Nepotism vs. Intergenerational Transmission of Human Capital in Academia (1088–1800)*

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Abstract

We argue that the waning of nepotism in academia bolstered scientific production in pre-industrial Europe. We build a database of families of scholars (1088–1800), measure their scientific output, and develop a general method to disentangle nepotism from inherited human capital—two determinants of occupational persistence. This requires jointly addressing measurement error in human capital proxies and sample selection bias arising from nepotism. Our method exploits multi-generation correlations together with parent-child distributional differences to identify the structural parameters of a first-order Markov process of human capital transmission with nepotism. We find an intergenerational human capital elasticity of 0.59, higher than that suggested by parent-child elasticities, yet lower than multi-generation estimates ignoring nepotism. On average, 16 percent of scholars' sons achieved their position because of nepotism. Nepotism was lower in science than in law and in Protestant than in Catholic institutions, and declined during the Scientific Revolution and the Enlightenment—two periods of buoyant scientific advancement.

Keywords: *Intergenerational mobility, human capital transmission, nepotism, university scholars, upper-tail human capital, pre-industrial Europe.*

JEL Codes: *C31, E24, J1*

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1 Introduction

Universities and scientific academies are often seen as being essential for having brought Europe through the Commercial Revolution (Cantoni and Yuchtman 2014), Scientific Revolution (Applebaum 2003), and Enlightenment (Mokyr 2009). Yet, these institutions are not immune to criticism: some remained attached to old paradigms, others sold diplomas, and many accepted appointments and nominations of relatives.[1] This may indicate that children benefitted from their parents' social connections and used them to get jobs ahead of better qualified candidates (henceforth, nepotism). That said, family dynasties are common in high-talent occupations,[2] which may be optimal if talent is scarce and children's human capital depends on parental investments, inherited knowledge, abilities, and skills (henceforth, inherited human capital). Disentangling inherited human capital from nepotism is important as their economic implications are fundamentally different: while inherited human capital increases productivity, nepotism leads to a misallocation of talent. Such misallocation is particularly damaging in high-talent markets (Murphy, Shleifer, and Vishny 1991) where it can affect the production of ideas, and in turn technological progress and economic development (Mokyr 2002).

However, disentangling inherited human capital from nepotism is challenging from an econometric perspective. The reason is that these two elements are associated with two different biases: on the one hand, inherited human capital is only imperfectly reflected in socio-economic outcomes, which can lead to measurement error. Recent studies suggest that this bias can be large: Earnings, wealth, or occupation are considerably more persistent across multiple generations than suggested by parent-child elasticities[3] because children inherit a set of unobserved endowments (e.g., human capital, ability, genetic advantages) which are later transformed into observed outcomes with measurement error.[4] On the other

[1] See Dulieu (1983) on Montpellier's medical faculty, Slottved and Tamm (2009) on the University of Copenhagen, and Connor (1947) on the Cassini dynasty at the Paris Observatory and the French Academy of Sciences.

[2] 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).

[3] Güell, Rodríguez Mora, and Telmer (2015), Clark (2015), Clark and Cummins (2015), Lindahl et al. (2015), Braun and Stuhler (2018). For reviews on parent-child elasticities, see Solon (1999), Corak (2006), and Black and Devereux (2011).

[4] Alternatively, it has been suggested that grandparents can have independent effects on their grandchildren (Mare 2011; Zeng and Xie 2014; Lindahl et al. 2015; Adermon, Lindahl, and Waldenström 2018; Long and Ferrie 2018; Colagrossi, d'Hombres, and Schnepf 2019).

hand, nepotism introduces a different econometric bias: selection. For example, nepotism can bias intergenerational mobility estimates by generating barriers of entry to certain occupations. Traditional estimates that bundle inherited human capital and nepotism do not address both biases jointly, and hence, provide unreliable estimates of intergenerational inequality.

In this paper, we develop a general method to disentangle inherited human capital from nepotism and examine its implications for talent allocation and the production of ideas in pre-industrial Europe. We build a dataset with families of scholars in 1088–1800 and their scientific output. Using our novel method, we show that human capital endowments were inherited with an intergenerational elasticity of 0.59—higher than suggested by father-son correlations in scientific publications, and lower than estimates proposed in the literature that omit nepotism. Hence, in settings where nepotism is prevalent, failing to account for it can overstate the true rate of persistence of human capital endowments. We find that 16 percent of scholars' sons were themselves scholars because of nepotism, which reduced scientific output by 19 percent. In the Scientific Revolution and the Enlightenment, nepotism declined dramatically and families of scholars emerged as a byproduct of inherited human capital. This suggests that nepotism distorted the production of ideas and that removing this barrier was crucial for Europe's scientific advancements before the Industrial Revolution.

Our first contribution is to propose a general method to disentangle human capital transmission from nepotism. We argue that standard two-generation elasticities in socio-economic outcomes provide biased estimates of the transmission of underlying endowments like human capital due to (i) measurement error in these underlying endowments and (ii) selection bias arising from nepotism. While the literature has addressed each of these biases separately, we develop a new method to jointly address them. Specifically, we use two sets of moments to characterize intergenerational persistence: one standard in the literature, another new. The first is correlations in observed outcomes across multiple generations, which have been used to address measurement error.[5] Under the assumption that measurement error is constant across generations, these 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. We consider an occupation which selects individuals from the upper-tail of the human-capital distribution and where the entry criterion may be different for sons of insiders. In this setting, father-son

[5] Lindahl et al. (2015), Braun and Stuhler (2018).

distributional differences may be the result of two forces: on the one hand, if human capital strongly reverts to the mean, the sons of individuals at the top of the human-capital distribution will perform worse than their fathers.[6] On the other hand, nepotism lowers the selected sons' human capital relative to that of the selected fathers. Even when human capital slowly reverts to the mean, this generates distributional differences in observed outcomes across generations, especially at the bottom of the distribution, i.e., closer to the selection thresholds. Hence, the excess distributional differences, net of reversion to the mean, can be used to identify nepotism.[7]

Our second contribution is to quantify nepotism vs. inherited human capital in explaining the prevalence of families in pre-industrial academia, as well as its effects on talent allocation, scientific production, and upper-tail human capital accumulation. We build a new dataset of $1,440$ lineages of scholars in 100 universities and 40 scientific academies in pre-industrial Europe. We do so by using university catalogues and secondary sources, such as books on the histories of the universities and compendia of university professors. We then match the names found with old biographical dictionaries (e.g., Michaud 1811) and online encyclopedias (e.g., the *Allgemeine Deutsche Biographie*, the *Treccani*, and the Dictionary of National Biography). Our database contains $1,257$ fathers and $1,440$ sons who were members of the same university or scientific academy in 1088–1800. We also observe 145 families with three or more generations of scholars. Finally, we use WorldCat to count the number of library holdings by or about each author. By using library holdings in modern libraries, we measure the size as well as the long-term relevance of a scholar's scientific output (henceforth, publications). Publications is an outcome variable that is noisily correlated with inherited human capital endowments.

We document two facts for lineages of scholars in pre-industrial Europe. The first fact is a high elasticity of publications across generations: we estimate a 0.35 elasticity on the intensive margin, comparable, e.g., to the elasticity of wealth in pre-modern agricultural societies (Borgerhoff Mulder et al. 2009). However, 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 human-capital endowments determining publications were strongly transmitted from parents to children—probably at a higher rate than father-son

[6] To gauge how much do distributional differences depend on mean reversion, we follow the literature and assume stationarity in the distribution of human capital over all potential scholars.

[7] In addition, we use the fact that an increase in nepotism (measurement error): increases (does not) the variance of the sons' outcomes relative to their fathers' and increases (reduces) how well father-son correlations in outcomes reflect human capital transmission.

correlations in publications reflect. This is consistent with a slow rate of reversion to the mean in human capital. The second fact is that the publications' distribution of fathers first-order stochastically dominates that of sons. The distributional differences are large, especially below the median. This suggests that, compared to selected sons, selected fathers had substantially higher human capital endowments, which then translated into a better publication record. As argued above, this difference in endowments could be the result of a fast rate of reversion to the mean in human capital. That said, the high inter-generational elasticities in observed publications (fact 1) suggest a slow rate of reversion to the mean, which is hard to reconcile with the large distributional differences between fathers and sons (fact 2). We reconcile these two apparently contradictory facts with nepotism, which allowed sons of scholars to become scholars even when their human capital endowments were low. Formally, we use these two facts to estimate the structural parameters of a first-order Markov process of endowments transmission (Clark and Cummins 2015; Braun and Stuhler 2018), extended to account for nepotism. Using the Simulated Method of Moments, we obtain estimates for nepotism and the rate at which children inherited their parent's human capital.

Our first result is that nepotism was quantitatively important in pre-industrial universities and scientific academies. We estimate that the son of a scholar could become a scholar even if his human capital endowment was 2.2 standard deviations lower than the average potential scholar, and 2.1 standard deviations lower than marginal outsider scholars. Overall, around 16 percent of scholars' sons would not have become scholars under the same criteria than outsiders. This distorted the production of ideas: A counterfactual exercise suggests that removing nepotism would increase scientific output by 19 percent between 1088 and 1800.

We document a large decline in nepotism in the Scientific Revolution (1543–1687) and the Enlightenment (1687–1800). Before 1543, forty percent of scholars' sons were nepotic. Nepotism declined to 14-16% in the Scientific Revolution and to 3.8% in the Enlightenment. This was the result of the foundation of modern, meritocratic institutions and not of structural reforms in existing institutions. Nepotism was not prevalent in Protestant universities and scientific academies. In contrast, Catholic institutions were less open and relied heavily on knowledge transmission within families. This partially explains the divergent path of Catholic and Protestant universities after the Reformation (Merton 1938). We also show that nepotism was higher in law and physician's faculties than in sciences, more prominent for sons appointed during their father's lifetime and for sons in their father's field of study, and similar in universities and scientific academies. Finally,

we validate our identification strategy with a falsification test: we consider fathers and sons appointed at different institutions, and hence, not subject to nepotism.

Altogether, this suggests that nepotism resulted in a misallocation of talent, distorted the production of ideas, and slowed the accumulation of upper-tail human capital. Eventually, modern, open universities were established, contributing to Europe's scientific advancements before the Industrial Revolution.

Our second result is that human capital endowments were transmitted with an intergenerational elasticity of 0.59. This value is higher than what father-son correlations in observed outcomes (publications) would suggest. Yet our estimate is in the lower range of elasticities estimated elsewhere via multiple generations, group-averages, or the informational content of surnames. We show that in our setting, where nepotism and selection are prevalent, standard multi-generation estimates overstate the true rate of persistence of human capital endowments—that is, the persistence of endowments, talents, skills, etc. affecting children's productivity. Similarly, if we set nepotism to zero, our method delivers large intergenerational elasticities, close to the 0.7–0.8 range estimated by Clark (2015). Finally, our findings do not support Clark's hypothesis that the rate of persistence is constant through different historical periods. The transmission of human capital endowments and nepotism follow an inverse relationship over time: after the Scientific Revolution, nepotism declined but lineages of scholars did not disappear; they became meritocratic. This suggests that institutional factors can affect the intergenerational transmission of occupations even if family dynasties persist.

Relative to the existing literature, we make the following contributions. First, we show that to obtain reliable intergenerational elasticities it is crucial to jointly address measurement error in a child's inherited endowments and the selection bias arising from nepotism. One branch of the literature addresses measurement error by using multiple generations (Lindahl et al. 2015; Braun and Stuhler 2018; Colagrossi, d'Hombres, and Schnepf 2019), group-averages for siblings (Braun and Stuhler 2018), 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). We show that, by ignoring selection in the form of nepotism, multi-generation estimates can overstate the persistence of endowments like human capital, abilities, or genetic advantages.[8]

[8] A related literature uses twins, adoptees, and natural experiments to test whether intergenerational associations are genetically inherited (selection) or depend on parental investments (causation). See Holmlund, Lindahl, and Plug 2011 and Black and Devereux 2011 for reviews. Differently, we address the selection bias resulting from of nepotism to disentangle it from human capital endowments—but not whether such endowments are determined by nature or nurture.

