Alfonso:

> After sixty years of teaching canon law in Salamanca, Juan Alfonso Benavente (–1478) retired in 1463. He retained his chair and his

[16]Specifically, we plot the number of scholars families over a known reference date for the father.

> lectures were taught by substitutes, including his son Diego Alfonso Benavente (c. 1430–1512). Finally, on 1477, Benavente resigned to his chair on the condition that his son was firmly appointed to it.

Diego Alfonso Benavente proofed less productive than his father. He only has one publication, a compendium of his father's work.

Table 3 documents three stylized facts for lineages of scholars in pre-industrial Europe. These facts reflect the patterns outlined by the examples above: On the one hand, sons strongly inherited underlying endowments, e.g., human capital, from their fathers, which later reflected in their publication outcomes. On the other hand, nepotism was prevalent amongst pre-industrial scholars.

TABLE 3: Moments used in the estimation.

		value	s.e.	obs.
A. Intergenerational correlations				
Father-son, intensive m.	$\rho(y_t, y_{t+1} \mid_{y_t, y_{t+1}>0})$	0.340	0.044	601
Father-son with zero pubs.	$\Pr(y_t{=}0 \wedge y_{t+1}{=}0)$	0.228	0.013	1,103
Father-grandson, intensive m.	$\rho(y_t, y_{t+2} \mid_{y_t, y_{t+2}>0})$	0.292	0.128	54
B. Publications' distribution				
Fathers with zero pubs.	$\Pr(y_t{=}0)$	0.302	0.015	969
Sons with zero pubs.	$\Pr(y_{t+1}{=}0)$	0.375	0.015	1,103
Fathers median	$Q50(y_t)$	4.304	0.182	969
Sons median	$Q50(y_{t+1})$	3.045	0.263	1,103
Fathers 75th percentile	$Q75(y_t)$	6.707	0.107	969
Sons 75th percentile	$Q75(y_{t+1})$	5.940	0.114	1,103
Fathers 95th percentile	$Q95(y_t)$	8.576	0.098	969
Sons 95th percentile	$Q95(y_{t+1})$	7.879	0.077	1,103
Fathers mean	$E(y_t)$	3.932	0.103	969
Sons mean	$E(y_{t+1})$	3.177	0.092	1,103

Notes: The baseline sample are families in which the father and the son are scholars.

Fact 1: High elasticity of publications across generations. Table 3, Panel A presents father-son correlation in publications, measured as the logarithm of 1 + the number of library holdings. We distinguish correlations conditional on both father and son having at least one observed publication (intensive margin) from the proportion of lineages where father and son have zero publications (extensive margin). The correlation on the intensive margin is 0.340. This implies that an increase in one percent in a father's publications is associated to an increase in 0.340 percent in his son's publications. The elasticity of scholar's publications, hence, is comparable to the the elasticity of wealth in pre-modern agricultural societies (Mulder et al. 2009) and of educational attainment in modern Sweden (Lindahl et al. 2015). As for the extensive margin, in 23 percent of lineages both father and son have zero publications.

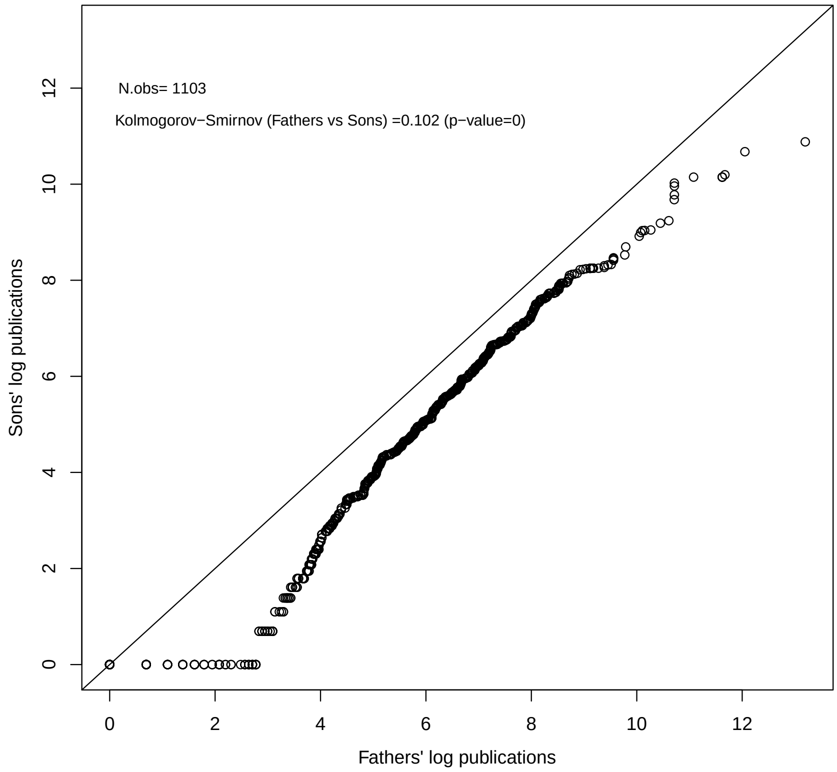
In sum, publication records were persistent across two generations. This suggests that endowments determining publications, e.g., human capital, were partly transmitted from parents to children. In addition, lineages with at least three generations of scholars display high correlations in publications on the intensive margin. Specifically, the correlation is 0.229. This number is larger than predicted by the iteration of the two-generation correlation, i.e., $0.34^2 = 0.116$. In other words, the persistence of the underlying endowments is probably higher than what father-son correlations reflect.

Fact 2: The publication's distribution of fathers first order stochastically dominates (FOSD) that of sons. In Panel B, we present ten moments describing the empirical distribution of publications for fathers and sons. As before, we use the logarithm of 1 + the number of library holdings. On the bottom end of the distribution of scholars, we find that 37 percent of sons had zero publications. The corresponding percentage for fathers is 30 percent. The average father has twice as many publications as the average son (50 vs. 25, in levels). We find similar differences in the 75th and the 95th percentile of the distribution. The difference between father's and sons is larger at the median: there, fathers published more than three times more than sons.

To illustrate these differences, Figure 4 presents a QQ-plot. Specifically, we plot the quantiles of the father's distribution against the quantiles of the son's distribution. If the two distributions were similar, the points would approximately lie on the 45 degree line. In contrast, we observe that, in all quantiles, fathers display larger publication records. In other words, the father's publication distribution FOSD that of their sons. A Kolmogorov-Smirnov test confirms that the two distributions are different. The QQ plot also suggests that the distributional differences are stronger at the bottom of the distribution.

In sum, fathers and sons present large distributional differences in observed publications. This suggests that, compared to sons, fathers had higher endowments of human capital, abilities, skills etc. which then translated into a better publication record. These different endowments could be the result of nepotism. Specifically, fathers may have used their power and influence in the profession to allocate jobs to their sons, even when the later had low endowments of, e.g., human capital.

FIGURE 4: Quantile-quantile plot



Notes: The sample are 1,103 families of scholars. Publications are the log of 1 + the number of publications by or about.

4 Theory

We extend a standard first order Markov process of endowments transmission across generations (Clark and Cummins 2015; Braun and Stuhler 2018) to account for nepotism. We consider a population of potential scholars heterogeneous with respect to their human capital. The human capital of each potential scholar depends on a human capital endowment inherited from his father and on random ability shocks.[17] Individuals with a high human capital are selected into being a scholar. We account for the possibility of nepotism by allowing this selection criterium to be softer for sons of scholars. Once an individual becomes a scholar, his unobserved human capital translates into an observed outcome, publications, with a noise.

[17]Our model focuses on father-son human capital transmission for two reasons. First, in our empirical application, most of the scholars are men. Second, while individuals inherit a human capital endowment from both their parents, nepotism only depends on the parent that is selected into the occupation of interest—in this case, father scholars. In addition, for a relatively high level of assortative matching, the father's and mother's human capital endowment will be correlated. Under this assumption, the potential bias emerging from focusing on fathers should be small.

Specifically, each potential scholar is indexed by $i \in \mathbb{I}$, their family, and by $\mathbf{t} = \{t, t+1, ...\}$, their generation. A potential scholar in generation t of family i is endowed with an unobserved human-capital level $h_{i,t}$. This is distributed according to a log-normal distribution with mean μ_h and standard deviation σ_h. Formally:

$$h_{i,t} \sim N(\mu_h, \sigma_h^2) \ . \tag{4}$$

The offspring of this generation, indexed $t+1$, partly inherit the unobserved human capital endowment. Specifically,

$$h_{i,t+1} = \beta h_{i,t} + u_{i,t+1} \ , \tag{5}$$

where β captures the inheritability of the endowment h. In other words, β is the intergenerational elasticity of human capital. The noise term $u_{i,t+1}$ represents an i.i.d. ability shock affecting generation $t+1$. This shock is distributed according to a normal distribution, $N(\mu_u, \sigma_u^2)$.

At each generation, only a selected group of potential scholars actually becomes a scholar. Specifically, only those with human capital above $\tau \in \mathbb{R}$ become scholars. We account for the possibility of nepotism by allowing sons of scholars to become scholars if their human capital is above $\tau - \nu$. If $\nu \geq 0$, then the selection process into becoming a scholar is subject to nepotism. Formally, the set $\mathbb{P}$ denotes lineages of observed scholars, i.e., families in which father and son become scholars:

$$\mathbb{P} = \{i \mid h_{i,t} > \tau, h_{i,t+1} > \tau - \nu\} \subset \mathbb{I} \ . \tag{6}$$

Scholars use their (unobservable) human capital to produce scientific knowledge in the form of publications. However, human capital translates imperfectly into observable publications. On the one hand, we consider idiosyncrasies in the publication process, shocks to an individual's health, luck, etc. that can affect a scholar's publications independently of his human capital. On the other hand, in our empirical application we need to account for the possibility that some publications might be lost or are not held in modern libraries anymore. That is, that we are more likely to observe the publications of a scholar with a larger record of publications. Specifically, the publications for fathers, $y_{i,t}$, and sons, $y_{i,t}$, in the set of scholar lineages $\mathbb{P}$ are:

$$y_{i,t} = \max(\kappa, h_{i,t} + \epsilon_{i,t}) \tag{7}$$

$$y_{i,t+1} = \max(\kappa, h_{i,t+1} + \epsilon_{i,t+1}) \tag{8}$$

where $\epsilon_{i,t}$, $\epsilon_{i,t+1} \sim N(0, \sigma_e^2)$ are mean-preserving shocks affecting how human capital translates into publications. Parameter κ is the minimum number of publications to observe a scholar's publications.