Another branch of literature quantifies nepotism in top professions (e.g., doctors, lawyers, politicians) by exploiting natural experiments that altered the importance of connections to accessing jobs.[9] By looking at a snapshot, these papers cannot characterize long-run persistence or address measurement error in children's inherited human capital. In addition, our findings shed new light on the debate about whether intergenerational mobility is associated with the economic environment (Chetty et al. 2014; Güell et al. 2018) or is constant across historical periods Clark (2015). Finally, scholars constitute a well-defined universe of individuals at the top of the human capital distribution. Hence, we provide new evidence on the rate of mean-reversion in upper-tail human capital in pre-industrial Europe. We find a slow rate of mean reversion, especially for later periods. This lends credence to Galor and Moav (2002) and Galor and Michalopoulos (2012), who show that natural selection of growth-promoting traits (e.g., upper-tail human capital) is more likely when parents pass on such traits, genetically or culturally, with a high probability.[10]

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, horizontal kinship relations or the entire surname distribution. Such data may be difficult to obtain, particularly in historical settings. Our method only requires observing a well-defined universe, e.g., an occupation. Similarly, we can estimate nepotism across time and space, beyond the specific instances in which a natural experiment is available.

Third, our paper is related to a literature on patronage and favoritism. This literature considers family ties but also other social and geographic connections between principals and agents. Hence, the focus is on disentangling favoritism[11] from the principal's private information about the unobserved abilities of connected agents. One approach is to exploit the fact that promotions of connected candidates look more random to the econometrician due to the principal's private information (Bramoullé and Huremović 2018). Another approach is to compare objective performance measures of connected and unconnected agents. For example, scholars appointed by someone with hometown ties (Fisman et al. 2018) or evaluated by an acquaintance (Zinovyeva and Bagues 2015) underperform unconnected individuals in, respectively, the Chinese Academy of Science and among Full Professors in Spain. In contrast, Voth and Xu (2019) find evidence against

[9] See references in footnote 2.

[10] They typically assume an intergenerational elasticity of one for growth-promoting traits.

[11] Favoritism (nepotism) is the promotion of connected agents (relatives) with weaker criteria.

favoritism in the British Navy. By narrowing the focus to parent-child ties, we can disentangle favoritism from the transmission of human capital across generations.

Fourth, our empirical application sheds new light on a growing literature that highlights the importance of upper-tail human capital for economic growth in pre-industrial Europe. This literature argues that upper-tail human capital—such as the knowledge produced at universities—is important to explain the Commercial Revolution (Cantoni and Yuchtman 2014), the rise of new Science after the adoption of the printing press (Dittmar 2019), and the Industrial Revolution (Mokyr 2002; Galor and Moav 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 rapid advancement in sciences 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 was not slowed down by narrow family networks or kin groups. That said, we find that human capital transmission within nuclear families was important. We also shed new light on the divergent path of Catholic and Protestant universities after the Reformation. We show that nepotism and the transmission of knowledge within families of scholars may have played an important role beyond traditional explanations based on religious values (Merton 1938) or institutional factors (Landes 1998). More generally, our results relate to a large literature showing that distortions in high-talent markets can drastically affect the production of ideas. Examples of such distortions include family-successions of CEOs (Pérez-González 2006; Bennedsen et al. 2007) and lack of exposure to innovation (Bell et al. 2018).

The article proceeds as follows: Section 2 discusses different methods for measuring intergenerational persistence and our model with nepotism. Section 3 presents the institutional background, the data, and two stylized facts about scholar's lineages. Identification and main results are in Section 4. Section 5 contains validation exercises and heterogeneous effects. Section 7 concludes.

2 Methods

In this Section, we discuss different methods for measuring intergenerational persistence and highlight two potential biases: measurement error and selection. We then present our general model to account for nepotism.

2.1 Parent-child elasticities

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 reflects social status (e.g., income, wealth, education, occupational status) and is in logarithms. The coefficient b 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 generations until the gap to the mean halves) is $t_{1/2} = -\ln(2)/\ln(|b|)$, which depends negatively on b.

Table 1, Panel A summarizes estimates of b in the literature.[12] Parent-child elasticities vary across time and space, but are generally below 0.5. This implies a half-life of $t_{1/2} = 1$. That is, half the gap to the mean will be filled after one generation, 3/4 after two generations, and, in three generations, almost all advantages will have reverted to the mean.

2.2 Measurement error

Recent studies looking at multiple generations show that, in the long-run, social status is more persistent than suggested by parent-child elasticities. One possibility is that there is a highly-persistent inherited endowment that wealth, income, or occupation only reflect noisily. Children do not inherit their socio-economic outcomes directly from their parents. Instead, children inherit an unobserved human capital endowment h (e.g., knowledge, skills, genes, preferences) which then transforms into the observed outcome y imperfectly. This is modeled as a first-order Markov process of endowments transmission where endowments are observed with measurement error (Clark and Cummins 2015; Braun and Stuhler 2018):

$$h_{i,t+1} = \beta h_{i,t} + u_{i,t+1}\ , \tag{2}$$

$$y_{i,t+1} = h_{i,t+1} + \varepsilon_{i,t+1}\ , \tag{3}$$

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 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

[12] 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 (Borgerhoff Mulder et al. 2009)
0.48–0.59	Wealth	UK (Harbury and Hitchins 1979)
0.225	Wealth	Norway (adoptees) (Fagereng, Mogstad, and Ronning)
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	USA (Classen 2010)
Panel B: Estimates of β		
$\hat{\beta}$	y_t	Data & Source
0.70–0.75	Wealth	UK probate (1858–2012) (Clark and Cummins 2015)
0.70–0.90	Oxbridge	UK (1170–2012) (Clark and Cummins 2014)
0.61–0.65	Occupation	Germany, 3 gen. (Braun and Stuhler 2018)
0.49–0.70	Education	Germany, 4 gen. (Braun and Stuhler 2018)
0.6	Education	Spain, census (Güell, Rodríguez Mora, and Telmer 2015)
0.61	Schooling	Sweden, 4 gen. (Lindahl et al. 2015)
0.49	Earnings	Sweden, 4 gen. (Lindahl et al. 2015)
0.74	Education	EU-28, 3 gen. (Colagrossi, d'Hombres, and Schnepf 2019)
0.8	Education	Spain, census (Collado, Ortuno-Ortin, and Stuhler 2018)

† Rank-rank correlations instead of elasticities.

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.

The intergenerational elasticity of outcome y estimated from equation (1) is:

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

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

Several methods have been used to identify the true rate of persistence, β. One is to exploit correlations in y across multiple generations.[13] According to the first-order Markov process described above, the elasticity of outcome y is $\beta\theta$ between parents, t, and children, $t+1$, and $\beta^2\theta$ between grandparents, t, and grandchildren, $t+2$ (as long as the signal-to-noise ratio is stable across generations). Hence,

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

the ratio of these elasticities identifies β. Intuitively, β is identified because the endowment h is inherited, but the estimation bias θ is not—it is the same across two or three generations. 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 sharing rare surnames (Clark and Cummins 2015). By grouping individuals with similar inherited endowments, the noise term ε is averaged away. Güell, Rodríguez Mora, and Telmer (2015) propose 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.[14] This method only requires cross-sectional data, i.e., it does not require linking 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 elasticities b. 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-averages.

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 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 these estimates may be subject to another source of bias in settings where favoritism and nepotism are prevalent. That is, where those with power and influence give preference to friends and relatives ahead of better-qualified outsiders. For example, estimates of occupational or wage persistence may be affected by the fact that certain jobs have higher entry barriers for outsiders than for sons of insiders. Econometrically, this introduces a different source of bias: selection.

[14]The ICS is the difference in the R^2 of a regressions of y on a vector of dummies indicating surnames vs. a regression in which this vector indicates "fake" surnames. This moment is used to structurally estimate the true rate of persistence in education.

2.3 Selection

Beyond measurement error, parent-child elasticities may be subject to sample selection: whether observations are sampled or not may be correlated with the unobserved endowment h inherited by children.

This additional source of bias is is inherent to data used to evaluate social mobility. It is present in applications that focus on a subgroup of the population, e.g., one occupation and those leaving wills. Specifically, in certain occupations relatives of insiders may be more likely to be observed. This kind of selection bias is typically addressed using natural experiments.[15] Similarly, wealth elasticities rely on wills and probate records, where only those leaving wealth above a minimum legal requirement are sampled (Clark and Cummins 2015). This sampling criterion is likely to be correlated with h, an individual's inherited endowments (e.g., social competence, skills, genes). Sample selection may also arise in applications covering the entire population (Lindahl et al. 2015; Braun and Stuhler 2018). In census data linking several generations, families are not observed if a generation migrates or dies before outcomes are realized (e.g., wage, occupational choice). This attrition can be correlated with the underlying endowment h. Finally, life-history data collected retrospectively may suffer from recall bias. This bias depends on h if families with large endowments have better knowledge of their ancestors.

To see how selection affects 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 y estimated from equation (1) is:

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

If $\text{Cov}\left(s_i y_{i,t},\ s_i e_{i,t+1}\right) = 0$, then $\hat{b}$ is an unbiased estimate of b and a biased estimate of β due to measurement error, i.e., $\hat{b} = \theta\beta$. If the selection indicator s_i is correlated with 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 are fundamentally different. As described above, measurement error can be corrected using multiple generations. The reason is that across n generations, the underlying endowment is inherited $n-1$ times at a rate β but only twice transformed into the observed outcome y with measurement error. This is not true for the selection bias, which depends on the h, and hence is 'inherited' $n-1$ times. For example, consider grandparent-grandchild (and parent-child)

[15] See footnote 2 for detailed references.

correlations in outcomes: The correlations depend on β—which is inherited twice (once), on the measurement error with which h is twice (twice) transformed into y, and on the selection bias—which is also 'inherited' twice (once). Hence, the ratio of grandparent-grandchild to parent-child correlations does not correct for selection. Moreover, if selection changes over time (e.g., due to changes in the prevalence of nepotism) the selection bias may differ across two and three generations. In other words, the ratio of grandparent-grandchild to parent-child correlations may provide upward or downward biased estimates of β.[16]

Henceforth, we restrict our analysis to sample selection—the bias emerging when inherited human capital is correlated to whether families are sampled or not. Another selection issue is whether human capital endowments (h) are genetically inherited (selection) or are determined by parental investments (causation). See Holmlund, Lindahl, and Plug (2011) and Black and Devereux (2011) for reviews.[17] We abstract from this selection story as our main purpose is to disentangle nepotism from human capital endowments, regardless of whether the latter are determined by nature or nurture. That said, in our empirical application it is possible that a scholar strategically invests in the human capital of his most endowed son, i.e., the son with higher chances of becoming a scholar *ex ante*. Unfortunately, we only observe the children of scholars who become scholars themselves. Hence, we cannot use sibling comparisons to address this issue. That said, under this type of selection, our estimates would understate the rate of mean reversion in scholars' human capital and overstate nepotism—which we already estimate to be low in periods of rapid scientific advancement.

2.4 Model with nepotism

To address measurement error and selection, we develop a new model that incorporates nepotism into the standard first-order Markov process of endowments transmission described above. This section presents this model using the terminology of our empirical application.

We consider a population of potential scholars who are heterogeneous with respect to their human capital. The human capital of each potential scholar depends on a human capital endowment inherited from his father[18] and on random

[16]Formally, this ratio is an upward biased estimate of β if $\frac{\text{Cov}(s_i y_{i,t},\ s_i e_{i,t+2})}{\text{Cov}(s_i y_{i,t},\ s_i e_{i,t+1})} > 1$.

[17]Different strategies have been used to address this kind of selection, ranging from twin studies (Behrman and Rosenzweig 2002), adoptees (Plug 2004; Björklund, Lindahl, and Plug 2006; Sacerdote 2007; Majlesi et al. 2019; Fagereng, Mogstad, and Ronning), and policy changes that affect parents' outcomes exogenously (Black, Devereux, and Salvanes 2005).

[18]In our empirical application we do not observe mothers. Under the assumption of positive

ability shocks. Individuals with high human capital are selected to be a scholar. To account for the possibility of nepotism, we allow this selection criterion to be different for sons of scholars. Once an individual becomes a scholar, his unobserved human capital translates into an observed outcome, publications, with noise.

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 $h_{i,t}$ (in logarithms). This is distributed according to a normal distribution with mean μ_h and standard deviation σ_h:

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

The offspring of this generation, indexed $t+1$, partly inherit the unobserved human capital endowment under a first-order Markov process:

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

where β is the intergenerational elasticity of human capital. The noise term $u_{i,t+1}$ represents an i.i.d. ability shock affecting generation $t+1$, which has a normal distribution, $N(\mu_u, \sigma_u^2)$.

At each generation, only a selected group of potential scholars actually become scholars. 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 became scholars:

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

As in Section 2.2, human capital is transformed into an observable outcome y with measurement error. In our case, scholars use their (unobservable) human capital to produce scientific knowledge in the form of (observable) publications. We depart from the previous literature and consider two sources of measurement error: one on the intensive margin, another on the extensive margin. 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 number of 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

assortative matching, though, the endowment inherited from father and mother is similar.

libraries anymore. That is, that we are more likely to observe the publications of a scholar with a larger record of publications. Formally, the publications for fathers, $y_{i,t}$, and sons, $y_{i,t}$, in the set of scholar lineages $\mathbb{P}$ are:

$$y_t = h_t + \varepsilon \quad \text{if} \quad h_t + \varepsilon > \kappa, \quad y_t = 0 \text{ otherwise} \tag{7}$$

$$y_{t+1} = h_{t+1} + \epsilon \quad \text{if} \quad h_{t+1} + \epsilon > \kappa, \quad y_{t+1} = 0 \text{ otherwise} \tag{8}$$

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. The former captures measurement error on the intensive margin, the latter on the extensive margin.

We assume that human capital among the population of potential scholars is stationary. This assumption allows us to put some structure into how much of the distributional differences between fathers and sons can be explained by pure reversion to the mean—that is, independently of nepotism. Formally 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 stationarity 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 $N(0, (1-\beta^2)\sigma_h^2)$.

Equation (11) suggests that a son 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 shock ω. Hence, β determines the speed at which inherited human capital advantages revert to the mean. For low values of β, the rate of mean reversion will be large—and so will the distributional differences across generations independently of nepotism. Note, however, that this describes the mean-reversion process among *potential* scholars; 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 only imperfectly proxied by y (see eq. (7) and (8)). Next,

we describe our data and how we identify our model's parameters.

3 Institutional background and data

In this section, we describe the recruitment process in universities and academies. Next, we describe the original sources used to construct our data and its coverage. We then present qualitative evidence and two stylized facts on the importance of nepotism vs. the transmission of human capital across generations.

3.1 Recruitment

Although norms varied across universities and academies, the recruitment process shared some general characteristics. The recruitment of university professors typically involved the faculty and an external authority. Specifically, the faculty proposed to appoint a candidate to a chair and the authority (e.g., Monarch, Church, Municipality, Corporation) approved it. Most chairs were filled by public competition, but professors' appointments were sometimes transferred to a representative of the authorities (Rashdall 1958: vol 2, p. 192). For example, the University of Copenhagen initially appointed its professors. Following the introduction of Absolute Monarchy in 1660, these appointments had to be approved by the King. Both steps of the recruitment process were subject to nepotism. Slottved and Tamm 2009: pp. 42-43, argues that Thomas Bartholin (1616–80) used his social connections at the University of Copenhagen as well as at the court to promote his relatives' careers. On the one hand, his permanent position as Dean of the Medical Faculty gave him influence over matters of importance at the University, particularly over appointments. On the other hand, Bartholin ingratiated himself with the King's chancellor, who also served as Chancellor of the University.

In academies, new members were elected by co-option—that is, they were elected at the discretion of existing members. In general, a member (or a group of members) sponsored an external candidate. All academy members then voted whether to accept this candidate (Foster and Rücker 1897). The available election certificates of Royal Society fellows shows that fathers never sponsored their sons. This suggests that, if there was nepotism, it was the result of fathers influencing the vote of their fellows rather than directly sponsoring their sons. In some academies, the candidates had to submit a written work for evaluation (Galand 2009). As in universities, the nomination of new academy members was sometimes subject to the approval of external authorities. For example, in the French and

Spanish Academies, the votes for new members had to be approved by the King.

Besides chaired professors and ordinary academy members, we find in our database a myriad of other scholarly positions. This includes university regents in France, docents in Germany, or fellows in England, and different academy memberships (e.g., corresponding member, honorary member, free member). These positions were used as a stepping stone to a university chair or an academy membership. Recruitment rules for these intermediate positions varied across institutions, but in general they involved insiders; i.e., faculty or academy members.

3.2 Data: Original sources and coverage

We build a new database of families of scholars in pre-industrial Europe. Our database contains $1,257$ fathers and $1,440$ sons who were members of the same university or scientific academy. We also observe 145 families with three or more generations of scholars. We cover 100 universities and 40 scientific academies[19] between 1088 and 1800. We measure scientific output using the number of publications by or about each individual that are available in libraries today. We also collect their birth and death year, the date on which each scholar was appointed, and his field of study (law, medicine, theology, science, and other arts and humanities). Finally, we collect information at the institution level: we use Frijhoff (1996) and McClellan (1985) to record the foundation date of universities and scientific academies as well as its religious affiliation after the Protestant reformation.

To reconstruct the lineages of scholars in pre-industrial Europe, we use two sources of information. First, we use secondary sources on individual universities and scientific academies. These sources include catalogues of members of a university or a scientific academy, books with scholars' biographies and bibliographies, and books on the history of each university or scientific academy. Second, we use biographical dictionaries and encyclopedias. Specifically, we focus on sources about universities or covering the regions where universities and scientific academies were located. Altogether, these sources allow us to code fathers and sons who were members of the same university or scientific academy.

Table 2 reports the ten institutions with more lineages of scholars. 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 of each professor. This, together with the Italian encyclopedia Treccani, allows

[19]This includes some important language academies, e.g., the Académie Française, the Accademia della Crusca, and the Real Academia Española.

us to reconstruct family relations among scholars in Bologna. The second largest institution is the Royal Society. This academy has list of members online, but provides no family links. We identify family links from various biographical dictionaries, e.g., the Dictionary of National Biography. For other universities, there is neither a catalogue of members nor a reference on the history of the institution. This is the case of the University of Avignon, which became important thanks to the presence of the papacy in the city.[20] In this case, we can reconstitute a sample of professors by combining various sources: Laval (1889) for the medical faculty, Fournier (1892) and Teule (1887) for lawyers, and Duhamel (1895) for rectors. To reconstruct family links, these professors are matched with their entries in the biographical dictionary of the Department of Vaucluse, France (Barjavel 1841). In our database, the University of Tübingen is the institution in the Holy Roman Empire with more lineages of scholars. In his thesis, Conrad (1960) provides a list of chair holders since the foundation of the University.[21] We established family links among Tübingen professors using the *Allgemeine Deutsche Biographie*. Specifically, we checked manually whether professors with similar names were related. The second largest academy in our dataset 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 encyclopedias. Appendix A details the institutions covered and the primary sources used for the remaining universities and scientific academies.[22]

We complement the list of scholar lineages with information on their birth, nomination, death year and field of study. We consider four fields: lawyers, physicians, theologians, and scientists. These categories correspond to the three higher faculties of early universities plus the arts faculty, where scientists gained importance over time. This information 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 77% of the observations, the death year for 88%, the nomination date for 91%, and the field of study for all scholars.

Another issue with measuring academic output from contemporaneous library catalogues arises from the possible loss of some publications over time. This does not seem to be of major importance, though. Chaney (2020) compares the books

[20] Alice Fabre compiled Avignon's lawyers and rectors for de la Croix et al. (2020).

[21] The list was digitalized by Robert Stelter for de la Croix et al. (2020).

[22] In 33 institutions, we observe only one family. These families were mentioned in sources about other institutions. That said, these families are only 2.3 percent of our sample; their exclusion does not affect the moments used in our estimations (descriptives available upon request).

Table 2: Institutions with the largest number of lineages.

Institution (dates)	N	Main Sources	Bio. dictionary†
Univ. of Bologna (1088-)	171	Mazzetti (1847)	Treccani
Royal Society (1660-)	76	www.royalsociety.org/	DNB
Uni. of Avignon (1303-1793)	58	Laval (1889), Fournier (1892) Teule (1887), Duhamel (1895)	Barjavel (1841)
Uni. of Padova (1222-)	49	Facciolati (1757)	Treccani
Uni. of Copenhagen (1475-)	47	Slottved (1978)	www.geni.com
Uni. of Tübingen (1476-)	47	Conrad (1960)	ADB
Uni. of Basel (1460-)	45	Herzog (1780)	Michaud (1811)
Leopoldina (1652-)	40	www.leopoldina.org/	ADB
Uni. of Montpellier (1289-1793)	34	Dulieu (1975, 1979, 1983)	Clerc (2006)
Uni. of Leipzig (1409-)	31	Hehl (2017)	ADB

Notes: ADB: Allgemeine Deutsche Biographie; DNB: Dictionary of National Biography; Treccani: Enciclopedia italiana; N: number of lineages; †Main biographic dictionary used.

contained in the Universal Short Title Catalogue database of St. Andrews (2019) (https://ustc.ac.uk/) with those referenced in VIAF (Virtual International Authority File). The USTC aims to cover all books published in Europe between the invention of printing and 1650. Chaney successfully located 81% of these authors in the VIAF data. Such a high level of coverage is consistent with the claim that VIAF provides a reasonable approximation to the population of known European authors. As Worldcat relies on VIAF, this also holds for Worldcat.

Finally, 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. [23] 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 he wrote that are available in WorldCat libraries today. It also includes publications about his work 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

[23] Chaney (2020) shows that the coverage of this catalogue is very good. Comparing the Universal Short Title Catalogue database of St. Andrews (2019) (https://ustc.ac.uk/) with the references found in VIAF (Virtual International Authority File), Chaney successfully located 81% of USTC authors in the VIAF data. As Worldcat relies on VIAF, this also holds for Worldcat.