We assume that human capital among the population of potential scholars is stationary. That is, we assume that, conditional on the model's parameters being constant, the human capital of generations t and $t+1$ is drawn from the same distribution. Formally, $h_{i,t} \sim N(\mu_h, \sigma_h^2)$ and $h_{i,t+1} = \beta h_{i,t} + u_{i,t+1}$ implies $h_{i,t+1} \sim N(\beta\mu_h + \mu_u, \beta^2\sigma_h^2 + \sigma_u^2)$. Imposing stationary, hence, leads to the following two restrictions:

$$\mu_u = (1-\beta)\mu_h \tag{9}$$
$$\sigma_u^2 = (1-\beta^2)\sigma_h^2 \; . \tag{10}$$

Using these stationarity conditions, we can re-write equation 5 as:

$$h_{i,t+1} = \beta h_{i,t} + (1-\beta)\mu_h + \omega_{i,t+1} \; , \tag{11}$$

where $\omega_{i,t+1}$ is a shock distributed according to $N(0, (1-\beta)^2\sigma_h^2)$. In words, this equation suggests that the son of a *potential* scholar inherits a fraction β of his father's human capital, draws a fraction $(1-\beta)$ from the population mean, and is subject to a mean-preserving random shock ω. Hence, β determines the speed at which inherited human-capital advantages revert to the mean. Note, however, that this equation describes the mean-reversion process among *potential* scholars. In practice, the set of observed families is determined by equation (6). Hence, estimates of equation (11) need to address issues related to selection and nepotism. Estimation is further complicated by measurement error, i.e., the fact that h is not observable and is only imperfectly proxied by y (see equations (7) and (8)).

In sum, the model's main parameters are the intergenerational elasticity of human capital, β, and the degree of nepotism in the selection of scholars' sons, ν. In addition, the parameters σ_e and κ capture the extent to which the human capital endowment translates into the observed publications, and the parameters μ_u and σ_u capture random ability shocks affecting each generation's human capital. These four parameters determine, in combination, the measurement error problem described in Section 2.1. Finally, μ_h and σ_h shape the human capital distribution and τ the selection into being a scholar independent of nepotism. Next, we describe how we identify these parameters and present our main results.

5 Identification of parameters and main results

5.1 Identification

We estimate the model's parameters using a minimum distance estimation procedure. Specifically, we identify β, ν, σ_e, κ, μ_h, and σ_h by minimizing the distance between 13 simulated and empirical moments summarized in Table 3. The remaining parameters, μ_u and σ_u, are pinned down from the stationarity conditions (9) and (10). We assume $\tau = 0$ without loss of generality.

The empirical moments used in the estimation can be grouped into two categories: First, as it is standard in the literature, we consider three moments capturing correlations in observed outcomes across generations. Specifically, we consider the father-son correlation in publications conditional on both having at least one observed publication (intensive margin) and the proportion of families where father and son have zero publications (extensive margin). When observed, we also consider the father-grandson correlation in the intensive margin. Second, we depart from the previous literature and consider ten moments describing the empirical distribution of publications for fathers and sons. These moments are the mean, the median, the 75th and 95th percentiles, and the proportion of zeros in the publications' distribution.

Next, we describe how these moments identify the model's parameters. Father-son correlations provide biased estimates of β due to measurement error, governed by σ_e and κ, and due to selection in the form of nepotism, ν. We address both biases by comparing not only observed *outcomes* across generations, but also the corresponding *distributions*. These comparisons respond differently to measurement error and nepotism, and hence can be used to identify the model's parameters. In terms of observed *outcomes*, an increase in measurement error reduces the extent to which father-son correlations reflect β (see Section 2.1). The reason is that measurement error alters these correlations but not the underlying human capital endowments. In contrast, an increase in nepotism alters the human capital distributions for selected fathers and sons, and also the corresponding father-son correlations. Hence, these correlations may become more informative of β.

In terms of observed *distributions*, nepotism and measurement error also have different implications. If the distribution of the underlying endowment h is stationary, measurement error is not associated to differences in the distribution of the observed outcome y across generations. In contrast, larger levels of nepotism lower the selected sons' human capital relative to that of their fathers. This generates distributional differences across generations, as suggested by Figure 4. Intuitively, these differences are stronger at the bottom of the distribution, i.e., closer to the selection thresholds. Our estimation strategy, hence, will put additional weight to the proportion of father's and sons with zero publications. In addition, the variance of the distributions—captured by the 75th and 95th percentiles—also helps to disentangle measurement error from nepotism: An increase in measurement error increases the variance of both distributions, while an increase in nepotism increases the variance of the sons' distribution relatively more. In theory, this allows us to correct for measurement error without resort to father-grandson correlations—which, in many empirical applications, may be difficult to get. That said, in our empirical application measurement error is governed by two parameters, σ_e and κ. This additional moment, i.e., father-grandson correlations, helps to identify σ_e and κ separately.[18]

In sum, our identification strategy exploits the fact that an increase in the degree of nepotism (measurement error):

(i) generates (does not generate) distributional differences in observed outcomes across generations;

(ii) increases (does not increase) the variance of the sons' outcomes relative to their fathers';

(iii) increases (reduces) the information that father-son correlations convey about the human-capital transmission.

Hence, by comparing both outcomes and distributions across generations, we can disentangle measurement error from selection and identify our model's parameters. In Appendix C, we further illustrate our identification strategy with simulations.

5.2 Minimum distance estimation

Formally, we use the following minimum distance estimation procedure:

$$\min_p V(p) = \sum_j \lambda_j \left(\frac{\hat{m}_j(p) - m_j}{\sigma_{m_j}} \right)^2 \tag{12}$$

where j indexes each of the 13 moments described above, $p' = [\beta\nu \ \sigma_e \ \kappa \ \mu_h \ \sigma_h]$ is the vector of the parameters of the model, m is an empirical moment, $\hat{m}(p)$ is a simulated moment, σ_{m_j} is the standard deviation of empirical moment j, and λ_j is

[18] In other words, for datasets in which κ is not binding, the measurement error bias is governed by only one parameter, σ_e. In this case, one can identify it by comparing the variance of the observed outcome's distribution across generations, without resort to father-grandson correlations.

the weight of moment j. As explained above, we use the λ_j to attach higher weights to two moments which are most useful for identification: the proportion of fathers and sons with zero publications. We also attach additional weight to the standard moment used in this literature: the father-son correlation in publications (in the intensive margin). Specifically, λ_j is arbitrarily large for these three moments, and $\lambda_j = 1$ otherwise.

The above estimation problem belongs to the family of the Simulated Method of Moments (Gourieroux, Monfort, and Renault 1993; Smith 2008), a structural estimation technique to be applied when the theoretical moments cannot be computed explicitly and need to be simulated. To compute the vector of the simulated moments, we proceed as follows. We draw 50,000 families consisting of three generations: father, son, and grandson. Each generation's human capital endowment and publications are calculated as is described in Equations (4), (5), (7), and (8). We then compute our simulated moments from a sample of families in which fathers and sons meet the criterium to become scholars, i.e., equation (6). To calculate father-grandson correlations, we further restrict the simulated sample to families in which scholar's grandsons also meet the (nepotic) criterium to become scholars, i.e., $h_{t+1} > \tau - \nu$.

We then minimize the objective function $V(p)$ using the Differential Evolution algorithm (Price, Storn, and Lampinen 2006) as implemented in R by Mullen et al. (2011). To compute standard errors, we draw 100 random samples from the original data with replacement. For each bootstrap sample, we generate the 13 moments and estimate the corresponding parameters. We then use these bootstrapped estimates to compute the standard errors.

5.3 Results

Table 4 presents the identified parameters. The most important findings are our estimated values for ν (nepotism) and β (intergenerational elasticity of human capital). In sum, we find that nepotism was prevalent among university scholars in pre-industrial Europe. Our estimates suggest that the intergenerational elasticity of human capital among scholars lies around 0.6. This is higher than standard estimates based on father-son correlations, but lower than previous estimates in the literature that correct for measurement error. Next, we discuss the identified parameters in detail.

Nepotism. We find that nepotism was prevalent among university scholars in pre-industrial Europe. To interpret the magnitude of ν, remember that the son

TABLE 4: Identified parameters.

Parameter		value	s.e.
Intergenerational elasticity of human capital	β	0.581	0.049
Nepotism	ν	5.632	1.526
Std. deviation of shock to publications	σ_e	0.386	0.130
Threshold of observable publications	κ	2.201	0.188
Mean of human capital distribution	μ_h	2.444	0.490
Std. deviation of human capital distribution	σ_h	3.451	0.241

Note: τ normalized to 0. Standard errors obtained by estimating parameters on 100 bootstrapped samples with replacement. Degrees of overidentification: 6.

of a scholar becomes a scholar if his human capital is above $\tau - \nu = -5.632$. This number is substantially lower than the estimated mean human capital in the population of potential scholars, $\mu_h = 2.444$, and than the human capital an outsider requires to become a scholar, $\tau = 0$. To see this, note that we estimate a standard deviation of $\sigma_h = 3.451$ for the human capital of potential scholars. This implies that the son of a scholar could become a scholar himself even if his human capital was 2.4 standard deviations lower than the average potential scholar, and 1.6 standard deviations lower than the marginal outsider scholar.

Alternatively, we quantify the magnitude of nepotism through two counterfactual exercises. First, we simulate our model with the estimated parameters and remove nepotism by setting $\nu = 0$. Our simulations suggest that 15.04 percent of sons of scholars are nepotic scholars. That is, they would not have become scholars under the same selection criterium than outsiders. Second, we evaluate the impact of nepotism on scientific production. Specifically, we identify the nepotic scholars from the previous counterfactual exercise and replace them by an average potential scholar. We find that this would increase by 17.94 percent the scientific output of the average scholar in the simulated economy.