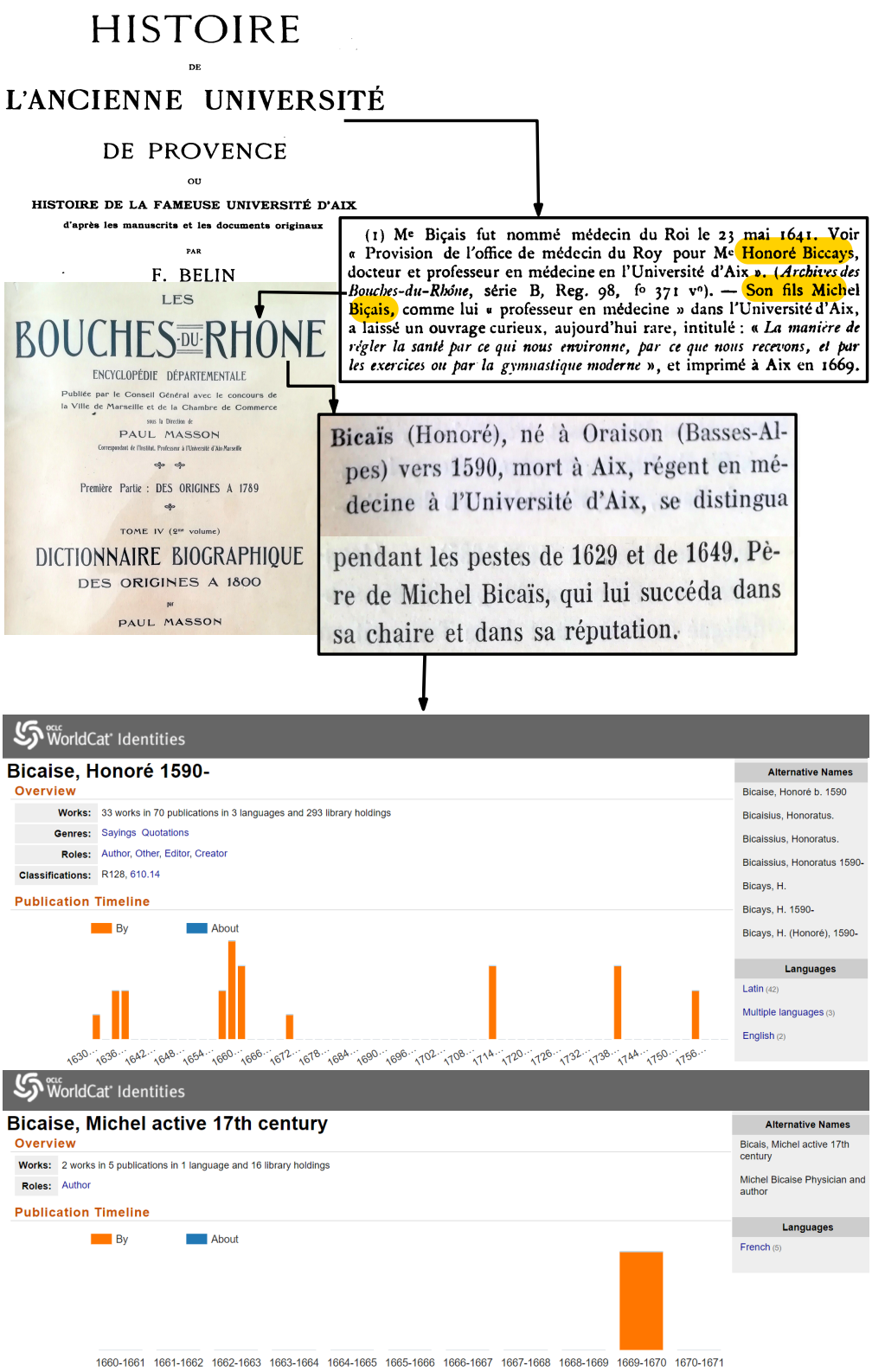
a scholar. Levels are different, but the properties of the distribution of unique works are very similar to those of library holdings.

We do not find WorldCat entries for 36.7 % of sons and for 29.5 % of fathers in our dataset. This does not necessarily mean that these scholars did not publish, but only that WorldCat libraries hold no copies of their work. To take this into account, 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 or not).

Figure 1 illustrates our data collection through an example: Honoré Bicais and his son Michel, both professors at the University of Aix. The University of Aix does not have a historical catalogue of their professors. Instead, we identify scholar families from de la Croix and Fabre (2019), who compiled a list of professors using books on the history of the University. Honoré Bicais is listed as a professor in Belin's *Histoire de l'Ancienne Universite de Provence* (1905). His entry states that his son, Michel, also became professor at Aix in the field of medicine. For birth and death year, 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, Bicays, and the latinized versions Bicaisius and Bicaissius. This facilitates matching scholars to their WorldCat entries. Honoré Bicais was a prolific scholar: there are 293 library holdings on his work. These are all copies of books originally published by Honoré himself. In contrast, there are only 16 library holdings of his son Michel's work available in modern libraries. While Michel succeeded his father in his chair, it is less clear that he did so too in his academic reputation.

Our database covers most of Europe. Figure 2 shows the geographical distribution of the covered institutions (green circles). In north-west and central Europe, we cover 27 universities (and 6 academies) in the Holy Roman Empire (HRE), 26 (and 16) in France, 6 (and 4) in England and Scotland, and 7 universities in the Netherlands. For southern Europe, the data mostly comes from 15 universities and 9 scientific academies in Italy. We also cover universities in eastern (e.g., Moscow, St. Petersburg) and northern Europe (e.g., Copenhagen, Lund, Turku, Uppsala). Universities had, on average, 10 families of scholars. Figure 2 also displays birth places (orange for fathers, red for sons). Most scholars in our dataset originate from north-west and central Europe and from Italy. In southern Europe, many

Figure 1: Example of data collection.



scholars were ordained priests who (officially) could not have children.

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, e.g., the University of Paris (officially established in 1200, but starting before), Oxford (1200), Cambridge (1209), Salamanca (1218), Prague (1348). That said, most of the scholars under analysis are from after the 1400s. Figure 3 plots the number of scholar lineages over time. Before 1400, we observe around 90 families of scholars. The number of families increases after 1400 and peaks during the Scientific Revolution of the 16th and 17th centuries. The Figure also plots the number of scholar's publications over time. Specifically, we consider the logarithm of one plus the library holdings in WorldCat 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 the number of families is stable, there is not a clear upward trend in publications. To illustrate this, we regressed the number of publications (conditional on being positive) on a constant and a time trend. The time-trend coefficient is not statistically different from zero.

3.3 Evidence on nepotism and human capital transmission

Anecdotal evidence suggests that both nepotism and the human capital transmitted from fathers to sons mattered for pre-industrial scholars' careers. For example, Jean Bauhin (1541–1613), professor in Basel, holds a remarkable publication record: there are 1,180 library holdings of 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 with the case of the Benavente family at the University of Salamanca. Juan Alfonso Benavente has 96 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 lectures were taught by substitutes, including his son Diego Alfonso Benavente (c. 1430–1512). Finally, on 1477, Benavente resigned his chair on the enforceable condition that his son was appointed to it.

FIGURE 2: Geographical distribution of scholars' lineages

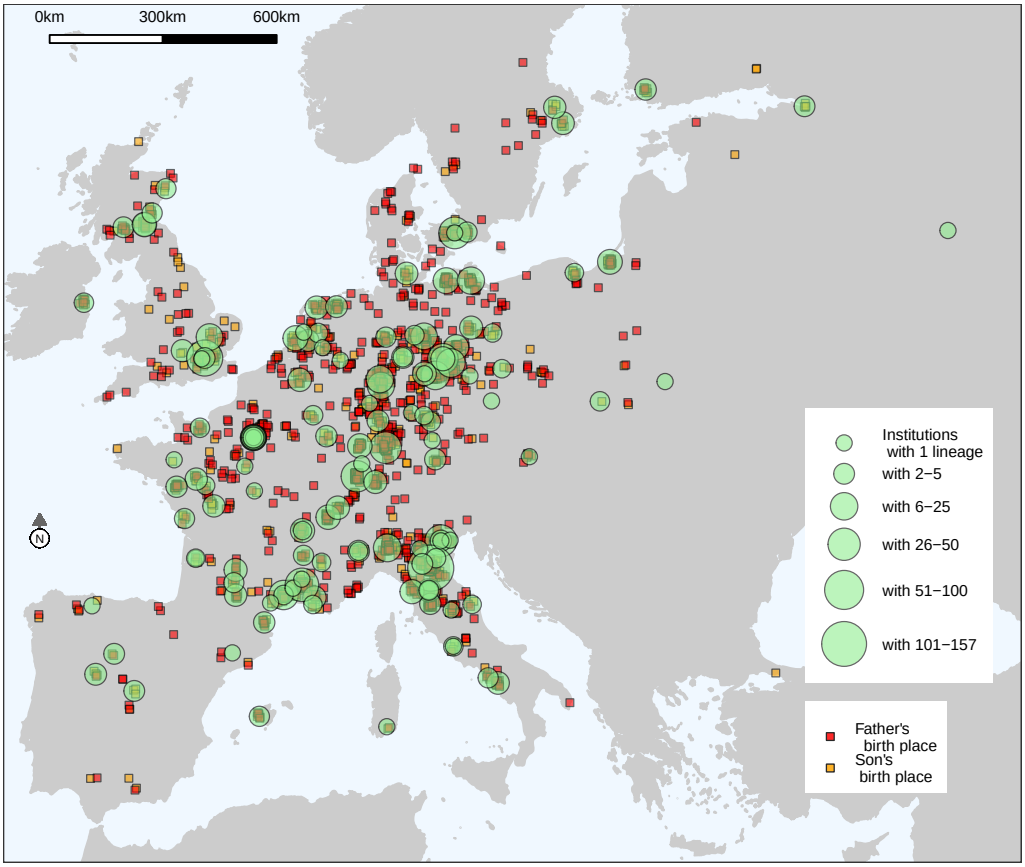
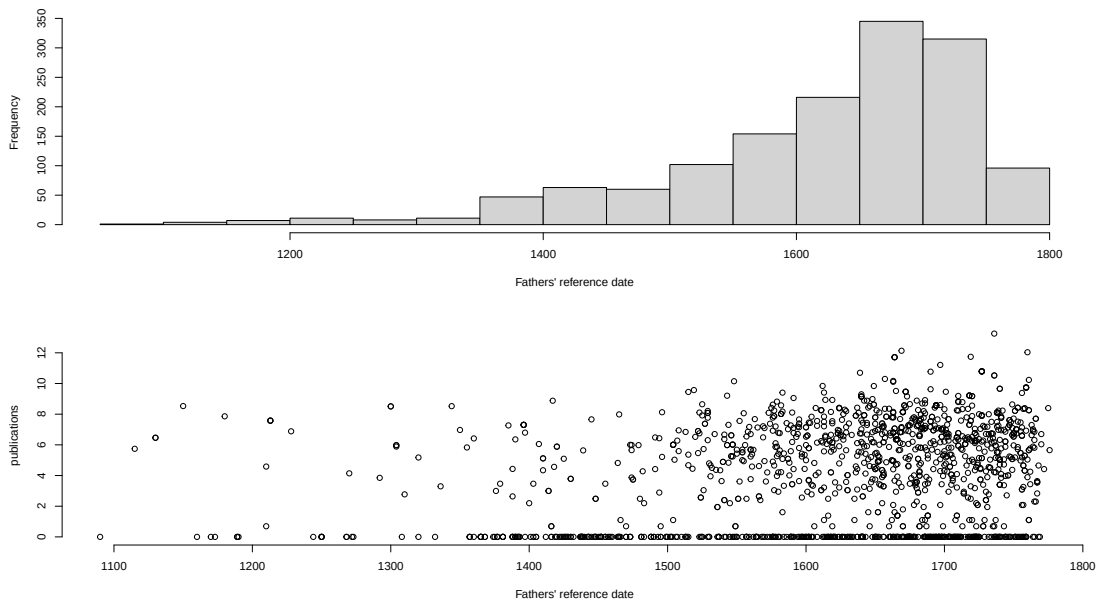


FIGURE 3: Number of families of scholars over time and their publications



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

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

Table 3 documents two 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 were later reflected in their publication outcomes. On the other hand, nepotism was also present among pre-industrial scholars.

Table 3: Moments used in the estimation.

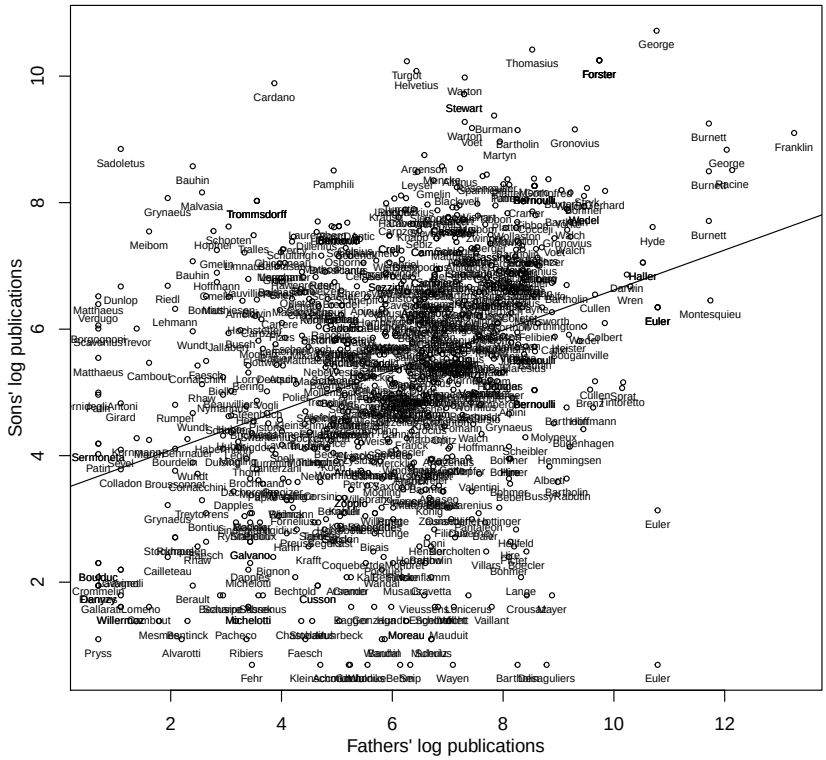
		value	s.e.	obs.
A. Intergenerational correlations				
Father-son, intensive margin	$\rho(y_t, y_{t+1} \mid_{y_t, y_{t+1}>0})$	0.35	0.04	795
Father-son with zero pubs.	$\Pr(y_t{=}0 \wedge y_{t+1}{=}0)$	0.22	0.01	1,440
Grandfather-grandson, intensive margin	$\rho(y_t, y_{t+2} \mid_{y_t, y_{t+2}>0})$	0.20	0.18	74
B. Father-son distributional differences				
Fathers with zero pubs.	$\Pr(y_t{=}0)$	0.29	0.01	1,257
Sons with zero pubs.	$\Pr(y_{t+1}{=}0)$	0.37	0.01	1,440
Fathers median	$\mathrm{Q50}(y_t)$	4.43	0.16	1,257
Sons median	$\mathrm{Q50}(y_{t+1})$	3.18	0.21	1,440
Fathers 75th percentile	$\mathrm{Q75}(y_t)$	6.79	0.08	1,257
Sons 75th percentile	$\mathrm{Q75}(y_{t+1})$	5.90	0.10	1,440
Fathers 95th percentile	$\mathrm{Q95}(y_t)$	8.67	0.13	1,257
Sons 95th percentile	$\mathrm{Q95}(y_{t+1})$	7.90	0.07	1,440
Fathers mean	$\mathrm{E}(y_t)$	4.03	0.09	1,257
Sons mean	$\mathrm{E}(y_{t+1})$	3.20	0.08	1,440

Notes: The baseline sample are families in which the father and the son are scholars; y: publications (log of 1 + library holdings by or about each author).

Fact 1: High elasticity of publications across generations. Table 3, Panel A presents father-son correlations 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 0.35 (see Figure 4 for details). This implies that an increase of one percent in a father's publications is associated with an increase of 0.35 percent in his son's publications. This elasticity of scholar's publications is comparable to the the elasticity of wealth in pre-modern agricultural

societies (Borgerhoff Mulder et al. 2009) and of educational attainment in modern Sweden (Lindahl et al. 2015). As for the extensive margin, in 22 percent of families 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.

FIGURE 4: Father-son correlation in publications



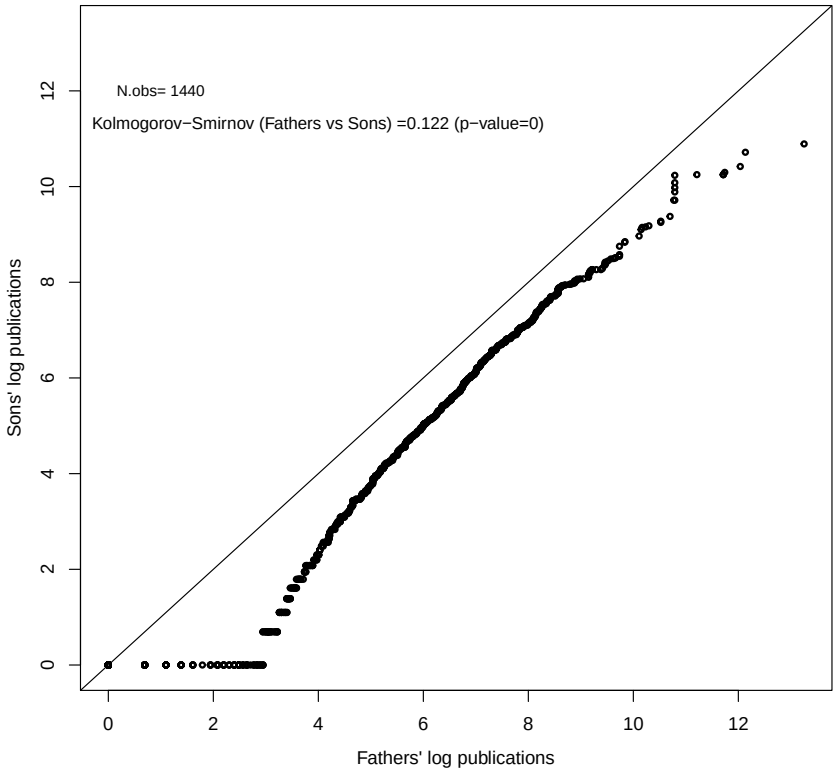
Notes: The sample are 795 father-son dyads in academia where both have at least one publication. Log-publications are log of 1 + library holdings by or about each author.

In addition, lineages with three generations of scholars display high correlations in publications on the intensive margin. The correlation between grandfathers and grandsons is 0.20. This number is larger than predicted by the iteration of the two-generation correlation, i.e., $0.35^2 = 0.12$. In other words, underlying endowments are probably more persistent than suggested by father-son correlations.

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 29 percent. The average father has twice as many publications as the average son (55 vs. 24, in levels). Fathers also have

twice as many publications as their sons in the 75th and the 95th percentile of the distribution. The differences are larger at the median: there, fathers published more than three times more than sons (83 vs. 23, in levels).[24]

FIGURE 5: Quantile-quantile plot



Notes: The sample are 1,440 families of scholars. Publications are the log of 1 + the number of library holdings by or about each author.

To illustrate these differences, Figure 5 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 lie approximately on the 45 degree line. Differently, we observe that in all quantiles fathers have 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.

The large distributional differences suggest that, compared to sons, fathers had higher endowments of human capital, which translated into a better publication record. Partly, the difference in human capital endowments between fathers and

[24]Specifically, the differences in levels are $\exp(4.03) - 1 = 55.3$ vs. $\exp(3.20) - 1 = 23.5$ in the mean and $\exp(4.43) - 1 = 82.9$ vs. $\exp(3.18) - 1 = 23.0$ in the median.

sons can be explained by reversion to the mean. We are looking at a sample of individuals at the top of the human capital distribution, and hence, if there is reversion to the mean, sons should to some extent be worse than fathers. That said, the rate of mean reversion needed to explain away the observed distributional differences is implausibly high, especially in light of the high correlation in publications across generations (fact 1). Instead, much of these distributional differences likely reflect nepotism. That is, that fathers may have used their power and influence in the profession to allocate jobs to their sons ahead of outsiders, even when the former had low human capital endowments. For example, Figure A.II in the appendix uses data from de la Croix (2021) to compare scholar's sons to outsiders—that is, scholars whose parents were not academics. The figure shows that sons of scholars had a worse publication record not only than their fathers, but also than outsiders. Even when human capital slowly reverts to the mean, this kind of nepotism generates father-son distributional differences in observed outcomes, especially at the bottom of the distribution, i.e., closer to the selection thresholds. We can use these excess distributional differences, net of reversion to the mean, to identify nepotism.

In sum, the strong father-son correlations in observed publications (fact 1) suggest that the rate of mean-reversion in human capital is slow. In contrast, the distributional differences alone (fact 2) seem to suggest that human capital reverts to the mean rapidly. We argue that these two apparently contradictory facts can be reconciled with the existence of nepotism, which allows sons of scholars to become scholars with low human capital endowments.

4 Identification of parameters and main results

4.1 Identification

The model's main parameters are the intergenerational elasticity of human capital, β, and the degree of nepotism, ν. In addition, the parameters σ_e and κ capture the extent to which the human capital endowment translates into the observed publications, and 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 above. Finally, μ_h and σ_h shape the human capital distribution and τ the selection into being a scholar independent of nepotism.

We estimate these 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 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 grandfather-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 distribution of publications.

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 2.2). 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 with differences in the distribution of the observed outcome y across generations. In contrast, nepotism lower the selected sons' human capital relative to that of their fathers. This generates distributional differences across generations (beyond those generated by reversion to the mean), as suggested by Figure 5. Intuitively, the distributional differences generated by nepotism are stronger at the bottom of the distribution, i.e., closer to the selection thresholds. Our estimation strategy, hence, will put additional weight on 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 disentan-

gle 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 to correct for measurement error without resorting to grandfather-grandson correlations. That said, in our empirical application measurement error is governed by two parameters, σ_e and κ. This additional moment, i.e. grandfather-grandson correlations, helps to identify σ_e and κ separately.[25]

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

(i) generates (does not generate) father-son distributional differences;

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

(iii) increases (reduces) the information that father-son correlations convey about intergenerational 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.

4.2 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 model's parameters, 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 the weight of moment j. As explained above, λ_j attaches 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 in the 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 used when the theoretical moments cannot be computed explic-

[25] In other words, for datasets in which κ is not binding, the measurement error bias is governed by one parameter, σ_e. This can be identified with the variance of the observed outcome's distribution across generations, without resorting to grandfather-grandson correlations.

itly 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 and publications are calculated as 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 criteria to become scholars, i.e., equation (6). To calculate grandfather-grandson correlations, we further restrict the simulated sample to families in which scholar's grandsons also meet the (nepotic) criteria to become scholars, i.e., $h_{t+2} > \tau - \nu$.

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.

4.3 Aggregate results (1088–1800)

Table 4 presents the identified parameters for the entire period 1088 to 1800. The most important estimates are ν (nepotism) and β (intergenerational elasticity of human capital). In sum, we find that one in six scholar's sons became scholars thanks to nepotism and that human capital was inherited with an intergenerational elasticity of 0.59. Next, we discuss the identified parameters in detail.

Nepotism. We find that nepotism was non-negligible among university scholars in pre-industrial Europe. To interpret the magnitude of ν, note that the son of a scholar becomes a scholar if his human capital is above $\tau - \nu = -7.515$. This number is substantially lower than the estimated mean human capital in the population of potential scholars, $\mu_h = 2.383$, 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 $\sigma_h = 3.616$ for the human capital of potential scholars. This implies that the son of a scholar could become a scholar even if his human capital was 2.2 standard deviations lower than the average potential scholar, and 2.1 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 $\nu = 0$. That is, we impose the same selection criteria for sons of scholars and outsiders. Our simulations suggest that, in 1088–1800, around sixteen percent of sons of scholars were nepotic scholars who would not

have become scholars under the same selection criteria as outsiders. Second, we evaluate the impact of nepotism on scientific production. We identify the nepotic scholars from the previous counterfactual exercise and replace them with an average potential scholar. We find that this would increase by 19 percent the scientific output of the average scholar in the simulated economy.