Human capital transmission. We estimate an intergenerational elasticity of human capital, β, equal to 0.581. This implies that, in lineages of scholars, sons inherited 58 percent of their father's human capital. Relative to the existing literature, this value is higher than the elasticities in wealth, earnings, or education estimated through parent-child correlations (see Table 1). This finding supports the hypothesis that the underlying endowments transmitted across generations (in this case, human capital) are more persistent than suggested by parent-child correlations in outcomes.

That said, our estimate of β implies a substantially lower persistence than estimates based on comparing average outcomes across surname groups, which cluster around 0.75 (Clark 2015). In addition, our estimate is near the bottom of the range of estimates using multiple-generation correlations (Braun and Stuhler 2018) and the informational content of surnames (Güell, Rodríguez Mora, and Telmer 2015). As explained in Section 2.1, these estimates are based on methods that address the measurement error bias in parent-child correlations but that ignore selection and nepotism. In other words, the divergence in estimates for β may stem from the selection bias inherent to nepotism (see Section 2.2).

To evaluate this possibility empirically, we use our data on pre-industrial European scholars to calculate intergenerational elasticity estimates based on two standard methods in the literature. Table 5 reports the results. First, we estimate a standard elasticity based on regressing sons' outcomes on their fathers' outcomes. Specifically, we estimate b from equation (1), where the outcome y is the logarithm of 1 + number of publications. The estimated coefficient is $\hat{b} = 0.513$, which implies that an increase in one percent in a father's publications is associated to an increase in 0.5 percent in his son's publications. That is, there is a strong persistence of publication attainment across two generations of scholars.[19] That said, this elasticity estimate is lower than our model's estimate for β. The discrepancy is more striking when we compare our model's estimate for β to elasticities in the intensive margin of publications, b_I. Altogether, this suggests that the measurement error and the selection bias inherent to father-son regressions leads to an attenuation bias. In other words, human capital, the endowment determining scholar's outcomes that children inherit from their parents, is more persistent than what parent-child correlations in publications suggest.

Next, we compare our estimates of β to those obtained using the multiple-generations method proposed by Braun and Stuhler (2018). Specifically, they argue that—in the absence of selection—the elasticity in outcomes across n generations is $\beta^n\ \theta$, where $\theta = \sigma_h^2 \ / \ (\sigma_h^2 + \sigma_\varepsilon^2)$ is the measurement error bias. Hence, the ratio between the father-grandson elasticity ($n = 2$) and father-son elasticity ($n = 1$) identifies β. We use our sample of c. 130 scholar lineages with three generations to estimate this ratio ($\hat{\beta}$). We also report estimates of $\hat{\beta}_A$, the ratio of the father-grandson elasticity ($n = 2$) to the average of father-son and grandfather-father elasticities ($n = 1$). These methods suggest that β ranges between 0.835 and

[19]For example, this estimate is comparable to the persistence of educational attainment across two generations in Germany (Braun and Stuhler 2018).

TABLE 5: Intergenerational elasticites under different methods.

method		value	s.e.	N	reference
Two-generations, all	$\hat{b}$	0.513	0.023	1,103	Equation (1)
Two-generations, intensive marg.	$\hat{b}_I$	0.342	0.036	601	Equation (1)
Multiple-generations	$\hat{\beta}$	0.835	0.118	135	Braun and Stuhler (2018)
Multiple-generations	$\hat{\beta}_A$	0.861	0.105	135	Braun and Stuhler (2018)
Model's β	β	0.581	0.049	1,103	-

Note: $\hat{\beta} = b_{G1-G3} \ / \ b_{G1-G2}$ and $\hat{\beta}_A = b_{G1-G3} \ / \ average\left(b_{G1-G2}, b_{G2-G3}\right)$, where $b_{G1-G2} = cov(y_{G1}, y_{G2}) \ / \ var(y_{G1})$ is the elasticity in publications between fathers (G1) and sons (G2); b_{G1-G3} the corresponding elasticity between fathers and grandsons (G3); and b_{G2-G3} the corresponding elasticity between sons and grandsons. Bootstrapped standard errors in parenthesis.

0.861, a substantially larger value than our model-based β. In fact, we obtain a similarly large $\beta = 0.857$ when we estimate our model setting $\tau = \nu = 0$, that is, when we assume there is no nepotism (see Table 6). Altogether, this suggests that in empirical applications where nepotism is prevalent, the multiple-generation estimates of β proposed by the literature can be upward biased.

Other parameters. We find that the stationary distribution of human capital in the population of potential scholars has a mean of $\mu_h = 2.444$ and a standard deviation of $\sigma_h = 3.451$. Since we normalized $\tau = 0$, this implies that the average potential scholar can become a scholar, but those with a human capital one standard deviation lower than the mean cannot become scholars unless their fathers are scholars. Using the stationarity conditions (9) and (10), we pin down $\mu_u = 1.024$ and $\sigma_u = 2.091$. These parameters are, respectively, the mean and the standard deviation of the random ability shocks that affect a potential scholar's human capital, independently of the endowments inherited from his father.

As for the production function of scientific output, we find an imperfect relation between human capital and publications. The shock affecting how the selected scholar's human capital translates into publications, ϵ, has a standard deviation of $\sigma_e = 0.386$. This number is lower that the standard deviation of the human capital distribution (σ_h) and of the random ability shocks (σ_u). That said, our estimates suggest that publications are a noisy proxy for human capital. The reason is that we estimate a relatively high $\kappa = 2.201$. This implies that the publication record of pre-industrial scholars who published only up to four ($\exp \kappa - 1$) "library holdings" is likely to be unobserved in our data. In other words, observing a zero publications outcome may reflect a scholar's low human capital level or the fact that some of his publications have been lost or are not held in modern libraries anymore.

5.4 Model fit

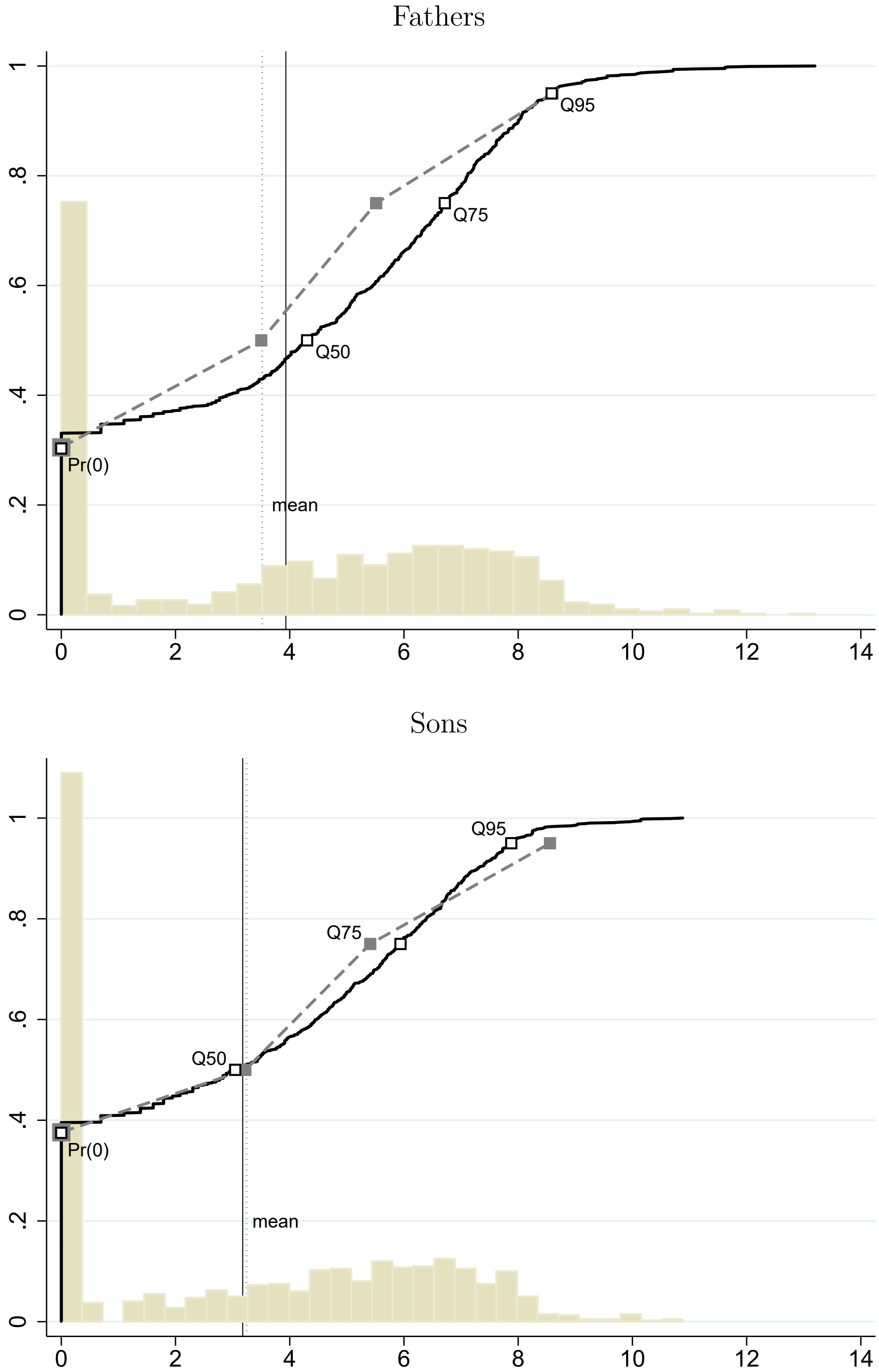
Next, we compare the empirical moments to those simulated by our model. We reproduce both the high elasticity of publications across generations of scholars (Fact 1) as well as the distributional differences between fathers and sons (Fact 2).