TABLE 4: Identified parameters.

Parameter		value	s.e.
Intergenerational elasticity of human capital	β	0.594	0.046
Nepotism	ν	7.515	1.552
Std. deviation of shock to publications	σ_e	0.340	0.128
Threshold of observable publications	κ	2.144	0.159
Mean of human capital distribution	μ_h	2.383	0.410
Std. deviation of human capital distribution	σ_h	3.616	0.210

Notes: τ normalized to 0; s.e. obtained by estimating parameters on 100 bootstrapped samples with replacement; degrees of overidentification: 6

Human capital transmission. We estimate an intergenerational elasticity of human capital, β, equal to 0.59. This implies that, in lineages of scholars, sons inherited 59 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 (Clark 2015).

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 2.2, 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 2.3). Of course, it could also be that our lower elasticities are specific to our empirical application.

To evaluate these possibilities empirically, we use our data on pre-industrial scholars to calculate intergenerational elasticities using two standard methods in

the literature. The results are in Table 5. First, we estimate a standard elasticity based on regressing sons' outcomes on fathers' outcomes. Specifically, we estimate b from equation (1), where outcome y is the logarithm of 1 + number of publications. The estimated coefficient is $\hat{b} = 0.478$, which implies that an increase of one percent in a father's publications is associated with an increase of 0.5 percent in his son's publications. This strong persistence of publication attainment across two generations is comparable, e.g., to the persistence of education attainment in Germany (Braun and Stuhler 2018). That said, this elasticity is lower than our model's estimate for $\beta = 0.59$. The discrepancy is more striking when we compare our β-estimate to elasticities in the intensive margin, b_I.[26] 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 a scholar's outcomes that children inherit from their parents, is more persistent than what parent-child correlations in publications suggest.

Table 5: Intergenerational elasticites amongs scholars, different methods.

method		value	s.e.	N	reference
Two-generations, all	$\hat{b}$	0.478	0.021	1,440	Equation (1)
Two-gener., intensive marg.	$\hat{b}_I$	0.345	0.031	795	Equation (1)
Multiple-generations	$\hat{\beta}$	0.751	0.086	183	Braun and Stuhler (2018)
Multiple-generations	$\hat{\beta}_A$	0.679	0.080	183	Braun and Stuhler (2018)
Model's β	β	0.594	0.046	1,440	-

Notes: The sample are 1,440 scholars and their fathers. In row 2, this is restricted to 795 families in which both father and son have at least one publication. In rows 3 and 4, the sample are 183 scholars (G3), their fathers (G2), and grandfathers (G1); $\hat{\beta} = b_{G1-G3} \ / \ b_{G2-G3}$ and $\hat{\beta}_A = b_{G1-G3} \ / \ average\left(b_{G1-G2}, b_{G2-G3}\right)$, where $b_{Gi-Gj} = cov(y_{Gi}, y_{Gj}) \ / \ var(y_{Gi})$ is the elasticity of publications between generations Gi and Gj. Bootstrapped standard errors in parenthesis.

Next, we compare our β-estimates to those obtained using the multiple generations method proposed by Braun and Stuhler (2018). 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 grandfather-grandson elasticity ($n = 2$) and father-son elasticity ($n = 1$) identifies β. We use our sample of lineages with three generations to estimate this ratio. Specifically, we use 183 scholars (generation 3) with their fathers (generation 2) and one of their grandfathers (generation 1) in academia. We report estimates of

[26] A means t-test rejects the null that our model's β is the same as the estimates $\hat{b}$ and $\hat{b}_I$.

$\hat{\beta}$, the ratio of the elasticity between generations 1 and 3 to the elasticity between generations 2 and 3. We also report $\hat{\beta}_A$, the ratio of the elasticity between generations 1 and 3 to the average elasticity between generations 2 and 3 and generations 1 and 2. These methods yield a β between 0.679 and 0.751, a substantially larger value than our model-based β and close to the estimates of Clark (2015). This suggests that in empirical applications where nepotism is prevalent, the multiple-generation β-estimates proposed by the literature can be upward biased.

Other parameters. We find that the distribution of human capital in the population of potential scholars has a mean of $\mu_h = 2.383$ and a standard deviation of $\sigma_h = 3.616$. Since we normalized $\tau = 0$, this implies that the average potential scholar can become a scholar, but not those with human capital one standard deviation lower than the mean—unless their fathers are scholars. Using stationarity conditions (9) and (10), we pin down $\mu_u = 0.967$ and $\sigma_u = 2.909$. That is, the mean and the standard deviation of the random ability shocks to a (potential) scholar's human capital, independent of his inherited endowments.

As for the production function of scientific output, we find an imperfect relation between human capital and publications. The shock affecting how scholar's human capital translates into publications, ϵ, has a standard deviation of $\sigma_e = 0.340$. 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, publications are a noisy proxy for human capital. We estimate a relatively high $\kappa = 2.144$. This implies that the publication record of pre-industrial scholars who published three works ($\exp \kappa - 1$) is likely to be unobserved in our data. In other words, observing zero publications may reflect a scholar's low level of human capital or the fact that some of his publications have been lost and are not held in modern libraries.

4.4 Model fit

Next, we compare the empirical moments to those simulated by our model. Here we show that we match the father-son distributional differences (Fact 2). Appendix D shows that we also reproduce the high elasticity of publications across generations (Fact 1) and the empirical fact that the grandfather-grandson correlation is larger than predicted by iterating the two-generation correlation.

Figure 6 shows the distributional differences between fathers and sons. Specifically, we plot 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 both distributions: we perfectly match the proportion

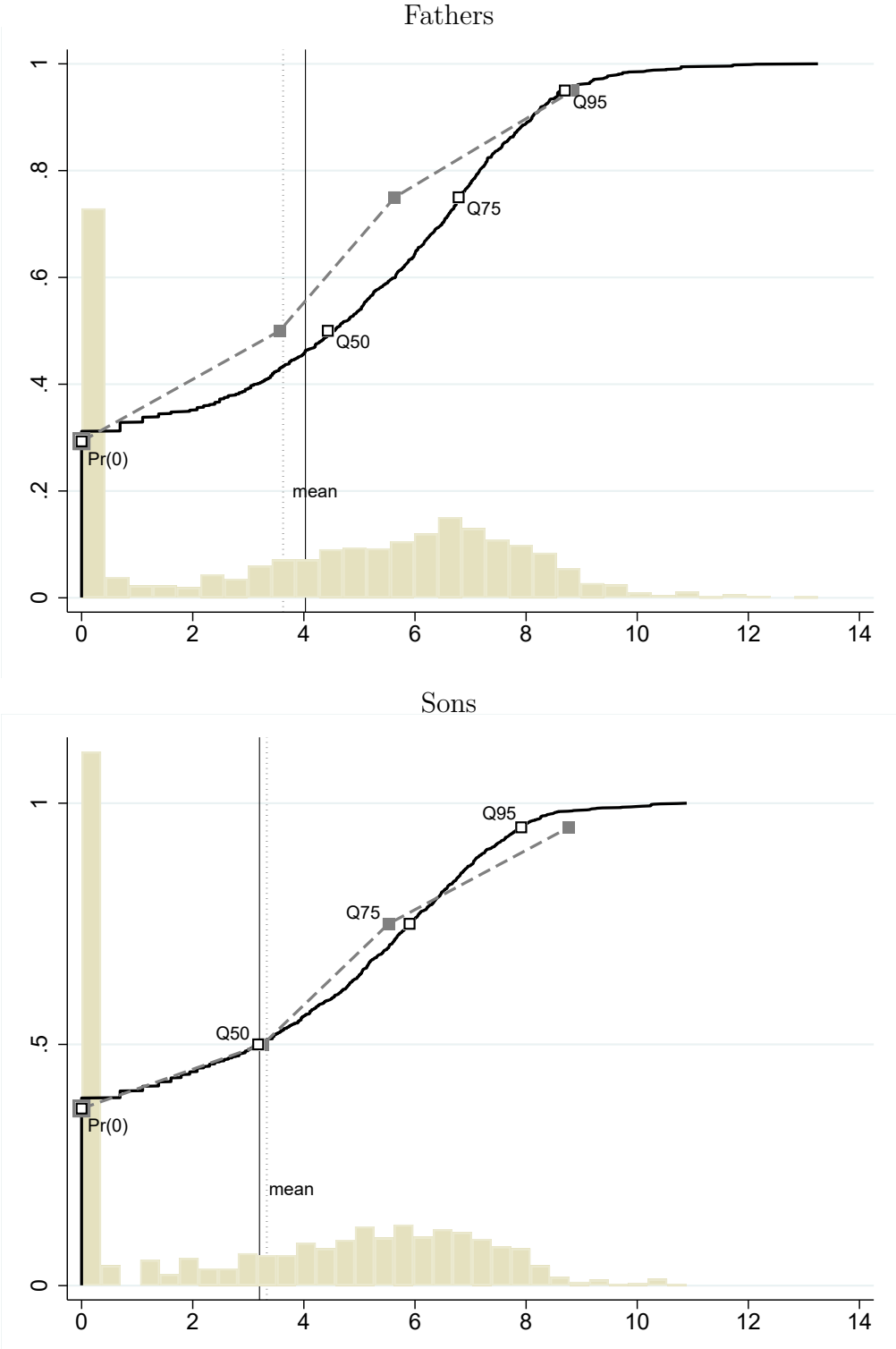
of fathers and sons with zero publications. These are the two moments to which our objective function attaches additional weight (see eq. (12)). We also match their means, medians, 75th and 95th percentiles. For fathers, we underestimate the number of publications, especially in the 75th percentile.

Importantly, we reproduce the distributional differences between fathers and sons (Fact 2). The fathers' 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 father and the father on the 75th and 95th percentile published more than the corresponding sons. We also reproduce the empirical observation that the gap between fathers' and sons' publications is more prominent at the bottom of the distribution: 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. For example, the gap between fathers and sons (in levels) in the median is more than two times larger than in the 75th percentile.

Nepotism is crucial for reproducing the father-son distributional differences in publications. To show this, we estimate an alternative model ignoring the selection bias emerging from nepotism. We set $\nu = \tau = 0$, that is, we assume that sons of scholars were selected into becoming a scholar under the same criteria as outsiders. Note that, in this alternative model, the only force that can generate distributional differences is mean reversion—since scholars are at the top of the human capital distribution, reversion to the mean will worsen the sons' publications relative to that of their fathers. This effect should be larger for top scholars' sons than for average scholars' sons. Table A.viii (appendix D) presents the estimated parameters and the simulated moments. Consistent with our theoretical prediction, the model without nepotism is able to reproduce some distributional differences at the top: in the 95th percentile, sons perform slightly worse than their fathers. That said, this alternative model fails to match Fact 2, that is, that the fathers' distribution of publications first order stochastically dominates that of sons: the simulated mean, median, and the proportion of non-zero publications are not larger for fathers than for sons. In other words, the observed distributional differences are hard to reconcile with a model of mean reversion that ignores nepotism.

The alternative model estimates a substantially larger β than our baseline model. When we ignore nepotism we find an intergenerational elasticity of 0.72, close to the 0.75 estimate by Clark (2015) and to the 0.68-0.75 estimate that we obtained applying standard multi-generation estimates to our data (see Table 5). This strongly suggests that ignoring the selection bias arising from nepotism can

FIGURE 6: Publication's distribution, lineages of scholars



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

overstate the rate at which children inherit their parents' underlying endowments.

4.5 Results over time

So far we have shown that, between 1088 and 1800, sixteen percent of scholars' sons became scholars because of nepotism, which reduced scientific output by 19 percent. These aggregate effects, however, mask interesting dynamics. Next, we evaluate whether periods of rapid scientific advancement are associated with a decline in nepotism, and hence, a better allocation of talent in academia. We narrow our focus to the two proclaimed roots of all modern technological advances: the Scientific Revolution (Wootton 2015) and the Enlightenment (Mokyr 2009).

We divide our families of scholars into four periods based on the father's reference date. These periods correspond to the standard dates marking the Scientific Revolution and the Enlightenment: **(i)** before 1543, when Copernicus' *De revolutionibus orbium coelestium* was published; **(ii)** 1543–1632, the beginning of the Scientific Revolution, which focused on recovering the knowledge of the ancients; **(iii)** 1632–1687, the Scientific Revolution, from Galileo's *Dialogue Concerning the Two Chief World Systems* to Newton's 1687 *Principia*; and **(iv)** 1687–1800, the age of Enlightenment.

For the sake of illustration, Figure A.III in the appendix presents QQ-plots comparing the fathers' and sons' distribution of publications across historical periods. For all periods, the father's publication record dominates their son's. That said, the distributional differences decrease over time: they are the largest before 1543, are substantially reduced during the Scientific Revolution (1543–1632 and 1632–1687), and are the smallest around the Enlightenment (1687–1800). This suggests that, over time, selected sons became more similar to their fathers in terms of underlying endowments, e.g., human capital.

Table 6 shows that this was due to a decrease in nepotism. We simulate our model with the estimated parameters in each period and remove nepotism by setting $\nu = 0$. Our simulations show that, before 1543, almost fourty percent of the sons of scholars were nepotic scholars. That is, they would not have become scholars under the same selection criteria as outsiders. This percentage is dramatically reduced to 14-16 percent during the Scientific Revolution, and drops to only 3.8 percent during the Enlightenment. In other words, the increase in scientific production during the Scientific Revolution and the Enlightenment is negatively associated with the practice of nepotism in universities and scientific academies.

The decline of nepotism could be the result of two different processes: one pos-

sibility is that *existing* universities and academies undertook structural reforms to eliminate nepotism from their hiring decisions. Another possibility is that *new* institutions were established under more modern, meritocratic principles. The evidence supports the latter. In Table 6, we compare families of scholars in institutions established before and after 1543, the start of the Scientific Revolution (see appendix Figure A.IV for the QQ-plot). We only consider families of scholars after 1543 such that both groups are comparable. We find that nepotism was three times smaller in new universities and scientific academies than in institutions which had been funded before the Scientific Revolution (14.38 vs 5.89 percent).

Finally, this analysis allows us to shed new light on Clark's (2015) hypothesis that β, the rate at which children inherit endowments from their parents, is close to a universal constant over time. Our findings do not support this hypothesis. Our β-estimate ranges from 0.42 before 1543 to 0.59 in 1688–1800. Interestingly, we find an increasing trend over time. During the Scientific Revolution (1543–1632), scholars inherited human capital and other underlying endowments from their parents at a higher rate than pre-1543 scholars. Similarly, the Enlightenment (1715–1789) is characterized by a persistent transmission of underlying endowments within lineages of scholars. These findings suggest that the intergenerational transmission of human capital endowments is subject to changes in the environment. In other words, among pre-industrial scholars, β reflects nature but also nurture.

TABLE 6: Results over time.

	β	ν	σ_e	κ	μ_h	σ_h	% nep	N
Pre-Scientific Rev. (1088-1543)	0.42	7.86	1.73	2.70	-0.48	3.75	39.89	288
Scientific Revolution (1543-1632)	0.59	6.63	0.35	2.09	2.58	3.46	14.38	305
Scientific Revolution (1633-1687)	0.58	9.44	0.32	1.51	2.44	3.81	16.31	343
Enlightenment (1688-1800)	0.59	5.61	0.19	2.75	4.34	2.68	3.78	502
Institution established pre-1534	0.61	5.45	0.53	2.37	2.35	3.29	14.38	604
Institution established post-1534	0.54	5.69	0.25	1.69	4.33	3.06	5.89	548

Altogether, our estimates suggest an inverse relationship between nepotism and β, the rate at which scholars inherited human capital endowments from their parents. In the early stages of universities and scientific academies, families of scholars emerged as a result of nepotism: scholars used their power and influence to appoint their sons, even those who had low human capital. 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. In other words, lineages of scholars became more meritocratic. This suggests that the establishment of open universities and the emergence of meritocratic lineages in pre-industrial Europe was a stepping stone to the production of new ideas and to the accumulation of upper-tail human capital.

5 Validation and heterogeneity

In this section, we perform a validation test by estimating our model on an alternative sample where, *ex ante*, we expect no nepotism. We then explore heterogeneous effects in Protestant vs. catholic institutions, by field of study, by sons nominated before vs. after their father's death, and by universities vs. academies.

5.1 Validation using families at different universities

Our baseline sample considers fathers and sons in the same university or scientific academy. *Ex ante*, one would expect sons who also held positions at a different institution than their fathers to be more meritocratic; they should reflect a strong transmission of human capital across generations and not nepotism. The reason is that social connections may be more important for obtaining a job where one's father is employed than in a different university or scientific academy.

We exploit this to conduct a validation test. We estimate our model for an alternative sample of 390 scholars who were appointed to at least one different university or scientific academy than their fathers. Seventy percent of these families are also in the baseline sample—that is, they held positions in the same and in different institutions. The remaining 30 percent are scholar families in which fathers and sons were never in the same institution. Since we expect these lineages to be meritocratic, a large estimate for our nepotism parameter would falsify our identification strategy. It would suggest that our nepotism parameter captures other elements of the university's hiring process—e.g., information frictions affecting scholars' sons and outsiders differently.

Table 7 provides the empirical moments and the model's estimates for this alternative sample. As expected, fathers and sons appointed to at least one different institution have a better publication record: the percentage of fathers and sons with zero publications is higher in the baseline sample, and the mean, median, 75th and 95th percentile are higher for fathers and sons in different institutions. Importantly, the distribution of publications of fathers no longer first-order stochas-

tically dominates that of sons. In fact, for families in different institutions, sons outperform their fathers. Finally, the father-son correlation is lower for families in different institutions, especially in the extensive margin.

TABLE 7: Fathers and sons at different universities.

		Baseline sample		Different universities	
Parameters					
Interg. elasticity human capital	β	0.59	(0.05)	0.50	(0.14)
Nepotism	ν	7.52	(1.55)	0.03	(2.29)
S.D. shock to publications	σ_e	0.34	(0.13)	1.53	(0.33)
Threshold observable publications	κ	2.14	(0.16)	1.64	(0.41)
Mean human capital distribution	μ_h	2.38	(0.41)	4.73	(0.27)
S.D. human capital distribution	σ_h	3.62	(0.21)	3.12	(0.41)
% nepotism		15.7%		0.11%	
Data moments					
Fathers with zero publications		0.29		0.16	
Sons with zero publications		0.37		0.10	
Median, fathers		4.43		5.49	
Median, sons		3.18		6.40	
75th percentile, fathers		6.79		7.21	
75th percentile, sons		5.90		7.45	
95th percentile, fathers		8.67		8.79	
95th percentile, sons		7.90		9.16	
Mean, fathers		4.03		4.87	
Mean, sons		3.20		5.70	
Father-son correlation†		0.35		0.26	
Father-son with zero publications		0.22		0.05	
Grandfather-grandson correlation†		0.20		-0.04	
N (sons)		1,440		390	

Notes: †correlation on the intensive margin. Standard errors from estimating parameters on 100 bootstrapped samples with replacement in parenthesis.

Our estimates show that nepotism was negligible when sons were appointed to a different institution than their fathers: the parameter ν is close to zero.[27] Admittedly, this estimate has large standard error. Nevertheless, it suggests that the (unobserved) human capital required to become a scholar was not statistically different for fathers and sons when they were appointed to different institutions. Consistent with this, our model simulations show that, for this alternative sample, only 0.11 percent of scholars' sons were scholars because of nepotism. Finally,

[27]For this estimation, we restricted ν to be greater than or equal to zero.

families of scholars in different institutions transmitted their human capital endowments with an elasticity of 0.50.

Other than validating our identification strategy, this result is interesting in its own right. It shows that mobile families of scholars, in which fathers and sons had appointments in different institutions, were not the result of nepotism. This suggests that the establishment of a broader academic market with hiring across universities (de la Croix et al. 2020) might have been crucial for the establishment of modern, open universities that were not subject to nepotism.

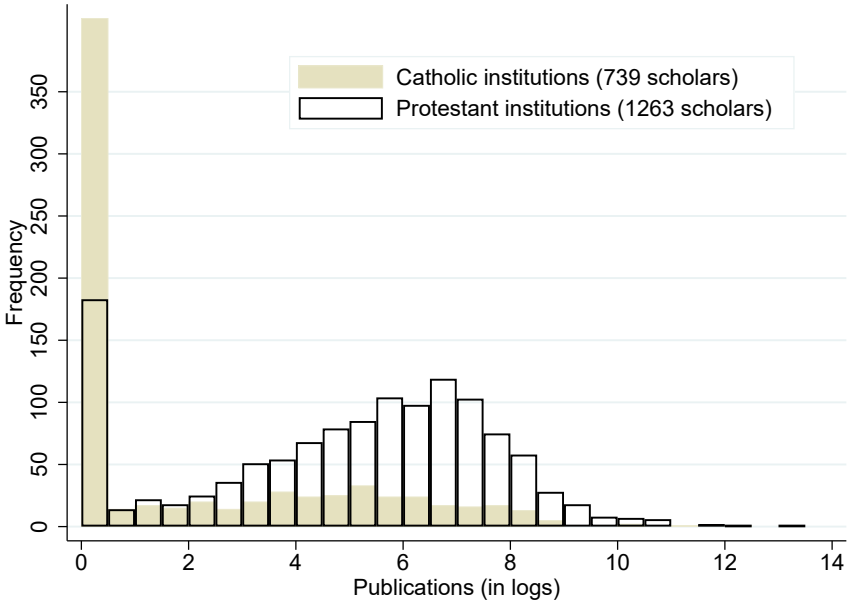
5.2 Protestant reformation

Here we narrow the focus on a historical event often deemed crucial for the rise of modern science: the Protestant Reformation. Merton (1938) argued that there was a direct link between Protestantism and the Scientific Revolution; Protestant values encouraged scientific research because they 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).[28] We shed new light on this debate by showing that differences in the scientific output of Protestant vs. Catholic universities are associated with differences in both nepotism and in the transmission of human capital across generations of scholars.

Figure 7 shows that scholars in our dataset (i.e., those belonging to a lineage of scholars) were more productive in Protestant than in Catholic institutions. Specifically, we sort scholars according to the religious affiliation of their university or scientific academy. We exclude all lineages before 1527—when the first Protestant university was created in Marburg. The figure shows that 55 percent of scholars in Catholic institutions had zero publications. The corresponding percentage was 14.5 in Protestant institutions. Conditional on having at least one publication, the average scholar in a Protestant institution had thrice the number of publications than the average scholar in a Catholic institution (93 vs. 295 in levels). Differences are also visible at the upper-tail of scientific production. For example, we observe a much higher frequency of Protestant scholars with more than 1,000 library holdings (more than 7 log-publications).

[28]Lenski argued that, after the Reformation, Catholic leaders identified intellectual autonomy with Protestantism and heresy (p. 176): "In the centuries before the Reformation, southern Europe was a center of learning and intellectual inquiry [...] The Protestant Reformation, however, changed the rules. It gave a big boost to literacy, spawned dissents and heresies, and promoted the skepticism and refusal of authority that is at the heart of the scientific endeavor. The Catholic countries, instead of meeting the challenge, responded by closure and censure."

Figure 7: Publications, by institution's religious affiliation.



Notes: The sample are 2,002 scholars who (1) were nominated after 1527 and (2) belong to a scholar's lineage. Log-publications are the log of 1 + library holdings by or about each author.