We begin by considering the ten moments capturing distributional differences between fathers and sons. Figure 5 shows the histogram for the logarithm of 1 + number of publications, the empirical cdf, and the simulated mean, median, 75th and 95th percentile, and the proportion of zeros. We fit the distribution of publications for fathers and sons in our sample of scholar's lineages: We perfectly match the proportion of fathers and sons with zero publications. These are the two moments to which our objective function attaches additional weight (see equation (12)). We also match the mean, median, 75th and 95th percentile for son. For fathers, we only underestimate the number of publications in the 50th and 75th percentiles.

Importantly, we reproduce the distributional differences between fathers and sons (Fact 2). The father's simulated distribution of publications first order stochastically dominates that of sons. We match the fact that fewer fathers have zero publications, that fathers on average published more than sons, and that the median fathers and fathers on the 75th percentile published more than the corresponding sons. Only at the 95th percentile we fail to predict large differences in publications across generations. Finally, we also reproduce the empirical observation that the gap between fathers and sons' publications is more prominent at the bottom of the distribution. Specifically, our simulated moments reflect larger father-son gaps in the proportion of zero publications, the mean, and the median than in the 75th and 95th percentile.

Nepotism is crucial to reproduce the distributional differences in publications across generations. To show this, we estimate two alternative models: one without selection and another with selection but no nepotism. Specifically, the first model sets τ to minus infinity. This is equivalent to assuming that we observe the full population of potential scholars. The second model introduces selection, $\tau = 0$, but omits nepotism by setting $\nu = \tau = 0$. Table 6 presents the estimated parameters and the corresponding simulated moments. Neither of these models reproduces the fact that the fathers' distribution of publications first order stochastically dominates that of sons. The simulated mean, median, 75th and 95

Figure 5: Publication's distribution, lineages of scholars



Notes: This figure displays the histogram and the cdf of father's and son's publications. Data (black), simulated moments (grey), and moments (labels).

percentiles, and the proportion of zero publications are identical for fathers and sons in both models.

Interestingly, these alternative models estimate a much larger β than our baseline model with nepotism. As explained above, this suggests that omitting nepotism can bias the estimate of β upwards. That it, it can overstate the extent to which endowments that children inherit from their parents persist over time.

TABLE 6: Simulated and empirical moments for different estimated models.

	Model w/o selection	Model w/o nepotism	Baseline model	Data
Parameters				
β	0.548	0.857	0.581	.
ν	0	0	5.632	.
τ	$-\infty$	0	0	.
σ_e	0.266	1.388	0.386	.
κ	3.603	3.664	2.201	.
μ_h	4.412	4.415	2.444	.
σ_h	2.293	1.873	3.451	.
Moments				
Fathers with zero pubs.	0.362	0.365	0.305	0.305
Sons with zero pubs.	0.364	0.365	0.376	0.375
Median, fathers	4.408	4.457	3.502	4.302
Median, sons	4.409	4.451	3.223	3.055
75th percentile, fathers	5.971	6.030	5.513	6.721
75th percentile, sons	5.952	6.020	5.409	5.930
95th percentile, fathers	8.216	8.313	8.600	8.580
95th percentile, sons	8.209	8.218	8.557	7.874
Mean, fathers	3.681	3.705	3.518	3.912
Mean, sons	3.672	3.694	3.243	3.177
Father-son correlation†	0.349	0.357	0.348	0.349
Father-son with zero pubs.	0.215	0.215	0.175	0.228
Father-grandson correlation†	0.160	0.284	0.163	0.294

Notes: † correlation on the intensive margin.

Second, we compare the empirical and simulated moments based on multi-generation correlations (Table 6). Overall, we reproduce the high elasticity of publications across generations (Fact 1). Our full-model matches perfectly the father-son correlation in the intensive margin of publications—that is, conditional on both father and son having at least one observed publication. This is the correlation to which our objective function attaches additional weight. Interestingly, this correlation is below the estimate of β in all specifications. This implies that father-son correlations in outcomes can under-predict the extent to which endowments that children inherit from their parents persist over time.

Our model with nepotism under-predicts the proportion of families where father and son have zero publications (extensive margin) and the correlation between fathers and grandsons in the intensive margin. That said, we match the empirical fact that the father-grandson correlation is larger than predicted by iterating the two-generation correlation. Specifically, our simulated father-grandson correlation is 0.163. In contrast, iterating the simulated two-generation correlation yields $0.348^2 = 0.121$.

6 Extensions

6.1 Results over time

Here we estimate our model for different historical periods. This exercise is interesting in two respects. First, it allows to shed new light on Clark's hypothesis that β is close to a universal constant across time (Clark 2015). Second, our dataset covers eight centuries that saw crucial changes in universities and in the production of upper-tail human capital, e.g., the invention of the printing press, the Scientific Revolution, and the Enlightenment. Hence, we can evaluate the extent to which these events are associated with changes in the transmission of human capital across generations or in the prevalence of nepotism.

Specifically, we divide our lineages of scholars into four periods based on the father's reference date: before 1527, 1528 to 1625, 1626 to 1724, and 1725 to 1800. Table 7, Panel A presents the identified parameters for each period. Our findings do not support the hypothesis that β, the rate at which children inherit endowments from their parents, is constant across time. Overall, our estimate for β ranges from 0.24 before 1527 to 0.62 in 1626–1724. Interestingly, we find an increasing trend over time. For example, during the Scientific Revolution (1543-1632), scholars inherited human capital and other underlying endowments from their parents at a higher rate than pre-1527 scholars. Similarly, the age of Enlightenment (1715-1789) is characterized by a high persistence of underlying endowments among lineages of scholars. These findings suggest that β, the parameter governing the persistence of status among scholars, is subject to changes in the

TABLE 7: Heterogeneity.

	β	ν	σ_e	κ	μ_h	σ_h	% nep	N
A. Results over time								
Before 1527	0.24	9.01	1.67	3.17	-0.81	3.85	46.37	210
1528 to 1625	0.47	6.08	0.31	1.79	2.59	3.24	15.05	236
1626 to 1724	0.62	5.02	0.31	2.15	3.24	3.26	8.97	467
1725 to 1800	0.52	4.40	0.14	3.06	4.99	2.13	0.22	190
B. University's religion (after 1527)								
Protestant	0.40	5.06	0.13	1.70	4.83	2.59	2.77	532
Catholic	0.74	5.83	0.76	2.15	-0.92	3.97	30.97	357
C. Field of study (of fathers)								
Lawyer	0.64	7.39	1.04	2.60	-0.34	3.89	29.04	296
Physician	0.46	7.61	0.37	2.38	2.51	3.21	14.91	331
Theologian	0.53	3.75	0.27	1.19	4.54	2.61	3.19	138
Scientist	0.70	5.97	0.18	1.69	3.03	3.68	11.27	170
D. Son nomination date								
After father's death	0.51	4.62	0.27	2.07	3.13	3.16	11.46	463
Before father's death	0.67	6.70	0.42	1.87	2.30	3.68	15.1	453
Before age 30	0.63	6.81	0.36	2.38	4.27	2.81	4.29	307
After age 29	0.39	3.73	0.33	2.43	4.53	2.37	2.03	460
Birth date unknown	0.91	2.05	0.10	0.66	-0.97	0.84	90.63	275

environment. In other words, among pre-industrial scholars, β reflects nature but also nurture.

Consistently, we find substantial differences in the prevalence of nepotism over time. For the sake of illustration, Figure A.II in appendix presents QQ-plots comparing the fathers' and sons' distribution of publications across historical periods. For all periods, the father's publication record dominates that of their sons. That said, the distributional differences decrease over time: they are the largest before 1527, are substantially reduced during the Scientific Revolution (1543-1632), and are the smallest around the Enlightenment (1715-1789). This suggests that, over time, selected sons became more similar to their fathers in terms of underlying endowments, e.g., human capital. Table 7 shows that this was due to a decrease in nepotism. Specifically, we simulate our model with the estimated parameters in each period and remove nepotism by setting $\nu = 0$. Our simulations show that, before 1527, half of the sons of scholars were nepotic scholars. That is, they would not have become scholars under the same selection criterium than outsiders. This percentage is dramatically reduced to 15.05 percent during the Scientific Revolution, and drops to only 0.22 percent at the end of our sample period—that is, at the age of Enlightenment. In other words, the increase in scientific production and the accumulation of upper-tail human capital during the Scientific Revolution and the Enlightenment is strongly associated to a decrease in the prevalence of nepotism in universities and scientific academies.

Altogether, our estimates suggest an inverse relationship between nepotism and β, the rate at which scholars inherited human capital and other underlying endowments from their parents. In the early stages of universities and scientific academies, lineages of scholars emerged as a result of nepotism: Scholars used their power and influence to appoint their sons, even when these had low human capital endowments. With the Scientific Revolution and, especially, the Enlightenment, nepotism lost prevalence but scholar lineages did not disappear. The reason is that sons of scholars inherited large human capital endowments from their parents, giving them a natural advantage over outsiders to become a scholar. In other words, lineages of scholars became more meritocratic. This likely contributed to the rise in scientific output production and upper-tail human capital accumulation associated with these historical periods.

Finally, these estimates allow us to validate our assumption that the distribution of human capital is stationary (among potential scholars). For example, the variance of the human capital distribution, σ_h, is relatively stable across the 800 years covered by our data. Admittedly, this is not true for the mean of the human capital distribution, μ_h. Specifically, before 1527 we estimate a mean of $\mu_h = -0.81$, more than five times lower than that for 1725–1800. The reason for this divergence is that our stationarity assumption is conditional on the remaining model parameters being constant. This is not true for κ, the minimum number of publications above which we are likely to observe a scholar's publications. This parameter is 3 before 1527 and about 2 from 1528 to 1724. The structural break in κ is explained by the invention of the printing press around 1450. Specifically, the printing press lowered the cost of publishing after 1450, and hence, allowed the work of obscure scholars to survive until today—i.e., it reduced the number of scholars with zero library holdings. That said, it is unlikely that the printing press increased the number of library holdings today of *successful* scholars. Formally,

$Pr(y_{i,t}>0)$ increased but $E[y_{i,t}|y_{i,t}>0]$ remained stable. Given that

$$E[y_{i,t}|y_{i,t}>0] = \frac{\mu_h + \mu_\epsilon}{2}\,\mathrm{erfc}\,(\omega) + \frac{\sqrt{\sigma_h^2 + \sigma_\epsilon^2}}{\sqrt{2\pi}}\exp\omega^2,$$

with $\omega = \frac{+\kappa - \mu_h - \mu_\epsilon}{\sqrt{2}\sqrt{\sigma_h^2+\sigma_\epsilon^2}}$, the constancy of $E[y_{i,t}|y_{i,t}>0]$ implies a negative relation between μ_h and κ. In other words, it explains why the high κ before 1527 is associated to a lower μ_h than in other periods.

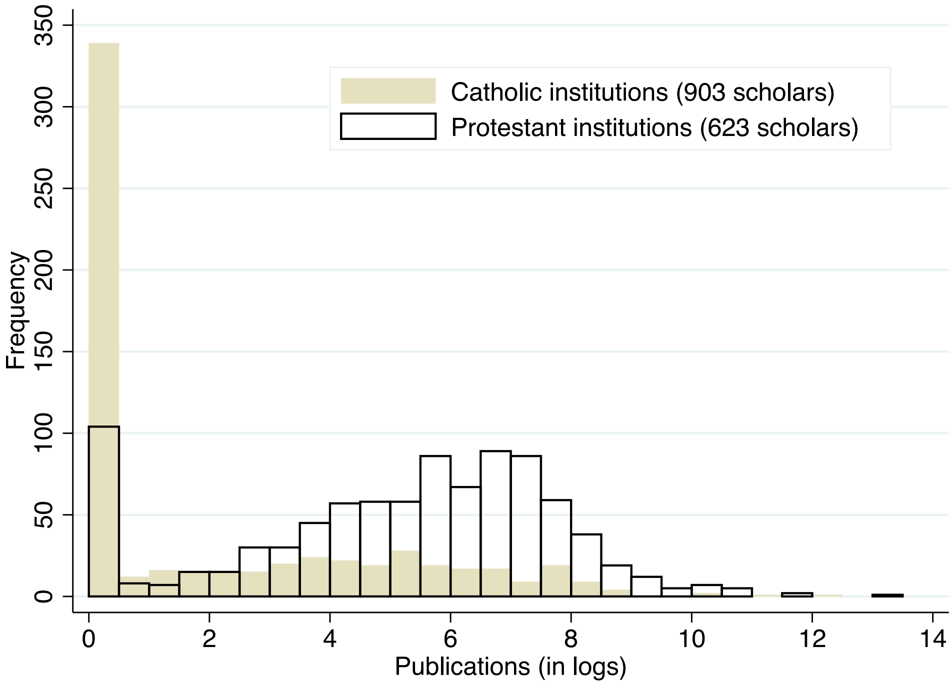
6.2 Protestant reformation

Next, we narrow the focus on a historical event often deemed crucial for the rise of modern science: the Protestant Reformation. Merton (1938) famously argued that there was a direct link between protestantism and the Scientific revolution. According to Merton, protestant values encouraged scientific research because it showed God's influence on the world. Similarly, other authors have argued that, in catholic regimes, the Scientific Revolution was hindered by the closure and censure imposed by the Counter-Reformation (Lenski 1963; Landes 1998). We shed new light on this debate by showing that differences in the scientific output of protestant vs. catholic universities are associated to differences in both nepotism and in the transmission of human capital across generations of scholars.

Figure 6 shows that scholars in our dataset, i.e., individuals belonging to a scholar's lineage, were more productive in protestant than in catholic institutions. Specifically, we sort scholars according to the religious affiliation of their university or scientific academy and exclude all lineages before 1527. The figure shows that the number of scholars with zero publications is three times larger in catholic institutions than in their protestant counterparts. In contrast, the average scholar in a protestant institution has thrice the number of publications than the corresponding scholar in a catholic institution (702 vs. 2,285). Differences are also visible at the upper-tail of scientific production. For example, we observe a much higher frequency of protestant scholars with 3,000 to 20,000 publications (4 to 8 in logs).

The larger scientific output in protestant institutions is associated to a less persistent transmission of human capital across generations of scholars and to lower levels of nepotism. Table 7, Panel B presents our estimated model's parameters for protestant and catholic universities (QQ plot in Appendix, see Figure A.III). Our findings suggest that β was almost twice as large in catholic than in protestant institutions. In other words, relative to protestant institutions, catholic institutions relied on the human capital and abilities that children inherited from their

FIGURE 6: Publications, by institution's religious affiliation.



Notes: The sample are 1,526 unique individuals who (1) were nominated after 1527 and (2) belong to a scholar's lineage. Publications are the log of 1 + the number of published works.

parents.

As a result, lineages of scholars in catholic universities were a by-product of nepotism. As before, we simulate our model with the estimated parameters in each subgroup and remove nepotism by setting $\nu = 0$. Our simulation exercise suggests that, in catholic institutions, 31 percent of the sons of scholars were nepotic scholars. Nepotism was much less prevalent in protestant universities: there, we only identify 2.8 percent of nepotic scholars' sons. These large differences in nepotism are potentially associated to the large catholic-protestant gap in terms of scientific production.

6.3 Results by field of study

Here, we estimate the prevalence of nepotism and the strength of human capital transmission in different fields of study. Distinguishing fields of study is important as different types of upper-tail human capital may have different implications, e.g., for economic growth.[20] We consider four fields: science (arts), law (canon and

[20] For example, Murphy, Shleifer, and Vishny (1991) emphasize the importance of engineers for modern economic development. Earlier on, Cantoni and Yuchtman (2014) show that university

Roman law), medicine (including pharmacy and surgery), and theology. These fields correspond to the four faculties into which early universities were organized.

Table 7, Panel C presents our estimates of the model's parameters, by field (QQ plot in Appendix, see Figure A.IV). Specifically, lineages are sorted into fields according to the father's field of study. The transmission of human capital across generations was strong among lawyers and scientists. For them, our estimates of β are around 0.70. In contrast, we estimate a lower persistence parameter among physicians and (protestant) theologians. As stressed in Section 6.1, this finding does not support the hypothesis that β is a universal constant, but instead shaped by different institutional environments.

We also find that nepotism was more prevalent in law faculties. Our model simulations suggest that 29 percent of sons of law scholars were nepotic scholars. For scientist, only 11 percent of scholar's sons were nepotic. This figure is similar for physicians, suggesting that applied sciences were more open to newcomers.

6.4 Sons' nomination date

Nepotism can take on two forms: one the one hand, fathers may use their social connections and influence in the profession to nominate their sons—in this case, to a university chair. On the other hand, influential scholars may secure university chairs as part of their family's assets. Under this scenario, chairs may have been inherited by children upon their father's death. Next, we distinguish these two expressions of nepotism by estimating our model for two sets of lineages: lineages in which the son was nominated before vs. after his father's death.

Table 7, Panel D presents the estimated parameters for these two subgroups. The transmission of human capital was stronger in lineages where the son was nominated during his father's lifetime. For them, we estimate a β close to 0.70, forty percent larger than for lineages in which the son was nominated after his father's death.

Similarly, we find that nepotism was more prevalent among sons nominated before their father's death. Specifically, our model simulations suggest that 15 percent of sons nominated during his father's lifetime were nepotic. That is, had they been outsiders, they would not have been nominated. In contrast, we only find 11 percent of nepotism among sons nominated after their father's death. This suggests that, in our setting, nepotism is mostly characterized by fathers using

training in Roman law played an important role in the establishment of markets during the "Commercial Revolution" in medieval Europe.

their social connections to nominate their sons rather than by father's passing down their chairs after their death as part of the inheritance.

Admittedly, a son nominated during his father's lifetime may have been younger than a son nominated after his father's death. Table 7, Panel E shows that this age difference does not drive the results described above. The simulated percentage of nepotic sons is similar in lineages in which the son was nominated before or after age 30 (the corresponding QQ plot is in Appendix Figure A.v). Note that the sample used here comprises sons with a known birth date. Hence, this sample is likely to contain well-known, successful scholars, who are less likely to be nepotic. That said, the evidence is indicative that nepotism depended on whether a son nominated during his father's lifetime and not on the son's age at nomination.

This exercise also suggests that the transmission of human capital was stronger in lineages where the son was nominated earlier. Specifically, we find a human capital elasticity of 0.63 among sons nominated before age 30, and of 0.39 for sons nominated at an older age.

7 Conclusions

From the Bernouillis to the Eulers, families of scholars have been common in academia since the foundation of the first medieval university in 1088. In this paper, we have shown that this was the result of two factors: First, scholar's sons benefited from their fathers' connections to be nominated to academic positions in their father's university. Between 1088 and 1800, one in ten scholars' sons were nepotic scholars. They became academics even when their underlying human capital was 2.4 standard deviations lower than that of marginal outsider scholars. Second, scholars transmitted their sons a set of underlying endowments, i.e., human capital and abilities, that were crucial for the production of scientific knowledge. Our estimates suggest a large intergenerational elasticity of such endowments, as high as 0.6.

To disentangle the importance of nepotism vs. inherited human capital endowments, we proposed a new method to characterize intergenerational persistence. Our method exploits two sets of moments: one standard in the literature—multigeneration correlations in observed outcomes—another novel—distributional differences between adjacent generations in the same occupation. We argue that, under a standard first-order Markov process of human-capital endowments' transmission, distributional differences within occupations must reflect the fact that the observed parents and children are selected under different criteria. In other words, parent-child distributional differences within an occupation can be used to identify the importance of nepotism.

Our results have two important implications for measuring the rate of intergenerational persistence. First, we argue that estimates that bundle the transmission of underlying endowments and nepotism together may provide biased estimates of the true rate of intergenerational persistence. The reason is that each of these two elements is associated to a different econometric bias: measurement error and selection. Our estimate for the transmission of underlying human-capital endowments is higher than estimates ignoring both biases—i.e., parent-child correlations—but in the lower-range of estimates ignoring selection—i.e., multi-generational correlations, group-averages, or the informational content of surnames. Specifically, when we omit selection and, especially, nepotism, our method delivers large intergenerational human-capital elasticities, close to the 0.7–0.8 range estimated by Clark (2015). Hence, failing to account for nepotism can overstate the true rate of persistence of underlying human-capital endowments.