The larger scientific output in Protestant institutions is associated with lower levels of nepotism. Table 8, Panel A presents our estimated parameters for Protestant and Catholic universities (QQ plot in Appendix, see Figure A.v). 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 parents. That said, lineages of scholars in Catholic universities were a by-product of nepotism. 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, 29 percent of the sons of scholars were nepotic scholars. Nepotism was much less prevalent in Protestant universities: there, we only identify 4 percent of scholars' sons as nepotic.

The difference in nepotism between Catholics and Protestants can account for substantial differences in scientific output. We perform a counterfactual exercise in which we replace nepotic scholars for average potential scholars. By removing nepotism, the publications of the average scholar increase by 42 percent in catholic institutions and by only 4.3 percent in Protestant institutions. This accounts for 18.7 percent of the Catholic-Protestant gap in mean publications.[29]

[29]The Protestant-Catholic gap in the son's mean log-publications is 2.9. Removing nepotism increases publications by 4.3 and 42%, leading to a counterfactual gap of 2.47 log-publications.

In sum, these results suggest that Catholic universities fell behind their Protestant counterparts after the Reformation, and that nepotism and inherited human capital were crucial factors behind this divergence. First, the dissemination of knowledge in Catholic universities relied heavily on the transmission of knowledge within families. As argued by Greif (2006) and de la Croix, Doepke, and Mokyr (2018), this can lead to distortions ultimately affecting the production of ideas. Second, nepotism was considerably smaller in Protestant institutions. This improved the allocation of talent in Protestant academia, and hence, contributed to the advancement of science and the accumulation of upper-tail human capital.

Table 8: Heterogeneity.

	β	ν	σ_e	κ	μ_h	σ_h	% nep	N
A. University's religion (after 1527)								
Protestant	0.46	6.50	0.16	1.79	4.61	2.79	4.08	753
Catholic	0.73	8.08	0.63	2.14	-0.99	3.97	29.48	424
B. Field of study (of fathers)								
Lawyer	0.74	3.86	1.61	2.56	-0.72	3.87	25.37	357
Physician	0.61	7.75	0.63	2.08	1.58	3.80	19.83	423
Theologian	0.48	4.49	0.26	1.82	4.69	2.62	2.99	206
Scientist	0.58	8.08	0.33	2.00	3.89	3.35	8.38	231
Father & son in same field	0.65	7.18	0.37	2.08	1.53	3.94	19.18	1053
Father & son in diff. field	0.52	9.38	0.28	2.05	3.58	3.20	9.42	387
C. Son appointment date								
After father's death	0.55	5.93	0.50	2.10	3.23	3.19	10.48	606
Before father's death	0.65	7.09	0.37	1.73	1.95	4.03	17.38	602
D. Universities vs. Academies								
Universities	0.61	4.41	0.26	2.25	3.14	3.22	10.17	841
Academies	0.55	7.19	0.29	1.70	3.80	3.49	9.47	311

5.3 Results by field of study

Here, we estimate the prevalence of nepotism and the strength of human capital transmission in different fields of study. This is important as different types of upper-tail human capital may have different implications. For example, Murphy, Shleifer, and Vishny (1991) and Maloney and Valencia Caicedo (2017) emphasize the importance of engineers for modern economic development. In medieval Europe, university training in Roman law helped in establishing markets during the Commercial Revolution (Cantoni and Yuchtman 2014). During the Scientific

Revolution, research and teaching in science gained importance within the faculty of arts, which also encompassed philosophy, music, and history.[30]

We consider four fields: science (arts), law (canon and Roman law), medicine (including pharmacy and surgery), and theology.[31] Table 8, Panel B presents our estimates of the model's parameters, by field (QQ plot in Appendix, see Figure A.VI). Specifically, lineages are sorted into fields according to the father's field of study. The transmission of human capital across generations ranges between 0.48 among (Protestant) theologians[32] and 0.74 amongst lawyers. As stressed in Section 4.5, this finding does not support the hypothesis that β is a universal constant, but instead is shaped by different institutional environments.

Nepotism was most prevalent in law faculties. Our simulations suggest that 25.4 percent of law scholars' sons were nepotic scholars. Nepotism was also a common among physicians: 19.8 percent of physicians' sons became scholars thanks to nepotism. This is in line with Lentz and Laband (1989), Mocetti (2016), and Raitano and Vona (2018), who find high levels of nepotism for modern lawyers, pharmacists, and doctors. We find that 8.4 percent of scientists' sons were nepotic scholars, suggesting that applied sciences were more open to newcomers. This reinforces our previous finding that the Scientific Revolution, a period when science gained importance, was associated with a decline in nepotism.

This data also allows us to compare sons who followed their father's footsteps in the same field of study with those who published or taught in a different field. This exercise is interesting in two respects: first, one would expect families in the same field to be less meritocratic—a son's inherited social connections may be more important for obtaining a job in the same faculty as his father (science, law, medicine, and theology). Second, comparing these two types of families allows us to separate the transmission of general human capital from the transmission of human capital specific to the father's field of study.[33]

Table 8 presents the results.[34] As expected, families with fathers and sons in different fields were more meritocratic: they had larger human-capital endowments (μ_h 3.58 vs. 1.53) and were less nepotic. In contrast, we estimate that 19.2 percent

[30]Some faculties of arts, however, were slow to respond to rapidly evolving fields, such as cartography and astronomy. This led major scientists to quit their universities before the end of their careers (Copernicus, Kepler, or Galileo). See Pedersen (1996).

[31]We omit other fields belonging to the faculty of arts, e.g., Hebrew, Philosophy, and Rhetoric.

[32]Scholars in Catholic theology faculties were ordained priests and had no legitimate children.

[33]Note that, in our framework, human capital includes any inherited endowment that affects a child's productivity: abilities, skills, genetic advantages, etc. as well as the knowledge acquired from one's parents. This knowledge can be general or specific human capital.

[34]Some fathers and sons published in more than one field. We consider them to be in the same field if any of their multiple fields of study coincided.

of scholars sons became scholars in their father's field because of nepotism; more than twice the percentage of nepotism for families in different fields.

We also find a stronger transmission of human capital between fathers and sons in the same field. For them, we estimate a β of 0.65, thirteen percentage points larger than for families in different fields. This difference can be attributed to the transmission of field-specific human capital. That said, the fact that human capital was also strongly inherited by sons who ended up working in a different field than their parents highlights the importance of general human capital.

Finally, this finding adds credence to our identification strategy. Altough, in general, we find that nepotism and inherited human capital are negatively related (see Table 6 and discussion), this is not an artificial byproduct of our model or of our estimation strategy. In settings where we expect both high transmission of human capital and high nepotism—such as among fathers and sons in the same field—our estimates for β and for nepotism are positively related.

5.4 Son's nomination date

Nepotism can take 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 8, Panel C presents the estimated parameters for these two subgroups. Our model simulations suggest that 17.4 percent of sons nominated during their father's lifetime were nepotic scholars. That is, had they been outsiders, they would not have been nominated. Alternatively, we find nepotism in 10.5 percent of sons nominated after their father's death. This suggests that, in our setting, nepotism is characterized by fathers using their social connections to nominate their sons rather than by fathers passing down their chairs upon their death as part of the inheritance—although the later form of nepotism is not negligible.

Finally, note that 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 of 0.65, ten percentage points larger than for lineages in which the son was nominated after his father's death. This suggests that scholars nominated at an early age strongly inherited their parents' human capital endowments.

5.5 Universities vs. Academies

In Section 4.5 we have shown that nepotism declined during the Scientific Revolution. At that time, however, some saw universities as an obstacle to modernity. For example, Manuel (1968) described Cambridge as "an intellectual desert, in which a solitary man [Newton] constructed a system of the world." In contrast, many scholars became members of the academies created during the Scientific Revolution (e.g., Académie des Sciences (1666), the Royal Society of London (1662), and the Academia Leopoldina (1677)). These academies formalized the Republic of Letters and were a key engine of cultural change (Mokyr 2016).

Table 8, Panel D compares families of scholars in universities vs. academies (see also Figure A.viii). We do this to examine whether academies were the (only) modern, meritocratic research institutions during the Scientific Revolution. We restrict our sample to families of scholars active after the start of the Scientific Revolution in 1543. Our estimated parameters are similar for universities and academies. With regards to nepotism, our simulations suggest that one in ten sons of university professors got a job at a university because of nepotism. The same proportion as in academies.

These findings do not support the negative views about universities during the Scientific Revolution. Nepotism declined as a result of the establishment of new academies, but also in newly established universities (see Table 6), paving the way for Europe's scientific advancements after 1543.

6 Robustness

We perform several robustness checks. This section briefly describes them; the detailed results are available in the online appendix.

Stationarity. In our estimation, we assume that the human capital distribution is stationary among potential scholars. This assumption is standard in the literature, but its importance to estimate the transmission of endowments across generations is rarely discussed (Nybom and Stuhler 2019). Appendix F presents evidence supporting this assumption in our setting. We examine trends among potential scholars using a dataset on 42,954 scholars—not only fathers and sons—collected by de la Croix (2021). The mean and the standard error of publications, our proxy for human capital, are stable over time, suggesting a stationary human capital distribution. The appendix also shows that under stationarity our nepotism estimates are conservative, lower-bound estimates. The reason is that our

estimation uses father-son distributional differences to identify nepotism but does not attribute all these differences to it. We allow for distributional differences to be the result of a second force: mean reversion. That is, that top scholar's sons may be "naturally" worse than their fathers, even if no nepotism is involved. In a non-stationary environment where the human capital distribution improves over time, mean reversion would explain less of the father-son distributional differences in publications. Hence, our (already large) nepotism estimates would have to be larger to match the observed distributional differences.

Shocks from fat-tailed distributions. In our estimation, we assume that shocks affecting human capital are drawn from a normal distribution – like most of the literature. An attractive alternative to normality consists in drawing shocks from fat-tailed distributions, giving higher likelihood to the emergence of geniuses. In Appendix G we analyze whether changing distributions affects our results. We show that, although fat tailed distributions for shocks to human capital seem *a priori* to be an appealing alternative, they do not fit the data well, which are very normal after all. The estimated importance of nepotism is however robust to assuming such shocks, although the estimated intergenerational persistence is not.

7 Conclusions

From the Bernoullis 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, scholars' sons benefited from their fathers' connections to receive nominations to academic positions in their fathers' university. Between 1088 and 1800, one in six scholars' sons were nepotic scholars. They became academics even when their underlying human capital was 2.1 standard deviations lower than that of marginal outsider scholars. Second, scholars transmitted to their sons a set of underlying endowments, i.e., human capital, that were crucial to produce scientific knowledge. Our estimates suggest a large intergenerational elasticity of such endowments, as high as 0.59.

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—correlations in observed outcomes across multiple generations—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, a slow rate of reversion to the mean strengthens the

correlations across generations and (should) reduce the distributional differences between fathers and sons. When this distributional differences are larger than predicted by reversion to the mean, it reflects the fact that the observed parents and children are selected under different criteria, i.e., nepotism. In other words, excess parent-child distributional differences within a top occupation can be used to identify and to quantify the prevalence 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 with 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 nepotism, we estimate large intergenerational human capital elasticities among scholars, 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 modeling selection explicitly, our method only requires the use of 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 pre-industrial Europe's take-off (Cantoni and Yuchtman 2014, Mokyr 2002, 2016, Squicciarini and Voigtländer 2015, de la Croix, Doepke, and Mokyr 2018). Our findings suggest that the transmission of human capital within the family 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 adhering to Protestantism. In contrast, nepotism is prevalent in periods of stagnation and in Catholic institutions that fell behind in the production of scientific knowledge. Altogether, this suggests that the establishment of modern, open universities during the Scientific Revolution and the Enlightenment was crucial to 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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