Second, our proposed method circumvents some of the data requirements that have limited the study of intergenerational persistence in historical contexts. By modelling selection explicitly, our method only requires using data from a well-defined universe, for example, a top occupation. Historical data of such occupations, e.g., scholars, artisans, artists, or government officers, is more common than the census-type evidence required by some of the alternative methods proposed by the literature (Güell, Rodríguez Mora, and Telmer 2015, Lindahl et al. 2015, Braun and Stuhler 2018, Collado, Ortuno-Ortin, and Stuhler 2018). Finally, relative to the literature examining the concentration of certain families in top occupations, our approach allows us to estimate nepotism across time and space, beyond the specific instances in which a natural experiment is available.

Finally, this paper sheds new light on the production of upper-tail human capital and its importance for the take-off of pre-industrial Europe (Cantoni and Yuchtman 2014, Mokyr et al. 2002, Mokyr 2016, Squicciarini and Voigtländer 2015, de la Croix, Doepke, and Mokyr 2018). Specifically, our findings suggest that the transmission of human capital endowments and nepotism follow an inverse relationship over time. Periods of advancement in sciences, like the Scientific Revolution or the Enlightenment, were associated with lower degrees of nepotism in universities and scientific academies—especially, those adherent to protestantism. In contrast, nepotism is prevalent in periods of stagnation and in catholic institutions that fell behind in the production of scientific knowledge. These institutions seem to rely more on the transmission of human capital within the family. Altogether, this suggest that the establishment of modern, open universities during the Enlightenment is crucial to understand Europe's scientific advancements. The extent to which these changes explain Europe's rise to riches is an intriguing question for future research.

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Lineages of Scholars in pre-industrial Europe: Nepotism vs Intergenerational Human Capital Transmission
Online appendix

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A Data Sources

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Table A.i: Number of Families (Father-Son) by Institution (1/5)

Institution	City	Cntry	Dates		Nb.	Sources
University of Bologna	Bologna	ITA	1088		157	Mazzetti (1847)
Royal Society of London (···)	London	GBR	1660		71	https://royalsociety.org/
University of Avignon	Avignon	FRA	1303	1793	58	Laval (1889), Fournier (1892), Teule (1887), Duhamel (1895), Barjavel (1841)
University of Tubingen	Tübingen	DEU	1476		42	Conrad (1960)
Academy of Sciences Leopoldina	Halle	DEU	1652		37	http://www.leopoldina.org/
University of Basel	Basel	CHE	1460		34	Herzog (1780), Junius Institute (2013), Michaud (1811)
University of Padua	Padova	ITA	1222		32	Pesenti (1984), Casellato and Rea (2002), Facciolati (1757)
University of Montpellier	Montpellier	FRA	1289	1793	30	Astruc (1767), Dulieu (1975, 1979, 1983), Clerc (2006)
University of Jena	Jena	DEU	1558		27	Günther (1858)
Univ. of Pavia	Pavia	ITA	1361		27	Raggi (1879)
University of Marburg	Marburg	DEU	1527		24	Gundlach and Auerbach (1927)
University of Greifswald	Greifswald	DEU	1456		24	
University of Giessen	Gieen	DEU	1607		23	Haupt and Lehnert (1907)
University of Helmstedt	Helmstedt	DEU	1575	1809	20	Gleixner (2019)
University of Paris	Paris	FRA	1200	1793	19	Antonetti (2013), Courtenay (1999), Hazon and Bertrand (1778)
French Academy of Sciences	Paris	FRA	1666	1793	18	http://www.academie-sciences.fr
University of Rostock	Rostock	DEU	1419		18	Krüger (2019)
Leiden University	Leiden	NLD	1575		15	Leiden (2019)
University of Knigsberg	Kaliningrad	RUS	1544		14	Naragon (2006)
University of Strasbourg	Strasbourg	FRA	1538		14	Berger-Levrault (1890)
Acadmie Royale (···) de Lyon	Lyon	FRA	1700	1790	13	https://academie-sbla-lyon.fr/Academiciens/, Bréghot Du Lut and Péricaud (1839)

Table A.ii: Number of Families (Father-Son) by Institution (2/5)

Institution	City	Cntry	Dates		Nb.	Sources
Collège Royal	Paris	FRA	1530		13	de France (2018)
University of Copenhagen	Kbenhavn	DNK	1475		13	Københavns Universitet (2017)
University of Aix	Aix-en-Provence	FRA	1409	1793	11	Belin (1896), Belin (1905), Fleury and Dumas (1929), Masson (1931), de la Croix and Fabre (2019)
Accademia Fiorentina	Firenze	ITA	1540	1783	11	Boutier (2017)
University of Cahors	Cahors	FRA	1332	1751	9	Ferté (1975)
University of Wittenberg	Wittenberg	DEU	1502	1813	9	Kohnle and Kusche (2016)
University of Gottingen	Göttingen	DEU	1734		9	Ebel (1962)
Académie des inscriptions (···)	Paris	FRA	1663		9	Boutier (2018)
Royal Prussian Academy of Sciences	Berlin	DEU	1700		9	BBAW (2019)
University of Cambridge	Cambridge	GBR	1209		9	Walker (1927), Venn (1922)
Academy of(···) Mainz	Erfurt	DEU	1754		9	Kiefer (2004)
University of Franeker	Franeker	NLD	1585	1811	8	Feenstra, Ahsmann, and Veen (2003)
University of Poitiers	Poitiers	FRA	1431	1793	8	Boissonade (1932)
University of Louvain	Leuven	BEL	1425	1797	8	Ram (1861), Nève (1856), Brants (1906), Lamberts and Roegiers (1990)
University of Angers	Angers	FRA	1250	1793	8	Rangeard and Lemarchand (1868), de Lens (1880), Denéchère and Matz (2012), Port (1876)
University of Toulouse	Toulouse	FRA	1229	1793	8	Deloume (1890), Barbot (1905), Lamothe-Langon (1823)
University of Kiel	Kiel	DEU	1652		8	Volbehr and Weyl (1956)
Utrecht University	Utrecht	NLD	1636		7	Dorsman (2011)
Jardin Royal des Plantes Mdicinales	Paris	FRA	1635	1793	7	Jaussaud and Brygoo (2004)
French Academy	Paris	FRA	1635		7	http://www.academie-francaise.fr/

TABLE A.III: Number of Families (Father-Son) by Institution (3/5)

Institution	City	Cntry	Dates		Nb.	Sources
Uppsala University	Uppsala	SWE	1477		7	Von Bahr (1945), Astro.uu.se (2011)
University of Groningen	Groningen	NLD	1612		7	https://hoogleraren.ub.rug.nl/
Societas Privatas Taurinensis	Torino	ITA	1757	1792	7	https://www.accademiadellescienze.it/accademia/soci/
University of Edinburgh	Edinburgh	GBR	1582		7	Junius Institute (2013)
University of Salamanca	Salamanca	ESP	1218		7	Addy (1966), Rodríguez San Pedro Bezares (2004), Arteaga (1917)
University of Perpignan	Perpignan	FRA	1350	1793	6	Carmignani (2017), Capeille (1914),Izarn (1991)
University of Geneva	Genève	CHE	1559		6	Junius Institute (2013)
bo Akademi University	Turku	FIN	1640		6	
University of Nantes	Nantes	FRA	1460	1793	6	Chenon (1890), Grünblatt (1961)
Bavarian Academy of (···)	München	DEU	1759		5	https://badw.de/en/community-of-scholars/
Royal Society of Edinburgh	Edinburgh	GBR	1783		5	RSE (2006)
Royal Spanish Academy	Madrid	ESP	1713		5	https://www.rae.es/la-institucion/los-academicos/
University of Pont-à-Mousson	Pont-à-Mousson	FRA	1572	1768	5	Martin (1891)
University of Oxford	Oxford	GBR	1200		4	Emden (1959), Foster (1891)
Accademia dei Ricovrati	Padova	ITA	1599		4	https://www.bl.uk/catalogues/ItalianAcademies/
Heidelberg University	Heidelberg	DEU	1386		4	Drüll (1991), Drüll (2002)
University of Valence	Valence	FRA	1452	1793	4	Brun-Durand (1901), Nadal (1861)
Leipzig University	Leipzig	DEU	1409		4	von Hehl and Riechert (2017)
University of Lund	Lund	SWE	1666		4	Tersmeden (2015)
Majorcan cartographic school	Palma	ESP	1330	1500	4	http://www.cresquesproject.net
Accademia della Crusca	Firenze	ITA	1583		4	Parodi (1983)
Universty of Naples	Napoli	ITA	1224		4	Origlia Paolino (1754)
Académie d'agriculture de France	Paris	FRA	1761	1793	4	https://cths.fr/an/societe.php?id=502

TABLE A.IV: Number of Families (Father-Son) by Institution (4/5)

Institution	City	Cntry	Dates		Nb.	Sources
University of Altdorf	Altdorf bei Nürnberg	DEU	1578	1809	3	Flessa (1969)
Socit Royale des Sciences	Montpellier	FRA	1706	1793	3	Dulieu (1983)
Academy of St Petersburg	Saint-Petersburg	RUS	1724	1917	3	
University of Siena	Siena	ITA	1246		3	Frova, Catoni, and Renzi (2001)
University of Harderwijk	Harderwijk	NLD	1647	1811	3	van Epen (1904)
Acadmie des arts et belles lettres	Caen	FRA	1705	1793	3	de Pontville (1997a)
Braunschweig University (···)	Braunschweig	DEU	1745		3	Albrecht (1986)
Royal College of Physicians	London	GBR	1518		3	Munk (1878)
Académie (.) de la Rochelle	La Rochelle	FRA	1732	1744	3	`https://cths.fr/an/societe.php?id=682`
University of Rome	Roma	ITA	1303		3	Renazzi (1803)
University of Sedan	Sedan	FRA	1599	1681	3	Bourchenin (1882)
University of Rinteln	Rinteln	DEU	1620	1809	2	Hänsel (1971)
Royal Swedish Academy of Sciences	Stockholm	SWE	1739		2	
University of Halle	Halle (Saale)	DEU	1694	1817	2	
University of Torino	Torino	ITA	1404		2	
University of Florence	Firenze	ITA	1321	1515	2	
University of Glasgow	Glasgow	GBR	1451		2	
Viadrina European University	Frankfurt (Oder)	DEU	1506	1811	2	Junius Institute (2013)
Universite of Die	Die	FRA	1601	1684	2	Bourchenin (1882)
Collegium Carolinum	Zurich	CHE	1525		2	Junius Institute (2013)
University of Macerata	Macerata	ITA	1540		2	Serangeli (2010)
Gottingen Academy of Sciences	Göttingen	DEU	1752		2	Krahnke (2001)
University of Saumur	Saumur	FRA	1596	1685	1	Bourchenin (1882)
Acadmie des belles-lettres, (···)	Marseille	FRA	1726	1793	1	

Table A.v: Number of Families (Father-Son) by Institution (4/5)

Institution	City	Cntry	Dates		Nb.	Sources
University of Ferrara	Ferrara	ITA	1391		1	
University of Salerno	Salerno	ITA	1231		1	
Academy of the Unknown	Venezia	ITA	1626	1661	1	https://www.bl.uk/catalogues/ItalianAcademies/
Athenaeum Illustre of Amsterdam	Amsterdam	NLD	1632	1877	1	http://www.albumacademicum.uva.nl/
Academy of the Burning Ones	Padova	ITA	1540	1545	1	https://www.bl.uk/catalogues/ItalianAcademies/
University of Caen	Caen	FRA	1432	1793	1	de Pontville (1997b)
University of St Andrews	Saint-Andrews	GBR	1411		1	
University of Wrzburg	Wrzburg	DEU	1402		1	Walter (2010)
Freiberg University (· · ·)	Freiberg	DEU	1765		1	
Zamojski Academy	Zamosc	POL	1594	1784	1	
Nijmegen University	Nijmegen	NLD	1655	1679	1	
Veneziana (Seconda Accademia)	Venezia	ITA	1594	1608	1	https://www.bl.uk/catalogues/ItalianAcademies/
University of Orléans	Orléans	FRA	1235	1793	1	Bimbenet (1853), Duijnstee (2010)
University of Perugia	Perugia	ITA	1308		1	
Jagiellonian University	Krakow	POL	1364		1	Pietrzyk and Marcinek (2000)
University of Nimes	Nmes	FRA	1539	1663	1	Bourchenin (1882)
University of Aberdeen	Aberdeen	GBR	1495		1	
University of Moscow	Moskow	RUS	1755		1	Andreev and Tsygankov (2010)
Academy of the Invaghiti	Mantova	ITL	1562	1738	1	https://www.bl.uk/catalogues/ItalianAcademies/
University of Rennes	Rennes	FRA	1735	1793	1	Chenon (1890)
University of Lausanne	Lausanne	CHE	1537		1	Junius Institute (2013)
University of Freiburg	Freiburg	DEU	1457		1	
University of Prague	Prague	CZE	1348		1	
University of Erfult	Erfurt	DEU	1379		1	

Table A.vi: Number of Families (Father-Son) by Institution (5/5)

Institution	City	Cntry	Dates		Nb.	Sources
Royal Botanic Garden	Kew	GBR	1759		1	
University of Bordeaux	Bordeaux	FRA	1441	1793	1	
University of Montauban	Montauban	FRA	1598	1659	1	Bourchenin (1882)
Academie de Beziers	Béziers	FRA	1723	1793	1	

B Robustness to Measures of Publications

Table A.vii: Two Different Measures of Publications

Moment	library holdings	nb. of works
mean publi son	3.177	2.383
mean publi father	3.932	2.994
b (OLS)	0.513	0.517
b (OLS) intens.	0.361	0.326
corr 2G intens.	0.340	0.340
Q50/Q75 son	0.513	0.488
Q50/Q95 son	0.386	0.352
Q50/mean son	0.958	0.922
Q50/Q75 father	0.642	0.616
Q50/Q95 father	0.502	0.460
Q50/mean father	1.095	1.061
corr 3G intens.	0.292	0.219

C Identification Example

Figure A.1 illustrates our identification strategy by simulating our model. We show the simulated distributions of the underlying (human capital) and the observed outcome (publications), father-son correlations in publications and the corresponding QQ plot.

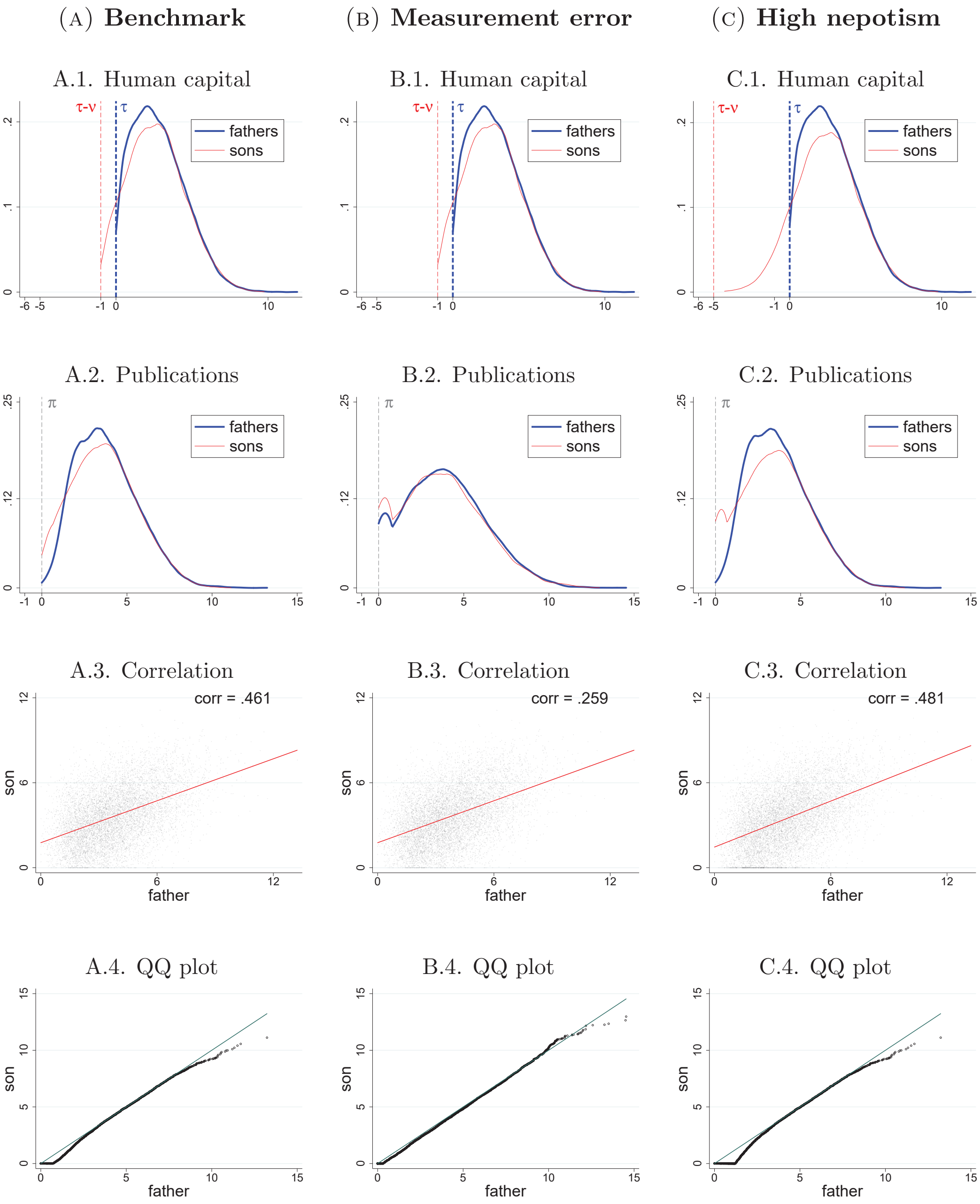
Column A presents a benchmark simulation for 10,000 potential scholars with $\beta = 0.6$, $\nu = -1$, $\tau = 0$, $\mu_e = 1$, $\pi = 0$, $\mu_h = 2$, $\sigma_h^2 = 5$, and $\sigma_e^2 = 0.25$. In Column B, we increase σ_e^2 to 3. That is, we generate measurement error by reducing the extent to which human capital translates into publications. The distribution of h is not altered with respect to the benchmark case, but that of y is: both fathers and sons present a larger mass of zero publications and a larger variance. Since y is similarly affected for fathers and sons, the QQ plot does not reflect distributional differences across generations. However, the increase in measurement error attenuates the father-son correlation in y, which drops from 0.46 to 0.26 with respect to the benchmark case.

Next, Column C increases nepotism with respect to the benchmark case by setting $\nu = -5$. In contrast to the previous exercise, this affects the distribution of both h and y, as sons with low levels of human capital now can become a scholar.[1] This generates distributional differences in observed publications between fathers and sons, reflected in the QQ plot. Most evidently, the mass of sons with zero publications and the variance of sons' publications is now larger than their fathers'. Since nepotism alters both the human capital's and the observed outcome's distribution, father-son correlations become more informative of β than in the benchmark case: the correlation increases from 0.46 to 0.48.

In sum, measurement error and nepotism have different implications for father-son correlations, distributional differences (especially, at the bottom of the distribution), and relative variances of the observed outcome.

[1] The father's h distribution is also affected, albeit to a lesser degree. The reason is that marginal fathers, i.e., fathers with an h just above the threshold τ, are now more likely to be in the set of selected families. Before, these fathers were mostly excluded, as their sons were likely to have low realizations of h, falling below the (nepotic) threshold to become a scholar. Similarly, this may decrease the variance of fathers' publications.

Figure A.i: Identification example based on model simulations



Notes: The benchmark simulation is for 10,000 potential scholars with $\beta = 0.6$, $\nu = -1$, $\tau = 0$, $\mu_e = 1$, $\pi = 0$, $\mu_h = 2$, $\sigma_h = 5$, and $\sigma_e = 0.25$. Column B increases σ_e to 3, Column C increases nepotism by setting $\nu = -5$.

D Heterogeneity in Nepotism: QQ plots

FIGURE A.II: Quantile-quantile plot by historical period

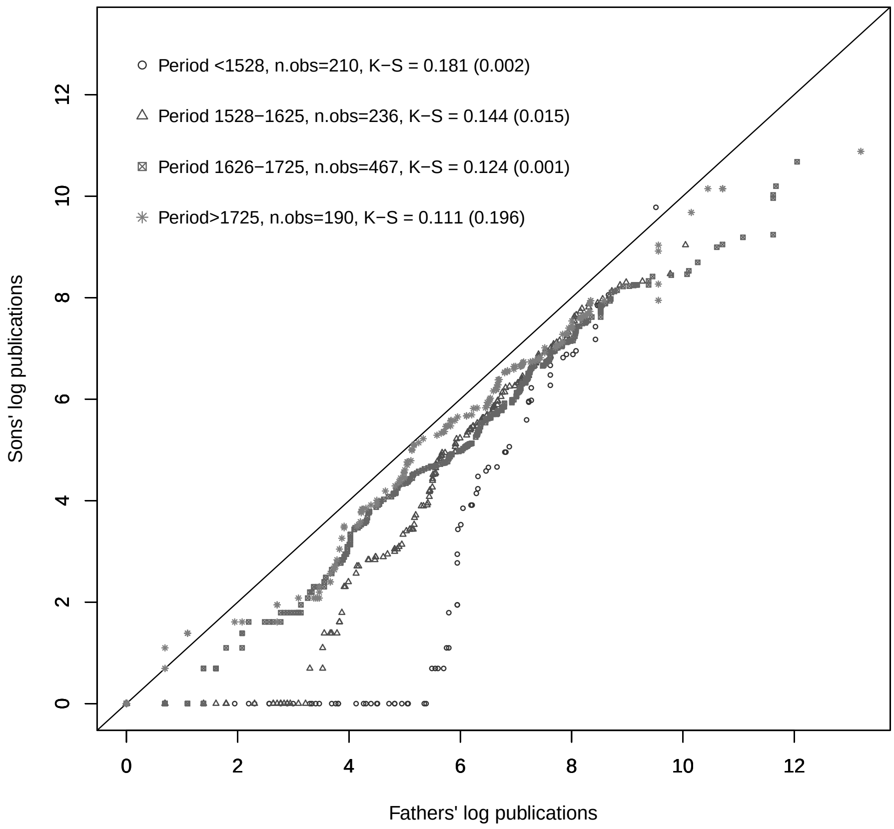


FIGURE A.III: Quantile-quantile plot by Religion

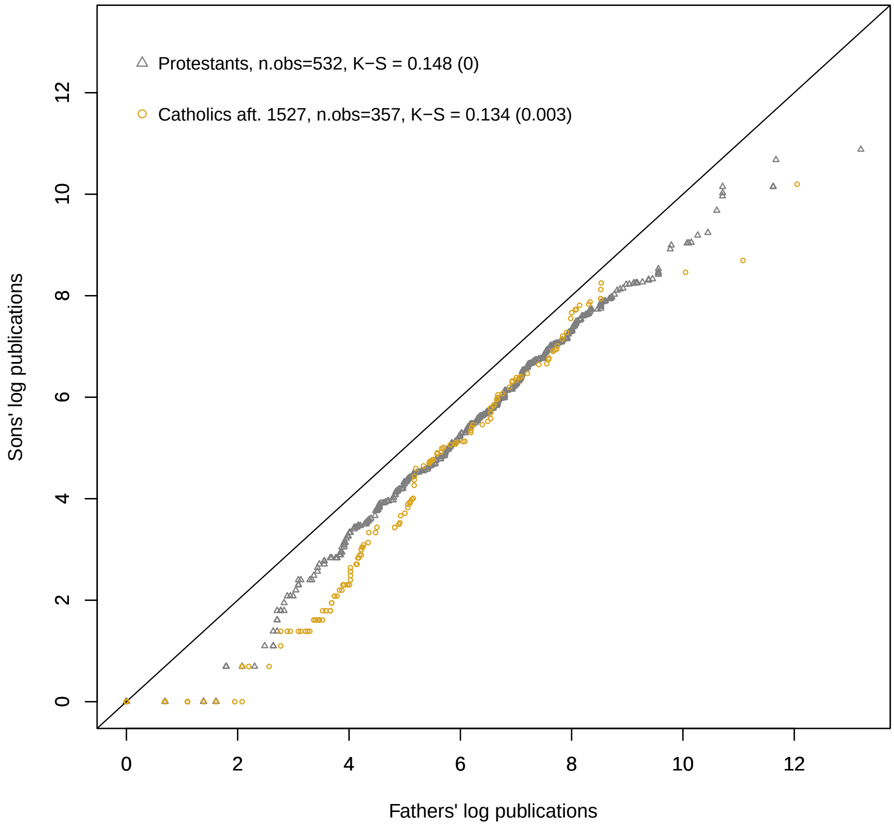


FIGURE A.IV: Quantile-quantile plot by field of study

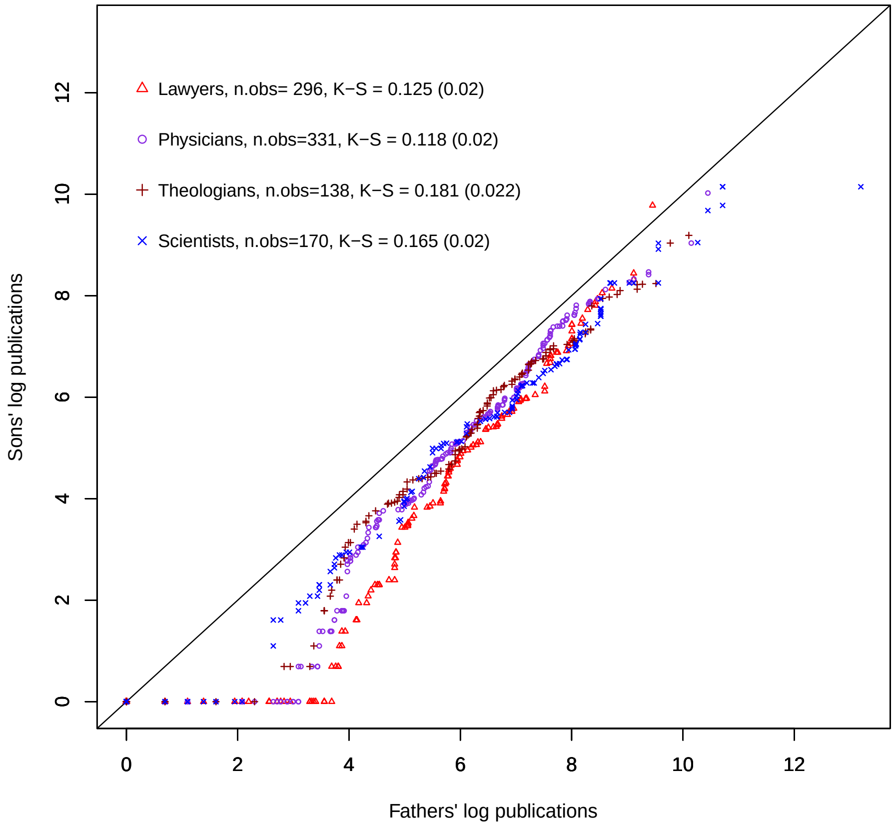
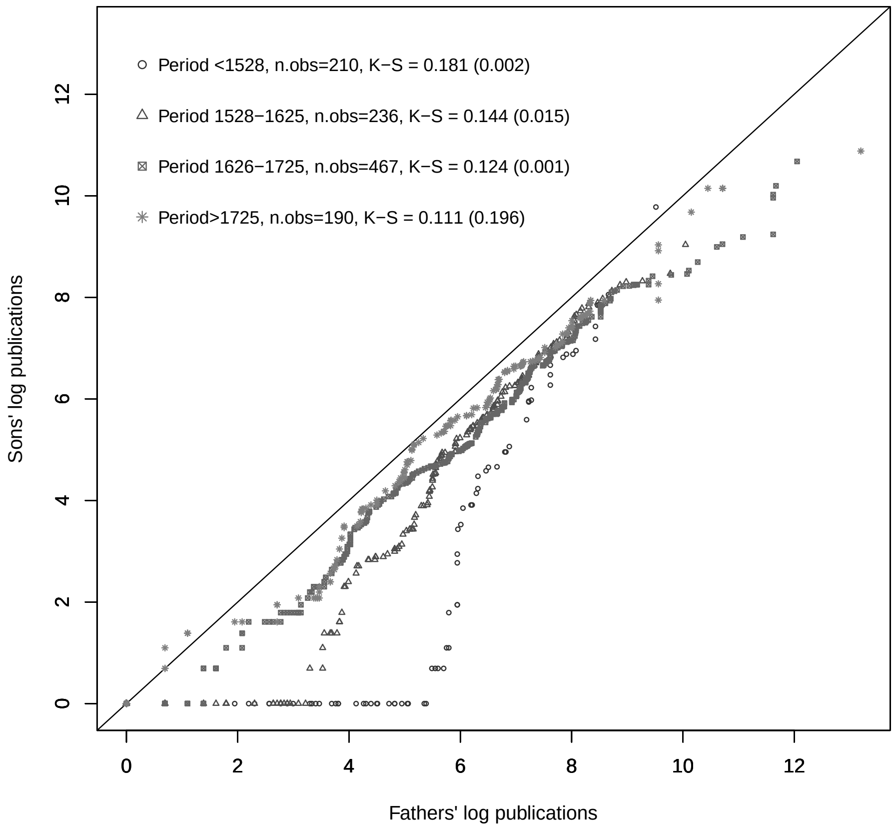


Figure A.v: Quantile-quantile plot by Nomination Bef/After Death of Father



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